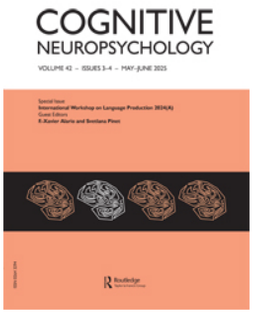

Cognitive Neuropsychology

ISSN: 0264-3294 (Print) 1464-0627 (Online) Journal homepage: www.tandfonline.com/journals/pcgn20

Inflectional morphology and word order in agrammatic production: A cross-linguistic study of Moroccan Arabic and English

Loubna El Ouardi & Yasmeen Faroqi-Shah

To cite this article: Loubna El Ouardi & Yasmeen Faroqi-Shah (02 Dec 2025): Inflectional morphology and word order in agrammatic production: A cross-linguistic study of Moroccan Arabic and English, Cognitive Neuropsychology, DOI: 10.1080/02643294.2025.2594986

To link to this article: https://doi.org/10.1080/02643294.2025.2594986

COGNITIVE NEUROPSYCHOLOGY
https://doi.org/10.1080/02643294.2025.2594986

Routledge
Taylor & Francis Group

Inflectional morphology and word order in agrammatic production: A cross-linguistic study of Moroccan Arabic and English

Loubna El Ouardi [a] and Yasmeen Faroqi-Shah[b]

[a]Faculty of Educational Sciences, Mohammed V University, Rabat, Morocco; [b]Department of Hearing and Speech Sciences, University of Maryland, College Park, MD, USA

ABSTRACT

This cross-linguistic study examined inflectional morphology and word order in Moroccan Arabic (MA) and English-speaking persons with agrammatic aphasia (PWAA). MA has rich verbal morphology and flexible word order, whereas English has limited morphology and rigid order, providing a strong test of accounts of agrammatism. The closed-class deficit hypothesis predicts selective impairment of inflections with preserved word order, while the syntactic deficit hypothesis (SDH) attributes the disorder to a syntactic impairment affecting both domains. Speech from nine MA speakers (four PWAA, five typical participants (TP)) and ten English speakers (five PWAA, five TP) was analyzed. In both languages, PWAA showed deficits in morphology and word order, supporting the SDH. Severity patterns differed: MA-speaking PWAA trended toward greater morphological impairment, whereas English-speaking PWAA showed greater word order disruption. MA-speaking PWAA also deviated from TP's canonical VSO pattern, suggesting compensatory subject-initial strategies. Findings support a core syntactic deficit modulated by language typology.

ARTICLE HISTORY
Received 18 August 2025
Revised 23 September 2025
Accepted 6 October 2025

KEYWORDS
Agrammatism; cross-linguistic; inflectional morphology; production; word order

Introduction

Agrammatism is a hallmark of non-fluent aphasia, typically characterized by slow, effortful speech, the omission of function words and bound morphemes, and simplified syntactic structure (Goodglass, 1993; Menn & Obler, 1990). Numerous studies have shown that persons with agrammatic aphasia (PWAA) produce a disproportionately high rate of errors in verb inflection, often between 50% and 70%, across a range of production tasks (Faroqi-Shah & Thompson, 2007; Rochon et al., 2000; Saffran et al., 1989). In contrast, basic word order is typically preserved, even in languages with considerable word order flexibility (Bates et al., 1988; Menn & Obler, 1990). This dissociation, severe impairment in inflectional morphology alongside relatively intact basic word order, has been interpreted as evidence that the capacity to arrange major lexical items into a grammatical sequence remains largely preserved in agrammatism, despite profound deficits in morphological marking (Bates et al., 1988).

One account that has been developed to explain this dissociation is the Closed-Class Deficit Hypothesis (CCDH, Bradley et al., 1980). In many languages, including English and Moroccan Arabic (MA), verbs carry inflectional affixes that encode tense, agreement and aspect. These markers are drawn from a small, fixed set of closed-class forms, whose primary function is grammatical rather than lexical. For example, English regular verbs take the -s suffix for 3rd person singular present (e.g., *walks*), -ed for past (*walked*), and may combine with auxiliaries to express tense/aspect (e.g., *is walking*). In MA, verbs obligatorily mark person, number, gender and tense through a combination of prefixes and suffixes (e.g., *ka-j-ktbu* "they are writing"), creating multiple inflectional slots that must be correctly filled. According to the CCDH, the primary impairment in agrammatism lies in accessing, retrieving, or integrating these bound morphemes during speech production, rather than in building the syntactic frame itself. As a result, verbs are often produced without the required inflections, replaced with bare stems, or marked with incorrect affixes, leading to high rates of morphological errors across production tasks (Faroqi-Shah & Thompson, 2003; Menn & Obler, 1990; Miceli et al., 1989). Because the underlying ability to sequence major lexical items remains intact, basic word order is typically preserved even when verbal inflection is severely compromised (Bates et al., 1988; Menn & Obler, 1990). The CCDH, therefore, predicts a consistent cross-linguistic

CONTACT Loubna El Ouardi loubna-wardi@outlook.fr

pattern: in both rigid word order languages (e.g., English) and flexible word order languages (e.g., MA), PWAA would show preserved word order alongside marked deficits in verbal morphology (Bates et al., 1988). Canonical word order will be favoured because non-canonical word order requires additional closed-class elements. For instance, producing a wh-question in English (*What is the boy eating?*) requires both an auxiliary (*is*) and a wh-word (*what*). These extra grammatical markers place added demands on the already vulnerable closed-class system, making non-canonical word orders less likely to be produced by PWAA.

An alternative account, the Syntactic Deficit Hypothesis (SDH; Caramazza & Zurif, 1976; Friedmann & Grodzinsky, 1997), challenges the CCDH by proposing that agrammatic impairments are not limited to difficulties retrieving bound grammatical morphemes, but instead reflect a broader disruption of the syntactic system, affecting both morphology and word order. Friedmann and Grodzinsky (1997) argue that this results from loss of access to higher functional nodes in the syntactic tree, such as the Inflection Phrase (IP) and Complementizer Phrase (CP). These projections play distinct structural roles: IP is responsible for tense and agreement morphology and provides the structural position for the clause's subject, whereas CP licenses complementizers and supports marked word orders via operations such as wh-fronting, topicalization and focus movement. Damage to or "pruning" of a functional layer disrupts both the morphological features and syntactic configurations it licenses. For example, pruning IP would compromise not only tense marking but also the mechanisms that determine subject licensing and the arrangement of subject and verb. Pruning CP would block CP-related morphology and the syntactic operations that target it. The SDH, therefore, predicts that agrammatism will yield both morphological impairments and word order deficits, since both depend on the successful computation of hierarchical structure and the availability of higher functional projections such as IP and CP. However, because languages vary in the extent to which grammatical information is encoded through morphology versus word order, a structural deficit can manifest differently across languages: in morphologically rich languages like MA, much of the grammatical information, such as tense, aspect, agreement, person, number and gender, is carried by inflectional morphology on verbs. Since each feature must be licensed and realized through syntactic computation, a breakdown in structure-building creates multiple points of potential failure. By contrast, MA's relatively flexible constituent order limits the contexts in which sequencing mistakes result in outright ungrammaticality, reducing the likelihood of detectable word order errors. This difference in error opportunity predicts that morphological errors should be more frequent than word order errors in MA. By contrast, English relies far less on verbal morphology to convey grammatical relations, encoding them primarily through rigid SVO word order. The rigidity of English word order means that even small deviations result in ungrammatical sentences, creating many opportunities for word order errors. In comparison, English morphology is relatively impoverished, offering fewer opportunities for inflectional errors. Consequently, in English, word order errors are predicted to be more prominent than morphological errors. Additionally, the SDH predicts that non-canonical structures will occur less frequently in PWAA speech, as they often require movement operations supported by higher functional projections (e.g., CP), which are hypothesized to be inaccessible to PWAA (Dickey & Thompson, 2007; Friedmann & Grodzinsky, 1997).

The present study aims to test these competing accounts by leveraging the typological contrasts between MA and English in a cross-linguistic investigation of inflectional morphology and word order in agrammatic production. The CCDH posits a selective vulnerability of bound morphemes, predicting a consistent morphology-word order relation across languages. The SDH predicts a broader syntactic disruption, with the relative frequency of errors shaped by the grammatical system of each language: more inflectional errors in morphologically rich, flexible word order MA, and more word order errors in morphologically sparse, rigid word order English, reflecting the different error opportunities each system provides. Figure 1 summarizes these predictions. The next section outlines the relevant characteristics of inflectional morphology and word order in MA and English, including the distinction between canonical and non-canonical orders, to establish the linguistic context for the study.

Inflectional morphology and word order in MA and English

Inflectional morphology

Compared to English, MA's inflectional morphology is both rich and non-concatenative. That is, rather than forming inflected words by simply adding prefixes or suffixes (as in English walk → walked), MA builds verb

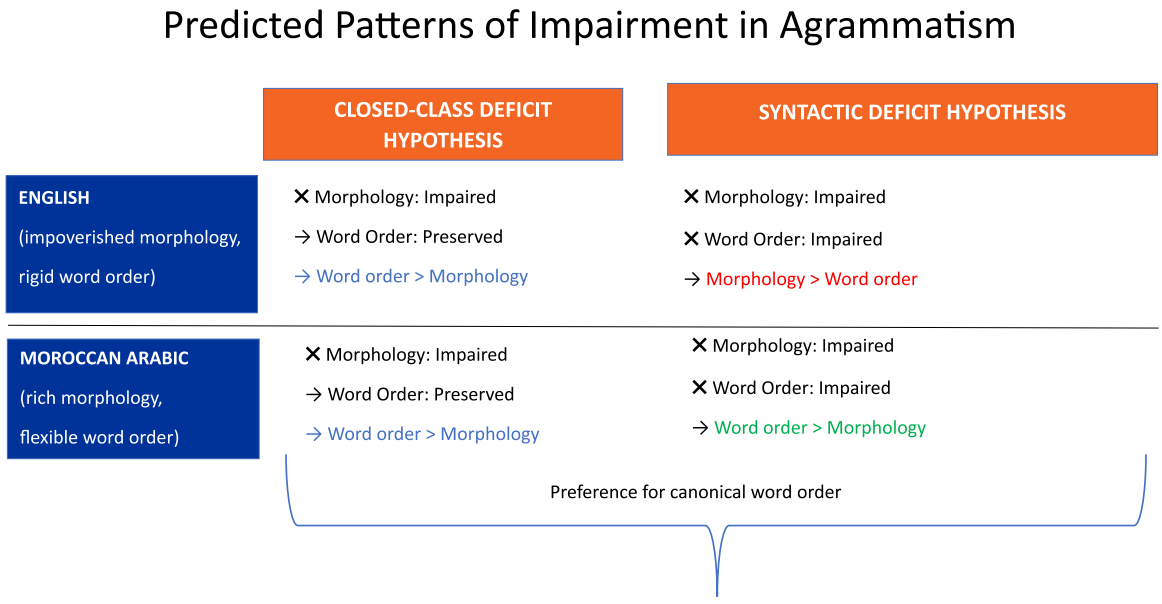

Figure 1. Hypothesized patterns of impairment according to the closed-class deficit and the syntactic deficit hypotheses.

Notes: > indicates that the first domain is predicated to be better preserved than the second (e.g., Morphology > Word order means that morphology is predicted to be less impaired). [To view this figure in colour, please see the online version of this journal.]

forms by inserting vowel patterns into a root composed typically of three consonants. For instance, the root /k-t-b/ "write" can produce a range of morphologically and semantically distinct forms depending on the inserted vowels and affixes: /ktəb/ "he wrote" (past tense, 3rd person masculine singular), /ka-t-ktəb/ "she is writing" (present progressive, 3rd person feminine singular), /ɣa-t-ktəb/ "she will write" (future, 3rd person feminine singular), /ma-ktab/ "a desk" (noun derived from the same root using the ma-CCaC pattern often denoting places).

The verb stem corresponds to the 3rd person masculine singular in the perfective aspect (e.g., /ktəb/ "he wrote"). MA verbs inflect for tense through morphological changes to the stem and the use of affixes. The present tense (habitual or continuous) is marked by the aspectual particle /ka/ or /ta/ preceding the imperfective stem (e.g., /ka-t-ktəb/ "she is writing"). The future is indicated by particles like /ɣadi/ or its reduced form /ɣa/, as in /ɣa-t-ktəb/ "she will write". The past tense lacks an overt tense particle and is instead marked by the suffix agreement pattern that is specific to the perfective and by the internal structure of the stem (e.g., /ktəbt l-bareħ/ "I wrote yesterday").

Verb-subject agreement in MA is expressed through both prefixes and suffixes, depending on the aspect. In the perfective, the verb retains all its agreement features regardless of whether the subject precedes or follows the verb, as illustrated below (1, 2):

1. /l-bnat ktb-u/
   The-girls wrote. 3Fem.Plur.
   "The girls wrote."
2. /ktb-u l-bnat/
   wrote. 3Fem.Plur. the-girls
   "The girls wrote."

In the imperfective, agreement is discontinuously expressed through both prefixes (encoding person and gender) and suffixes (encoding number), as exemplified below (3):

3. /ta-j-ktb-u/
   PAR-3Masc.-write-Plur.
   "They write."

English lacks a rich inflectional morphology for tense and subject-verb agreement. Verbal inflection is minimal: only the third person singular present tense is morphologically marked (e.g., "he writes"), while other persons (e.g., "I/you/we/they write") remain unmarked. Past tense is typically marked by the suffix "-ed" in regular verbs (e.g., "walked") or by suppletion in irregular forms (e.g., "went"), and agreement distinctions are neutralized (e.g., "he eats", "she eats"). The future tense is not morphologically marked on the verb; instead, it is formed using modal auxiliaries like "will" (e.g., "she will go").

Word order

Languages differ in the degree to which word order is fixed or flexible. For example, while English has a rigid word order (SVO, *The boy stole the cookie)*, MA permits greater variation in active declarative sentences; that

is, basic statements used to convey information (as opposed to questions or commands). In particular, MA allows a range of active declarative word orders such as VSO, SVO, VOS, OVS and OSV (Benmamoun, 2017) (see Table 1 for examples of these word orders). However, this flexibility is not without constraints. For example, SOV is not grammatical in MA, and both OSV and OVS require a resumptive object clitic[1] on the verb to be acceptable (see Table 1).

Word orders can be broadly divided into canonical and non-canonical, a distinction that has had considerable theoretical import in agrammatism research (Bastiaanse et al., 2003; Bastiaanse & Van Zonneveld, 2005; Dragoy & Bastiaanse, 2010).

Canonical word order is defined as the syntactic configuration that is most frequently used by speakers of a given language, pragmatically neutral (i.e., does not carry special emphasis, focus or contrastive meaning) and reflects the default alignment between thematic roles and grammatical function, with the agent realized as the subject and the patient as the object in active declarative sentences (Dryer, 2007). In English, large-scale corpus analyses confirm that the SVO order dominates in neutral active declarative sentences. For instance, in the Longman Spoken and Written English Corpus, over 85% of transitive clauses follow the SVO order, with passives, clefts, and other marked structures occurring far less frequently (Biber et al., 1999). This statistical dominance supports the view that SVO constitutes the canonical word order in active declarative sentences in English and aligns with typological generalizations in the World Atlas of Language Structures (WALS), which classifies English as a rigid SVO language (Dryer, 2005). Non-canonical word orders in English include structures such as passives (e.g., "*The ball was kicked by the boy*"), clefts (e.g., "*It is the boy who kicked the ball*"), topicalized sentences (e.g., "*The ball, the boy kicked*") and interrogative constructions (e.g., "*What did the boy kick?*"). These forms displace constituents for pragmatic purposes such as focus, emphasis, or contrast (Leuckert & Pham, 2025). For instance, in the passive, the patient (*the ball*) is moved to subject position while the agent (*the boy*) is demoted, resulting in a mismatch between grammatical roles and thematic roles. While these non-canonical orders are fully grammatical, they are less frequent and pragmatically marked compared to the basic (SVO) word order (Brooks & Tomasello, 1999).

Table 1. Word order flexibility in Moroccan Arabic.

Word order	Moroccan Arabic	Gloss
VSO	/kla l-wəld l-banana/	ate.3Masc.SG. the-boy the-banana "The boy ate the banana."
SVO	/l-wəld kla l-banana/	the-boy ate.3Masc.SG. the-banana "The boy ate the banana."
VOS	/kla l-banana l-wəld/	ate.3Masc.SG. the-banana the-boy "The boy ate the banana."
OVS	/l-banana kla-ha l-wəld/	the-banana ate.3Masc.SG.-it the-boy "The boy ate the banana."
OSV	/l-banana l-wəld kla-ha/	the-banana the-boy ate.3Masc.SG.-it "The boy ate the banana."

Notes: Masc: masculine; O: object; S: subject; SG: singular; V: verb.

In contrast, in MA, the canonical order in active declarative sentences is widely argued to be VSO, not only on syntactic grounds (Dkhissi & Boutabia, 2023; Ennaji, 1985), but also based on distributional tendencies across spoken Arabic varieties. Although large-scale corpora for MA are limited, studies of closely related dialects consistently report VSO as the most frequent word order in pragmatically neutral contexts. For example, Brustad's (2000) data show that VSO order is consistently dominant across four dialects (Moroccan, Egyptian, Syrian and Kuwaiti Arabic), serving primarily to narrate events in pragmatically neutral discourse (e.g., no topicalization). In contrast, SVO is typically used in contexts featuring topic-prominent constructions, where the subject is placed in sentence-initial position to reflect its topical status. Similarly, Al-Khuli (1982), analysing 80 paragraphs from diverse Standard Arabic sources (e.g., newspapers, textbooks, literary texts), found that verbal (V-initial) sentences accounted for 64.21% of the data. The early acquisition of VSO structures by children further supports its canonical status. In a study on Palestinian Arabic, Khamis-Dakwar (2011) found that children between the ages of one and three produced VSO structures more frequently and accurately than SVO ones in a repetition task, with SVO emerging later. These results parallel findings from English, where children consistently use SVO word order in transitive constructions from the earliest stages of language development (Brown, 1973). Non-canonical word orders in MA include variations such as SVO, VOS, OSV and OVS. These orders often arise due to pragmatic or discourse-related factors such as topicalization, focus, or emphasis, which can shift constituents from their canonical positions (Abdul-Raof, 1998). For example, SVO order typically signals a topic-prominent structure where the subject is fronted for emphasis. While grammatical, these non-canonical variants are marked relative to the dominant VSO pattern and may require additional syntactic mechanisms such as resumptive clitics to maintain grammaticality and clarity of thematic roles.

Illegal word order refers to ungrammatical sequences that violate both canonical and non-canonical patterns and thus fall outside the grammatical system of the

Table 2. Examples of the word order errors produced by the MA- and English-speaking PWAA.

Sentence	Error description
Moroccan Arabic	
/l-wəld l-ħəlwā ʒbəd/	SOV word order
English	
Stole the cookies the boy	VOS word order
Stole the boy the cookies	VSO word order
Boy the cookies stole	SOV word order
The cookies the boy stole	OSV word order
The cookies stole the boy	OVS word order
The cookies by the boy stole/The boy by the girl hit	Misplaced by-phrase in passive

Notes: O: object; S: subject; V: verb.

language. In English, the only permissible word order in active declarative sentences is SVO. Impermissible permutations, including VSO, VOS, SOV, OVS and OSV, are considered word order errors. In MA, five of the six possible S, V, O permutations (see Table 1) are grammatical, with the sole exception of SOV. Table 2 provides examples of the word order errors produced by the English-speaking and MA-speaking PWAA in this study.

The present study

To evaluate the contrasting predictions of the CCDH and SDH accounts presented earlier, the present study investigates the production of inflectional morphology and word order in the narrative speech of MA- and English-speaking PWAA. Specifically, we ask the following questions:

(1) Is inflectional morphology consistently more impaired than word order across languages, as predicted by the CCDH, or does this relation vary depending on a language's morphosyntactic profile, as predicted by the SDH?
(2) Do PWAA show a preference for canonical word order production in both languages, and how does this pattern (if any) compare to that of typical controls?

Method

Ethics approval was obtained from the institutions in which the data were collected: the Faculty of Medicine, Pharmacy, & Dentistry of Sidi Mohammed Ben Abdellah University (protocol #28/22) and the University of Maryland-College Park (protocol #385623-12). All the participants provided written informed consent prior to participation in the study.

Participants

MA-speaking participants

Ten MA-speaking participants took part in the present study: five had agrammatic aphasia and five were typical control participants (TP). Participants from the two groups were matched on the basis of age (Mann Whitney U test: $p = .548$) and level of education ($p = 1.000$). However, one participant, M-PWAA1, had a severe verb and sentence production deficit (producing only one verb and four sentences) and was excluded from the detailed analyses. As a result, the group characteristics for the MA-speaking PWAA are based on the remaining four participants ($M_{age} = 48.25$, $SD_{age} = 7.08$, $Range_{age} = 41\text{-}58$; $M_{education} = 8.75$, $SD_{education} = 4.5$, $Range_{education} = 5\text{-}15$; two females). The two groups remained matched on the basis of age ($p = 0.79$) and level of education ($p = 0.90$). The MA-speaking PWAA were recruited from the neurology unit of the Hassan II University Medical Hospital in Morocco. They were all native speakers of MA and reported no significant proficiency in or regular use of other languages. All participants were right-handed and experienced a single left-hemisphere ischemic cerebrovascular accident (ICVA) at least two years prior to testing. The mean years post-stroke for PWAA was 6.5 ($SD_{years\ ps} = 2.3$; $Range_{years\ ps} = 5\text{-}10$). None of the participants reported a history of neurological or psychiatric disturbances. Inclusionary criteria for all participants included passing vision (at least obtain 3/5 on both eyes) (Lea chart, Godbole et al., 2018) and hearing screenings (40 dB at 500, 1000 and 2000Hz frequencies) (Masalski, 2013). The demographic (and clinical) information on the participants is presented in Table 3.

Initial language testing for the MA-speaking persons with aphasia

The diagnosis of agrammatic Broca's aphasia was determined on the basis of the MA Bedside Western aphasia battery-revised (MA-B-WAB-R, El Ouardi et al., 2023) and two connected speech tasks: picture description and semi-structured interview. The speech samples were transcribed and analysed using the MA version of the Rating Scale Profile of Speech Characteristics (MA-RSPSC, Rami et al., 2022). Linguistic metrics like Mean Length of Utterance (MLU), open-to-closed class ratios, noun-to-verb ratios and accuracy of tense marking were calculated. The results are presented in Table 4.

All participants met the diagnostic criteria for Broca's aphasia, as indicated by MA-B-WAB-R fluency scores of 3–4/10 and relatively preserved auditory comprehension (9–10/10). In contrast to TP who had perfect scores on both the MA-RSPSC and the tense

Table 3. Demographic (& clinical) information on the participants.

PP	Gender	Age (years)	Education (years)	Occupation	YPO	AoS?	Hemiplegia?/Side
MA Speakers							
M-PWAA1*	F	44	6	Division head	2	No	No/ Recovered
M-PWAA2	F	47	9	Primary school teacher	5	No	Yes/Right
M-PWAA3	F	47	15	Quranic school teacher	5	No	No/ Recovered
M-PWAA4	M	58	5	Sewer worker	6	Yes/Mild	Yes/Right
M-PWAA5	M	41	6	Small business owner	10	No	Yes/Right
Mean (SD)	—	*48.2 (7)*	*8.7 (4)*	—	*6.5 (2)*	—	—
M-TP1	F	43	15	High school teacher	—	—	—
M-TP2	M	55	9	Nurse	—	—	—
M-TP3	F	45	6	Office clerk	—	—	—
M-TP4	M	43	6	Office clerk	—	—	—
M-TP5	M	43	5	Unemployed	—	—	—
Mean (SD)	—	*45.8 (5)*	*8.2 (4)*	—	—	—	—
English Speakers							
E-PWAA1	F	68	18	Case manager	3	No	Yes/Right
E-PWAA2	M	74	NA	Engineer	18	Yes/Mild	Yes/Right
E-PWAA3	M	46	18	Paramedic	14	No	Yes/Right
E-PWAA4	M	47	20	Consultant	0.9	No	Unknown
E-PWAA5	M	65	15	Salesperson	1	No	Unknown
Mean (SD)	—	*60 (12)*	*17.7 (2)*	—	*7.3 (8)*	—	—
E-TP1	F	54	17	Appraisal agent	—	—	—
E-TP2	F	44	11	NA	—	—	—
E-TP3	F	64	16	Resource manager	—	—	—
E-TP4	F	63	17	Physical therapist	—	—	—
E-TP5	M	50	14	Contractor	—	—	—
Mean (SD)	—	*55 (8)*	*15 (2)*	—	—	—	—

Notes: AoS: apraxia of speech; F: female; M: male; MA: Moroccan Arabic; NA: not available; PP: participant; PWAA: person with agrammatic aphasia; TP: typical participant; YPO: years post-onset; *M-PWAA1 was excluded from the detailed analyses due to a severe verb and sentence production deficit, precluding meaningful inferences to be made.

accuracy measure, PWAA showed a characteristic profile of agrammatic sentence production in connected speech tasks: slow and halting speech with a maximum of three uninterrupted words, severely reduced phrase length (MA-RSPSC phrase length: 1–2/7; MLU: 1.78–2.90) and impoverished grammatical morphology (MA-RSPSC grammatical form: 2-3/7; tense accuracy: 12–55%). Additionally, PWAA produced significantly higher noun-to-verb ratios than TP, indicating a greater reliance on nouns over verbs (Mann–Whitney U test: $p = .001$). They also had significantly higher open-to-closed class ratios ($p = .001$), reflecting the frequent omission of both bound and free grammatical morphemes. None of the PWAA experienced significant apraxia of speech, as per the checklist of apraxic symptoms listed in the

Table 4. Results of the initial language evaluation for the MA-speaking PWAA.

Measure	Participants M-PWAA2	M-PWAA3	M-PWAA4	M-PWAA5	TP Mean (SD)
MA-B-WAB-R					
SS-Content (10)	7	5	5	5	10 (0)
SS-Fluency (10)	4	3	4	4	10 (0)
Auditory comprehension (10)	9	9	10	10	10 (0)
Commands (10)	2	10	10	6	10 (0)
Repetition (10)	5.5	4	5	5	10 (0)
Object naming (10)	8	6.5	7.5	8	10 (0)
Action naming (10)	7	4	3.5	4	10 (0)
AQ (100)	63.3	63.3	62.5	59.1	100 (0)
MA-RSPSC					
Articulatory agility (7)	4	3	4	3	7 (0)
Phrase length (7)	1	2	2	2	7 (0)
Grammatical form (7)	3	2	3	3	7 (0)
Melodic line (7)	1	2	2	2	7 (0)
Paraphasia in RS (7)	2	3	4	4	7 (0)
Word finding (7)	3	4	4	3	7 (0)
Syntactic measures					
MLU	1.78	2.45	2.9	2.72	4.63 (1.1)
Open-to-closed class ratio	0.94	0.87	0.79	0.84	0.70 (0.04)
Noun-to-verb ratio	0.84	0.85	0.86	0.77	0.61 (0.04)
Accuracy of tense	22%	12%	55%	53%	100% (0)

Notes: AQ: aphasia quotient; MLU: mean length of utterance; MA-B-WAB-R: Moroccan Arabic bedside Western aphasia battery-revised (El Ouardi et al., 2023); MA-RSPSC: Moroccan Arabic rating scale profile of speech characteristics (Rami et al., 2022); PWAA: person with agrammatic aphasia; RS: running speech; SD: standard deviation; SS: spontaneous speech; TP: typical participants; The maximum score for the different measures is indicated in the parentheses.

Apraxia Battery for Adults-2nd edition (Dabul, 2000) (see Table 3).

English-speaking participants

Ten English-speaking participants took part in the present study: five had agrammatic aphasia and five were TP. Participants from the two groups were matched on the basis of age (Mann Whitney U test: $p = .347$) and level of education ($p = .111$). The English-speaking participants were recruited from the Aphasia Research Center of the University of Maryland-College Park in the United States. All participants were native speakers of American English and reported no significant proficiency in or regular use of other languages. The English-speaking PWAA were right-handed individuals who had experienced a single left-hemisphere ICVA at least nine months prior to testing. The mean years post-stroke for PWAA was 7.38 ($SD_{years\ ps} = 8.03$; $Range_{years\ ps} = 0.9\text{-}18$). None of the participants reported a history of neurological or psychiatric disturbances. Inclusionary criteria for all participants included passing vision (at least obtain 3/5 on both eyes) (Lea chart, Godbole et al., 2018) and hearing screenings (40 dB at 500, 1000 and 2000Hz frequencies) (Masalski, 2013). The TP data were retrieved from the RHDBank English Minga Control Corpus (Minga et al., 2021). The demographic (and clinical) information of the participants is presented in Table 3.

Initial language testing for the English-speaking persons with aphasia

The diagnosis of agrammatic Broca's aphasia was established using the Western Aphasia Battery-Revised (WAB-R; Kertesz, 2006), alongside two connected speech tasks: picture description and retelling the story of Cinderella from a wordless picture book. Additionally, the Verb Inflection Test (VIT, Faroqi-Shah, 2005) was administered. Speech samples were transcribed in CHAT format and analysed with CLAN software using the EVAL programme (MacWhinney et al., 2011), which generated linguistic metrics including Mean Length of Utterance (MLU), open-to-closed class ratios and noun-to-verb ratios. Language was rated for features of agrammatism using Casilio et al.'s (2019) Auditory-Perceptual Rating of Connected Speech in Aphasia (APROCSA) rating system, which assesses four features: stereotypies, short and simplified utterances, omission of function words and omission of bound morphemes. Each feature is rated on a scale from 0 ("not present") to 4 ("severe"). The results are summarized in Table 5.

All participants met the diagnostic criteria for Broca's aphasia, as indicated by WAB-R fluency scores of 4-6/10 and relatively preserved auditory comprehension (48-60/60). In contrast to the TP, who scored 0 ("not present") on all APROCSA features, PWAA showed features of agrammatic sentence production in connected speech, characterized by short and simplified utterances (APROCSA ratings of 3-4; MLU: 3-6.53) and reduced use of function words and bound morphemes (APROCSA ratings of 2-4). All PWAA also demonstrated impaired verb morphology, defined as less than 60% accuracy on the VIT (Faroqi-Shah, 2005). In addition, PWAA produced significantly higher open-to-closed class ratios ($p = .01$), reflecting the frequent omission of both bound and free grammatical morphemes. None of the participants experienced significant apraxia of speech, as per the checklist of apraxic symptoms listed in the Apraxia Battery for Adults-2nd edition (Dabul, 2000) (see Table 3).

A potential confound in cross-linguistic aphasia research is variation in the severity of language impairment across language groups. In the current study, the MA- and English-speaking PWAA were matched on the basis of WAB-R AQ (Mann Whitney U test: $p = 0.17$) and WAB-R fluency ($p = 0.07$) to ensure that the differences, if any, observed between the two language groups are not artefacts of differences in initial aphasia severity (Bates et al., 1988).

Materials and procedures

Connected speech was elicited from the MA and English-speaking participants using a picture description task and a semi-structured interview. The first task consisted of a description of the Cookie Theft picture stimulus (Goodglass & Kaplan, 1972) for the English speakers and a culturally adapted version for the MA speakers (El Ouardi et al., 2023). The semi-structured interview task consisted of the Stroke Story taken from the AphasiaBank protocol (MacWhinney et al., 2011) for the English-speaking PWAA and a linguistically and culturally adapted version from the MA Montreal-Toulouse protocol of aphasia linguistic examination (El Alaoui Fares et al., 1994) for the MA-speaking PWAA. Since TP had no stroke story to tell, they were asked to tell their illness story, which consisted of the following questions (Minga et al., 2021):

(1) Tell me about any time you've been sick or hurt.
(2) Tell me about your recovery from that illness (or injury). What kinds of things did you do to get better?

Table 5. Results of the initial language evaluation for the English-speaking PWAA.

Measure	Participants E-PWAA1	E-PWAA2	E-PWAA3	E-PWAA4	E-PWAA5	TP Mean (SD)
WAB-R						
SS-Content (10)	7	8	9	7	9	10 (0)
SS-Fluency (10)	6	4	6	4	6	10 (0)
Auditory comprehension (60)	57	60	57	48	54	60 (0)
Commands (80)	34	80	58	12	44	80 (0)
Repetition (100)	81	42	80	42	41	100 (0)
Object naming (100%)	78%	75%	90%	90%	93%	100 (0)
Action naming (100%)	81.8%	27%	90%	32%	95%	100 (0)
AQ (100)	77.2	67.3	78.7	56	69.9	100 (0)
APROCSA (0-4)						
Stereotypies	2	2	1	2	2	0 (0)
Short and simplified utterances	4	4	4	4	3	0 (0)
Omission of function words	3	3	3	3	2	0 (0)
Omission of bound morphemes	4	4	3	3	3	0 (0)
Syntactic measures						
MLU	5.63	3.00	3.68	4.46	6.53	9.59 (1.63)
Open-to-closed class ratio	1.63	2.49	3.98	2.78	1.71	0.90 (0.13)
Noun-to-verb ratio	0.51	1.58	1.29	1.47	1.06	1.05 (0.09)
VIT (100%)	50%	20%	40%	25%	5%	NA

Notes: APROCSA: Auditory-Perceptual Rating of Connected Speech in Aphasia (Casilio et al., 2019); AQ: aphasia quotient; MLU: mean length of utterance; NA: not available; PWAA: person with agrammatic aphasia; SD: standard deviation; SS: spontaneous speech; TP: typical participants; VIT: Verb Inflection Test (Faroqi-Shah, 2005); WAB-R: Western aphasia battery-revised (Kertesz, 2006); The maximum score for the different measures is indicated in the parentheses.

Data coding

The narrative speech samples were analysed following the guidelines of the Quantitative Production Analysis (QPA, Saffran et al., 1989). QPA is a coding system for morphological and syntactic characteristics of language produced by persons with aphasia.

Transcription and utterance segmentation

Common procedures

All speech samples were orthographically transcribed, and pauses of one or more seconds were marked with " … ". The examiner's speech was included in the transcript and clearly distinguished from the participant's speech by a new line. Following established exclusion criteria (Saffran et al., 1989), the following were removed from the narrative corpus: comments on the task, starters, direct discourse markers (e.g., *he said*, *she reported*), repetitions (only the last occurrence was retained), self-corrections (only the last occurrence was retained) and uninterpretable neologisms.[2] The speech was then segmented into utterances based on three criteria: syntactic, prosodic and semantic (Rossi, 2015; Rossi & Bastiaanse, 2008). Starting with the syntactic criterion, a word sequence was considered an utterance if it corresponded to a well-formed, grammatical sentence, such as S + V + O (e.g., *The man hit the boy*). The phonological criterion relied on prosodic features. Falling intonation indicated the end of an utterance, while neutral intonation suggested the continuation of an utterance. Falling intonation was marked with ↓, and neutral intonation was marked with →. The semantic criterion required the utterance to convey at least one complete idea or meaning. The three criteria (syntactic, phonological and semantic) were considered together in determining utterance boundaries. For instance, even if the sequence was ill-formed (syntactically incorrect, e.g., *she to the store went*), as long as it conveyed meaning with clear pauses or neutral intonation, it was still considered an utterance. Each utterance was entered on a scoring sheet and classified as either a sentence (utterances containing at least a subject-predicate structure), a topic-comment structure (utterances lacking an overt verb but conveying a propositional meaning (e.g., *girl beautiful*)) and other utterances (e.g., isolated NPs, VPs) (Saffran et al., 1989). Only utterances classified as sentences were included in the word order analyses. However, all utterances were considered in the counts of verbs and inflectional morphology errors (apart from utterances not containing a verb).

Language-specific procedures for MA

While sentences containing verbs without overt subjects (e.g., *dˤrˤəb l-wəld* "hit (he) the boy") are grammatical and acceptable in MA, they were excluded from the word order analyses (error rate and canonicity), because the absence of an overt subject made it impossible to determine canonical versus non-canonical order. Across the entire MA dataset, there were only two such instances, so their exclusion is unlikely to affect the word order error rates. Applying the utterance segmentation criteria described above resulted in 79 sentences from PWAA and 124 from TP in the MA group.

Language-specific procedures for English

For English, the speech samples were transcribed and segmented by trained undergraduate and graduate

student raters using the CHAT software (MacWhinney, 2000). Applying the same segmentation criteria as described above, there were 183 sentences from PWAA and 129 from TP in the English group.

Linguistic measures

Inflectional morphology error rate

This measure captures the percentage of inflectional morphology errors produced by each participant in each language. Errors were analysed at the level of individual verbs, and a verb was considered to contain an inflectional morphology error if it contained a tense error, an agreement error, or both. In instances where a verb included both types of errors, it was counted once in the combined inflectional morphology measure to avoid double-counting. To quantify these errors systematically, tense and agreement errors were first assessed separately. The proportion of tense errors was calculated by dividing the number of verbs with tense errors by the total number of verbs assessed. The proportion of agreement errors was calculated in the same way. The combined error proportion was then derived by counting all verbs with either a tense error, an agreement error, or both (counted as a single error instance), and dividing this by the total number of verbs assessed.

Word order error rate

This measure captures the percentage of word order errors relative to the total number of sentences produced in each language. Each sentence was first evaluated for completeness, defined as the presence of all obligatory constituents (e.g., subject, verb and object, where required). Only complete sentences were included to ensure that word order errors were assessed independently of omissions potentially due to lexical retrieval difficulties. Word order errors were defined as sentences violating the grammatical word order patterns permissible in each language. In English, the only permissible word order in active declarative sentences is SVO. Other constructions such as passives ("*The ball was kicked by the boy*") and clefts ("*It was the ball that the boy kicked*") are derived from this base order and were treated as grammatical. Errors included impermissible permutations (e.g., "*kicked the girl the ball*" (VSO), "*the girl the ball kicked*" (SOV)) and misplacement of constituents within passives (e.g., "*The cookies by the boy stole*"). In MA, the only strictly ungrammatical order is SOV (e.g., *l-mra ṭ-ṭbāṣəl ɣsəl* "the woman the dishes wash"), which was therefore coded as a word order error. Representative examples from both English- and MA-speaking PWAA are provided in Table 2.

Distribution of canonical and non-canonical word order

This measure classifies sentences based on canonicity. Sentences were coded for canonicity only if they had correct word order; that is, sentences with all obligatory constituents present and no word order violations. In English and MA, SVO and VSO were identified as the canonical word orders in active declarative sentences, respectively. Deviations from these canonical forms were coded as non-canonical. Non-canonical constructions in English included passives ("*The ball was kicked by the boy*") and clefts ("*It was the ball that the boy kicked*"). In MA, non-canonical orders included topic-prominent SVO structures ("*l-wəld ḍrəb l-bənt*"), object topicalized structures with resumptive clitics (OVS: "*l-bənt ḍrbha l-wəld*"/ OSV: "*l-bənt l-wəld ḍrəbha*") and object-focused VOS structures ("*ḍrəb l-kura l-wəld*").

Scoring verification

The coding accuracy of the above measures was verified by two independent raters, each a native speaker of either English or MA with linguistic training. The raters verified the coding accuracy of 30% of the speech samples for each language. Disagreements were resolved by consensus.

Data analysis

All analyses were conducted using R (version 4.3.2). To examine group-level effects, generalized linear mixed-effects models (GLMMs) were fitted using the lme4 package (Bates et al., 2015), with a binomial distribution and logit link function. For each language group, a GLMM was constructed with error type (inflectional morphology vs. word order) as a fixed effect and participant as a random effect, with intercept. Given the small number of participants and potential variability across individuals, the group-level analyses were complemented with individual-level analyses using Fisher's exact tests to determine whether each participant made significantly more errors in one domain. To compare performance between each agrammatic group and its corresponding control group (who performed at ceiling), Fisher's exact tests were also used for each error type. Fisher's exact tests were implemented in R via the fisher.test() function.

For each of the four groups (MA-speaking PWAA, MA-speaking TP, English-speaking PWAA, English-speaking TP), we fitted separate binomial GLMMs with a logit link function to test for differences in the production of canonical versus non-canonical sentence structures.

In each model, sentence type (canonical vs. non-canonical) was entered as a fixed effect, and participant as a random effect, with intercept. These models assessed whether each group produced significantly more canonical than non-canonical sentences. To complement the group-level models, individual binomial tests were conducted to evaluate whether the observed difference between canonical and non-canonical sentence production for each participant significantly deviated from chance (i.e., an expected proportion of 0.5). These tests were performed using the binom.test() in R. All statistical tests used a significance threshold of $p < .05$.

Results

The results of the inflectional morphology and word order measures are presented in Table 6, and the results of the distribution of canonical and non-canonical word orders are presented in Table 7 for the MA speakers and in Table 8 for the English speakers.

Inflectional morphology versus word order

MA-speaking participants

The binomial GLMM for the MA-speaking PWAA indicated a non-significant trend toward greater difficulty with inflectional morphology compared to word order ($\beta = 0.78$, $SE = 0.47$, $z = 1.66$, $p = 0.09$). Individual-level Fisher's exact tests failed to show significant differences between error types in any single participant (Table 6). However, descriptive analysis suggests that the group-level trend may have been driven by two individuals, particularly M-PWAA2, who produced 54% errors in inflectional morphology versus 18% in word order, and M-PWAA4, who showed 22% vs. 5%, respectively. Fisher's exact tests comparing the MA-speaking PWAA with TP (who had ceiling performance with zero errors) showed that PWAA made significantly more errors on both inflectional morphology ($p < 0.001$) and word order ($p < 0.001$), confirming an overall impairment in both domains.

English-speaking participants

The binomial GLMM for the English-speaking PWAA indicated a significant difference between error types ($\beta = -0.63$, $SE = 0.26$, $z = -2.40$, $p = 0.01$), with significantly lower accuracy on word order compared to inflectional morphology. Individual-level analysis via Fisher's exact test indicated that two out of five English-speaking (E-PWAA1, E-PWAA4) made significantly more word order errors than morphology errors, consistent with the group-level GLMM results (Table 6). Although the difference in the remaining participants did not reach statistical significance per Fisher's exact test, their performance patterns were descriptively informative. E-PWAA2 made more inflectional morphology errors (60%) than word order errors (14%), suggesting greater difficulty with morphology. E-PWAA3 showed a relatively balanced error profile (11% word order errors vs. 13% inflectional errors), while E-PWAA5 converged with the group's pattern, showing a higher, though non-significant, rate of word order errors (22%) compared to morphology errors (10%). These findings suggest that, although word order deficits may predominate in the English-speaking PWAA, morphological impairments may present more challenges for some (e.g., E-PWAA2). Comparisons with controls (at ceiling) confirmed that the English-speaking PWAA made significantly more errors on both inflectional morphology ($p < .001$) and word order ($p < .001$) than controls.

Table 6. Inflectional morphology and word order errors in the MA- and English-speaking PWAA.

	Verbs	Inflectional morphology errors		Sentences	Word order errors		Fisher's Exact Test
Participant	*N*	*N*	%	*N*	*N*	%	*p*
MA Speakers							
M-PWAA2	11	6	54.4	11	2	18.2	*0.18*
M-PWAA3	9	1	11.1	12	1	8.3	*1.00*
M-PWAA4	18	4	22.2	19	1	5.3	*0.17*
M-PWAA5	39	4	10.2	37	4	10.8	*1.00*
Mean (SD)	19.2 (13.7)	3.7 (2)	24.4 (20.5)	19.7 (12)	2.0 (1.4)	10.6 (5.5)	–
Mean TP (SD)	30.6 (8.7)	0 (0)	0 (0)	24.8 (5.3)	0 (0)	0 (0)	–
English Speakers							
E-PWAA1	74	4	5.4	61	13	21.3	*0.00**
E-PWAA2	10	6	60.0	7	1	14.3	*0.13*
E-PWAA3	95	13	13.6	60	7	11.7	*0.80*
E-PWAA4	39	7	18.0	33	15	45.5	*0.01**
E-PWAA5	29	3	10.3	22	5	22.7	*0.26*
Mean (SD)	49.4 (34.5)	6.6 (3.9)	21.4 (22.2)	36.6 (23.6)	8.2 (5.7)	23.1 (13.3)	–
Mean TP (SD)	41.8 (13.3)	0 (0)	0 (0)	25.8 (7.4)	0 (0)	0 (0)	–

Notes: PWAA: person with agrammatic aphasia; *N*: Number; SD: standard deviation; TP: typical participants; *$p < .05$ (Fisher's Exact Test comparing the proportion of inflectional morphology errors versus word order errors); Percentages for each error type were calculated as the number of errors divided by the total number of opportunities (verbs for inflectional morphology; sentences for word order) × 100.

Table 7. Distribution of canonical, non-canonical and illegal word orders in the speech of the MA-speaking PWAA.

Participant	Sentences	Correct sentences		Illegal word order		Canonical word order		Non-canonical word order				Binomial Test
						VSO		SVO		VOS, OVS, OSV		
	N	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*p*
M-PWAA2	11	9	81.8	2	18.2	5	55.5	3	33.3	1	11.2	*0.50*
M-PWAA3	12	11	91.7	1	8.3	4	36.3	4	36.3	3	27.4	*0.88*
M-PWAA4	19	18	94.7	1	5.3	10	55.5	7	38.8	1	5.7	*0.40*
M-PWAA5	37	33	89.2	4	10.8	23	69.6	9	27.2	1	2.9	*0.01**
PWAA Mean (SD)	19.7 (12)	17.7 (10.8)	89.3 (5.5)	2 (1.4)	10.6 (5.5)	10.5 (8.7)	54.2 (13.9)	5.7 (2.7)	33.7 (5.1)	1.5 (1)	11.8 (11.1)	–
M-TP1	24	24	100	0	0	18	75.0	3	12.5	3	12.5	*0.01**
M-TP2	25	25	100	0	0	20	80.0	0	0.0	5	20.0	*0.00**
M-TP3	33	33	100	0	0	30	90.9	0	0.0	3	9.1	*0.00**
M-TP4	18	18	100	0	0	13	72.2	2	11.1	3	16.7	*0.04**
M-TP5	24	24	100	0	0	20	83.3	1	4.1	3	12.6	*0.00**
TP Mean (SD)	24.8 (5.3)	24.8 (5.3)	100 (0)	0 (0)	0 (0)	20.2 (6.1)	80.2 (7.2)	1.2 (1.3)	5.5 (6.1)	3.4 (0.8)	14.1 (4.2)	–
Group Mean (SD)[#]	22.5 (8.7)	21.6 (8.5)	95.3 (6.5)	0.88 (1.3)	4.7 (6.5)	15.8 (8.5)	68.7 (16.8)	3.2 (3.0)	18.1 (15.8)	2.5 (1.3)	13.2 (7.4)	–

Notes: *N*: Number; PWAA: person with agrammatic aphasia; SD: standard deviation; TP: typical participants; *$p < .05$ (Binomial test comparing the proportion of canonical vs. non-canonical word order to chance level of 50%). [#]A binomial GLMM examining the proportion of canonical versus non-canonical sentences produced by the MA-speaking participants (PWAA and TP) indicated a significant overall preference for canonical sentences ($\beta = 0.96$, SE = 0.25, $z = 3.91$, $p < 0.001$).

Table 8. Distribution of canonical, non-canonical and illegal word orders in the speech of the English-speaking PWAA.

Participant	Sentences	Correct sentences		Illegal word order		Canonical word order (SVO)		Non-canonical word order		Binomial Test
	N	*N*	%	*N*	%	*N*	%	*N*	%	*p*
E-PWAA1	61	48	78.7	13	21.3	46	96	2	4	*0.00**
E-PWAA2	7	6	85.7	1	14.3	4	67	2	33	*0.34*
E-PWAA3	60	53	88.3	7	11.7	51	97	2	3	*0.00**
E-PWAA4	33	18	54.5	15	45.5	15	84	3	16	*0.00**
E-PWAA5	22	17	77.3	5	22.7	16	94	1	6	*0.00**
PWAA Mean (SD)	36.6 (23.6)	28.4 (20.7)	76.9 (13.3)	8.2 (5.7)	23.1 (13.3)	26.4 (20.7)	87.6 (12.6)	2 (0.7)	12.4 (12.6)	–
E-TP1	29	29	100	0	0	28	96	1	4	*0.00**
E-TP2	15	15	100	0	0	15	100	0	0	*0.00**
E-TP3	23	23	100	0	0	23	100	0	0	*0.00**
E-TP4	35	35	100	0	0	35	100	0	0	*0.00**
E-TP5	27	27	100	0	0	25	92	2	8	*0.00**
TP Mean (SD)	25.8 (7.4)	25.8 (7.4)	100 (0)	0 (0)	0 (0)	25.2 (7.2)	97.6 (3.5)	0.6 (0.8)	2.4 (3.5)	–
Group Mean (SD)[#]	31.2 (17.5)	27.1 (14.7)	88.5 (15.0)	4.1 (5.7)	11.5 (15.0)	25.8 (14.7)	92.6 (10.2)	1.3 (1.0)	7.4 (10.2)	–

Notes: PWAA: person with agrammatic aphasia; *N*: Number; SD: standard deviation; TP: typical participants; *$p < .05$ (Binomial test comparing the proportion of canonical vs. non-canonical word order to chance level of 50%); [#]A binomial GLMM examining the proportion of canonical versus non-canonical sentences produced by the English-speaking participants (PWAA and TP) indicated a significant overall preference for canonical sentences ($\beta = 3.03$, SE = 0.36, $z = 8.46$, $p < 0.001$).

Canonical vs. non-canonical word order

MA-speaking participants

The binomial GLMM examining the proportion of canonical versus non-canonical sentences produced by the MA-speaking PWAA indicated no significant group-level preference for canonical structures ($\beta = 0.35$, $SE = 0.29$, $z = 1.23$, $p = 0.22$). This lack of statistical significance may be attributed to high inter-individual variability. Individual-level analysis via binomial tests indicated that only one out of four MA-speaking participants (M-PWAA5) produced a significantly higher proportion of canonical sentences compared to non-canonical ones (Table 7). Although the difference in the remaining participants did not reach statistical significance per binomial tests, their production patterns were descriptively informative. M-PWAA3 produced more non-canonical sentences (64%) than canonical ones (36%), suggesting a preference for non-canonical structures. M-PWAA2 and M-PWAA4 showed more balanced distributions, producing 55.5% canonical sentences and 44.5% non-canonical sentences. Importantly, across all PWAA in the MA-speaking group, non-canonical productions predominantly consisted of SVO word order. On average, SVO accounted for 77% of non-canonical sentences produced (range: 57-90%). The canonicity effect was robust in the control group ($\beta = 1.48$, $SE = 0.23$, $z = 6.40$, $p < 0.001$), indicating that TP produced significantly more canonical than non-canonical sentences. This group-level finding was supported by individual binomial tests, which showed that all five control participants had a statistically significant preference for canonical word order ($p < .05$) (Table 7). In contrast to the pattern observed in the PWAA group, the TPs' non-canonical productions were not predominantly composed of SVO structures. On average, SVO accounted for only 23% of their non-canonical sentences (range: 0-50%).

English-speaking participants

The binomial GLMM examining the proportion of canonical versus non-canonical sentences produced by the English-speaking PWAA showed a significant effect of canonicity ($\beta = 2.52$, $SE = 0.41$, $z = 6.13$, $p < 0.001$), indicating that non-canonical sentences were produced significantly less often than canonical ones. This group pattern was supported by binomial tests on individual data, with four out of five PWAA producing significantly more canonical than non-canonical sentences (Table 8). The same pattern was observed in the control group, who also showed a significant effect of canonicity ($\beta = 3.80$, $SE = 0.90$, $z = 4.20$, $p < 0.001$), producing non-canonical sentences significantly less frequently than canonical ones. All five control participants demonstrated this preference in binomial tests at the individual level ($p < .05$) (Table 8).

Discussion

This study examined the production of inflectional morphology and word order in the narrative speech of PWAA in MA and English. To evaluate the contrasting predictions of the CCDH (Bradley et al., 1980) and the SDH (Caramazza & Zurif, 1976; Friedmann & Grodzinsky, 1997), we asked whether inflectional morphology is consistently more impaired than word order across the two languages, as predicted by the CCDH, or whether the relative severity of these impairments varies with a language's morphosyntactic profile, as predicted by the SDH. We also asked whether PWAA show a preference for producing canonical word order in both languages, and how this pattern compares to that of typical controls. The observed patterns of impairment are summarized in Figure 2.

Inflectional morphology versus word order in MA and English agrammatism

Both the MA- and English-speaking PWAA showed significant deficits in inflectional morphology and word order relative to controls, consistent with earlier reports of morphological impairment (Faroqi-Shah & Thompson, 2003, 2007; Menn & Obler, 1990; Miceli et al., 1989) and word order problems in agrammatism (Cho & Thompson, 2010; Saffran et al., 1980; Schwartz et al., 1980). In a seminal two-part study, Schwartz et al. (1980) and Saffran et al. (1980) showed that PWAA struggle with syntactic structures in which semantic roles are determined by the linear order of constituents. In Part I (comprehension), participants performed poorly on reversible sentences where thematic role assignment depended solely on constituent order, whether in spatial preposition contexts (e.g., *The square is above the circle*) or verb-argument structures (e.g., *The dancer applauds the clown*). Part II (production) documented a parallel profile: when constructing sentences, either by arranging written words or through oral production, participants' choices were driven more by semantic cues such as animacy or salience than by syntactic rules. Together, these findings point to a core syntactic impairment in agrammatism, consistent with the SDH and at odds with the CCDH, which predicts that arranging major lexical items into grammatical sequences should remain largely intact. Instead, our results show that word order can break down alongside inflectional morphology, indicating a broader syntactic deficit rather than a selective closed-class impairment. This pattern

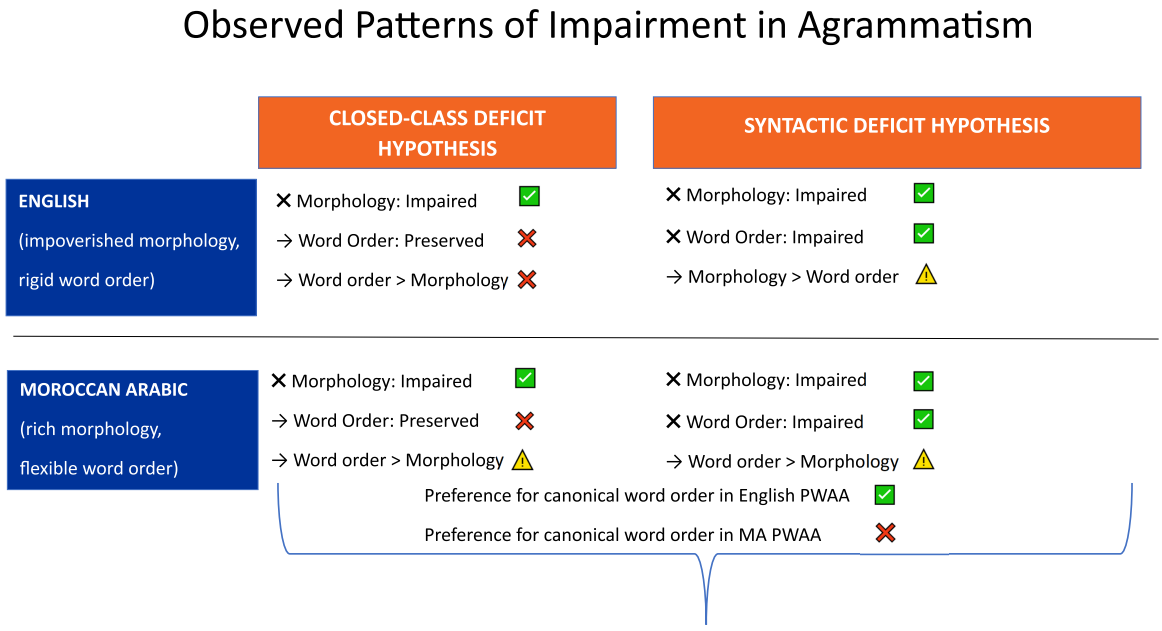

Figure 2. Evaluation of hypothesized patterns of morphological and word order impairments in MA and English agrammatism.

Notes: MA: Moroccan Arabic; PWAA: persons with agrammatic aphasia; fx2 indicates that the prediction was met; fx1 indicates that the prediction was not met; fx3 indicates that the pattern was supported (or showed a statistical trend) at the group level, but individual-level data showed inter-individual variability. [To view this figure in colour, please see the online version of this journal.]

holds even in MA, a highly permissive language (see Table 1), highlighting the vulnerability of constituent ordering principles in agrammatism.

The critical test for adjudicating between the CCDH and the SDH is whether the relation between morphological and word order deficits remains stable across typologically distinct languages (as predicted by the CCDH) or varies systematically (as predicted by the SDH). In the present study, the MA-speaking PWAA showed a non-significant trend toward greater difficulty with inflectional morphology than with word order, whereas the English-speaking PWAA displayed the reverse pattern, with more pronounced difficulties in word order than in morphology. This pattern runs counter to the CCDH, which predicts a stable cross-linguistic profile in which word order is relatively preserved and morphological deficits predominate regardless of language. The observed shift, where the relative severity of morphological versus word order deficits changes across languages, undermines the CCDH's central claim and demonstrates that word order can be compromised in agrammatism (Saffran et al., 1980). By contrast, the SDH readily accommodates these findings. According to this account, both morphological and word order errors are downstream consequences of a core impairment in syntactic computation (e.g., Caramazza & Zurif, 1976; Friedmann & Grodzinsky, 1997). Morphological errors arise when disruptions to structure-building prevent the correct licensing and realization of morpho-syntactic features, while word order errors emerge when the hierarchical organization of constituents is not properly computed. Crucially, the SDH explains the observed cross-linguistic shift. In morphologically rich languages such as MA, grammatical information, including tense, aspect, agreement, person, number and gender, is carried primarily by verbal inflection. Because these features rely on syntactic computation, any breakdown in structure-building creates multiple points where morphological errors can occur. By contrast, the flexible word order of MA reduces the number of contexts in which misordering leads to ungrammaticality, potentially explaining why word order errors tended to be less frequent than morphological errors in the speech of the MA-speaking PWAA. In English, grammatical relations are encoded mainly through rigid SVO word order, and even minor deviations disrupt the mapping from hierarchical structure to linear order, accounting for the greater visibility of word order errors in this language. By contrast, morphology in English is relatively impoverished, providing fewer opportunities for inflectional errors, hence potentially explaining the predominance of word order over morphology errors in the speech of the English-speaking PWAA.

It is noteworthy that the group-level trends in each language were not uniform across individuals. In MA, for example, two participants (M-PWAA3 and M-PWAA5) showed low and roughly balanced rates of morphological (10-11%) and word order errors (8-10%), contrasting with the group's overall tendency toward greater morphological impairment. Rather than

indicating substantial deficits in both domains, these profiles suggest that some PWAA may preserve both morphosyntactic feature licensing and constituent ordering. Individual variability was also observed in the English-speaking group: for instance, E-PWAA3 displayed low, balanced word order-morphology error rates (11-13%), whereas E-PWAA2 produced more morphological (60%) than word order errors (14%). These findings indicate that the severity or locus of syntactic disruption varies across individuals, and that some PWAA may retain sufficient hierarchical structure to support accurate production of morphology and word order. This variability aligns with SDH predictions, which allow for graded impairments depending on which functional projections are affected (Friedmann, 2006), and is consistent with longstanding observations that agrammatism manifests with substantial individual differences (Kolk & Van Grunsven, 1985; Miceli et al., 1989).

In summary, the results provide stronger preliminary support for the SDH than for the CCDH. They show that in both MA and English, agrammatism can affect both morphological marking and word order, but the relative impact shifts with the language's grammatical architecture. Morphologically rich languages like MA tend to show greater vulnerability in inflectional morphology, while morphologically sparse but word order rigid languages like English tend to show greater vulnerability in word order. This cross-linguistic shift contradicts the CCDH's prediction of a stable profile with preserved word order and instead aligns with the SDH's view that both deficits are downstream consequences of a single impairment in syntactic computation, whose surface manifestation is modulated by typological features of the target language.

Canonical vs. non-canonical word order production

The English-speaking PWAA showed a marked preference for canonical word order, mirroring the pattern observed in typical controls. This shared preference for SVO may reflect general production tendencies rather than being solely attributable to agrammatic deficits. The fact that TP also favoured SVO implies that frequency-based or usage-based factors likely contribute to this preference across groups (Gahl & Menn, 2016; Martínez-Ferreiro et al., 2020). Canonical structures are more frequent and more deeply entrenched in usage, which may account for their dominance irrespective of syntactic impairment (Bates et al., 1988; Martínez-Ferreiro et al., 2020; Menn & Obler, 1990). By contrast, the MA-speaking PWAA showed no preference for canonical word order. While typical MA-speaking participants predominantly produced canonical VSO constructions, reflecting both the base-generated nature and the high frequency of this word order in MA, most PWAA (with the exception of M-PWAA5) had a more balanced distribution between canonical VSO and non-canonical SVO structures. This pattern may indicate a compensatory strategy in response to challenges with verb retrieval or morphosyntactic encoding. Initiating sentences with the subject may serve as a stalling mechanism, affording additional time for lexical access and morphophonological planning before the production of the morphologically complex verb. Such timing-based compensations are well-documented in agrammatic speech (e.g., Faroqi-Shah, 2023; Salis & DeDe, 2022) and may be especially pronounced in morphologically rich languages like MA, where verb-initial constructions place a high processing demand due to the inflectional complexity of the verb.

In summary, the similarity between the English-speaking PWAA and TP in favouring canonical SVO structures preliminarily points to a broader, frequency-based production bias. In contrast, the MA data provide a more informative divergence: unlike TP who favoured canonical VSO, the MA-speaking PWAA showed a more balanced distribution between VSO and SVO. This pattern likely reflects compensatory strategies aimed at easing processing demands associated with morphologically complex, verb-initial structures in MA.

Conclusions

This cross-linguistic study compared the production of inflectional morphology and word order in the narrative speech of PWAA in MA and English to adjudicate between the contrasting predictions of the CCDH and SDH. Across both languages, PWAA demonstrated impairments in both domains, but the relative severity shifted with the morphosyntactic profile of the language: MA speakers tended to show greater difficulty with inflectional morphology, while English speakers showed greater difficulty with word order. This typologically driven shift challenges the CCDH's prediction of a stable profile characterized by preserved word order and instead supports the SDH's view that both deficits stem from a core impairment in syntactic computation, whose surface manifestation is shaped by language-specific grammatical architecture. Patterns of canonical word order use further revealed language-specific strategies. In English, both PWAA and controls favoured canonical SVO order, suggesting that frequency-based production tendencies may underlie this pattern rather than agrammatism-specific constraints.

In MA, however, PWAA departed from the canonical VSO preference of typical speakers, producing a more balanced mix of VSO and SVO orders. This divergence likely reflects compensatory strategies, such as initiating sentences with the subject to ease morphosyntactic planning, particularly in light of MA's inflectionally complex verb-initial structures. Overall, the findings support a core syntactic deficit in agrammatism while also demonstrating the influence of typological and frequency-based factors on sentence production across impaired and typical speakers.

Notes

1. A resumptive clitic is a bound pronominal element that appears on the verb to refer back to a fronted noun phrase. For instance, the grammatical version of the sentence "*l-ħəlwā l-wəld ʒbəd*" (*the cookie the boy grabbed*) would be "*l-ħəlwā l-wəld ʒbed-ha*" *(the cookie the boy grabbed-it)*, where *-ha* "*it*" is a clitic resuming reference to *l-ħəlwa* "*the cookie*".
2. In MA, neologisms were distinguished from omission errors based on the presence of a recognizable verbal root. For example, a response that preserved the root K-T-B but omitted a tense or agreement marker (e.g., /ktb/ for /jktəb/) was not considered a neologism, as the root K-T-B was recoverable. In contrast, responses with no identifiable root corresponding to the target or any real verb in the lexicon were classified as neologisms and excluded from further analysis. Thus, errors were only excluded if they lacked a recoverable root structure, not merely due to missing affixes.

Acknowledgements

We thank the Editor, Cristina Romani, for her excellent handling of this submission and her generous guidance throughout the process. We are grateful to the participants and their families for their contributions to data collection, and to Faouzi Belahsen for assistance with participant recruitment in Morocco. Mina Nichols and Youssef Rami are acknowledged for their contributions to data coding verification for the English and MA datasets, respectively. We also thank Davida Fromm for her assistance in accessing and retrieving the speech samples from the RHDBank.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

Loubna El Ouardi was supported by the National Center for Scientific and Technical Research [grant number 4UCD2021] and by the Fulbright Joint-Supervision program. Yasmeen Faroqi-Shah was supported by the National Institute on Deafness and Other Communication Disorders [grant number 1R01DC020483].

Data availability statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

ORCID

Loubna El Ouardi http://orcid.org/0000-0002-1798-3985

References

Abdul-Raof, H. (1998). *Subject, theme and agent in modern standard Arabic*. Routledge.

Al-Khuli, M. (1982). *Al-Tarākīb al-ḥaqīqiyya fī al-lugha al-'Arabiyya [Common structures in Arabic]*. Dar Al-Uloom Publishing Co.

Bastiaanse, R., Koekkoek, J., & Van Zonneveld, R. (2003). Object scrambling in Dutch Broca's aphasia. *Brain and Language*, *86*(2), 287–299. https://doi.org/10.1016/s0093-934x(02)00545-x

Bastiaanse, R., & Van Zonneveld, R. (2005). Sentence production with verbs of alternating transitivity in agrammatic Broca's aphasia. *Journal of Neurolinguistics*, *18*(1), 57–66. https://doi.org/10.1016/j.jneuroling.2004.11.006

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Bates, E. A., Friederici, A. D., Wulfeck, B. B., & Juarez, L. A. (1988). On the preservation of word order in aphasia: Cross-linguistic evidence. *Brain and Language*, *33*(2), 323–364. https://doi.org/10.1016/0093-934x(88)90072-7

Benmamoun, E. (2017). VSO word order, primarily in Arabic languages. In H. van Riemsdijk, & M. Everaert (Eds.), *The Wiley Blackwell companion to syntax* (pp. 1–28). John Wiley & Sons.

Biber, D., Johansson, S., Leech, G., Conrad, S., & Finegan, E. (1999). *Longman grammar of spoken and written English*. Pearson Education.

Bradley, D. C., Garrett, M. F., & Zurif, E. B. (1980). Syntactic deficits in Broca's aphasia. In D. Caplan (Ed.), *Biological studies of mental processes* (pp. 269–286). MIT Press.

Brooks, P. J., & Tomasello, M. (1999). Young children learn to produce passives with nonce verbs. *Developmental Psychology*, *35*(1), 29–44. https://doi.org/10.1037/0012-1649.35.1.29

Brown, R. (1973). *A first language: The early stages*. George Allen & Unwin.

Brustad, K. (2000). *The syntax of spoken Arabic: A comparative study of Moroccan, Egyptian, Syrian and Kuwaiti dialects*. Georgetown University Press.

Caramazza, A., & Zurif, E. B. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language*, *3*(4), 572–582. https://doi.org/10.1016/0093-934x(76)90048-1

Casilio, M., Rising, K., Beeson, P. M., Bunton, K., & Wilson, S. M. (2019). Auditory-perceptual rating of connected speech in aphasia. *American Journal of Speech-Language Pathology*, *28*(2), 550–568. https://doi.org/10.1044/2018_ajslp-18-0192

Cho, S., & Thompson, C. K. (2010). What goes wrong during passive sentence production in agrammatic aphasia: An

eyetracking study. *Aphasiology*, *24*(12), 1576–1592. https://doi.org/10.1080/02687031003714442

Dabul, B. L. (2000). *Apraxia battery for adults–second edition*. Pro-Ed.

Dickey, M. W., & Thompson, C. K. (2007). The relation between syntactic and morphological recovery in agrammatic aphasia: A case study. *Aphasiology*, *21*(6–8), 604–616. https://doi.org/10.1080/02687030701192059

Dkhissi, Y., & Boutabia, A. (2023). A cartographic-minimalist approach to Wh questions in Moroccan Arabic and Moroccan Amazigh. *Journal of Applied Language and Culture Studies*, *6*(3), 70–90.

Dragoy, O., & Bastiaanse, R. (2010). Verb production and word order in Russian agrammatic speakers. *Aphasiology*, *24*(1), 28–55. https://doi.org/10.1080/02687030802586902

Dryer, M. S. (2005). Order of subject, object, and verb. In M. Haspelmath, M. S. Dryer, D. Gil, & B. Comrie (Eds.), *The world atlas of language structures* (pp. 330–333). Oxford University Press.

Dryer, M. S. (2007). Word order. In T. Shopen (Ed.), *Clause structure, language typology and syntactic description* (pp. 61–131). Cambridge University Press.

El Alaoui Fares, M., Ettahiri, L., Fennich, R., & Benbelaid, F. (1994). *Montreal–Toulouse protocol of aphasia linguistic examination: MA version [Unpublished]*. Rabat.

El Ouardi, L., Yeou, M., Rami, Y., & Belahsen, M. (2023). The Moroccan Arabic Bedside Western aphasia battery-revised: Linguistic and psychometric properties. *Journal of Speech, Language, and Hearing Research*, *66*(7), 2376–2389. https://doi.org/10.1044/2023_JSLHR-22-00475

Ennaji, M. (1985). *Contrastive syntax: English, Moroccan Arabic, and Berber complex sentences*. Königshausen & Neumann.

Faroqi-Shah, Y. (2005). *The verb inflection test [Unpublished]*. University of Maryland-College Park.

Faroqi-Shah, Y. (2023). A reconceptualization of sentence production in post-stroke agrammatic aphasia: The synergistic processing bottleneck model. *Frontiers in Language Sciences*, *2*. https://doi.org/10.3389/flang.2023.1118739

Faroqi-Shah, Y., & Thompson, C. K. (2003). Effect of lexical cues on the production of active and passive sentences in Broca's and Wernicke's aphasia. *Brain and Language*, *85*(3), 409–426. https://doi.org/10.1016/s0093-934x(02)00586-2

Faroqi-Shah, Y., & Thompson, C. K. (2007). Verb inflections in agrammatic aphasia: Encoding of tense features. *Journal of Memory and Language*, *56*(1), 129–151. https://doi.org/10.1016/j.jml.2006.09.005

Friedmann, N. (2006). Speech production in Broca's agrammatic aphasia: Syntactic tree pruning. In K. Amunts, & Y. Grodzinsky (Eds.), *Broca's region* (pp. 63–82). Oxford University Press.

Friedmann, N., & Grodzinsky, Y. (1997). Tense and agreement in agrammatic production: Pruning the syntactic tree. *Brain and Language*, *56*(3), 397–425. https://doi.org/10.1006/brln.1997.1795

Gahl, S., & Menn, L. (2016). Usage-based approaches to aphasia. *Aphasiology*, *30*(11), 1361–1377. https://doi.org/10.1080/02687038.2016.1140120

Godbole, N. J., Seefeldt, E., Raymond, W. W., Karesh, J. W., Morgenstern, A. S., Egan, J. A., Colyer, M. H., & Mazzoli, R. A. (2018). Simplified method for rapid field assessment of visual acuity by first responders after ocular injury. *Military Medicine*, *183*(suppl_1), 219–223. https://doi.org/10.1093/milmed/usx175

Goodglass, H. (1993). *Understanding aphasia*. Academic Press.

Goodglass, H., & Kaplan, E. (1972). *The Boston diagnostic aphasia examination*. Lea & Febiger.

Kertesz, A. (2006). *Western Aphasia Battery–Revised (WAB-R): Examiner's manual*. PsychCorp.

Khamis-Dakwar, R. (2011). Early acquisition of SVO and VSO word orders in Palestinian colloquial Arabic. In E. Broselow, & H. Ouali (Eds.), *Perspectives on Arabic linguistics: Papers from the annual symposia on Arabic linguistics* (pp. 281–292). John Benjamins.

Kolk, H. H., & Van Grunsven, M. M. (1985). Agrammatism as a variable phenomenon. *Cognitive Neuropsychology*, *2*(4), 347–384. https://doi.org/10.1080/02643298508252666

Leuckert, S., & Pham, T. (Eds.). (2025). *Non-canonical English syntax: Concepts, methods, and approaches*. Cambridge University Press.

MacWhinney, B. (2000). *The CHILDES project: Tools for analyzing talk*. Erlbaum Associates.

MacWhinney, B., Fromm, D., Forbes, M., & Holland, A. (2011). Aphasiabank: Methods for studying discourse. *Aphasiology*, *25*(11), 1286–1307. https://doi.org/10.1080/02687038.2011.589893

Martínez-Ferreiro, S., Bastiaanse, R., & Boye, K. (2020). Functional and usage-based approaches to aphasia: The grammatical-lexical distinction and the role of frequency. *Aphasiology*, *34*(8), 927–942. https://doi.org/10.1080/02687038.2019.1615335

Masalski, M. (2013). Hearing test. https://play.google.com/store/apps/details?id=mobile.eaudiologia&hl=en

Menn, L., & Obler, L. (Eds.). (1990). *Agrammatic aphasia: A cross-language narrative sourcebook*. John Benjamins.

Miceli, G., Silveri, M., Romani, C., & Caramazza, A. (1989). Variation in the pattern of omissions and substitutions of grammatical morphemes in the spontaneous speech of so-called agrammatic patients. *Brain and Language*, *36*(3), 447–492. https://doi.org/10.1016/0093-934x(89)90079-5

Minga, J., Johnson, M., Blake, M. L., Fromm, D., & MacWhinney, B. (2021). Making sense of right hemisphere discourse using RHDBank. *Topics in Language Disorders*, *41*(1), 99–122. https://doi.org/10.1097/tld.0000000000000244

Rami, Y., Yeou, M., & Kissani, N. (2022). Adaptation of the Boston diagnostic aphasia examination: Reliability and validity of the Arabic version for Moroccan speakers [Unpublished].

Rochon, E., Saffran, E. M., Berndt, R. S., & Schwartz, M. F. (2000). Quantitative analysis of aphasic sentence production: Further development and new data. *Brain and Language*, *72*(3), 193–218. https://doi.org/10.1006/brln.1999.2285

Rossi, E. (2015). Modulating the sensitivity to syntactic factors in production: Evidence from syntactic priming in agrammatism. *Applied Psycholinguistics*, *36*(3), 639–669. https://doi.org/10.1017/S0142716413000374

Rossi, E., & Bastiaanse, R. (2008). Spontaneous speech in Italian agrammatic aphasia: A focus on verb production. *Aphasiology*, *22*(4), 347–362. https://doi.org/10.1080/02687030701407093

Saffran, E. M., Berndt, R. S., & Schwartz, M. F. (1989). The quantitative analysis of agrammatic production: Procedure and data. *Brain and Language*, *37*(3), 440–479. https://doi.org/10.1016/0093-934x(89)90030-8

Saffran, E. M., Schwartz, M. F., & Marin, O. S. (1980). The word order problem in agrammatism: II. Production. *Brain and Language*, *10*(2), 263–280. https://doi.org/10.1016/0093-934x(80)90056-5

Salis, C., & DeDe, G. (2022). Sentence production in a discourse context in latent aphasia: A real-time study. *American Journal of Speech-Language Pathology*, *31*(3), 1284–1296. https://doi.org/10.1044/2022_ajslp-21-00232

Schwartz, M. F., Saffran, E. M., & Marin, O. S. (1980). The word order problem in agrammatism: I. Comprehension. *Brain and Language*, *10*(2), 249–262. https://doi.org/10.1016/0093-934x(80)90055-3