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PROCEEDINGS OF THE ICGL12
ΠΡΑΚΤΙΚΑ ΤΟΥ ICGL12

Thanasis Georgakopoulos, Theodossia-Soula Pavlidou, Miltos Pechlivanos, Artemis Alexiadou, Jannis Androutsopoulos, Alexis Kalokairinos, Stavros Skopeteas, Katerina Stathi (Eds.)

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Στη μνήμη του Gaberell Drachman (†10.9.2014)
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και την αγάπη τους για την ελληνική γλώσσα

ΣΗΜΕΙΩΜΑ ΕΚΔΟΤΩΝ

Το 12ο Διεθνές Συνέδριο Ελληνικής Γλωσσολογίας (International Conference on Greek Linguistics/ICGL12) πραγματοποιήθηκε στο Κέντρο Νέου Ελληνισμού του Ελεύθερου Πανεπιστημίου του Βερολίνου (Centrum Modernes Griechenland, Freie Universität Berlin) στις 16-19 Σεπτεμβρίου 2015 με τη συμμετοχή περίπου τετρακοσίων συνέδρων απ᾽ όλον τον κόσμο.

Την Επιστημονική Επιτροπή του ICGL12 στελέχωσαν οι Θανάσης Γεωργακόπουλος, Θεοδοσία-Σούλα Παυλίδου, Μίλτος Πεχλιβάνος, Άρτεμις Αλεξιάδου, Δώρα Αλεξοπούλου, Γιάννης Ανδρουτσόπουλος, Αμαλία Αρβανίτη, Σταύρος Ασημακόπουλος, Αλεξάνδρα Γεωργακοπούλου, Κλεάνθης Γκρώμαν, Σαβίνα Ιατρίδου, Mark Janse, Brian Joseph, Αλέξης Καλοκαιρινός, Ναπολέων Κάτσος, Ευαγγελία Κορδώνη, Αμαλία Μόζερ, Ελένη Μπουτουλούση, Κική Νικηφορίδου, Αγγελική Ράλλη, Άννα Ρούσσου, Αθηνά Σιούπη, Σταύρος Σκοπετέας, Κατερίνα Στάθη, Μελίτα Σταύρου, Αρχόντω Τερζή, Νίνα Τοπιντζή, Ιάνθη Τσιμπλή και Σταυρούλα Τσιπλάκου.

Την Οργανωτική Επιτροπή του ICGL12 στελέχωσαν οι Θανάσης Γεωργακόπουλος, Αλέξης Καλοκαιρινός, Κώστας Κοσμάς, Θεοδοσία-Σούλα Παυλίδου και Μίλτος Πεχλιβάνος.

Οι δύο τόμοι των πρακτικών του συνεδρίου είναι προϊόν της εργασίας της Εκδοτικής Επιτροπής στην οποία συμμετείχαν οι Θανάσης Γεωργακόπουλος, Θεοδοσία-Σούλα Παυλίδου, Μίλτος Πεχλιβάνος, Άρτεμις Αλεξιάδου, Γιάννης Ανδρουτσόπουλος, Αλέξης Καλοκαιρινός, Σταύρος Σκοπετέας και Κατερίνα Στάθη.

Παρότι στο συνέδριο οι ανακοινώσεις είχαν ταξινομηθεί σύμφωνα με θεματικούς άξονες, τα κείμενα των ανακοινώσεων παρατίθενται σε αλφαβητική σειρά, σύμφωνα με το λατινικό αλφάβητο· εξαίρεση αποτελούν οι εναρκτήριες ομιλίες, οι οποίες βρίσκονται στην αρχή του πρώτου τόμου.

Η Οργανωτική Επιτροπή του ICGL12

ΠΕΡΙΕΧΟΜΕΝΑ

SYNTACTIC COMPREHENSION IN APHASIA AND ITS RELATIONSHIP TO WORKING MEMORY DEFICITS

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Περίληψη

Στην παρούσα μελέτη εξετάζεται η συντακτική κατανόηση σε άτομα με αφασία και η σχέση της με τη μνήμη εργασίας. Παρουσιάζονται αποτελέσματα από γλωσσικές και μη γλωσσικές δοκιμασίες που χορηγήθηκαν σε τρεις ομάδες ατόμων με αφασία. Τα πορίσματα δείχνουν ότι (α) τα ελλείμματα στη συντακτική κατανόηση των σημασιολογικά αναστρέψιμων δομών με μη κανονική σειρά όρων παρατηρούνται όχι μόνο σε άτομα με αφασία τύπου Broca αλλά και σε ομιλητές με άλλους τύπους αφασίας και (β) τα ελλείμματα στη συντακτική κατανόηση συσχετίζονται με ελλείμματα στη λεκτική μνήμη εργασίας ανεξάρτητα από τον τύπο αφασίας, αλλά δεν συσχετίζονται με ελλείμματα στη μη λεκτική μνήμη εργασίας.

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Keywords: agrammatic aphasia, anomic aphasia, syntactic comprehension, working memory, object movement

1. Introduction

Aphasia is an acquired language disorder that has attracted much attention within theoretical linguistics over the past thirty years. The interaction of the two disciplines, theoretical linguistics and aphasiology, presented researchers novel ways to view language impairment as well as the normal cognition. The study of aphasia through linguistic theory offered researchers a deeper insight into the nature of language breakdown and allowed them to provide a characterization of the observed language deficits in terms of damage to underlying structures. At the same time, studies of aphasia contributed to a better understanding of the human unimpaired linguistic capacity (for an extended discussion of the interaction between linguistic theory and aphasiology see Levy & Kavé 1999, Avrutin 2001).

Agrammatism is a case of a more general linguistic impairment known as Broca's aphasia and has attracted most of the attention among researchers interested in the relationship between language deficits and linguistic theory. Broca's agrammatic aphasia is characterized by an effortful, "telegraphic" pattern of speech production, which includes frequent omission of functional categories, such as determiners, tense, complementizers. The nature of the deficit has been shown to be rather selective and has given rise to a number of interpretative hypotheses that attribute it to speakers' lack of grammatical knowledge (so-called 'representational' accounts or 'structural deficit hypothesis'; e.g., Friedmann & Grodzinsky 1997, Wenzlaff & Clahsen 2004). Psycholinguistic research in the 70's and 80' though showed that apart from the production deficit, agrammatic aphasia is also characterized by a comprehension deficit, which affects "semantically reversible" sentences with non-canonical word order (e.g., passive sentences, object clefts, object relative clauses etc.; Caramazza & Zurif 1976, Grodzinsky 1984). This unique pattern of comprehension was termed 'asyntactic' comprehension and ever since lead to several hypotheses that attempted to provide an explanation for its selective nature as well (e.g., Grodzinsky 1984, Mauner et al. 1993). However, some researchers have challenged the claim that the comprehension deficit in "semantically reversible" sentences with non-canonical word order is a pattern observed only in speakers with agrammatic aphasia (e.g., Caplan 1995). Moreover, a number of studies have shown that grammatical deficits co-exist with memory deficits in agrammatic aphasia (e.g., Caplan & Waters 1999, Caspari et al. 1998) and, thus, have reinforced those claims in the aphasiological literature that attribute the linguistic deficit of the speakers with agrammatic aphasia to their inability to implement grammatical knowledge due to lack of processing resources (so-called 'processing' accounts or 'processing limitation hypothesis'; e.g. Avrutin 2000, 2006, Grillo 2009). The within- and between-individual variability also observed across various studies has further complicated the picture, as it constitutes a problem for the 'definition' as well as the interpretative accounts of agrammatism (particularly, the representational ones).

The present paper, which is part of a broader study on grammatical deficits in aphasia and their relationship to non-linguistic deficits, addresses two questions: (a) Is the syntactic comprehension deficit affecting "semantically reversible" sentences with non-canonical word order a pattern observed only in speakers diagnosed with Broca's agrammatic aphasia or is it observed in speakers diagnosed with other aphasia types as well? (b) Do disorders of syntactic processing in sentence comprehension correlate with the speakers' working memory abilities?

2. Aphasia

2.1 Definition and types

Aphasia is an acquired language disorder usually caused by damage to an area (or some areas) of the left cerebral hemisphere. It can be caused by a cerebro-vascular accident (CVA), a traumatic brain injury (TBI), infections such as meningitis or encephalitis, or as the result of the existence or the removal of a brain tumor (De Roo 1999: 1, Mesulam 2000: 296). Aphasia is characterized by impairments in the production and comprehension of speech, by word-finding difficulties, by difficulties in reading and writing, etc. Deficits in aphasia can affect all linguistic levels (i.e., phonology, morphology, syntax, and semantics) to varying degrees depending on the site and the severity of the brain injury (Harley 2001: 23).

Despite the fact individuals with aphasia differ with respect to the kind of symptoms they show and the severity of their language disorder (from mild, to moderate and severe disorders), some *syndromes* can be distinguished that share a number of symptoms. The main split is between *fluent* and *non-fluent* syndromes, with fluency being categorized as the ability to express five or more words uninterrupted (Goodglass et al. 2001: 67). Although many different types of aphasia have been described within this split, the most widespread classification identifies two basic categories: *non-fluent aphasia* or *Broca's aphasia* and *fluent aphasia* or *Wernicke's aphasia*, each one of which has been associated with different neurological as well as linguistic characteristics (for different classifications see Goodglass 1993, Benson & Ardila 1996, Dronkers & Larsen 2001).

In Broca's aphasia, the brain damage is localized in the *frontal lobe* (typically Brodmann's areas 44 and 45) and the resulting speech is *non-fluent*, but language comprehension is relatively well-preserved. The speech of individuals with Broca's aphasia is described as "slow, deliberate and effortful" (Obler & Gjerlow 1999: 39) with "limited vocabulary, restricted grammar and awkward articulation" (Goodglass & Kaplan 1983, Goodglass et al. 2001: 61). They use one or two word utterances and their attempts to generate full sentences fail due to lack of syntactic support and poor naming (Goodglass et al. 2001: 62). In Wernicke's aphasia, the brain damage is localized in the posterior part of the *superior temporal gyrus*, the so-called Brodmann's area 22), and the resulting speech is *fluent* and characterized by *paraphasias* (erroneous production of phonemes, words or phrases, that is phonemic and semantic paraphasias) and poor comprehension (Goodglass & Kaplan 1983).

A third type of aphasia identified within the fluent vs. non-fluent split is *anomia*. Anomia is caused by damage to various parts of the *parietal or the temporal lobe* of the brain. Although the speech of individuals with anomic aphasia is *fluent* and grammatically correct, it is characterized by problems in recalling words, names, and numbers. Thus, individuals with anomic aphasia often use circumlocutions in order to avoid a word they cannot recall or to express a word they cannot remember. Nonetheless, they understand speech well and they can repeat words and sentences (Dronkers & Baldo 2009).

2.2 Agrammatic aphasia

A specific type of Broca's aphasia, very often described in the aphasiological literature, is *agrammatism* or *(Broca's) agrammatic aphasia*.[2,3] Agrammatism is a pattern of language production that appears to lack grammatical structure (Pick 1913, quoted in Grodzinsky 1990). It has traditionally been defined as a *morphosyntactic impairment* characterized by decrease in speech rate, by omission and/or substitution of bound and free grammatical morphemes (e.g., determiners, auxiliaries, verbal inflections, complementizers) and by use of simplified syntactic structures ('poor grammar'). This co-occurrence of symptoms has been described in the literature as *'telegraphic speech'* (e.g., Goodglass 1968, Caramazza & Berndt 1985).

Cross-linguistic studies have shown that individuals with agrammatic aphasia have *selective* grammatical deficits, affecting some but not all grammatical morphemes and functional categories. Thus, in the verbal domain, Tense has been shown to be significantly more impaired compared to subject-verb Agreement (e.g., for Dutch: Bastiaanse et al. 2002, for German: Burchert et al. 2005, Wenzlaff & Clahsen 2004, for Greek: Nanousi et al. 2006, Varlokosta et al. 2006, for Hebrew: Friedmann & Grodzinsky 1997). In the nominal domain, Case appears to be more impaired compared to Gender (Bastiaanse et al. 2003)[4]. Besides morphosyntactic deficits, core syntactic operations (i.e. *movement*) seem to be impaired in the production of agrammatic speakers, evidenced in structures with reversible word order, such as object scrambling (e.g., Lee & Thompson 2004, Thompson 2003), *wh*-questions, relative clauses, and passives (e.g., Bastiaanse & van Zonneveld 2005, Thompson & Shapiro 2007). Greater difficulty is also observed in the production of verbs as compared to nouns (e.g., Berndt, Mitchum, Haendiges & Sandson 1997, Miceli, Silveri, Villa & Caramazza 1984) and in the production of verbs with complex argument structure (transitives vs. ditransitives, unergatives vs. unaccusatives; e.g., Kegl 1995, Thompson 2003).

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2 The two terms, 'agrammatism' and 'Broca's aphasia', are often used as synonyms in the literature.

3 Agrammatism is often associated with damage to Broca's area. However, damage to Broca's area does not necessarily result in Broca's agrammatic aphasia, and Broca's agrammatic aphasia is not necessarily caused by damage to Broca's area (Mohr et al. 1978, Dronkers et al. 1992). The current consensus is that the damage in Broca's aphasia probably includes parts of Broca's area and some other adjacent structures; however, these structures still remain unknown (Lazar & Mohr 2011). Recent findings suggest that individuals with Broca's aphasia have damage to both Broca's and Wernicke's areas (Fridriksson et al. 2014).

4 According to Bastiaanse et al. (2003) most substitution errors in article production in Dutch agrammatic aphasia concern case.

Although the impairment in agrammatism was originally described for production, a number of studies have shown that speakers with agrammatic aphasia have a language comprehension problem that mirrors their speech production problems. Specifically, they have difficulties understanding syntactically complex structures such as "semantically reversible" sentences with non-canonical word order (e.g., object clefts, *wh-questions*, relatives) (e.g., Caramazza & Zurif 1976). This pattern of behavior in known in the literature as 'asyntactic comprehension' (Caramazza & Zurif 1976) and has been interpreted through representational as well as processing accounts (e.g., Grodzinsky 2000, Grillo 2009). However, the association of the pattern of 'asyntactic comprehension' to agrammatic aphasia has been questioned in the field. Caplan (1995) observes a number of methodological shortcomings in the agrammatism literature including inadequacies in the construction of materials, in the matching of participants with agrammatic aphasia and other aphasia types, in the statistical treatment of the data, as well as in the selection criteria used for subject grouping. He points out that detailed description of the participants' conversational speech is rarely used for patient selection in the studies that focus on syntactic comprehension problems. Moreover, Caplan (1995: 333) argues that there is nothing unique in the kind of comprehension problems observed in agrammatism, because the pattern of 'asyntactic comprehension' discussed in several studies is not found in all agrammatic speakers (Nespoulous et al. 1988), whereas it is present in non-agrammatic speakers (Caplan, Baker & Dehaut 1985). He concludes that despite the existence of several studies showing differences between small groups of speakers with agrammatism and speakers with other aphasia types, these studies do not establish that the syntactic comprehension problems of participants with agrammatism are different from those without agrammatism.

The within subject variability in the patterns of agrammatic performance observed in many studies across different languages has also been a problem for the definition of agrammatism and has raised questions regarding its existence as a distinct condition. Goodglass et al. (2001) describe a number of core features/characteristics that distinguish agrammatic from non-agrammatic speakers, which include omission and/or within-class substitution of function words, reduced use of coordination and subordination, fragmentary and incomplete phrases/sentences, loss of comprehension of inflections and function words, as well as loss of comprehension of complex syntactic structures with non-canonical word order. Nonetheless, the actual nature of 'asyntactic' comprehension and its relationship to agrammatic aphasia remains controversial and the questions raised by Caplan (1995) still remain open in the field.

Broca's agrammatic aphasia is also characterized by non-linguistic deficits, particularly deficits in short-term and working memory (for a review see Salis et al. 2015, Wright & Fergadiotis 2012). *Short-term memory* (STM) refers to the ability to remember information received through auditory and visual channels for a brief period of time, immediately after this information is registered. Thus, STM is a temporary memory system, with limited capacity in terms of encoded information memory units (see Cowan et al. 2005, 2008, Salis et al. 2015). *Working Memory* (WM) is another temporary memory system used for mentally manipulating information (Baddeley 2012). The difference between the two is that while STM refers to the ability to recall information immediately after its presentation in a relatively unprocessed state, that is, without mental manipulation, WM entails mental manipulation of information (see Baddeley 2012, Conway et al. 2005). A number of studies report a strong connection between linguistic and STM impairments, arguing that digit repetition (digit forward) is a major predictor of receptive as well as expressive language performance in speakers with (agrammatic) aphasia (e.g., Schuell et al. 1964, Crocket et al. 1981, Beeson et al. 1993, Leff et al. 2009, Laures-Gore et al. 2011). WM deficits have also been observed in aphasia. However, the precise relationship between WM deficits and language processing still remains unclear, as some studies report significant correlations between WM capacities and various language abilities (e.g., reading and listening comprehension, sentence comprehension; Caspari et al. 1998, Tompkins et al. 1994), while other studies do not (e.g., Christensen & Wright 2010, Ivanova & Hallowell 2014, Mayer & Murray 2012). The inconsistency in results has been partly attributed to the mixed aphasia groups that have been employed in the studies, which results in comparisons of WM capacities among individuals with distinct profiles of language impairments (Ivanova & Hallowell 2014, Ivanova et al. 2015). Some studies have shown that aphasia type contributes to the role WM plays in language processing. Friedmann & Gvion (2003) compared participants with agrammatic aphasia and participants with conduction aphasia and showed that only the former group performed poorly on the comprehension of object relative clauses despite the fact both groups had limited WM abilities. Similarly, Ivanova et al. (2015) showed that although individuals with non-fluent aphasia perform similarly to individuals with fluent aphasia on WM and language comprehension tasks, the relationship between WM and language comprehension is significant only for participants with non-fluent aphasia. Thus, although WM impairments have been associated with Broca's agrammatic aphasia in some studies (e.g., Garraffa & Learmonth 2013, Kolk and van Grunsven 1985), the role of WM in language processing in different types of aphasia remains open.

3. The study

3.1 Aims

The present study is part of a broader study on aphasia that aimed at (i) an in-depth investigation of different linguistic levels in aphasia and their interrelations, (ii) the study of the relationship between other neuropsychological disorders, including WM deficits, and language impairments, (iii) an evaluation of aphasic disorders, their symptoms and level of severity, in relation to the location and extent of left-hemisphere damage, and (iv) an in-depth investigation of the efficacy of different types of therapy intervention in aphasia.

We present results from three groups of participants with aphasia in order to investigate whether (a) syntactic comprehension deficits affecting "semantically reversible" sentences with non-canonical word order are observed not only in speakers diagnosed with Broca's agrammatic aphasia but also in speakers diagnosed with other aphasia types and (b) disorders of syntactic processing in sentence comprehension correlate with the speakers' working memory abilities.

3.2 Participants

For the purposes of the present study, we present results from 14 monolingual Greek-speaking participants with aphasia, who have been divided into three groups, according to their classification derived from their Boston Diagnostic Aphasia Examination (BDAE) scores (Goodglass & Kaplan 1983, Greek adaptation: Papathanasiou et al. 2008). Group I – Broca comprised 6 participants with Broca's aphasia (Mean age: 57.7 years, SD: 8.2, Mean years of education: 13.2, SD: 3.0), Group II – Anomic comprised 4 participants with anomia (Mean age: 54.8 years, SD: 6.9, Mean years of education: 12.0, SD: 4.6), and Group III – Unclassified comprised 4 participants with non-fluent output, that were unclassified on the basis of their BDAE scores (Mean age: 63.5 years, SD: 5.9, Mean years of education: 10.5, SD: 2.4). All brain-damaged participants had suffered a single left cerebral vascular accident (CVA) at least 12 months prior testing, which in most cases caused a right hemiparesis.

Tables 1, 2 and 3 summarize the demographic information and the classification of each participant with aphasia for each of the three groups.

	P1	P2	P3	P4	P5	P6
Gender	M	M	M	M	M	M
Age	63	60	69	56	52	46
Education	16	12	16	13	14	8
Type of lession	CVA	CVA	CVA	CVA	CVA	CVA
Hemiparesis	Right	None	None	Right	Right	Right
Classification (derived from BDAE)	Broca's	Broca's	Broca's	Broca's	Broca's	Broca's

Table 1 Demographic information and classification of participants for Group I – Broca

	P7	P8	P9	P10
Gender	F	M	M	M
Age	63	47	52	57
Education	6	16	11	15
Type of lession	CVA	CVA	CVA	CVA
Hemiparesis	Right	Right	Right	Right
Classification (derived from BDAE)	Anomic	Severe anomic	Mild anomic	Mild anomic

Table 2 Demographic information and classification of participants for Group II – Anomic

	P11	P12	P13	P14
Gender	M	M	M	M
Age	55	67	68	64
Education	9	14	9	10
Type of lession	CVA	CVA	CVA	CVA
Hemiparesis	Right	Right	Right	Right

Classification (derived from BDAE)	Unclassified	Non-fluent unclassified	Mild unclassified	Non-fluent unclassified

Table 3 Demographic information and classification of participants for Group III – Unclassified

Each participant with aphasia was matched to a Greek-speaking non-brain damaged control participant on age and years of education (Control group I: Age range: 48-71; Mean age: 60.7, SD: 8.0; Mean years of education: 11.7, SD: 2.0; Control group II: Age range: 49-58; Mean age: 53.5, SD: 4.2; Mean years of education: 12.5, SD: 4.7; Control group III: Age range: 56-69; Mean age: 62.8, SD: 6.7; Mean years of education: 10.8, SD: 1.7). There were no significant differences between aphasia and control groups with regards to mean age and mean years of education: Group I – Broca vs. Control group I: t(10)=-.643, p=.535 (age), t(10)=1.026, p=.329 (education); Group II – Anomic vs. Control group II: t(6)=.311, p=.766 (age), t(6)=-.152, p=.884 (education); Group III – Unclassified vs. Control group III: t(6)=.168, p=.872 (age), t(6)=-.171, p=.870 (education).

Participants had to pass a *Cognitive Screen* in order to participate in the study and be further assessed. The Cognitive Screen assessed non-verbal intelligence and included Raven's *Coloured Progressive Matrices* (Raven 2004) and the *Dementia Rating Scale* (Mattis 1988).

3.3 Materials

Baseline tasks

A battery of baseline tasks assessed the participants' verbal and non-verbal abilities:

a) *Boston Diagnostic Aphasia Examination (BDAE)* (Goodglass & Kaplan 1972, Greek adaptation: Papathanasiou et al. 2008) to diagnose aphasia and its type. The BDAE evaluates various perceptual modalities (auditory, visual, and gestural), processing functions (comprehension, analysis, problem-solving) and response modalities (writing, articulation, and manipulation).
b) *Boston Naming Test (BNT)* (Kaplan, Goodglass & Weintraub 1983, Greek adaptation: Simos et al. 2011) to assess participants' naming ability. Participants were

asked to correctly name 60 pictures depicting objects of different degrees of imageability. When necessary, participants were provided with a semantic cue (meaning), a phonemic cue (sounding out the first letter of the target word) or both.

c) *Spontaneous and more constrained speech* from the Greek Corpus of Aphasic Discourse (GREECAD, Varlokosta et al. 2016) to evaluate a number of metrics, such as fluency, % grammatical sentences, V/N ratio. The speech samples were obtained with tasks that were designed to elicit descriptive and narrative discourse: picture description (Cookie Theft from the BDAE) (see Figure 1), personal narrative (stroke story), narrative based on an original series of pictures ("the party") (see Figure 2), re-telling of an original story with the assistance of pictures ("the ring") (see Figure 3), and re-telling of a familiar story ("hare and tortoise" Aesop's fable) (Kakavoulia et al. 2014).

d) *THALES Neuropsychological Battery* to assess cognitive abilities (verbal and non-verbal). The battery comprised a number of tasks, including WMS-III Mental Control, verbal fluency, fluency animals, verbs and furniture, WMS-III Digit Span, WMS-III Spatial Span, word repetition, non-word repetition, sentence repetition, number sequencing, symbol-pointing span, picture-pointing span, retrieval of visuospatial information - immediate recall, phoneme discrimination, phonological awareness, non-word repetition (increased length), picture arrangement (WISC-III), fluid intelligence (GAMA), retrieval of visuospatial information - delayed recall. In the present study we analyze results from the following tasks:
   - *Non-word repetition*, to tap phonological STM: participants were asked to repeat pseudowords, which were presented in blocks (8 blocks, 2 trials each, progressively 2-9 words), e.g., *κέμα-ρίδα, ράζο-τροβός-κάμπα, πχιάμο-κόντι-σκόλος-πέρτα*.
   - *Sentence repetition*, to tap verbal STM: participants were asked to repeat sentences, which were presented in blocks (10 blocks, 2 trials each, sentence complexity and number of words progressively increased), e.g., *Το λεωφορείο άργησε* "The bus was late", *Η γάτα άρπαξε γρήγορα το πουλάκι αφού δάγκωσε τον σκύλο* "The cat snatched quickly the bird after biting the dog".
   - *Digit span (forward)* (WAIS III), to tap verbal STM: Participants were asked to repeat a list of digits that increase in length, in the order they heard it (8 blocks, 2 trials each, digits progressively increasing), e.g., 1 – 7, 6 – 3; 5 – 8 – 2, 6 – 9 – 4; 6 – 4 – 3 – 9, 7 – 2 – 8 – 6, 4 – 2 – 7 – 3 – 1, 7– 5 – 8 – 3 – 6.

- *Digit span (backward)* (WAIS III), to tap verbal WM: Participants were asked to recall a list of digits that increase in length from the end of the list to the beginning (7 blocks, 2 trials each, digits progressively increasing).
- *Spatial span (forward)* (WAIS III), to tap non-verbal STM: Participants were asked to touch a list of cubes that increase in length, in the order they were touched by the examiner (8 blocks, 2 trials each, number of blocks progressively increasing) (see Figure 4).
- *Spatial span (backward)* (WAIS III), to tap non-verbal WM: Participants were asked to touch a list of cubes that increase in length in the reverse order they were touched by the examiner (8 blocks, 2 trials each, number of blocks progressively increasing).

Linguistic tasks

A battery of linguistic tasks assessed different aspects of the participants' production (subject-verb agreement, tense, aspect, case, *wh*-questions, relative clauses) and comprehension abilities (nominal and verbal agreement, case, *wh*-question*s,* relative clauses, free relatives). In the present study, we focus on one comprehension task that assessed the participants' ability to comprehend "semantically reversible" sentences with non-canonical word order.

Picture pointing task: Participants were presented with black-and-white drawings on a computer screen – one at a time – (see Figure 5) while they heard a sentence (*wh*-question/ relative clause/ free relative) (see examples 1 and 2), and were asked to point

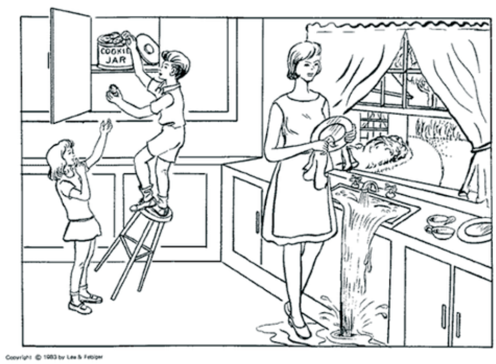

Figure 1 | The Cookie Theft

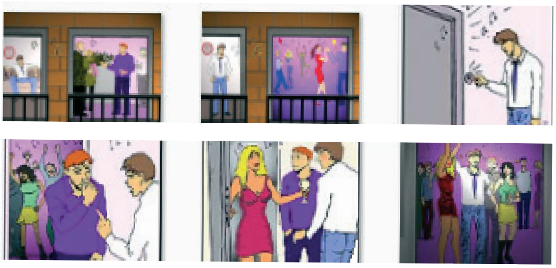

Figure 2 | The party

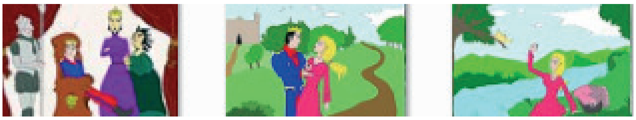

Figure 3 | The ring

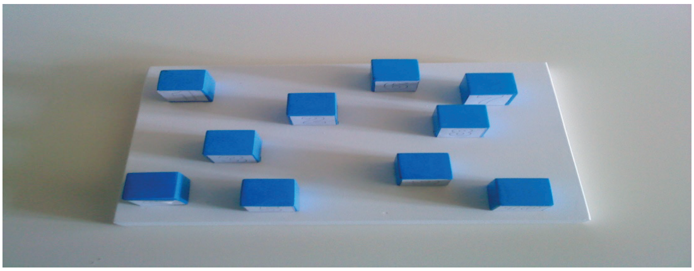

Figure 4 | Spatial span (WAIS III)

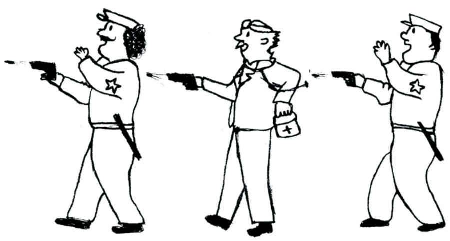

Figure 5 | Picture pointing task

to the correct agent of the action. The drawings depicted semantically reversible actions performed by animate agents (people or animals) of the same gender (grammatical and semantic). The task included: 16 non-referential *wh*-questions (*who* questions), 8 with a subject and 8 with an object dependency (1), 16 referential *wh*-questions (*which NP* questions), 8 with a subject and 8 with an object dependency (2), 16 relative clauses, 8 with a subject and 8 with an object dependency, and 16 free relatives, 8 with a subject and 8 with an object dependency.

(1) *Pjon pirovoli o jatros? (object who question)*
who_Acc shoots the doctor_Nom
'Who does the doctor shoot?'

(2) *Pjon astonimiko pirovoli o jatros? (object which NP question)*
which policeman_Acc shoots the doctor_Nom
'Which policeman does the doctor shoot?'

3.4 Results

Tables 4, 5, and 6 summarize the results of the BDAE and BNT for Group I – Broca, Group II – Anomic, and Group III – Unclassified, respectively.

BDAE & BNT scores	P1	P2	P3	P4	P5	P6
BDAE_auditory comprehension_words/72	100	100	91	100	87.5	86
BDAE_auditory comprehension_commands/15	100	80	93	86	46	60
BDAE_auditory comprehension_complex material/12	**66**	**50**	**50**	**75**	**33**	**16**
Total/99	96	91	86	94	74	73
BDAE_oral expression_word repetition/10	100	90	70	90	90	80
BDAE_oral expression_sentence repetition(1)/8	**100**	**75**	**50**	**87**	**62**	**37**
BDAE_oral expression_sentence repetition(2)/8	**75**	**50**	**62**	**62**	**37**	**12**
BDAE_oral expression_naming/114	98	76	61	78	60	20

Total/140	97	75	61	77	75	16
Boston Naming Test—correct without cue/45	68	26	37	28	70	11
Boston Naming Test—correct with semantic cue/45	0	0	4	0	0	11
Boston Naming Test—correct with phonemic cue/45	22	46	28	15	17	11

Table 4 | BDAE & BNT scores (%) for Group I – Broca

BDAE & BNT scores	P7	P8	P9	P10
BDAE_auditory comprehension_words/72	95	100	87	100
BDAE_auditory comprehension_commands/15	86	100	66	93
BDAE_auditory comprehension_complex material/12	**58**	**80**	**83**	**83**
Total/99	89	95	83	97
BDAE_oral expression_word repetition/10	100	100	100	100
BDAE_oral expression_sentence repetition(1)/8	**100**	**100**	**100**	**100**
BDAE_oral expression_sentence repetition(2)/8	**100**	**100**	**100**	**100**
BDAE_oral expression_naming/114	92	99	86	97
Total/140	93	99	88	98
Boston Naming Test—correct without cue/45	31	62	66	87
Boston Naming Test—correct with semantic cue/45	6.6	2.2	0	
Boston Naming Test—correct with phonemic cue/45	33	28	24	

Table 5 | BDAE & BNT scores (%) for Group II – Anomics

We observe that the participants of Group I – Broca have lower scores on the sentence repetition test of the oral expression part of the BDAE compared to the participants of Group II – Anomic, who exhibit very high performance. Group I – Broca has also lower performance compared to Group II – Anomic on the complex material test of the auditory comprehension part. Performance of the participants of Group III – Unclassified is lower compared to performance of the participants of Group I – Broca and Group II - Anomic on these tests.

BDAE & BNT scores	P11	P12	P13	P14
BDAE_auditory comprehension_words/72	88	97	91	70
BDAE_auditory comprehension_commands/15	53	80	93	53
BDAE_auditory comprehension_complex material/12	**16**	**33**	**33**	**25**
Total/99	74	86	84	68
BDAE_oral expression_word repetition/10	70	70	100	100
BDAE_oral expression_sentence repetition(1)/8	**25**	**37**	**75**	**75**
BDAE_oral expression_sentence repetition(2)/8	**12.5**	**0**	**65.5**	**62**
BDAE_oral expression_naming/114	49	75	79	43
Total/140	47	68	72	50
Boston Naming Test—correct without cue/45	51	46	40	35
Boston Naming Test—correct with semantic cue/45	2	4		2.2
Boston Naming Test—correct with phonemic cue/45	20	31		33

Table 6 | BDAE & BNT scores (%) for Group III – Unclassified

Table 7 summarizes the mean scores for fluency[5], % grammatical sentences, and V/N ratio, derived from the spontaneous speech data of the participants. Significant differences were observed between aphasia and control groups with respect to all measures: Group I – Broca vs. Control Group I: fluency: p=.000, % grammatical sentences: p=.000, V: p=.000, N: p=.000; Group II – Anomics vs. Control Group II: fluency: p=.000, % grammatical sentences: p=.013, V: p=.004, N: p=.000; Group III – Unclassified vs. Control Group III: fluency: p=.000, % grammatical sentences: p=.000, V: p=.000, N: p=.000. The differences between the three aphasia groups were not significant apart from % grammatical sentences, which was significant for Group I – Broca vs. Group II – Anomics (p=.013) and fluency which was close to significant for Group I – Broca vs. Group II – Anomics (p=.058). The low proportion of grammatical sentences in Group I – Broca is considered evidence for agrammatic production (Faroqi-Shah & Thompson 2004).

5 Fluency is calculated in terms of words per minute.

Group	Fluency	% Grammatical sentences	V/N
Mean Group I – Broca	22.9	34.2	12/14
Mean Group II – Anomics	45.5	78.1	24/15
Mean Group III – Unclas-sified	33.1	55.2	15/10
Mean Control I	104.9	100	37/36
Mean Control II	105.1	100	38/37
Mean Control III	103.7	100	36/37

Table 7 | Spontaneous speech (means for fluency, % grammatical sentences, V/N) for all groups

Figures 6, 7, 8, 9, 10 and 11 present the results of the non-word repetition, sentence repetition, digit span forward, digit span backward, spatial span forward and spatial span backward tasks from the THALES Neuropsychological Battery, for each aphasia group and for controls.

Performance of the three aphasia groups was significantly worse compared to controls on the non-word repetition task (Group I – Broca vs. Control: t(10)=-6.491, p<.001; Group II – Anomic vs. Control: t(8)=-3.073, p=.015; Group III – Unclassified vs. Control: t(8)=-5.656, p<.001). However, significant differences were not observed between the three groups (Group I – Broca vs. Group II – Anomic: t(8)= -1,592, p=.150; Group II – Anomic vs. Group III – Unclassified: t(6)=0.962, p=.373; Group I – Broca vs. Group III – Unclassified: t(8)=-0.569, p=.585).

Performance of the three aphasia groups was significantly worse compared to controls on the sentence repetition task as well (Group I – Broca vs. Control: t(10)=-8,691, p<.001; Group II – Anomic vs. Control: t(8)=-2.907, p=.020; Group III – Unclassified vs. Control: t(8)=-9.679, p<.001). Significant differences were also observed between Group I – Broca and Group II – Anomic (t(8)=-2.754, p=.025) but not between Group II – Anomic and Group III – Unclassified (t(6)= 2.301, p=.061) or Group I – Broca and Group III – Unclassified (t(8)=-0.297, p=.774).

Performance of the aphasia groups did not differ from performance of the controls on the digit span forward task apart from Group III – Unclassified and controls

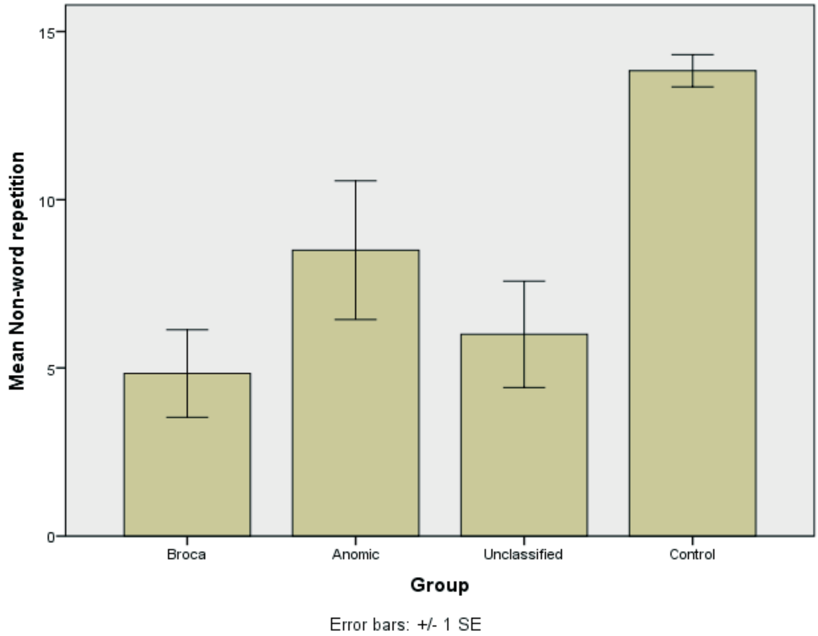

Figure 6 Non-word repetition

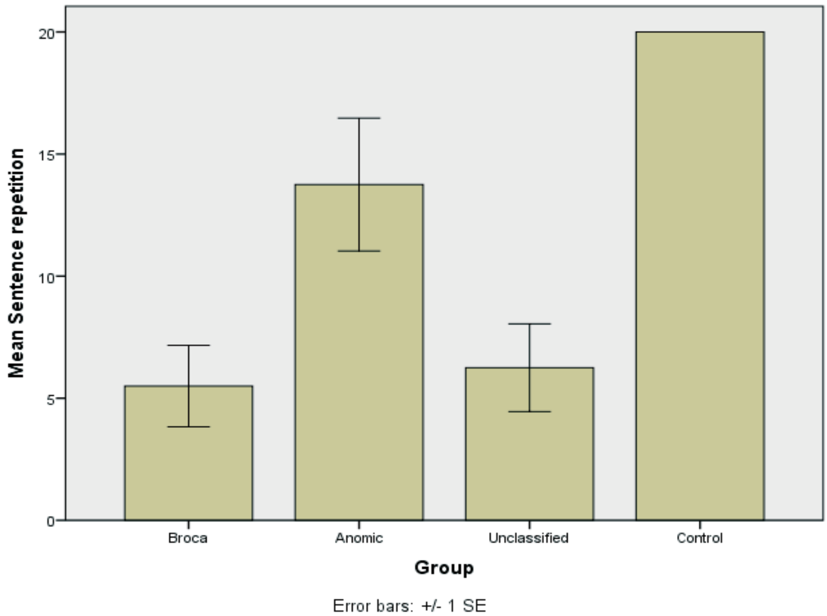

Figure 7 | Sentence repetition

(Group I – Broca vs. Control: t(10)=-2.011, p=.084; Group II – Anomic vs. Control: t(8)=-1.265, p=0.242; Group III – Unclassified vs. Control: t(8)=-3.067, p=.015). Moreover, significant differences were not observed between aphasia groups: Group I – Broca vs. Group II – Anomic t(8)=-0.414, p=.690; Group II – Anomic vs. Group III – Unclassified: t(6)= 1.095, p=.315; Group I – Broca vs. Group III – Unclassified: t(8)=0.845, p=.423.

Performance of the three aphasia groups was significantly worse compared to controls on the digit span backward task (Group I – Broca vs. Control: t(10)=-7.730, p<.001; Group II – Anomic vs. Control: t(8)=-3.335, p=.010; Group III – Unclassified vs. Control: t(8)=-5.741, p<.001). Significant differences were also observed between Group I – Broca vs. Group II – Anomic (t(8)=-3,863, p=.005) and Group II – Anomic vs. Group III – Unclassified (t(6)= 2.810, p=.031) but not between Group I – Broca vs. Group III – Unclassified (t(8)= 0.590 p=.572).

Performance of the aphasia groups did not differ from performance of the controls on the spatial span forward task: Group I – Broca vs. Control: t(10)=-0.720, p=.488; Group II – Anomic vs. Control: t(8)=-1.272, p=.239; Group III – Unclassified vs. Control: t(8)=-2.016, p=.079). Moreover, significant differences were not observed between aphasia groups: Group I – Broca vs. Group II – Anomic: t(8)=0.732, p=.485; Group II – Anomic vs. Group III – Unclassified: t(6)=0.319, p=.761; Group I – Broca vs. Group III – Unclassified: t(8)=1.358, p=.211.

Performance of the aphasia groups did not differ from performance of the controls on the spatial span backward task as well: Group I – Broca vs. Control: t(10)=-0.697, p=.501; Group II – Anomic vs. Control: t(8)=-0.659, p=.536; Group III – Unclassified vs. Control: t(8)=-1.210, p=.261). Moreover, significant differences were not observed between aphasia groups: Group I – Broca vs. Group II – Anomic: t(8)= 0.115, p=.911; Group II – Anomic vs. Group III – Unclassified: t(6)= 0.333, p=.750; Group I – Broca vs. Group III – Unclassified: t(8)= 0.539, p=.604.

Figure 12 presents the results of the three aphasia groups in the picture pointing task that assessed subject and object dependencies in *who* questions, *which NP* questions, relatives clauses and free relatives. The three control groups performed at ceiling and their data on the linguistic tasks will not be further discussed.

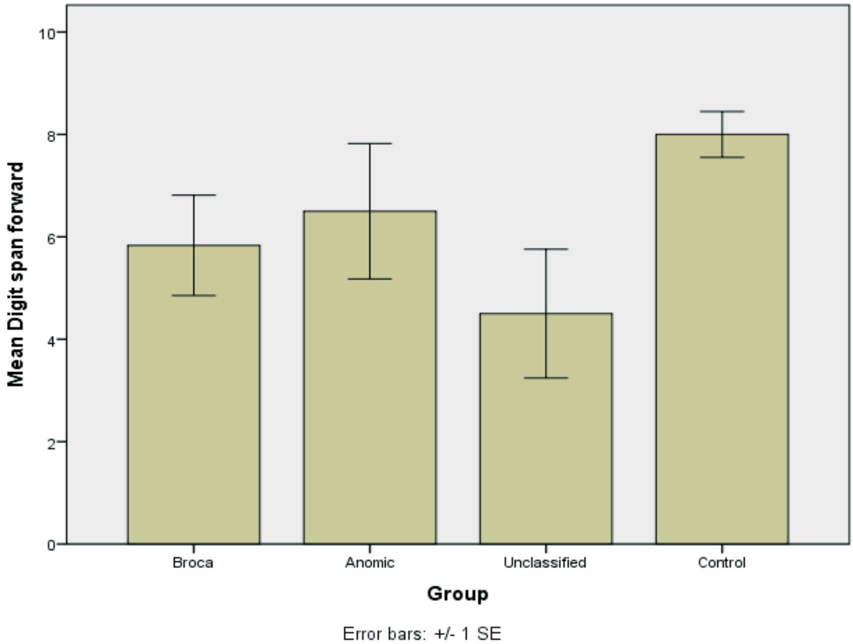

Figure 8 | Digit span forward

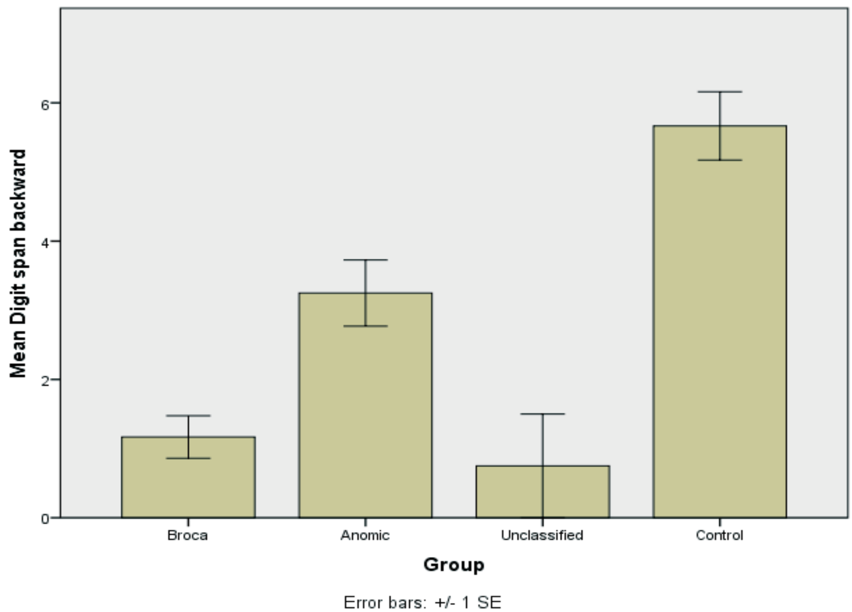

Figure 9 | Digit span backward

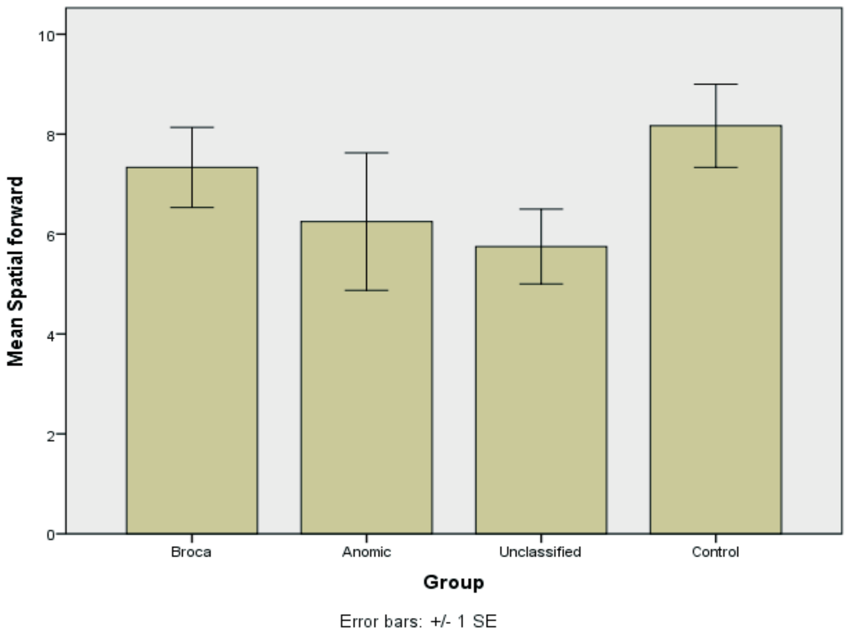

Figure 10 | Spatial span forward

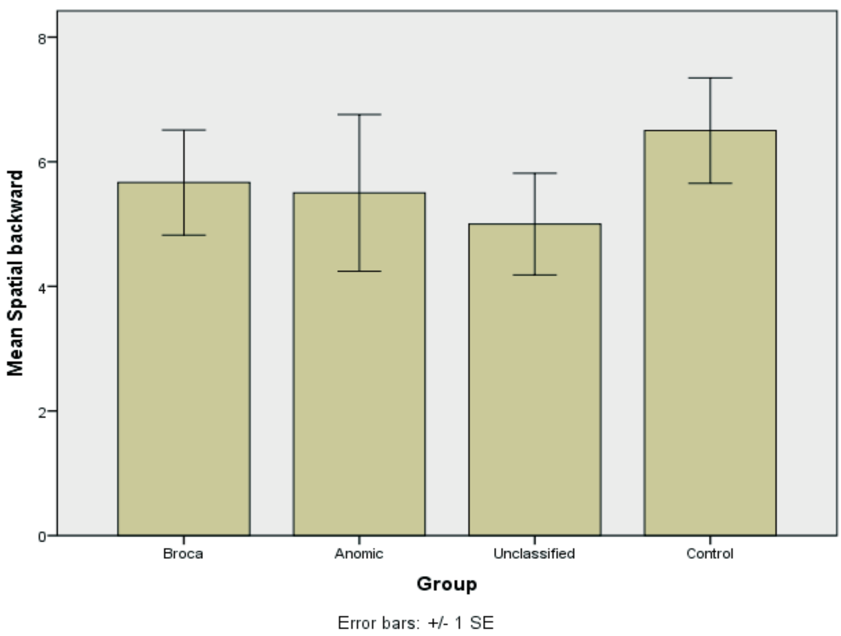

Figure 11 | Spatial span backward

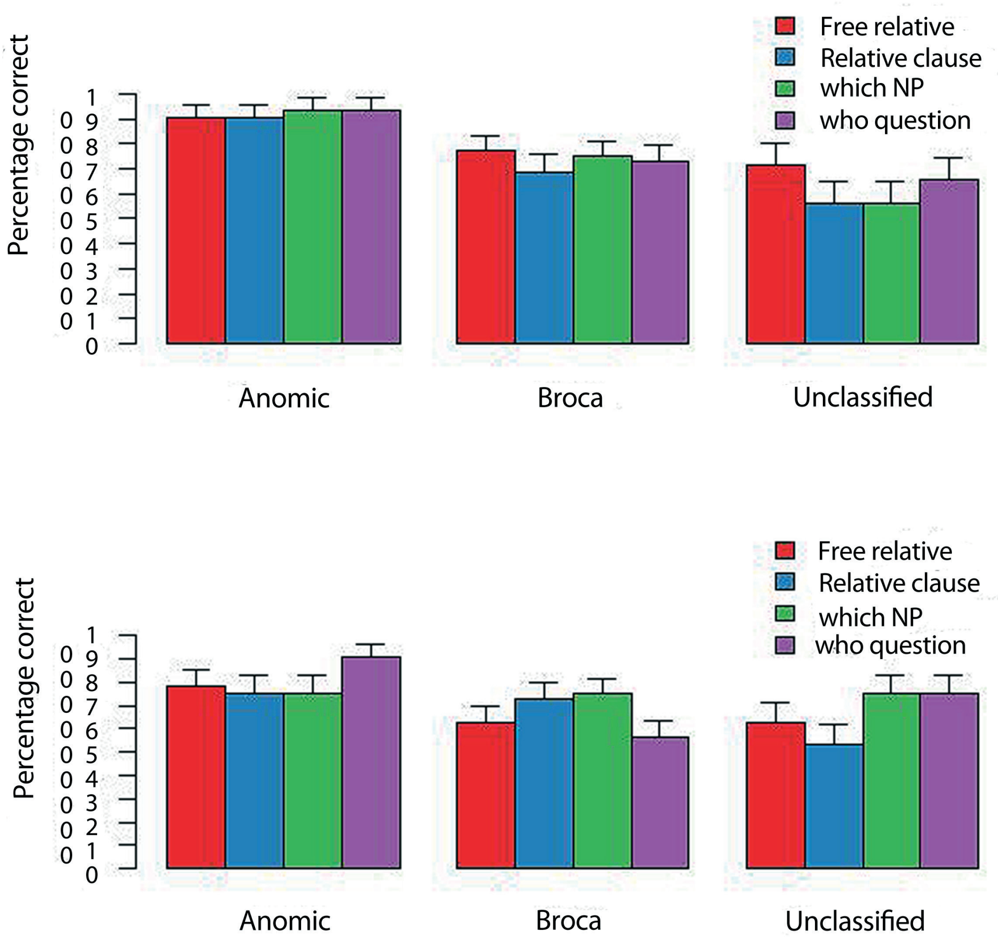

Figure 12 | Percentage of correct responses as a function of aphasia type, sentence type, and dependency type (subject vs. object). Top row: percentages for the subject dependency. Bottom row: percentages for the object dependency. Bar plots are given with standard errors.

A generalized mixed-effects model was applied to the data (Baayen, Davidson & Bates 2008). In the fixed effects component, sentence type (*who* question, *which NP* question, relative clause, free relative), aphasia type (Broca, Anomic, Unclassified), dependency type (subject vs. object) as well as the results of the digit backward test were included. In particular, all interactions of sentence type, aphasia type and dependency type, but only main effects (no interactions) of the digit backward test were included. In the random effects component, random intercepts for every participant and every sentence were included so as to minimize the random systematicities induced by the participants and items within the model. Because the model is a generalized one, it assumed that the dependent variable (i.e. correct or erroneous responses) is categorical and, thus, it transformed the variable into a continuous one through a logit function (Jaeger 2008). To perform hypothesis testing, likelihood ratio tests were used. Main effects of the dependency type ((1)=7.57, p=.006) and performance on digit backward were observed ((1)=4.75, p=.030) (Figure 13 and Figure 14). Furthermore, an interaction between aphasia type and dependency type was observed ((2)=7.53, p=.020). No further main effects or interaction were observed (all p values >.05). If the results of the digit backward test were not included in the model, then the aphasia type would become a significant main effect. The fact that it is not a main effect when the digit backward is included implies that the two variables are highly correlated. Moving on to specific group comparisons, subject-object asymmetries were observed in Group II – Anomic for *which NP* questions (z(2.012), p=.044). Moving on to interaction terms, a significant interaction was found with respect to dependency type in *who* questions between Group II – Anomic and Group I – Broca (z=-2.495, p=.012). In addition, an interaction was found between Group II – Anomic and Group III – Unclassified with respect to dependency type in *which NP* questions (z=-2.6, p=.009). Furthermore, a significant interaction was observed in object dependencies between *which NP* questions and *who* questions with respect to Group II – Anomic and Group I – Broca (z=-2.496, p=.012) and between *who* questions and relative clauses in Group I – Broca and Group III – Unclassified (z=-2.567, p=.01). Lastly, an interaction was found between Group III – Unclassified and Group II – Anomic with respect to dependency type in *who* questions (z=-2.601, p=.003). No further significant interactions were found.

4. Discussion

The present study investigated whether syntactic comprehension deficits affecting "semantically reversible" sentences with non-canonical word order are observed not only in speakers with Broca's agrammatic aphasia but also in speakers with other aphasia

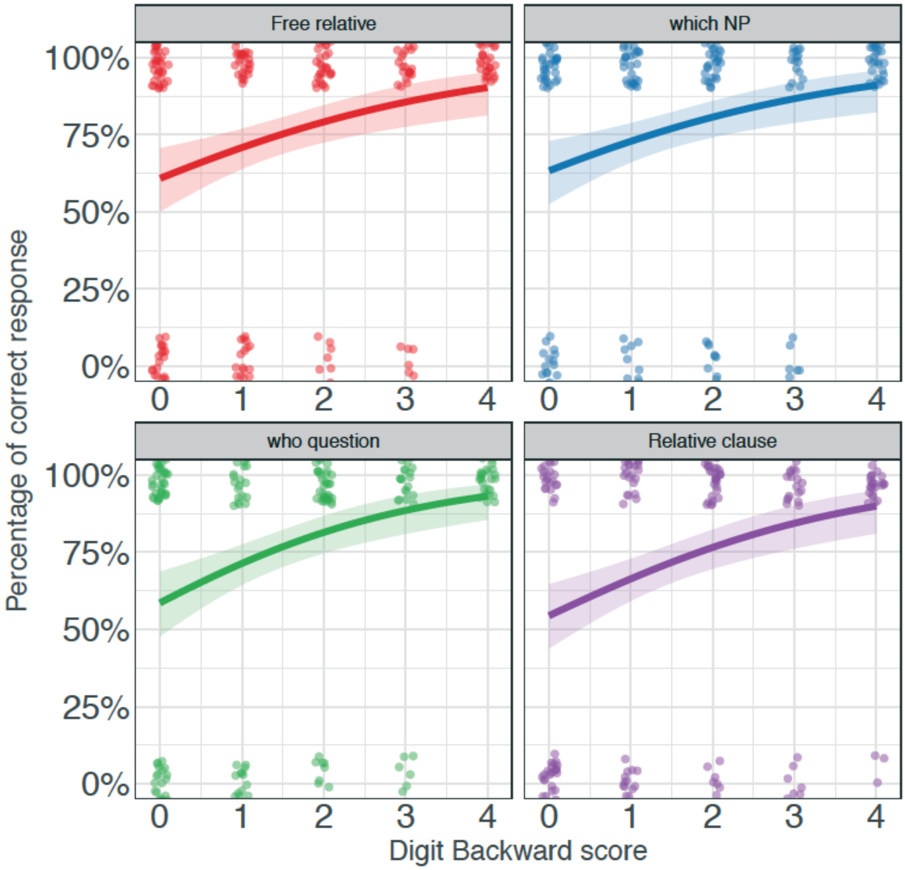

Figure 13 | Predicted probabilities of the generalized mixed-effects model of the responses of the individuals with aphasia as a function their digit backward score. The data are classified in terms of the type of the sentence. Points in the graphs represent the number of correct (1) or incorrect (0) response at each digit backward score. The predicted probabilities come with 95% confidence intervals.

types. We also examined WM impairments and their relationship to sentence comprehension disorders across different aphasia groups.

We assessed three groups of individuals with aphasia, classified to different aphasia groups on the basis of their BDAE scores: the first group consisted of 6 individuals with Broca's aphasia (Group I – Broca), the second group consisted of 4 individuals with anomic aphasia (Group II – Anomic), and the third one of 4 participants, who were not classified to a particular aphasia type (Group III – Unclassified). Each partici-

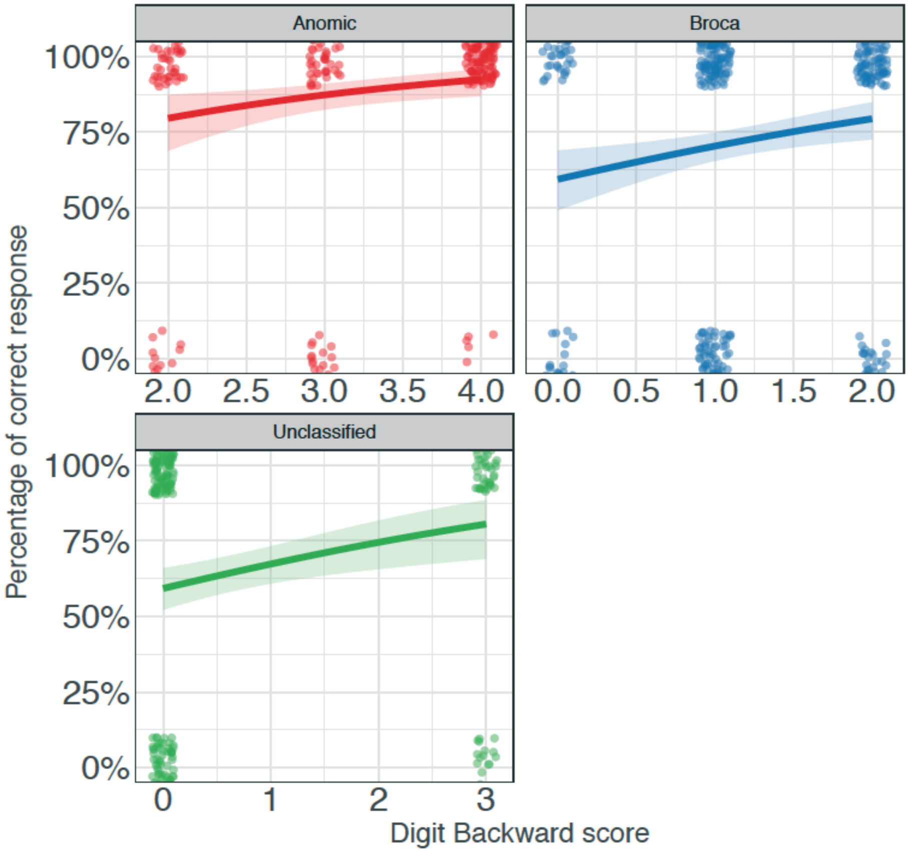

Figure 14 | Predicted probabilities of the generalized mixed-effects model of the responses of the individuals with aphasia as a function their digit backward score. The data are classified in terms of the type of impairment. Points in the graphs represent the number of correct (1) or incorrect (0) response at each digit backward score. The predicted probabilities come with 95% confidence intervals.

pant with aphasia was matched to a non-brain damaged control participant on age and education. The three aphasia groups had different scores in the sentence repetition test of the oral expression part and in the complex material test of the auditory comprehension part of the BDAE. Specifically, Group II – Anomic had higher scores in both tests compared to both Group I – Broca and Group III – Unclassified, while Group I – Broca had higher scores on both tests compared to Group III – Unclassified (relevant lines in Tables 4, 5 and 6). Moreover, the three aphasia groups exhibited significantly lower performance compared to the non-brain damaged controls in three measures derived from spontaneous and more constrained speech samples: fluency, % grammatical sentences, and V/N ratio. Crucially, Group I – Broca exhibited significantly lower scores on % grammatical sentences compared to Group II – Anomic, while their fluency scores were also lower compared to those of Group II – Anomic, although the difference did not reach significance. Thus, on the basis of their spontaneous and more constrained speech, Group I – Broca and Group II – Anomic displayed different language profiles and only Group I – Broca showed agrammatic production.

Differences among aphasia groups were also observed in some tests of the THALES Neuropsychological Battery. Performance of the three aphasia groups was significantly worse compared to controls on the non-word repetition task, on the sentence repetition task, and on the digit backward task, but not on the spatial span forward and backward tasks or the digit span forward task (apart from Group III – Unclassified and controls for the latter task). These results indicate a reduction in verbal STM and verbal WM, replicating thus previous studies (e.g., for WM see Ivanova & Hallowell 2014, Ivanova et al. 2015, Mayer & Murray 2012). They also show that the reduction in WM affects only verbal WM. So spatial WM, which lies to right hemisphere processing according to imaging studies, as in Smith et al. (1996) and Stern et al. (2000), seems not to be impaired, but verbal WM, which is left hemisphere processing according to the same studies, seems to be impaired. These results indicate also that the link between language comprehension and WM in aphasia may be specific to verbal WM and may not result from a domain general deficit that affects language processing.

Crucially, the three aphasia groups did not perform similarly on the verbal WM task. Group II – Anomic performed significantly better compared to the other two aphasia groups (Group I – Broca and Group III – Unclassified) on the digit backward task. The differences in the degree of verbal WM impairment observed between participants with non-fluent aphasia (Group I – Broca) and participants with fluent aphasia (Group II – Anomic) are not compatible with the findings in Ivanova et al. (2015) or with studies that do not show a differential impairment in cognitive abilities for specific aphasia types (e.g., Ivanova and Hallowell 2014, Friedmann and Gvion 2003; but see Seniów et al. (2009) for variability in cognitive impairments in people with different aphasia types). Nonetheless, previous studies on cognitive impairments across different aphasia groups have not compared Broca's agrammatic aphasia and anomic aphasia. For example, Ivanova and Hallowell (2014) compared mild versus moderate aphasia, while Friedmann and Gvion (2003) compared Broca's versus conduction aphasia. Thus, it remains open whether differences in the degree of verbal WM impairment are present in different aphasia types.

The three aphasia groups did not perform similarly on the picture pointing task that tapped syntactic comprehension. Although performance on subject dependencies tended to be higher than performance on object dependencies (asymmetries were observed for *who* questions in Group I – Broca, for *which NP* questions in Group II – Anomic, for relative clauses in Group II – Anomic and Group III – Unclassified, and for free relatives in all groups), only the subject-object asymmetry in Group II – Anomic for *which NP* questions turned out to be significant (subject-object asymmetries that were close to significant are not discussed in the present study). These results show that 'asyntactic' comprehension is not a pattern that characterizes only individuals with Broca's agrammatic aphasia but is also evident in individuals with fluent aphasia, specifically in individuals with anomic aphasia. Thus, with respect to our first research question, we conclude that syntactic comprehension deficits affecting "semantically reversible" sentences with non-canonical word order are observed not only in speakers with Broca's agrammatic aphasia but also in speakers with other aphasia types. Our findings support the claim in Caplan (1995: 333) that there is nothing unique in the kind of comprehension problems observed in agrammatism, since the impairments in the syntactic comprehension of "semantically reversible" sentences with non-canonical word order were observed in non-agrammatic speakers as well (see Caplan, Baker & Dehaut 1985).

Our data showed differences in performance across the three aphasia groups. Specifically, Group I – Broca performed significantly worse compared to Group II – Anomic with respect to object *who* questions, while Group II – Anomic performed significantly better compared to Group III – Unclassified with respect to object *who* questions and subject *which NP* questions. In addition, Group I – Broca performed significantly worse on object *who* questions compared to Group III – Unclassified, while Group III – Unclassified performed significantly worse on object relative clauses compared to Group I – Broca. These patterns indicate that, at least in our sample, subject-object asymmetries did not always surface within the different aphasia groups and that performance on subject versus object dependencies varied between the different sentence types across the three aphasia groups.

Coming to our second research question, that is the link between WM and sentence comprehension, our results showed that higher performance on the digit backward task was a predictor for higher performance on all sentence types (Figure 13) independently of aphasia type, since it was true that higher performance on digit backward was a predictor for higher performance in all aphasia groups (Figure 14). Thus, we conclude that sentence comprehension impairments correlate with verbal WM deficits in different aphasia types. These results are not compatible with recent findings in Ivanova et al. (2015), which show a differential relationship between WM abilities and language comprehension depending on aphasia type. As in the Ivanova et al. (2015) study though, our findings regarding the relationship between WM and sentence comprehension warrant further inquiry. In the present study, the number of participants in all groups was rather small. Moreover, we examined only performance on digit backward and not on other cognitive tasks tapping WM, we did not examine performance on other cognitive abilities (e.g., executive functions), and we employed only off-line tasks to assess syntactic comprehension and WM abilities. Thus, further research is necessary that will take into account the limitations of existing research on the nature of syntactic comprehension impairments in aphasia as well as on the relationship between these impairments and cognitive functions such as WM.

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