Research report

The representation of lexical-syntactic information: Evidence from syntactic and lexical retrieval impairments in aphasia

Michal Biran\textsuperscript{a,b} and Naama Friedmann\textsuperscript{a,*}

\textsuperscript{a} Tel Aviv University, Tel Aviv, Israel
\textsuperscript{b} Loewenstein Hospital Rehabilitation Center, Ra’anana, Israel

\textbf{A B S T R A C T}

This study explored lexical-syntactic information – syntactic information that is stored in the lexicon – and its relation to syntactic and lexical impairments in aphasia. We focused on two types of lexical-syntactic information: predicate argument structure (PAS) of verbs (the number and types of arguments the verb selects) and grammatical gender of nouns. The participants were 17 Hebrew-speaking individuals with aphasia who had a syntactic deficit (agrammatism) or a lexical retrieval deficit (anomia) located at the semantic lexicon, the phonological output lexicon, or the phonological output buffer. After testing the participants’ syntactic and lexical retrieval abilities and establishing the functional loci of their deficits, we assessed their PAS and grammatical gender knowledge. This assessment included sentence completion, sentence production, sentence repetition, and grammaticality judgment tasks. The participants’ performance on these tests yielded several important dissociations. Three agrammatic participants had impaired syntax but unimpaired PAS knowledge. Three agrammatic participants had impaired syntax but unimpaired grammatical gender knowledge. This indicates that lexical-syntactic information is represented separately from syntax, and can be spared even when syntax at the sentence level, such as embedding and movement are impaired. All 5 individuals with phonological output buffer impairment and all 3 individuals with phonological output lexicon impairment had preserved lexical-syntactic knowledge. These selective impairments indicate that lexical-syntactic information is represented at a lexical stage prior to the phonological lexicon and the phonological buffer. Three participants with impaired PAS (aPASia) and impaired grammatical gender who showed intact lexical-semantic knowledge indicate that the lexical-syntactic information is represented separately from the semantic lexicon. This led us to conclude that lexical-syntactic information is stored in a separate syntactic lexicon. A double dissociation between PAS and grammatical gender impairments indicated that different types of lexical-syntactic information are represented separately in this syntactic lexicon.
1. Introduction

Sentence construction and lexical retrieval of single words are two different processes, but there are close relations between them. One interface between them is the lexical-syntactic information — syntactic information that is stored in the lexicon. This lexical information dictates the syntactic environment in which a word can be inserted. Viewed differently, this information about words, and especially about verbs, creates the syntactic structure of the sentence. For example, the argument structure of a verb and its subcategorization are lexical properties that determine which arguments and phrases can and should occur with the verb. Similarly in the noun domain, the grammatical gender of a noun is a lexical property that determines in many languages the inflection of various constituents in the sentence that agree with the noun.

The lexicon includes (only) idiosyncratic properties of lexical items, that is, everything that does not stem from general principles of Universal Grammar or of a specific language (Chomsky, 1995). For example, the fact that verbs in certain languages are followed by their complements (I ate pasta and not I pasta ate) is a general property of those languages (head-first languages) and therefore not part of the lexical knowledge about each verb. In contrast, the set of complements that can follow a particular verb is an idiosyncratic property of that verb, hence part of the verb’s lexical entry. Similarly, a particular noun’s grammatical gender is an idiosyncratic property and therefore has to be listed in its lexical entry.

In this study, we explored the relations between single-word retrieval and sentence construction by looking at this interface between them, the lexical-syntactic information. More specifically, we asked two main questions about this relation: one was whether lexical-syntactic information is independent of sentence structure building beyond the verb phrase, by testing whether lexical-syntactic information can be preserved when syntax is impaired in agrammatism; the other question was where in the lexical retrieval process is lexical-syntactic information stored. This question was explored via the assessment of lexical-syntactic information of individuals with impairments at various stages of lexical retrieval. The basic rationale was that if an individual has a selective impairment located at a certain stage of the lexical retrieval process, then the status of lexical-syntactic information would be indicative as to the location of this lexical retrieval process, then the status of lexical-syntactic information.

1.1. Types of lexical-syntactic information

1.1.1. Predicate argument structure

The lexicon includes several types of information about arguments and complements of verbs: PAS, thematic grid, and subcategorization.

A verb’s PAS specifies the number of arguments it takes. Different verbs require different numbers of arguments, depending on the number of entities that can participate in an event described by the verb (see examples 1a–1c). Adding or omitting an argument creates an ungrammatical sentence. The verb sneeze, for example, can take only one argument, the sneezer; hence, adding a second argument leads to an ungrammatical sentence (e.g., *Danny sneezed Dana, where the asterisk marks ungrammaticality). The verb push, on the other hand, requires two arguments (someone who pushes and someone or something that is being pushed); here, omitting one argument causes ungrammaticality (e.g., ‘Danny pushed’). In the notation of PAS (example 1), the first argument \( x \) is an external argument that relates to the subject of the sentence (Danny in these sentences), and \( y \) and \( z \) are the verb’s complements. The common assumption is that PAS information is part of the representation of the verb in the lexicon (e.g., Levelt, 1989, 1992; Shapiro, 1997, 2000; Shapiro et al., 1987), as it is an idiosyncratic property of the verb (Haegeman, 1994).

(1) a. one argument: sneeze \( x \) \( \Rightarrow \) Danny sneezed
b. two arguments: push \( x, y \) \( \Rightarrow \) Danny pushed the car
c. three arguments: give \( x, y, z \) \( \Rightarrow \) Danny gave a book to Dana

Different arguments also have different semantic roles in relation to the verb. This fact is encoded in a verb’s thematic grid — that is, the thematic roles assigned to the arguments associated with the verb. Thematic roles (also known as theta roles or \( \theta \)-roles) are the roles played by the participants in an event. Very generally, they describe “who did what to whom” in the sentence. The main thematic roles include agent (the entity that performs the action or brings about some change), theme (the entity that the action is performed upon), and goal (the entity that is the target of transfer or motion) (Chomsky, 1986; Grimshaw, 1979, 2006; Pesetsky, 1991; Shapiro et al., 1987, 1989). For example, in sentence (1c) Danny is assigned the agent role, book the theme role, and Dana the goal.

Another characterization that is taken to be part of each verb’s lexical entry is its subcategorization frame, which specifies the number and syntactic types of phrases that can complement a verb (Chomsky, 1965; Friederici, 1995; Grimshaw, 1979). That is, subcategorization stipulates the syntactic environments associated with verbs (and nouns) and hence constrains the verbs to well-formed environments. Unlike PAS and thematic grid, subcategorization relates solely to the complements of the verb (the phrases that follow the verb in the basic word order in languages like Hebrew and English) and does not include the subject (Haegeman, 1994; Shapiro, 2000). For example, the verb push can only take a noun phrase (NP) as its complement, as illustrated in example (2a), and the verb depend can only take a prepositional phrase, by testing whether lexical-syntactic information can only take a noun phrase (NP) as its complement, as illustrated in example (2a), and the verb depend can only take a prepositional phrase.
phrase (PP), as illustrated in (2b). The verb give takes NP and PP as its complements (2c). Besides noun phrases and prepositional phrases, verbs can take sentences as their complements. For example, the verb hear in sentence (2d) takes a sentence (CP) as its complement.

(2) a. push [NP] → Danny pushed [NP the dancer]
   b. depend [PP] → Danny depends [PP on the spell checker]
   c. give [NP][PP] → Danny gave [NP the book] [PP to the dancer]
   d. hear [CP] → Danny heard [CP that Dana is writing a book]

Thus, subcategorization differentiates among types of verbs. Verbs differ both with respect to the type of subcategorization they select and with respect to the number of subcategorization options they allow. Whereas push and depend have only one subcategorization option, discover has two subcategorization options. It can take either an NP or a CP as its complement, as shown in example (3).

(3) a. Esther discovered [NP]
   b. Esther discovered [CP that the story is real]

In addition to the various types of arguments, a sentence can include adjuncts – phrases that are not arguments of the verb, but are rather optional phrases that add information, usually about the time, place, or manner of action. For example, the bracketed phrases in the sentence Anne wrote a book in a charming apartment last year are adjuncts. Unlike arguments, adjuncts do not contribute to the verb’s thematic roles, are not part of its lexical representation, and can be omitted without violating the grammaticality of a sentence in which they occur (Shapiro et al., 1993).

In sum, the lexical representation of a verb includes knowledge about its arguments: the number of arguments it takes (its PAS); the thematic role of each argument, describing “who did what to whom” in the sentence; and its subcategorization frame, which specifies the syntactic types of phrases that can complement the verb.

1.1.1.1. THE PSYCHOLINGUISTICS OF PREDICATE ARGUMENT STRUCTURE.

The complexity of a verb’s PAS and its subcategorization frame has been shown to affect access to its lexical entry in response–time studies as well as in brain imaging techniques (Shapiro et al., 1987, 1989, 1991, 1993; Shapiro and Levine, 1990; Shetreet et al., 2007, 2009a, 2009b, 2010a). Shapiro and his colleagues found that access to argument structure of verbs is exhaustive, and hence, accessing verbs with more argument structure options induces longer reaction times in a secondary task. This was found for individuals without language impairment, and, crucially, also for individuals with Broca’s aphasia. Shapiro and his colleagues found that individuals with Broca’s aphasia, who have a syntactic deficit at the sentence level, have intact PAS knowledge, as indicated by their showing the same effect of verb complexity as healthy adults. In contrast, individuals with Wernicke’s aphasia were found to have impaired PAS knowledge; they do not exhibit the normal PAS complexity effect in lexical access (Shapiro and Levine, 1990). These results are further supported by results from imaging studies. Shetreet et al. (2007, 2010a) found brain areas that are more active when hearing a verb with more complementation options (subcategorization options). Furthermore, whereas syntactic operations like Wh-movement are often found to activate Broca’s area (Ben-Shachar et al., 2004; Grodzinsky, 2000; Shetreet et al., 2010b). But see Wartenburger et al., 2003 who failed to find specific activation to syntactic operations in Broca’s area), information about argument structure activates other brain areas, specifically Wernicke’s area (Shetreet et al., 2007, 2009a, 2009b, 2010a). These behavioral and imaging findings indicate a possible dissociation between syntactic processing and lexical-syntactic information. Results from grammaticality judgment of PAS knowledge (more specifically, subcategorization knowledge) in agrammatic aphasia reach similar conclusions. Linebarger et al. (1983) found that their 4 agrammatic participants performed well on judgment of subcategorization violations, indicating that the agrammatic participants, although impaired in syntax, had preserved subcategorization knowledge.

Studies that examined the production of verbs with various PAS frames in agrammatism (Broca’s aphasia) (Kim and Thompson, 2000; Thompson et al., 1997a) report that individuals with agrammatism performed better in producing verbs with one obligatory argument than in producing verbs with two or three obligatory arguments (and produced verbs with two arguments better than verbs with three). They were better able to name verbs with two arguments (two-place verbs) than verbs with three arguments (three-place verbs). In addition, there was an effect of the number of argument structures a verb has: verbs with one argument structure were produced better than verbs with several optional argument structures. However, these studies required an oral response, which might have been affected by the participants’ word retrieval deficits and by their deficit in producing embedded sentences (sentences with a CP argument), as some of the verbs used in these studies had CP complements. (We will return to this point in the Discussion.) A deficit in PAS knowledge has been reported for individuals with Wernicke’s aphasia. Edwards (2002) tested PAS knowledge in three individuals with Wernicke’s aphasia using a picture description task, and reports omission of obligatory arguments and incorrect thematic role assignment in production.

The picture emerging from imaging studies and aphasial research thus converge to suggest that Wernicke’s area, but not Broca’s area, is responsible for PAS knowledge, and hence individuals with agrammatism may have intact PAS knowledge whereas individuals with a damage in Wernicke’s area show PAS impairment (aPASia). We do not know how individuals with various types of anomia process PAS. In the current study, we tested the knowledge of individuals with agrammatic aphasia and various types of anomia about the arguments of verbs, including their number and their syntactic and thematic properties. We refer below to all of these properties using the general term PAS.

1.1.2. Grammatical gender

In some languages, nouns are marked for grammatical gender. Unlike conceptual (natural) gender of animate nouns (such as mother and father), for which gender assignment is transparent and related to biological gender, the grammatical...
gender of inanimate nouns (masculine, feminine, or neuter) is determined arbitrarily, without any relation to their meaning. That is, grammatical gender is an arbitrary idiosyncratic lexical-syntactic property of the noun, distinct from its semantic properties. There are two sources of evidence for the arbitrariness of grammatical gender. One type of evidence comes from synonyms that refer to the same entity and carry different genders. For example, in Hebrew the moon has three names, two of them masculine (yare’ax, sahar) and one feminine (levana). The second source of evidence comes from words in different languages that refer to the same entity and carry different genders. For example, the word for ‘house’ is masculine in Hebrew and Arabic (bayit, bayt), feminine in Italian and Spanish (casa), and neutral in German (Haus). In some languages, grammatical gender is assigned primarily on the basis of the form of the noun, such as its morphological suffix. For example, in Spanish most nouns ending in -a are masculine, and most nouns ending in -o are feminine.

In many languages, the grammatical gender of the noun enters syntactic agreement relations with other elements in the phrase or sentence. In noun phrases, agreement occurs between the head noun and a determiner, an adjective, and so on. In sentences, agreement occurs between the subject (and in some languages also the object) and the predicate (a verb, a copula, or an adjectival predicate) or between a noun phrase (NP) and a pronoun that refers to it.

Hebrew, the language tested in the current study, has two genders for both animate and inanimate nouns: masculine and feminine. Most feminine nouns are marked with a suffix (-a, -et, or -it), and most masculine nouns are morphologically unmarked. Irregular nouns exist in both genders — that is, feminine nouns without a suffix and masculine nouns with a suffix. Verbs, adjectives, and pronouns inflect for gender and agree with the noun they are syntactically connected to. An adjective almost invariably follows the noun it modifies, and the main verb usually follows the noun in subject position. The definite article (ha-, the Hebrew word meaning ‘the’), which precedes the noun, is not inflected for gender.

1.1.2.1. The psycholinguistics of grammatical gender. Some studies that tested agreement between the head of the subject NP and an adjective almost invariably follows the noun it modifies, and the main verb usually follows the noun in subject position. The definite article (ha-, the Hebrew word meaning ‘the’), which precedes the noun, is not inflected for gender.

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in the phonological output lexicon: the representation of the spoken form of the word, which includes metrical information (number of syllables and stress pattern) and segmental information (the phonemes of the word — consonants and vowels and their relative position). This activation is in turn transferred to the phonological output buffer, a post-lexical stage in which the word is assembled from its metrical frame and segments, and which is responsible for morphological composition (Dotan and Friedmann, 2007, 2010; Kohn and Melvold, 2000). This buffer also holds the phonological representation until the word is produced (e.g., Biran and Friedmann, 2005; Butterworth, 1989, 1992; Dell, 1986, 1988; Garrett, 1976, 1992; Kempen and Huijbbers, 1983; Levelt, 1989, 1992; Nickels, 1997; Patterson and Shewell, 1987). Two separate phonological buffers exist — an input phonological buffer and an output phonological buffer (Franklin et al., 2002; Gvion and Friedmann, 2008; Shallice et al., 2000; Shallice and Warrington, 1977). In the current study we discuss only the phonological output buffer.

Some researchers refer to lemma as the lexical representation in the semantic lexicon which includes the word’s lexical-syntactic information,¹ and to lexeme as the lexical representation in the phonological output lexicon. Therefore, it is well-accepted that the lexical-syntactic and phonological information are stored separately (Caramazza, 1997; Garrett, 1976; Levelt et al., 1998; Roelofs, 1992, but see Caramazza and Hillis (1991) on grammatical category in the phonological lexicon). However, the relation between the lexical-syntactic and the lexical-semantic information is controversial. Some researchers claim that the lemma includes a word’s semantic representation as well as its syntactic representation (Kempen and Hoenkamp, 1987; Kempen and Huijbbers, 1983; Levelt, 1989, 1992). Other researchers assume that the lemma contains only the lexical-syntactic representation, separately from the lexical-semantic representation (Bock and Levelt, 1994; Levelt et al., 1998; Roelofs, 1992).

As for the relation between lexical-syntactic information and phonological information, whereas most researchers agree that they are represented separately, there are various theories about the way information flows between them. Some researchers assume a serial model according to which phonological information is accessible only after lexical-syntactic information has been accessed (Roelofs et al., 1998). This model was called “Syntactic Mediation” by Caramazza (1997). According to this model, a person who has access to the lemma but not to the lexeme has information about the syntactic properties of the word, even though s/he cannot retrieve it, or retrieves it with a phonological error due to missing phonological information. According to other approaches, the semantic representations activate the lexical-syntactic representations and the lexical-phonological representations in parallel (Caramazza, 1997; Caramazza and Miozzo, 1997). This model, entitled “Independent Network”, predicts a double dissociation: access to lexical-syntactic information with a deficit in accessing phonological information, and access to phonological information with a deficit in accessing lexical-syntactic information.

Thus, there are several approaches to the representation of lexical-syntactic information. In this study, we will explore where this information is represented by examining individuals with anomia who have deficits in various stages of lexical retrieval.

1.3. How lexical-syntactic information interacts with syntax

According to Levelt et al. (1998, 1999), when the syntactic representation in the lexicon (which they term lemma) is retrieved, its syntax becomes accessible for forming a syntactic environment that is appropriate for the word. For instance, the lexical-syntactic information includes the word’s grammatical category — whether it is, say, a noun or a verb. This in turn determines the type of phrase the word is the head of: a noun will project a noun phrase, and a verb, a verb phrase. When the lexical-syntactic representation of a noun is accessed, its grammatical gender becomes available, and the gender in turn determines the inflection of sentential components that agree with the noun, such as the determiner or the verb. Within linguistic theory, similar notions exist to explain gender agreement with a noun. For example, according to Chomsky (1995), the gender of a noun is retrieved as part of the numeration (the list of items retrieved from the lexicon before the structure is built), and then either the agreement features of the elements that agree with the noun enter the
numeration or, when the noun moves to an agreement phrase, syntactic operations create the agreement of the agreeing elements. Another possibility Chomsky mentions is that the words that agree with the noun reach the phonological component uninflected and the inflection is added at the phonological interface. (See Dotan and Friedmann, 2007, 2010 and Kohn and Melvold, 2000 for similar suggestions that morphological processes take place at the phonological output buffer.)

A similar process occurs at the interface between argument structure information in the lexicon and structure building. The syntactic component builds a syntactic structure from the numeration. Syntax operates on the selected elements and the lexical-syntactic information they bear, so that the arguments that appear in the lexical entry of the verb as required by the verb determine the syntactic structure of the verb phrase. For example, if the verb retrieved does not require a complement (like sneeze), then the syntactic structure of the verb phrase includes only the verb, without a complement. If, however, the verb retrieved requires two complements (like give), the verb phrase will include the verb and two complements.

How does lexical-syntactic information relate to the syntactic tree? In the syntactic tree, the VP forms the lowest layer of the syntactic tree, the lexical layer (Chomsky, 1986, 1995; Pollock, 1989; Rizzi, 1997). The layers above VP consist of functional nodes: the inflectional layer, which is responsible for the inflection of verbs for tense and agreement (this layer includes the tense phrase, TP, and, according to some accounts, an agreement phrase, AgrP, which represents agreement between the subject and the verb); and the complementizer CP-layer, which is responsible for embedded sentences, Wh-questions, and other elements that undergo Wh-movement, and also for the verb when it moves to second position in the sentence, in sentences with verb movement.

Thus, lexical-syntactic information about the PAS of the verb determines the verb phrase level. According to some accounts for agrammatism, individuals with agrammatism have deficits beyond the VP level — in the higher, functional nodes of the syntactic tree (Friedmann, 1999, 2001, 2005, 2006; Friedmann and Grodzinsky, 1997), and in sentences that involve syntactic movement (Grodzinsky, 1989; Grodzinsky et al., 1999). Are individuals who show impairment to these higher nodes also necessarily impaired in the ability to represent lexical-syntactic information and use it to build the VP? For this aim we will assess PAS knowledge of individuals with agrammatism who have impairments in sentences that involve Wh-movement, verb movement, tense inflection, and embedding, and see whether they may demonstrate intact PAS knowledge.

The lexical-syntactic information about the gender of the noun determines the inflection of elements within the NP, but also of elements in the inflectional layer, such as the agreement inflection of the verb. One question we will ask would be, like in the case of PAS, whether individuals with agrammatism who have deficits in the higher syntactic layers, are also necessarily impaired in the ability to represent lexical-syntactic information with respect to grammatical gender. We will further ask whether it is possible to distinguish between impairments of grammatical gender knowledge which lead to incorrect inflection also at the inflectional level, and syntactic impairments at the inflectional level. For this aim we will compare grammatical gender, which is stored as part of the lexical-syntactic knowledge, with conceptual gender, which is also encoded in the conceptual system and the semantic lexicon. A selective deficit at the lexical-syntactic knowledge of grammatical gender is expected to affect inflections at the inflectional layer for inanimate nouns, but not for animate nouns. Individuals with impaired access to lexical-syntactic knowledge may still be able to access the natural gender of animate nouns and hence may still be able to use correct inflection at the inflectional layer. On the other hand, individuals whose impaired gender inflection results from a syntactic deficit in the inflectional layer are expected to show similar impairment for grammatical and natural gender.

Therefore, the aims of the current study are to examine whether lexical-syntactic information (PAS and grammatical gender) can be intact when syntax beyond the verb phrase level is impaired. We will also test the specific relation between incorrect inflection that results from lexical-syntactic impairment and impaired inflection as a result of impaired syntactic mechanism; A further research aim, as we detailed above, is to find where lexical-syntactic information is stored in the lexical retrieval process. This will be tested by assessing lexical-syntactic information in individuals with impairments at different stages of lexical retrieval. The rationale is that if there are individuals with anoma who are impaired in a certain lexical retrieval stage but have intact lexical-syntactic information, this would indicate that lexical-syntactic information is not stored in that impaired lexical stage. A systematic exploration of all stages may then lead to a conclusion as to where lexical-syntactic information is stored. The last research question relates to whether different types of lexical-syntactic information, PAS of verbs and grammatical gender of nouns, can be selectively impaired. If they can, this would suggest that they are stored separately.

To explore these questions we first diagnosed the functional locus of deficit of each participant. We assessed whether it is a syntactic impairment or an impairment in lexical retrieval, and if the impairment was in lexical retrieval, we diagnosed which of the lexical retrieval stages is impaired, using an extensive battery of syntactic and lexical tests and analyses (detailed in Appendix B). Then, we administered two test batteries that examined the PAS and gender information of each of the participants, and compared the lexical-syntactic performance of individuals who are impaired in different components of syntax and lexical retrieval.

2. Participants

2.1. Individuals with aphasia

Seventeen individuals with aphasia, 11 men and 6 women, participated in the study. Sixteen participants had a lesion in the left hemisphere, and one (AE) had a lesion in the right hemisphere. The participants’ mean age was 51 years (range 23–73 years). Sixteen participants were native speakers of Hebrew, and one (RT) has spoken Hebrew for 44 years. Their mean number of years of education was 13 (range 8–19 years).
Thirteen participants were right-handed, three were left-handed, and one was ambidextrous. Fifteen participants had aphasia following stroke, and two (RA, AL) had a traumatic brain injury. Mean time post onset was 33 months (range 1 month to 13 years). See Appendix A for detailed background information on the participants.

Because we were interested in the relation between lexical-syntactic information and syntactic and lexical impairments, we included in the study participants who had a syntactic deficit (agrammatism) or a lexical retrieval deficit. We selected the 17 participants for the experiment on the basis of an initial diagnosis of lexical and/or syntactic problems (using the ILAT, Shechther, 1965, and the BAFLA, Friedmann, 1998). Ten participants showed lexical processing impairments, 4 participants had agrammatic aphasia, and 3 participants had a mixed syntactic and phonological impairment. We then administered an extensive battery of tests to establish and characterize the participants’ impairments and to identify the functional locus of each participant’s syntactic and lexical retrieval deficits. These tests are described in Appendix B. In Sections 2.1.1 and 2.1.2, and in Section 3 which evaluates the lexical-syntactic performance of the participants we present results for the individuals who had a selective deficit in syntax or lexical retrieval. We then present separately, in Section 4.1, the three participants with mixed syntactic and phonological impairment.

The tests were administered to each participant individually in a quiet room at the rehabilitation center, in our Language and Brain Lab at the university, or at their homes. Testing was performed over 5–10 sessions per participant; each session lasted between one and two hours, depending on the participant’s ability. All of the sessions were recorded and then transcribed by two independent judges. The reliability between the judges was very high for all tests.

2.1.1. Testing for inclusion in the syntactic impairment group
Four participants presented the characteristic agrammatic pattern in speech production: non-fluent speech, use of simple sentences, ungrammatical utterances, tense inflection errors, and impaired production of embedded clauses, relative clauses, and Wh-questions.

To make sure that they indeed had agrammatism and could be safely included in this study, and to determine the layer of the syntactic tree at which they are impaired, we tested these 4 individuals with a line of structured syntactic tasks of sentence comprehension and production from the BAFLA syntactic battery (Friedmann, 1998). In comprehension, we included individuals who failed to understand non-canonical semantically reversible object relatives and object Wh-

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<th>Table 1 – Performance of the agrammatic participants in the syntactic tasks (% correct).</th>
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<td>Subject relative</td>
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<td>Object relative</td>
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<td>Verb inflection – tense completionb</td>
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The repetition tests were not administered to RT. 

2 Indeed, some studies reported individuals with agrammatism who demonstrated other comprehension patterns (Berndt and Caramazza, 1980; Berndt, et al., 1996; Caplan, 1985; Caplan and Futter, 1986; Schwartz, et al., 1987). However, because we were mainly interested in identifying individuals who were clearly agrammatic in order to ask the research questions regarding lexical-syntactic information in individuals with agrammatism, we only included individuals who we could be sure are agrammatic. We therefore selected for this study individuals with impaired comprehension of non-canonical reversible sentences and relatively good comprehension of canonical sentences, in addition to agrammatic speech production.
2.1.2. Testing for inclusion in the lexical retrieval impairment group

The lexical impairment group included 10 individuals who had a marked lexical retrieval deficit. Their impairment was initially established on the basis of poor performance (under 70% correct) on the SHEMESH naming test (naming 100 pictures of objects, Biran and Friedmann, 2004). These individuals were later given conceptual, semantic, and phonological tests in order to determine the locus of their impairment within the lexical retrieval process. These tests included: picture naming, picture association, word association, semantic and phonological verbal fluency, synonym judgment, spoken/written word-picture matching, word and nonword repetition, and nonword reading. See Appendix B2 for a detailed description of the tests used to assess their lexical retrieval impairment.

Because we were interested in lexical deficits, rather than general conceptual deficits, we included only participants without a conceptual deficit. To identify a conceptual deficit, we administered a picture association test, and analyzed the error types in the SHEMESH naming test, looking for paraphasias that were semantically and phonologically unrelated to the target word (e.g., cherry-glasses). We only included in the study individuals with good performance in the picture association test and without unrelated paraphasias in naming.

A lexical-semantic deficit was diagnosed by the existence of semantic paraphasias in naming (errors that are semantically related to the target word; e.g., pineapple-coconut) and difficulty in various lexical-semantic tasks: semantic verbal fluency, synonym judgment, word association test, and spoken/written word-picture matching.

A phonological deficit, at the phonological output lexicon or the phonological output buffer, was diagnosed by the existence phonological paraphasias (errors that are phonologically related to the target word, e.g., trumpet-trumlet) in naming (for phonological lexicon impairment, typically alongside semantic paraphasias), and difficulty in a phonological verbal fluency task.

Given a phonological deficit, to distinguish between a deficit at the phonological output lexicon and a deficit at the phonological buffer we also tested nonword repetition and nonword reading. The distinction was made on the basis of the following criteria. A frequency effect in naming was taken to indicate a deficit at the phonological output lexicon (Jescheniak and Levelt, 1994). Several factors indicated a phonological buffer deficit: a length effect (Franklin et al., 2002; Nickels and Howard, 2004) and a syllable frequency effect (Laganaro, 2005), as well as impaired nonword reading and nonword repetition. A limited working memory span was also taken to support a phonological buffer deficit (Gvion and Friedmann, 2008; Shallice et al., 2000; Shallice and Warrington, 1977). A criterion we used to point to a phonological buffer impairment without a phonological lexicon impairment was the type of approximation produced. We considered faithful approximations (those that include only phonemes of the target word) to characterize a late phonological output impairment with correct input from the phonological lexicon (Dotan and Friedmann, 2007, 2010). Furthermore, semantic errors should be rare in phonological output buffer impairments and more frequent in a phonological output lexicon impairment.

The results of these tests are presented in Table 2. In the analysis of errors in the naming task, semantic errors include semantic paraphasias; Phonological errors include phonemic paraphasias and formal paraphasias; The unrelated errors include paraphasias that are semantically and phonologically unrelated to the target and neologisms; Hesitations, “don’t know” responses, perseverations, and visual errors were counted as part of the total number of errors (and are thus reflected in the Table in the naming score). We considered an effect to exist if a significant Point Biserial correlation \( p < .05 \) was found between success in producing each word or syllable, and the tested measure. The frequency effect was calculated for word frequency as judged by 75 Hebrew speakers on a scale of 1–7. The length effect was measured as the number of phonemes in a word, because this was found to be a more indicative measure than syllables (Dotan and Friedmann, 2007; Nickels and Howard, 2004). The syllable frequency effect (Laganaro, 2005) was evaluated according to the frequency (taken from Schocken, 2008) of each syllable in phonological paraphasias.

The results of the lexical retrieval tests are presented in Table 2, and the classification of the participants according to the results and the above considerations is explained in detail in Appendix B3. The results indicated that two participants (SN, AA) had a lexical-semantic deficit – although they performed well on the non-verbal conceptual tests, they performed poorly on tests of synonym judgment and semantic fluency. Three participants (AO, SM, BP) were diagnosed with a lexical-phonological deficit – they produced semantic and phonological paraphasias, showed a frequency effect in naming, had difficulties on the phonological fluency task, and performed well in tests of word-picture matching, synonym judgment, and nonword repetition. Five participants (YD, ND, MK, AG, BT) were diagnosed with a phonological output buffer deficit – they produced mainly phonological errors, many of them faithful approximations and metatheses, and showed a length effect and a syllable frequency effect in naming. They performed flawlessly on the semantic tests and poorly in the nonword reading and nonword repetition tests.

2.2. Control participants

Healthy individuals with normal language were examined in order to test the tests and to achieve indication as to the normal performance on the tests. The control group for each test consisted of 20–30 participants. Each control group included

\[3\] In this regard, we must note that verbal fluency tasks are problematic to interpret, because many factors can lead to poor performance. Individuals with a phonological deficit would be expected to perform poorly on both semantic and phonological fluency tasks, and it is unclear whether individuals with a semantic deficit can directly access the phonological output lexicon. Thus, although these tasks indicate a naming deficit, they are not a very good tool for distinguishing among possible sources of this deficit.

\[4\] In diagnosing a deficit at the phonological output lexicon we did not distinguish between a deficit at the lexicon itself and a possible deficit in accessing the lexicon or at the output from the lexicon. When considering a deficit at the phonological output buffer we relate only to a deficit at the buffer itself and not at the access to it.
5–8 men and 15–22 women. Their mean age was 36 years (range 19–61 years). All the control participants were native speakers of Hebrew, with no history of neurological deficits.

### 3. Assessment of lexical-syntactic abilities

After identifying each participant’s type and locus of deficit, we turned to assess the lexical-syntactic knowledge of each of them. We administered tests to examine their PAS and grammatical gender abilities. No time limit was imposed during testing, and no response-contingent feedback was given by the experimenter. The sentences were repeated as many times as the participant requested.

#### 3.1. Tests examining predicate argument structure – the PASTA battery (PAS tests for aphasia)

##### 3.1.1. Material selection

To select and classify the verbs to be used in the PAS tests, we requested six linguists and psycholinguists to classify Hebrew verbs according to the syntactic and thematic types of phrases they can take as complements, and the number of their complementation options. We selected only verbs for which all 6 judges assigned the same argument structure. These verbs were then given to larger groups of native speakers of Hebrew, in four tasks that assessed the PAS of each verb. For the sentence production task, in which 41 judges participated, a verb was presented and the judge was asked to produce a sentence with it. To assess the use of a clausal complement compared with other complements, the verbs that allow for an embedded complement were given to 57 native speakers in an incomplete sentence consisting of just a subject and the verb, and they were asked to complete the sentence. For the judgment task, each verb was incorporated into sentences with varying numbers and types of complements, and 30 native speakers judged the grammaticality of the sentences. For the sentence completion task, each verb was incorporated into a sentence with a subject and a complement. The sentence was then presented without the verb, and 30 native speakers were asked to insert an appropriate verb.

All sentence productions and completions complied with the original classifications and the judgments of the linguists and psycholinguists. There was no more than one different response for any of the verbs. We therefore kept all the original verbs.

#### 3.1.2. Tasks

(a) **Verb completion in a sentence.** This test included 35 sentences from which the verb was missing from the

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canonical verb position after the subject. Accompanying each sentence were four verbs, and participants were asked to choose the verb that could complete the sentence. For example, The baby ____ in bed. (sleeps, hugs, depends, says) (Here and throughout the article the word and sentence examples are English equivalents of the Hebrew words and sentences that were used in the tests). For each sentence, each of the four verbs had a different PAS: unergative, transitive, PP complement, and sentential complement (finite or nonfinite [CP or IP]). All options were related to the sentence semantically, but only one had a PAS that matched the arguments in the sentence. The sentences and the four verbs were written on a page in front of the participants and were also read to them as many times as they requested. We examined whether the PAS of the selected verb (number of arguments and their syntactic types) fit the arguments given in the sentence.

(b) Grammaticality judgment of PAS. This test included 65 sentences, 30 grammatical and 35 ungrammatical, randomly ordered. All the sentences were simple sentences, without movement. The ungrammaticality of each of the ungrammatical sentences resulted from one of three types of PAS violations: complement addition ("Tali fell the vase"); complement deletion ("Danny wears"); and complement substitution (subcategorization violation) of PP for NP or NP for PP ("Ron broke the glass; Ron relied the judge"). The participants heard the sentences, and for each sentence they were asked to judge whether it was grammatical or not. They were also asked to correct sentences they had judged as ungrammatical (Examples of corrections which were accepted as correct: for the sentence "Rami gave. — "What? to whom? Rami gave... the keys to his father"; for the sentence "The boy wore the coat. — "Wore the coat"). The participants who succeeded in the judgment task could all correct the ungrammatical sentences or explain why they are ungrammatical. The participants with the semantic deficit, who failed on the judgment task, also could not correct or explain the ungrammaticality. Namely, the performance on the ungrammaticality correction task was compatible with the participants’ performance on the other PAS tasks, and the preserved PAS information was manifested also in this task (one participant could not provide corrections due to his very severe production difficulties).

(c) Sentence production to a given verb. The participants heard a verb and were asked to use it to construct a sentence. The test included verbs with various numbers of arguments, types of complements, and numbers of complementation options. In all, participants were given 77 verbs, 7 verbs for each of 11 PAS frames: unergatives (no complement), transitives (one complement), ditransitives (two complements), unaccusatives (one argument, a theme), reflexives, verbs with two complementation options, verbs with 4 or 5 complementation options, verbs with a PP complement, verbs with an IP complement (nonfinite clause), verbs with a CP complement (finite clause), and alternating transitive-intransitive verbs (e.g., darken; Hebrew has only a few verbs of this type). The various types of verbs were presented in random order.

(d) Sentence repetition. The participants heard sentences and were asked to repeat them as accurately as they could. The test included 100 sentences, 10 with each of the following types of verbs: unergatives, transitives, ditransitives, unaccusatives, reflexives, verbs with two complementation options, verbs with 4 or 5 complementation options, verbs with a PP complement, alternating transitive-intransitive verbs, and transitive verbs with an adjunct (as a sentence-length control for the sentences with ditransitive verbs). The sentences with the various types of verbs were presented in random order. Most of the sentences were presented with an NP complement and the rest with a PP complement. Verbs that do not take a complement were presented with an adjunct. All the sentences were simple sentences, in the past tense, without Wh-movement or verb movement.

In the sentence production and the sentence repetition tests we examined (for the analysis in the current study) whether the sentences produced matched the PAS (including subcategorization) of the verbs, or whether complements were omitted, added, or substituted. A response was scored as correct or incorrect exclusively according to the PAS provided; we disregarded hesitations, lexical retrieval failures, and phonological errors. Thus, percentage correct (in Tables 3 and 5 below) was calculated as the number of sentences that were produced with correct PAS, i.e., sentences that did not include omission, substitution, or addition of an argument, out of the total number of sentences the participant produced. For example, for the verb “fixed”, in the sentence production test, the response: "The man fixed the... the car" was scored as correct. In the repetition test we also disregarded lexical substitutions that did not violate PAS information. (An example, translated to English: 'The suspect evaded the question’ instead of 'The suspect evaded the answer’ was scored as repetition with correct PAS).

3.2. Tests examining grammatical gender — the MINDY (MIN DIKDUKI) battery

The grammatical gender tests were presented only orally, so that participants would not use orthographic-morphological cues to the word’s written suffix.

3.2.1. Grammatical gender of inanimate nouns

(a) Verb completion in a sentence. In this task (from BAFLA, Friedmann, 1998), participants heard 24 test items. Each consisted of two conjoined sentences whose subjects were different inanimate nouns of either different genders or of

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5 In an earlier version of this test, we used free oral completion, without given options. This method turned out to be very difficult for the participants because of their word retrieval deficits. It led to poor performance even for participants who performed well on the task when it included selection from given options. Therefore, we preferred to use the selection-from-given-options method. MK was the only participant who was tested using only the free version, and his results in Table 3 are from this version.

6 Because this repetition test and the sentence production test were very long, not all of the participants completed it. However, since the tests were randomized, each individual participant responded to similar numbers of verbs from each type.
the same gender. In the second sentence, the verb was missing. Participants were asked to insert the missing verb using the verb that appeared in the first sentence, inflected for the gender of the new subject (e.g., etmol ha-otobus acar ve-ha-rakevet acar ‘Yesterday the busMASC stoppedMASC and the trainFEM stoppedFEM’; etmol ha-paamon cikel ve-ha-telefon cikel ‘Yesterday the bellMASC rangMASC and the phoneMASC rangMASC’). All sentences were presented in the past tense, to reduce the effect of tense impairment of the individuals with agrammatism. We disregarded tense errors in this task and only scored gender inflection as correct or incorrect.

(b) Phrase-level grammaticality judgment. The participants heard ‘80 noun phrases composed of an inanimate noun and an adjective (e.g., big house). Forty of the phrases were grammatical and 40 were ungrammatical, presented in random order. Violations involved gender mismatch between the adjective and the noun. Half of the nouns in the grammatical phrases and half of the nouns in the ungrammatical phrases were masculine, and half were feminine. Half of the nouns had a regular phonological gender marking (i.e., feminine nouns marked with one of the suffixes -a, -et, -it, such as maclama ‘camera’, and unmarked masculine nouns, such as dudevan ‘cherry’), and half of the nouns had an irregular ending (i.e., feminine nouns without a suffix, such as kos ‘glass’, and masculine nouns with a feminine suffix, such as taxshit ‘jewel’). The participants were asked to judge whether each phrase was grammatical or not. Nine of the participants (with syntactic and phonological deficits) spontaneously corrected some of the phrases they had judged as ungrammatical. Like in the PAS grammaticality judgment corrections, the success in the ungrammaticality corrections was compatible with the participants’ performance on the other grammatical gender tasks.

(c) Free completion of inanimate nouns in sentences. 15 sentences including a temporal adverb and a verb (unaccusative or unergatives) inflected for gender, without a noun, were presented to the participants, and they were asked to complete the sentence with an appropriate inanimate noun. (For example, etmol ____ nikre’a ‘Yesterday ____ was tornFEM’). We examined whether the noun they chose matched the gender inflection of the verb. If the participants could not find appropriate nouns because of a lexical retrieval deficit, two pictures of nouns, one masculine and the other feminine, were presented to them and they were asked to choose between them. (The version with the pictures was presented for two of the participants).

(d) Verb agreement in sentences produced with inanimate subjects. An additional source of information regarding the participants’ ability to access the gender of inanimate subjects was the sentences they produced in the PASTA test of sentence production for a given verb, described in the PAS tasks in Section 3.1. We examined, for sentences produced with inanimate subjects, whether the verbs agreed with the inanimate subjects in gender.

3.2.2. Grammatical gender of animate nouns: the contribution of conceptual gender
Unlike purely grammatical gender information, which is encoded at the lexical-syntactic level, conceptual gender draws on semantic properties of the word. Conceptual gender can be used to determine an animate noun’s grammatical gender, and this in turn can be used to determine the agreement inflection of other sentential elements.

To compare participants’ ability to determine grammatical gender for inanimate nouns with their ability to determine grammatical gender when the noun also has a conceptual gender, and to assess whether conceptual gender can be determined even when lexical-syntactic information is unavailable, we administered tests examining gender of animate nouns, and more specifically – of human nouns.

(a) Verb completion in a sentence. In this task (from BAFLA, Friedmann, 1998), participants heard 24 test items. Each consisted of two conjoined sentences whose subjects were different animate nouns of different genders or different number (singular/plural). In the second sentence, the verb was missing. Participants were asked to insert the missing verb using the verb that appeared in the first sentence, inflected for the gender of the new subject (e.g., etmol ha-yeled rakad ve-ha-yalda rakda ‘Yesterday the boyMASC dancedMASC and the girlFEM dancedFEM’).

(b) Phrase-level grammaticality judgment. The participants heard 30 noun phrases, 15 grammatical and 15 ungrammatical, randomly ordered, composed of an animate noun (referring to a profession or occupation) and an adjective. The adjective either matched the gender of the noun (e.g., melcarit xaxama, waitress smartFEM, ‘a smart waitress’), or created an ungrammatical phrase because of a mismatch between its gender and the gender of the noun (e.g., melcarit xaxam, waitress smartMAS). Half of the nouns in each condition (7 or 8) were unambiguously masculine and half were unambiguously feminine. The participants were asked to judge whether the phrase was grammatical or not. Two participants (RT, RA – with syntactic deficit) spontaneously corrected some of the phrases they had judged as ungrammatical.

(c) Free completion of animate nouns in sentences. 15 sentences from which a subject noun was missing were presented to the participants. The sentences included a temporal adverb and an intransitive verb that required an animate subject (unaccusative or unergatives) inflected for gender. The participants were asked to complete the sentence with an appropriate animate noun. (For example, etmol ____ hictanen ‘Yesterday ____ caught a coldMAS’). We examined whether the noun the participants chose matched the gender inflection of the verb. If the participants could not find appropriate nouns because of a lexical retrieval deficit, two pictures of nouns, one human masculine and the other human feminine, were presented to them and they were asked to choose between them. (The pictures were presented for two of the participants, the same participants who were assisted with the pictures in the inanimate nouns test).

(d) Verb agreement in sentences produced with animate subjects. An additional source of information regarding the participants’ ability to access the gender of animate subjects was the sentences they produced in the PASTA test of sentence production for a given verb, described among the PAS tasks in Section 3.1. We examined, for
sentences produced with animate subjects, whether the verbs agreed with the animate subjects in gender.

4. Results

Control group. The healthy individuals performed at ceiling in all the tests. Their percentage correct in the PAS sentence completion task was 99% (SD 0.38); PAS grammaticality judgment, 97% (SD 3.77); sentence production to a given verb, 99% (SD 0.84); grammatical gender sentence completion, 100%; grammaticality judgment of grammatical gender, 99% (SD 0.64); conceptual gender sentence completion, 100%; phrase-level grammaticality judgment of conceptual gender, 100%; gender agreement in sentences produced to a given verb with animate subject, 100%.

Because the control group scored 100% correct with no variance on four of the tests (and 99% correct on three other tests, with a very small standard deviation), it was impossible to use these tasks. Therefore, we based our analyses on the decision that for the healthy individuals, a score of 85% correct and above in each test indicates preserved knowledge of the relevant domain (along the lines advocated in Willmes, 1990, p. 419).

Aphasia group. The results of the PAS and gender tests for each participant with aphasia are presented in Table 3.

On the basis of these results, we are now in a position to answer the research questions we posed in the Introduction.

4.1. Where in the lexical retrieval process is lexical-syntactic information stored?

One of the main questions we explored was where in the process of lexical retrieval is lexical-syntactic information stored. The rationale was that data about individuals who are impaired at a certain lexical level and who still have intact lexical-syntactic information can indicate that lexical-syntactic information is not stored at that stage.

And indeed, two such dissociations were found in the performance of the 8 participants with a selective deficit in the phonological stages of lexical retrieval: a dissociation between impaired phonological output buffer and preserved lexical-syntactic information, and a dissociation between impaired phonological output lexicon and preserved lexical-syntactic information.

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### Table 3 – Participants’ performance on the PAS and gender tests (% correct).

<table>
<thead>
<tr>
<th>Deficit location</th>
<th>Syntax</th>
<th>Phonological buffer</th>
<th>Phonological lexicon</th>
<th>Semantic lexicon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RA</td>
<td>RT</td>
<td>AE</td>
<td>GR</td>
</tr>
<tr>
<td>PAS Verb completion in a sentence</td>
<td>100</td>
<td>63</td>
<td>92</td>
<td>91</td>
</tr>
<tr>
<td>Grammaticity judgment of PAS</td>
<td>95</td>
<td>85</td>
<td>100</td>
<td>91</td>
</tr>
<tr>
<td>Correction of the ungrammatical sentences</td>
<td>91</td>
<td>87</td>
<td>95</td>
<td>b</td>
</tr>
<tr>
<td>Sentence production to a given verb</td>
<td>90</td>
<td>79</td>
<td>93</td>
<td>85</td>
</tr>
<tr>
<td>Sentence repetition</td>
<td>95</td>
<td>95</td>
<td>96</td>
<td>100</td>
</tr>
<tr>
<td>Grammatical gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verb completion in a sentence – inanimate</td>
<td>63</td>
<td>100</td>
<td>92</td>
<td>96</td>
</tr>
<tr>
<td>Grammaticity judgment – inanimate</td>
<td>74</td>
<td>86</td>
<td>98</td>
<td>87</td>
</tr>
<tr>
<td>Correction of the ungrammatical phrases – inanimate</td>
<td>64</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Free completion of inanimate nouns in sentences</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verb agreement in sentences produced with animate subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Conceptual gender</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Verb completion in a sentence – animate</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Grammaticity judgment – animate</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Correction of the ungrammatical phrases – animate</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free completion of animate nouns in sentences</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Verb agreement in sentences produced with animate subjects</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Note. Shaded cells indicate good performance: above 85% correct on the task; Empty cells indicate that the test was not administered.

a RA did not make verb agreement errors, but in 35% of the sentences he either omitted the subject or any agreement on the verb would be acceptable, or produced the verb inflected for the first person, which does not require a gender agreement in the past and future tenses in Hebrew.

b YD had a severe production impairment with many phonological paraphasias which prevented him from providing a correction to the sentences he judged correctly as ungrammatical.

c Correct performance in 8/9 sentences.

d The participants with the semantic deficit were unable to understand and perform the sentence production task and most of the completion tasks, their performance was at floor level, and the tests were not administered fully. Because we could not be sure that the poor performance in these tasks could be ascribed to impaired lexical-syntactic information rather than to their failing to understand the task instructions, to be conservative we did not include these tests in the results.

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All of the participants with a selective phonological output buffer deficit (YD, ND, MK, AG, BT) performed well on both types of lexical-syntactic information. Namely, they all showed mastery of PAS and grammatical gender. This dissociation between impaired phonological buffer and preserved lexical-syntactic knowledge indicates that the lexical-syntactic information is not encoded at the buffer level; instead, it is expected to be encoded at an earlier lexical level. The next question is at which lexical level is this information encoded?

The three participants with a selective deficit at the phonological output lexicon (AO, SM, BP) also performed well on tasks of lexical-syntactic information: they showed preserved grammatical gender and PAS information (except for AO’s and SM’s performance on the PAS sentence completion test, in which they scored 80% and 77% correct, respectively, significantly above chance but below the threshold we considered as preserved knowledge). Thus, for the individuals with a lexical-phonological deficit, a clear disassociation between impaired phonological lexicon and preserved lexical-syntactic knowledge was observed. If lexical-syntactic information can be accessible when lexical-phonological information is not, this indicates that lexical-syntactic information is not encoded at the phonological lexicon level. Namely, it has to be encoded earlier than the phonological output lexicon.

As for the two participants who had a lexical-semantic deficit (SN, AA), both showed impaired lexical-syntactic information, failing on tests of both types of lexical-syntactic information—PAS and grammatical gender. These participants do not contribute to the question of whether lexical-syntactic information is stored at the semantic lexicon, together with the semantic attributes of words. Because they only demonstrate an association between two deficits, one cannot reliably conclude a shared functional locus on the basis of these results (Ellis and Young, 1996; Shallice, 1988).

Data that do provide a clear answer to the question of whether lexical-syntactic information is encoded in the semantic lexicon come from a different group of participants. AL, HY, ZH had a mixed deficit. As shown in Table 4, which summarizes their performance in the syntactic and lexical tests, the three of them had a syntactic impairment as well as a phonological deficit in lexical retrieval. HY had a deficit in the phonological lexicon, and AL and ZH had a deficit in the phonological lexicon and in the buffer.

After establishing their loci of deficit in syntax and lexical retrieval, we administered PAS and grammatical gender tests. The results of the lexical-syntactic information testing, presented in Table 5, demonstrate that these patients failed on both the PAS tests and the grammatical gender tests. Crucially, the lexical tests (Table 4) indicated that their lexical-semantic information was preserved. They performed well on the written association task, on the synonym judgment task, and on the word-picture matching task.

The dissociation observed for these three participants, between impaired lexical-syntactic information and intact semantic lexicon, suggests that lexical-syntactic information is not encoded in the semantic lexicon. Together with our earlier conclusion that lexical-syntactic information is not encoded in the phonological lexicon either, these dissociations point to the position of the lexical-syntactic information. They suggest that lexical-syntactic information is stored neither in the semantic lexicon nor in the phonological lexicon, but rather in a separate syntactic lexicon.

### 4.2. Can lexical-syntactic information be intact when syntax is impaired?

A very clear dissociation was found between impaired sentence-level syntax and preserved lexical-syntactic information: the 4 participants with a syntactic deficit showed preserved lexical-syntactic knowledge in at least one type of lexical-syntactic information. As Table 3 indicates, 3 of the 4 participants evinced mastery of PAS, with the notable

<table>
<thead>
<tr>
<th>Table 4 – Performance of the participants with a mixed deficit in the syntactic and in the lexical tests (%) correct unless otherwise noted.</th>
<th>AL</th>
<th>ZH</th>
<th>HY</th>
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<tbody>
<tr>
<td><strong>Syntactic tests</strong></td>
<td></td>
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<tr>
<td>Relative clause comprehension</td>
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<tr>
<td>Subject relative</td>
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<td>100</td>
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<tr>
<td>Object relative</td>
<td>63a</td>
<td>50b</td>
<td>53b</td>
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<td>Wh-question comprehension</td>
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<tr>
<td>Who subject</td>
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<td></td>
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<tr>
<td>Who object</td>
<td>57b</td>
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<td></td>
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<tr>
<td>Which subject</td>
<td>68</td>
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<td></td>
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<tr>
<td>Which object</td>
<td>65b</td>
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<td>Embedded-sentence repetition</td>
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<td>Relative clause elicitation</td>
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<td>Subject relative</td>
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<td>Object relative</td>
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<td>0</td>
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<td>Verb inflection — tense completion</td>
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<td>Naming (SHMESH)</td>
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<td>19</td>
<td>54</td>
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<tr>
<td>Number of semantic errors</td>
<td>6</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Number of phonological errors</td>
<td>17</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>Number of unrelated errors</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Frequency effect</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Length effect in phonemes</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>Syllable frequency effect</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Faithful approximations</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Associations</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>pictures</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>written words</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td><strong>Word-picture matching</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spoken</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Written</td>
<td>98</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Synonym judgment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td><strong>Semantic fluency</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td><strong>Phonological fluency</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Nonword repetition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>71</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nonword reading</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Empty cells indicate that the test was not administered.

A plus sign (+) indicates a significant effect (p < .05); a minus sign (−) indicates no effect.

a Average number of items in the two categories tested.
b Performance at chance level on the comprehension tasks.
exception of patient RT. Three of the 4 participants also exhibited mastery of grammatical gender, with the exception of RA (see below, Section 4.3). Thus, a clear dissociation between sentence-level deficits and syntactically-relevant lexical information was observed. These results show that although the ability of these participants to construct syntactic trees above VP was severely compromised, they had unimpaired lexical-syntactic information, and could construct the VP level, including the verb and its arguments, well. They could also access the grammatical gender of nouns. We can thus conclude that lexical-syntactic information is separate from the syntactic level of sentence construction.

These results thus indicate that individuals with agrammatism can have intact PAS and grammatical gender knowledge.

### 4.3. Can the two types of lexical-syntactic information be selectively impaired?

The results in Table 3 also bear on another research question: whether different types of lexical-syntactic information, in this case PAS and grammatical gender, are stored together.

A double dissociation was found between PAS and grammatical gender. One of the participants with agrammatism (RA) showed preserved PAS information and impaired grammatical gender information. Another participant with agrammatism (RT) showed the opposite pattern: her grammatical gender information was preserved but she had PAS impairment (which might be termed “aPASia”). Importantly, across all three PAS tasks, RT’s PAS errors did not just occur in sentences that included an embedded (CP) complement or sentences that required production of an embedded complement. Thus, embedding, which is known to be impaired in agrammatism, and was impaired for her as well, was not the source of her difficulty in the PAS tasks. (This pattern held also for the other agrammatic individuals who had PAS impairment – their production of CP complements was significantly worse than NP and PP complements, but their aPASia caused impairment in sentences with all the complement types. Individuals without aPASia and without agrammatism showed similar performance in the various complement types.)

Fig. 2 parses out the average performance in the various gender and PAS tasks of the two participants with agrammatism (RA, RT) who showed dissociations between PAS and grammatical gender. This double dissociation indicates that the different types of lexical-syntactic information can be selectively impaired, indicating that they are stored separately.

### 4.4. Can conceptual gender be preserved when grammatical gender is impaired?

Whereas grammatical gender of genderless objects (such as door, house, or kite) is stored only as part of the lexical-syntactic information, represented in the syntactic lexicon, the gender of nouns with a natural gender is not only grammatical but can also be accessed through semantic knowledge. Thus, it is possible that whereas grammatical gender of inanimate nouns would be affected by a damage in the syntactic lexicon, the gender of nouns with natural gender would still be accessible.

---

Table 5 - Performance of the participants with a mixed deficit in the PAS and gender tests (% correct).

<table>
<thead>
<tr>
<th>Participant</th>
<th>AL</th>
<th>ZH</th>
<th>HY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAS Verb completion in a sentence</td>
<td>48</td>
<td>74</td>
<td>63</td>
</tr>
<tr>
<td>Grammaticality judgment of PAS</td>
<td>71</td>
<td>75</td>
<td>77</td>
</tr>
<tr>
<td>Correction of the ungrammatical sentences</td>
<td>72</td>
<td>48</td>
<td>54</td>
</tr>
<tr>
<td>Sentence production to a given verb</td>
<td>75</td>
<td>75</td>
<td>87</td>
</tr>
<tr>
<td>Sentence repetition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grammatical gender Verb completion in a sentence – inanimate</td>
<td>63</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Grammaticality judgment – inanimate</td>
<td>65</td>
<td>76</td>
<td>68</td>
</tr>
<tr>
<td>Free completion of inanimate nouns in sentences</td>
<td>78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verb agreement in sentences produced with inanimate subjects</td>
<td>98</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Conceptual gender Verb completion in a sentence – animate</td>
<td>92</td>
<td>83</td>
<td>96</td>
</tr>
<tr>
<td>Grammaticality judgment – animate</td>
<td>77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verb agreement in sentences produced with animate subjects</td>
<td>98</td>
<td>98</td>
<td></td>
</tr>
</tbody>
</table>

Shaded cells indicate good performance: above 85% correct on the task. Empty cells indicate that the test was not administered.
The results in Table 3 and Fig. 3 show that conceptual gender information was preserved for all the participants who had intact semantic lexicon. The 4 agrammatic participants, the 5 participants with a phonological buffer deficit, and the 3 participants with a lexical-phonological deficit performed well on the conceptual gender tasks. Their good performance was evinced both in the structured tests of verb completion, noun completion and grammaticality judgment, and also in the test in which they were asked to produce a sentence to a given verb. When they produced a sentence with an animate subject, none of them produced any agreement error with animate nouns.

The preserved access to conceptual gender created a dissociation, with impaired grammatical gender and intact conceptual gender. This dissociation was evinced for RA, who had impaired grammatical gender but intact semantic lexicon, and also for two of the three individuals with the mixed syntactic-phonological deficit (see Table 5). AL and HY, who were impaired in the syntactic lexicon but had intact semantic lexicon, showed impaired grammatical gender but good performance with respect to conceptual gender.

Because conceptual gender is most probably a feature of the semantic lexicon (and the conceptual system), conceptual gender was impaired for SN, the participant with a lexical-semantic deficit. (Conceptual gender tests were not administered to AA, the other participant with a lexical-semantic deficit.)

The dissociation between grammatical and natural gender created an interesting pattern with respect to gender agreement, for RA, for example. Whereas RA showed impaired gender knowledge and impaired gender agreement when the agreement involved inanimate nouns (i.e., grammatical gender), he showed preserved gender agreement when the agreement involved animate nouns (i.e., conceptual gender). RA scored only 63% correct on the grammatical gender sentence completion task, but 100% correct on the parallel conceptual gender task, $\chi^2 = 12.63, p < .001$. He scored 74% correct on the grammatical gender judgment task but, again, 100% correct on the parallel conceptual gender task, $\chi^2 = 9.54, p = .002$. Similarly, he was the only participant who failed in the corrections of the phrases he had judged as ungrammatical in the grammatical gender condition, performing 64% correct, but he flawlessly corrected the ungrammatical phrases with the conceptual gender (100%). These results show that whereas RA’s syntactic machinery for agreement checking was intact, this ability could only manifest itself when he could access the gender of the subject— that is, when the subject was animate. However, when the subject was inanimate, the intact syntactic mechanism of subject–verb agreement (or noun–adjective agreement) could not lead to correct gender agreement, because RA could not determine the grammatical gender of the subject and therefore failed in agreement completion in sentences with inanimate subjects.

5. Discussion

This study explored lexical-syntactic knowledge and its relation to syntax and lexical retrieval by assessing lexical-syntactic information in individuals with syntactic and/or lexical retrieval deficits. We assessed the PAS and grammatical gender of 17 individuals with aphasia: individuals with agrammatism, a syntactic deficit, and individuals with amnesia, a lexical retrieval deficit. The lexical retrieval deficits of the amnestic participants resulted from impairments at various stages of lexical retrieval, a difference that we used to explore where in the lexical retrieval process the lexical-syntactic information is stored.

We focused on several main questions. We tried to find out, via the assessment of lexical-syntactic information in individuals with selective impairments at various stages of the lexical retrieval process, where lexical-syntactic information is stored. We also tested whether the two types of lexical-syntactic information that we tested in the current study, PAS and grammatical gender, can be selectively impaired, in order to learn whether they are stored separately. We were further interested in the relations between grammatical gender and natural gender and their intricate relations with the syntactic machinery of gender inflection. Finally, we tried to establish whether individuals who show impairments in syntactic abilities that are related to high nodes in the syntactic tree can still construct VP correctly, including the syntactically and thematically correct arguments for the verb. The dissociations found in the current study shed light on these questions. We will detail the answers these dissociations give to each of the questions below.

5.1. Lexical-syntactic information is stored in a separate syntactic lexicon

One of the main aims of this study was to find out, via the assessment of individuals with impaired lexical retrieval, where is lexical-syntactic information stored. The dissociations between deficits at different stages of the lexical retrieval process suggest a clear answer to this question. All the individuals who had a deficit at the phonological output buffer showed preserved lexical-syntactic information. This dissociation indicates that the lexical-syntactic information is not stored at the phonological output buffer. This should come as no surprise if we think about the phonological buffer as a short-term memory for phonological units. Therefore, the lexical-syntactic information is stored at one of the lexical levels. The individuals who had a deficit at the phonological output lexicon also showed preserved lexical-syntactic information. This dissociation indicates that the lexical-syntactic information is not stored at the phonological output lexicon either. If it had been stored at this stage, a deficit at the phonological output lexicon should have entailed a deficit in lexical-syntactic information too. Thus, we are left with two
options. Either lexical-syntactic information is stored in the semantic lexicon, or it is stored separately from the semantic lexicon, in a separate syntactic lexicon, located in parallel with or before the phonological output lexicon. The two participants with a deficit at the semantic lexicon could not shed light on this question, because they both showed a lexical-syntactic information impairment in addition to their lexical-semantic impairment. Such an association does not bear on whether or not the lexical-syntactic information is stored in the semantic lexicon. It might be that the semantic lexicon impairment blocked further access to the following separate syntactic lexicon, or it might be that the information is stored at the semantic lexicon, or it might even be that these two impairments, the lexical-syntactic and the lexical-semantic impairments, are unrelated but happened to occur together in these two participants.

The answer to the question of whether the lexical-syntactic information is located in the semantic lexicon or separately comes from a group of three patients demonstrating the other direction of the dissociation: a deficit in lexical-syntactic information with intact semantic lexicon. This dissociation indicates that the lexical-syntactic information is not encoded in the semantic lexicon, and the conclusion is that lexical-syntactic information is stored in a separate syntactic lexicon, distinct from the semantic lexicon.

This conclusion is in line with Miozzo and Caramazza (1997) and Nickels and Howard (2000), who also claimed, on the basis of TOT studies, that a type of syntactic information, grammatical gender, is stored separately from the semantic information. According to these researchers, the semantic representation is separately connected to syntactic information and to phonological information. The access to each of these types of information is independent. Miozzo and Caramazza (1997) base this conclusion on their findings of similar rates of correct recognition of gender and of initial phoneme in TOT states. Jescheniak and Levelt (1994) brought further evidence that Miozzo and Caramazza interpreted as indicating parallel access to the syntactic and phonological lexicons. Jescheniak and Levelt examined reaction times for gender decisions which followed a naming task. Before making the gender decision, the participants were required to name the pictures either by producing a bare noun or by producing a noun phrase (definite article + noun). A facilitatory effect for the gender decision was found only after a noun phrase. Miozzo and Caramazza suggest that this finding supports the claim that phonological information might be accessed independently of grammatical information. Namely, when a bare noun was produced (i.e., its phonology was accessed), its gender was not accessed, and thus, it did not affect the reaction times of the gender decision task as did the production of a noun phrase, which obligates access to gender information. (The suggestion of a parallel syntactic lexicon differs from the view expressed by Levelt et al., 1999 and Roelofs et al., 1998, who postulated a model in which the lemma links between the word’s meaning and phonology, i.e., a serial model in which the syntactic information precedes the phonological information).

In fact, after having established that the syntactic information is stored separately from the semantic information it makes conceptually more sense that the access from the semantic lexicon to the phonological lexicon will not be mediated by the syntactic lexicon, as it is hard to see why the access to phonological forms should depend on the existence of syntactic information.

Support for the idea of parallel access to syntactic and phonological lexicons from the semantic lexicon (as shown in Fig. 4) can also be seen in the current study. In the two production tasks, sentence production to a given verb and the sentence repetition task, there were cases in which a phonologically intact verb was produced with incorrect PAS (i.e., omission, addition, or substitution of arguments). This applied both for patient RT and for the three individuals with mixed syntactic and phonological impairments, who all had aPASia, and occasionally produced the target verb in a phonologically correct fashion but within an incorrect PAS environment.

To conclude, the findings of the current study indicate that lexical-syntactic information is stored at a separate syntactic lexicon, which is accessed in parallel to the phonological output lexicon (see Fig. 4).

Caramazza and Miozzo (1998) argued that “the lemma/lexeme distinction may be unnecessary” (p. 240. See also...
Our findings indicate the existence of a syntactic lexicon, separate from the phonological output lexicon, and hence the necessity of the distinction between a lexical-syntactic representation (lemma) and a lexical-phonological representation (lexeme). (See also Biedermann and Nickels, 2008 for evidence from homographic and heterographic homophones production for separate syntactic and phonological representations.) Therefore, our findings support a "lemma" representation, in which syntactic information is stored, as advocated by Levelt et al. (1999), Roelofs et al. (1998) and others, and at the same time determine that this lexical-syntactic representation is also coded separately from the lexical-semantic information, contrary to some perceptions of the lemma.

Another point with respect to grammatical gender information relates to its preservation in Hebrew-speaking individuals with a lexical deficit. Unlike speakers of other languages, for whom research reported knowledge of gender even when they could not access lexical-phonological information on the target word, Hebrew-speaking individuals with a lexical-phonological deficit were found in previous studies to lack gender knowledge in single-noun retrieval tasks both in TOT states (Gollan and Silverberg, 2001) and for individuals with deficits in various levels of the lexical retrieval process (Friedmann and Biran, 2003). How can this be reconciled with the current results in which three individuals with a lexical-phonological deficit showed good judgment and production of grammatical gender?

The explanation probably lies in the fact that whereas the previous studies tested access to grammatical gender at the single-noun level, gender information in the current study was tested within the syntactic context of phrases and sentences. This supports our earlier suggestion that grammatical gender is accessed only when it is needed — that is, in the context of a phrase or a sentence, when the syntactic structure requires syntactic agreement checking (Friedmann and Biran, 2003). (See also Cubelli et al., 2005; La Heij et al., 1998; Levelt et al., 1999; Schriefers, 1993; Schriefers and Jescheniak, 1999, for arguments regarding a difference between access to gender in syntactic contexts and in bare nouns.)

Some interesting open questions arise from the concept of a separate syntactic lexicon. For example: what it means to have aPASia, or, in general, a deficit in lexical-syntactic information — is this a deficit affecting the information itself, a deficit in accessing this information, or a deficit in implementing it into the syntactic representation. Another question that arises is where does the output of the syntactic lexicon go. In the model we suggested in Fig. 4, the syntactic lexicon is only connected to the phonological output lexicon. However, it may well be that it is connected to a component that is responsible to sentence structure building. Moreover, in line with linguistic theory that now argues that several morpho-syntactic operations do not take place in narrow syntax, but rather in the phonological component (Chomsky, 1995, 2001), the syntactic lexicon may be directly connected to the phonological output buffer.

5.2 Different types of lexical-syntactic information are stored separately

The results also shed light on the representation of different types of lexical-syntactic information. A double dissociation was found between the two types of lexical-syntactic information studied here. One individual with agrammatism showed intact PAS information and impaired grammatical gender information, whereas another individual with agrammatism showed the reversed pattern — impaired PAS information and intact grammatical gender information. This dissociation shows that different types of lexical-syntactic information can be impaired selectively (at least the two types examined in this study), indicating that they are stored separately.

5.3 Grammatical and conceptual gender are dissociable

Finally, a dissociation between impaired grammatical gender (of inanimate nouns) and preserved conceptual gender (of animate nouns) was found for one of the agrammatic participants, RA, as well as for two individuals with a mixed syntactic-phonological deficit. These participants had poor grammatical gender but good lexical-semantics. A possible explanation for this dissociation is that when a patient has a deficit in the syntactic lexicon that impairs access to grammatical gender, he cannot determine the gender of inanimate nouns, which only have arbitrary, grammatical gender. However, if his semantic lexicon and conceptual system are unimpaired, the gender of animate nouns may still be accessible for him. He would be able to rely on conceptual-semantic information to infer the gender of animate nouns. A consequence of this situation is that inflection that relies solely on the identification of grammatical gender in the syntactic lexicon, such as agreement with inanimate nouns, would be impaired following a deficit in the syntactic lexicon. However, when considering animate nouns, the inflection status would be different. When the morpho-syntactic processing of agreement is intact, the inflection of animate nouns is expected to be fine. This is exactly the picture that emerged from our participants’ inflection abilities: RA, for example, made errors on verbal inflection when the verb had to agree with an inanimate noun, but inflected the verb correctly for gender when the subject was animate.

One implication of this finding is that grammatical gender is stored separately from semantic aspects of gender. This may put lexical-syntactic information, or at least grammatical gender information, at a stage following the semantic lexicon. This explains why, when the semantic lexicon is impaired further access to the syntactic lexicon is blocked, but when the syntactic lexicon is impaired, patients can still access the semantic lexicon to retrieve semantic information that is relevant for the gender of the item. Not surprisingly, SN, who was impaired at the semantic lexicon, showed impairment in conceptual gender knowledge as well, and could not use conceptual-semantic information regarding the gender of animate nouns to determine their grammatical gender.

Another implication of this finding regards the way the syntactic ability of gender agreement should be assessed in individuals with agrammatism, for example. The results indicate that when assessing gender agreement inflection, it is necessary to examine animate (and specifically, nouns with a clear natural gender), rather than inanimate, nouns. An agreement test that includes inanimate nouns may create the incorrect impression of impaired agreement ability when administered to a patient with intact morpho-syntactic agreement ability and impaired grammatical gender.
information. Giving such a patient an agreement test with only animate nouns would allow her to show her intact agreement ability by using the semantic cues for gender that exist in the animate nouns. Otherwise, individuals who have intact agreement but impaired grammatical gender information can fail in an agreement task, a failure that might lead to a wrong conclusion as to their syntactic agreement ability.

5.4. PAS can be intact in agrammatism: lexical-syntactic information is separate from higher-level syntax

A dissociation was found between impaired syntax and preserved lexical-syntactic information. This dissociation supports the view that lexical-syntactic information is stored separately from syntactic knowledge of sentence construction, and that there are two separate abilities—one that constructs the syntactic tree up to is highest nodes and parses syntactic movement, the other encoding the syntactic environments in which a verb can appear. Whereas syntax uses lexical-syntactic information for structure building (specifically, for building the VP), structure building can be impaired when lexical-syntactic information is intact. This accords with results from imaging studies indicating that whereas the left IFG (inferior frontal gyrus, Broca’s area, Brodmann areas 44/45) is typically related to the processing of syntax (in fMRI and lesion studies of individuals with agrammatism, Ben-Shachar et al., 2004; Grodzinsky, 2000), other areas are related to the processing of lexical-syntactic information. Specifically, the left posterior STG (left superior temporal gyrus, Wernicke’s area) was found to be involved in PAS processing in neuroimaging (Shetreet et al., 2007, 2010a) and lesion studies (Shapiro et al., 1991, 1993). Other areas, BA 9 and BA 46, the precuneus and bilateral anterior MTG (middle temporal gyrus), also showed activation related to PAS information in neuroimaging studies (Shetreet et al., 2007, 2009a).

This dissociation, between impaired syntax at the sentence level and preserved lexical-syntactic information, also bears on constraint-based accounts of language processing that claim that syntactic processing is based only on lexical representations (e.g., MacDonald et al., 1994). MacDonald et al. (1994) claim that the information inherent to lexical items (including probabilistic information, argument structure, lexical-semantic constraints, and even phrase structure fragments) is used predictively to suggest the analysis of sentence input. Such lexicalist approaches argue that syntactic processing is simply the result of concatenated lexical processing (see Shapiro et al., 2003 for a review). Had syntax been only a reflection of lexical information, we would not expect dissociations between impaired syntactic ability and intact lexical-syntactic information.

This is not to say that PAS is not an important part of sentence construction. On the contrary, Shapiro et al. (2003), for example, showed that the initial stage of sentence processing parses input based on lexical categories and the skeleton of a verb’s argument structure, deriving a shallow representation of phrase structure and syntactic categories. This finding indicates that PAS information is a central axis in sentence processing. Thus, a deficit in PAS information (aPASia) will indeed affect sentence construction, but the manifestation of this deficit will be different from the deficit in agrammatism. In aPASia we expect errors of substitution, omission, and addition of arguments (Biran and Friedmann, 2008), which are not the characteristic errors of the agrammatism, but not, for example, a deficit in verb movement to the second sentential position.

An important finding of the current study is that agrammatic participants had intact PAS information. These findings are perfectly consistent with the studies of Shapiro and his colleagues (Shapiro et al., 1993; Shapiro and Levine, 1990), who found, using response-time measurements in online comprehension tasks, that individuals with agrammatic Broca’s aphasia show the same effect of PAS complexity as healthy adults, indicating that they have intact PAS knowledge. The results also support previous grammaticality judgment studies (Linebarger et al., 1983) on agrammatism. Prima facie, Shapiro et al.’s results, Linebarger et al.’s results, as well as the results of the current study do not seem to be consistent with studies that examined agrammatic individuals’ production of verbs with different PAS frames and reported a verb complexity effect: participants made more errors with verbs that have a more complex PAS (Kim and Thompson, 2000; Thompson et al., 1997a). However, two considerations—one methodological-clinical, the other logical—suggest that these production data cannot be taken to indicate a deficit in PAS in agrammatism, and even that they can be taken to demonstrate spared PAS. On the methodological-clinical side, the production studies required an oral response, which might be compromised because of the participants’ deficit in embedded-sentence production (sentences with a CP argument) and their word retrieval deficit. In the current study, we used also tasks that did not require production of full sentences, or even did not require an oral response at all, and used various types of complements, to prevent interference from other deficits, such as impaired embedded-sentence production and word retrieval. Consequently, the preserved PAS knowledge of the agrammatic participants emerged. On the logical-theoretical side, it can be argued that the studies by Kim and Thompson and Thompson et al. actually indicate preserved PAS knowledge in agrammatism. These authors report that the complexity of the verb affected agrammatic participants’ ability to produce verbs and sentences. Had these participants been impaired in PAS knowledge, no effect of the verbs’ PAS should have been found. The fact that participants’ responses were influenced by the verbs’ PAS suggests that their deficit lay not in PAS knowledge itself but in their ability to insert the verb into a syntactic construction. In this context, it is important to notice that the “optional three-place verbs” in Thompson et al.’s study take a CP complement as one of their options, thus causing a difficulty in production not because of the type of verb, but because of the participants’ impaired ability to produce CP constructions (Friedmann, 2001, 2006). Support for the unimpaired PAS knowledge of the agrammatic participants in Kim and Thompson’s study comes from their finding that all the participants in their study succeeded in a task requiring them to judge the grammaticality of sentences with missing and redundant arguments (6 participants scored above 90% correct and one scored 83% correct). Kim and Thompson explain this preserved performance by noting that only simple canonical sentences were used in this judgment task, and that
“only” subcategorization violations were involved (rather than sentences with Wh-movement). They indicate that “The grammaticality judgment task employed... minimally requires the subjects to access the lexical-syntactic entry of the verb at the lemma level” (p. 15). Indeed, if one is interested in subcategorization and in the lexical-syntactic ability of agrammatic patients, then their study indicates, like ours and like Shapiro’s and Linebarger’s, that access to lexical-syntactic knowledge can be intact in agrammatism.

The finding that individuals with agrammatism, who have great difficulty in producing embedded sentences and sentences with movement and in comprehending sentences derived by movement, can have unimpaired lexical-syntactic information – is very important for treatment. It suggests that treatment of syntactic movement, for example, can rely on the individual’s intact lexical-syntactic information – and specifically, on the ability to identify the roles of the arguments each verb in a sentence selects. This strategy has indeed been used in treatment by Shapiro, Thompson, and colleagues with promising results (Shapiro and Thompson, 2006; Thompson and Shapiro, 1995; Thompson et al., 1996, 1997b, 1998; and see also Levy and Friedmann, 2009, for a description of a treatment based on the intact PAS knowledge of a child with syntactic-SLI [Specific Language Impairment]).

To summarize: Rapp and Goldrick (2006) have emphasized the importance of investigating the relations between word production and sentence production. This study takes one step toward this goal, by investigating the relations between the word level and the sentence level. Knowledge about these relations can assist in planning a suitable therapy for each individual with aphasia, according to his or her deficit.

Specifically, our findings indicate that neither a syntactic deficit nor a lexical retrieval deficit automatically implies that an individual with aphasia has a deficit in lexical-syntactic knowledge. We have shown that individuals can have a severe syntactic impairment or a (phonological) lexical retrieval impairment and still normally access knowledge about the complements each verb takes and about the grammatical gender of nouns.

Acknowledgements

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Appendix A

Background information on the participants

<table>
<thead>
<tr>
<th>Participant</th>
<th>Diagnosis</th>
<th>Sex</th>
<th>Hand</th>
<th>Age</th>
<th>Native language</th>
<th>Education (years)</th>
<th>Etiology</th>
<th>Time post onset</th>
<th>Plegia/parexis</th>
<th>Lesion site</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA</td>
<td>Agrammatism</td>
<td>M</td>
<td>Right</td>
<td>32</td>
<td>Hebrew</td>
<td>12</td>
<td>TBI</td>
<td>13 years</td>
<td>Right hemiplegia</td>
<td>Left temporo-parietal hematoma due to a left frontal contusion.</td>
</tr>
<tr>
<td>RT</td>
<td>Agrammatism</td>
<td>F</td>
<td>Right</td>
<td>58</td>
<td>French (Hebrew 44 years)</td>
<td>8</td>
<td>CVA</td>
<td>7 years</td>
<td>Right hemiplegia</td>
<td>Left ischemic infarct.</td>
</tr>
<tr>
<td>AE</td>
<td>Agrammatism</td>
<td>M</td>
<td>Right</td>
<td>63</td>
<td>Hebrew</td>
<td>12</td>
<td>CVA</td>
<td>4 years</td>
<td>–</td>
<td>Right temporo-parietal ischemic infarct. Subcortical hypodense area. Several left frontal and temporal lacunar hypodense areas.</td>
</tr>
<tr>
<td>GR</td>
<td>Agrammatism</td>
<td>F</td>
<td>Right</td>
<td>37</td>
<td>Hebrew</td>
<td>12</td>
<td>CVA</td>
<td>8 years</td>
<td>Right hemiparesis</td>
<td>Left ischemic infarct involving temporo-parietal areas.</td>
</tr>
<tr>
<td>YD</td>
<td>Phonological buffer</td>
<td>M</td>
<td>Right</td>
<td>46</td>
<td>Hebrew</td>
<td>11</td>
<td>CVA</td>
<td>1.5 months</td>
<td>Right hemiparesis</td>
<td>Ischemic infarct in the territory of left MCA. Low density in left parietal area.</td>
</tr>
<tr>
<td>ND</td>
<td>Phonological buffer</td>
<td>M</td>
<td>Left</td>
<td>60</td>
<td>Hebrew</td>
<td>16</td>
<td>CVA</td>
<td>22 months</td>
<td>–</td>
<td>Ischemic infarct in the territory of left MCA.</td>
</tr>
<tr>
<td>MK</td>
<td>Phonological buffer</td>
<td>M</td>
<td>Left</td>
<td>38</td>
<td>Hebrew</td>
<td>12</td>
<td>CVA</td>
<td>9 months</td>
<td>Right hemiparesis</td>
<td>Left parietal hemorrhage and left subarachnoid hemorrhage. Left temporal craniotomy for evacuation of hemorrhage.</td>
</tr>
</tbody>
</table>

(continued on next page)
Appendix B
A detailed assessment of the syntactic and lexical abilities of the participants

B1 Tests for inclusion in the syntactic impairment group

Comprehension of reversible subject and object relative clauses was assessed by a sentence-picture matching test (BAFLA ZT). The test includes 90 semantically reversible sentences: 30 sentences with subject relative clauses (Show me the woman that is drawing the girl), 30 sentences with object relative clauses (Show me the girl that the woman is drawing), and 30 filler simple subject-verb-object (SVO) sentences (e.g., The woman is drawing the girl). All sentences include characters of the same gender and number. The participants heard a sentence as many times as they needed. They were shown two pictures – one where the roles matched the sentence and one where the roles were reversed – and were asked to point to the matching picture (see Friedmann and Shapiro, 2003 and Fattal et al., 2011 for details on this test).

Comprehension of Wh-questions was also assessed using a picture selection task (BAFLA ST). This test includes 120 questions: 30 which-subject questions (Which girl is kissing the grandma?), 30 which-object questions (Which grandma is the girl kissing?), 30 who-subject questions (Who is kissing the grandma?), and 30 who-object questions (Who is the girl kissing?). The experimenter asked a question while the participant was looking at a picture. The participant was then requested to point at the figure that answered the question, selecting one of three

<table>
<thead>
<tr>
<th>Participant</th>
<th>Diagnosis</th>
<th>Sex</th>
<th>Hand</th>
<th>Age</th>
<th>Native language</th>
<th>Education (years)</th>
<th>Etiology</th>
<th>Time post onset</th>
<th>Plegia/paresis</th>
<th>Lesion site</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG</td>
<td>Phonological buffer</td>
<td>M</td>
<td>Right</td>
<td>63</td>
<td>Hebrew</td>
<td>17</td>
<td>CVA</td>
<td>3 months</td>
<td>–</td>
<td>Left ischemic infarct.</td>
</tr>
<tr>
<td>BT</td>
<td>Phonological buffer</td>
<td>F</td>
<td>Right</td>
<td>53</td>
<td>Hebrew</td>
<td>12</td>
<td>CVA</td>
<td>9 months</td>
<td>Right hemiplegia</td>
<td>Ischemic infarct in the territory of left ACA and MCA. Large hypodense area in the left frontal lobe.</td>
</tr>
<tr>
<td>AO</td>
<td>Phonological lexicon</td>
<td>M</td>
<td>Mixed</td>
<td>73</td>
<td>Hebrew</td>
<td>19</td>
<td>CVA</td>
<td>1 month</td>
<td>–</td>
<td>Ischemic infarct in the territory of left MCA involving temporoparietal areas.</td>
</tr>
<tr>
<td>SM</td>
<td>Phonological lexicon</td>
<td>M</td>
<td>Right</td>
<td>49</td>
<td>Hebrew</td>
<td>12</td>
<td>CVA</td>
<td>3 months</td>
<td>–</td>
<td>Left periventricular white matter lesion. Subcortical hypodense area.</td>
</tr>
<tr>
<td>BP</td>
<td>Phonological lexicon</td>
<td>F</td>
<td>Right</td>
<td>23</td>
<td>Hebrew</td>
<td>12</td>
<td>CVA</td>
<td>3 months</td>
<td>Right hemiparesis</td>
<td>Left ischemic infarct involving temporoparietal areas.</td>
</tr>
<tr>
<td>SN</td>
<td>Semantic lexicon</td>
<td>M</td>
<td>Right</td>
<td>62</td>
<td>Hebrew</td>
<td>8</td>
<td>CVA</td>
<td>2.5 months</td>
<td>–</td>
<td>Left ischemic infarct involving temporoparietal areas.</td>
</tr>
<tr>
<td>AL</td>
<td>Phonological lexicon + Phonological buffer + Agrammatism</td>
<td>M</td>
<td>Right</td>
<td>56</td>
<td>Hebrew</td>
<td>12</td>
<td>TBI</td>
<td>7 months</td>
<td>–</td>
<td>Left ischemic infarct involving frontal and parietal areas. Subarachnoid and subdural hemorrhage. Left fronto-temporal craniotomy for evacuation of hemorrhage.</td>
</tr>
<tr>
<td>ZH</td>
<td>Phonological lexicon + Phonological buffer + Agrammatism</td>
<td>M</td>
<td>Left</td>
<td>55</td>
<td>Hebrew</td>
<td>16</td>
<td>CVA</td>
<td>13 months</td>
<td>–</td>
<td>Left ischemic infarct involving temporoparietal areas.</td>
</tr>
<tr>
<td>HY</td>
<td>Phonological lexicon + Agrammatism</td>
<td>F</td>
<td>Right</td>
<td>37</td>
<td>Hebrew</td>
<td>15</td>
<td>CVA</td>
<td>8 years</td>
<td>Right hemiplegia</td>
<td>Left ischemic infarct involving fronto-temporal areas. Hypodense area in the basal ganglia.</td>
</tr>
</tbody>
</table>
figures. Each picture included three figures: two of the same type, which differed in at least one feature (a blue and a purple elephant; a blond and a red-headed girl) and a third figure of a different kind. In the picture, the first figure was performing an action on the second, and the second figure was performing the same action on the third figure, which was of the same type of the first one. (A dark dog biting a cat, who is biting a light-colored dog, see Friedmann and Novogrodsky, 2011, and Friedmann and Szterman, 2011 for details on this test).

For both the relative clause and the Wh-question comprehension tasks, we were looking for individuals who show a clear indication of a deficit in non-canonical structures (or, under syntax-based theories, a deficit in movement derived sentences in which the object crosses the subject). Such a deficit manifests in these tests in impaired comprehension of the non-canonical structures — relative objects and object questions (at least which-object questions) — and better comprehension of subject relatives and subject questions, which can be comprehended on the basis of the canonical order of arguments, in which the agent precedes the theme. The relatively good comprehension of the canonical sentences also indicates the participants’ comprehension of the task, the words in the sentences, and the pictures.

The embedded-sentence repetition test includes 20 sentences: 10 with sentential complements (The-doctor knew that-the-child sneezed, which is a 4-word sentence in Hebrew) and 10 with semantically reversible object relatives (I-saw the-doctor that-the-child knew, also 4 words). The participants were asked to repeat each sentence immediately after hearing it. (See Friedmann, 1999, 2001 for a description of this test.)

The verb movement repetition test includes 40 sentences: 20 with verb movement to second position in the sentence, following a temporal adverb (AdvVSO), and 20 without verb movement (AdvSVO). The participants were asked to repeat the sentences. (See Friedmann, 2006 for this test and its rationale.)

Relative clause production was examined with a relative clause elicitation task (BAFLA ZIBUV). The task includes 20 target sentences (10 subject relatives and 10 object relatives), elicited by 10 pairs of drawings. The experimenter described the two pictures in simple sentences, and the participants were then asked to depict each figure using a single sentence, starting, for example, with “This is the girl...”. Some of the participants were also tested using another relative clause elicitation task (BAFLA ADIF), which includes six target subject relatives and six target object relatives. In this test, they were told about two people and were asked which one they would rather be, starting with “I would rather be the woman...”. (See Friedmann, 2001; Friedmann and Szterman, 2006; and Novogrodsky and Friedmann, 2006 for details on these two tests.)

The verb inflection completion test (BAFLA VE) includes 24 sentences. Each sentence included two parts. The first part included a verb in infinitival form, and in the second part a verb was missing. The participants were asked to insert the same verb in the empty space, in the correct tense and agreement inflection (e.g., Grandma wanted to draw, so she took a charcoal and ____ [drew-past-3rd-sg-fem]). (See Friedmann and Grodzinsky, 1997 for details on this test.)

Because relative clauses and embedded sentences without movement involve the highest node in the syntactic tree, CP, assessing their production indicates whether a participant can access CP or not. When the verb moves to second position in the sentence (etmol axla ha-yalda xumus, lit.- yesterday ate the-girl hummus), it moves to CP; hence, sentences involving this type of movement also serve as an indication for the availability of the CP node. Correct tense inflection relates to another functional node, TP. Failure to inflect the verb correctly for tense can thus indicate inaccessibility of TP.

B2 Tests for inclusion in the lexical impairment group

The SHEMESH naming test includes 100 pictures of objects of various semantic categories. The object names are one to four syllables long, with ultimate and penultimate stress and with various first phonemes; they include both masculine and feminine nouns, with regular and irregular gender morphology. The frequency of the nouns ranges from 2.39 to 6.84 on a scale of 1—7 (M = 4.90, SD = 1.09). The average performance of adults without a language deficit in this test is 97% correct naming.

We included in the study only participants whose conceptual level was intact. To rule out a conceptual deficit, we analyzed the error types in the SHEMESH naming test (looking for paraphasias that were semantically and phonologically unrelated to the target word) and administered a picture association test. The picture association test includes 35 items. The target picture is presented with two additional pictures. The items shown in the additional pictures are semantically related to each other, but only one relates to the target item, for example, a bottle of wine, presented with grapes and apples; an egg, presented with a hen and a dog. Participants had to point to the picture that was semantically more closely related to the target. Intact performance in the picture association test (no more than one error) and absence of unrelated paraphasias in naming were taken to rule out a conceptual deficit.

A lexical-semantic deficit was diagnosed by semantic paraphasias in naming (errors that are semantically related to the target word) and difficulty in various semantic tasks: semantic verbal fluency, synonym judgment, a word association test, and a spoken/written word-picture matching test (PALPA 47/48, Kay et al., 1992; Hebrew version by Gil and Edelstein, 2001). These tasks are described below.

In the semantic verbal fluency task, participants were asked to say as many names of clothes and as many names of wild animals as they could think of, each in 1 min.

The synonym judgment test includes 37 pairs of words, of which 16 pairs are synonyms (e.g., maxal-rikud ‘dance’), 16 are semantically related but not synonyms (sky-stars), and 5 are non-synonym (box-table). The participants were asked to judge for each pair whether the two words were synonyms. In the results we report the scores in the judgment of the unrelated non-synonym pairs.

The word association test includes 35 items. Each target word is presented in writing with two other written words, both words are semantically related to each other but only one is closely related to the target (e.g., pot—{soup, cake}; cold—{winter, summer}). Twenty five of the words depict imageable nouns that also appear in the picture association test, and 10 items are abstract nouns and adjectives. The participants were asked to point to the word related to the target word.
In the spoken/written word-picture matching tests (PALPA 47/48), a word is presented orally or in written form along with five pictures, and the participant is asked to point to the picture that matches the word. The four non-matching distracter pictures in each set are: semantically related to the target, semantically distant from the target, visually similar to the target, and unrelated to the target. The spoken and written tests include the same 40 target words and the same distracters.

A phonological deficit, at the phonological output lexicon or the phonological output buffer, was diagnosed by phonological paraphasias in naming (errors that are phonologically related to the target word) and difficulty in a phonological verbal fluency task (naming words starting with m and words starting with d, each in 1 min). To further distinguish between lexical and buffer deficits, we also tested word and nonword repetition (25 words and 30 nonwords, respectively, from the BLIP battery for the assessment of phonological abilities, Friedmann, 2003), and nonword reading (30 nonwords, from the TILTAN battery for the diagnosis of dyslexias, Friedmann and Gvion, 2003).

B3 Elaborated results and explanations about the diagnosis of the lexical impairment source

The tests in Section 2.1.2 summarized the deficit of each of the participants. In this Appendix we bring the more detailed results and considerations for the ascription of a locus of deficit to each participant’s performance. According to the results, presented in Table 2, two participants (SN, AA) were diagnosed with a lexical-semantic deficit. They had difficulty in the word-picture matching test, in which they produced mainly semantic errors — close and distant. SN performed at chance level on the synonym judgment test. Both could not name any picture in the naming test: SN produced semantic and unrelated paraphasias, and AA usually could not produce any response at all. Neither of them could retrieve even a single item on the semantic fluency task. In the picture association test SN’s performance was good (he had only one error), and AA’s performance was slightly below the threshold of preserved performance, with 3 errors (still considerably above chance level). AA’s slightly low performance in the pictures associations test and the existence of unrelated paraphasias in SN’s naming might indicate an involvement of a mild conceptual deficit for these two participants.

Three participants (AO, SM, BP) were diagnosed with a lexical-phonological deficit. They performed flawlessly in the associations test, in the word-picture matching test and in the synonym judgment test. AO and BP, who were tested on the fluency tasks, could retrieve more words on the semantic fluency task than on the phonological fluency task. The three of them produced semantic paraphasias in addition to phonological paraphasias (SM produced more semantic than phonological paraphasias) (see Caramazza and Hillis, 1990 and Howard and Gatehouse, 2006 regarding the existence of semantic paraphasias in a lexical-phonological deficit). Finally, the three participants showed a frequency effect in naming, an effect ascribed to the phonological output lexicon, but not a length effect or a syllable frequency effect, which are related to the phonological output buffer. Their performance in the word and nonword repetition tests was good. Their good nonword repetition indicates, in line with the effect analyses, that their deficit resides in the phonological output lexicon rather than in the phonological output buffer.

Five participants (YD, ND, MK, AG, BT) were diagnosed with a phonological buffer deficit. They performed flawlessly in the associations test, in the word-picture matching test and in the synonym judgment test. YD and ND, who were tested on the fluency tasks retrieved more words on the semantic fluency task than on the phonological fluency task. In the naming test and in spontaneous speech, they produced mainly phonological errors — many of them approximations: conduit d’approche and metatheses — and only few semantic errors. They were the only participants who produced only faithful approximations. A length effect was found for 3 participants (YD, MK, AG) and a syllable frequency effect was found for 4 them (YD, MK, AG, BT). ND had many hesitation responses and did not produce enough phonological errors to allow for a reliable assessment of syllable frequency effect and length effect on his errors. A lexical frequency effect, which is related to the phonological lexicon, was not found for 4 of the participants (ND, MK, AG, BT). The performance of these 5 participants in the nonword reading and nonword repetition tests was very poor. Two of the participants with a phonological buffer deficit (ND, MK) were tested with phonological working memory tests (FriGvi Battery for the Assessment of Working Memory; Friedmann and Gvion, 2002) by Friedmann and Gvion (2007) and Gvion and Friedmann (2008) and were found to have significantly shorter phonological working memory spans compared with healthy controls, a finding that supports the conclusion that they have a phonological buffer deficit. In addition, BT had a morphological deficit in production. This deficit was demonstrated in tasks of prepositions completion, reading of prepositions and determiners, reading and repetition of morphologically complex words, and in the production of inflected verbs. The existence of a morphological deficit in production also supports a deficit at the level of the phonological output buffer (Dotan and Friedmann, 2007).

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