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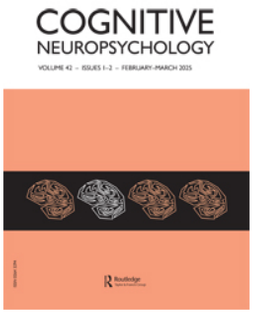

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Cross-linguistic asymmetries in language production and code-switching patterns in bilingual aphasia

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ABSTRACT

This study investigates cross-linguistic asymmetries in noun and verb production in a Hindi-English bilingual with Broca's aphasia (RZ), focusing on the influence of task demands (narrative vs. noun naming, verb naming, repetition), morphological richness, and code-switching (frequency and type). RZ exhibited features of agrammatism in both languages, with more pronounced deficits in English. RZ showed grammatical class asymmetries in noun-verb production across tasks. He produced more verbs than nouns in Hindi in the narrative task, likely due to its rich morphology, while showing comparable noun–verb production in naming. Verb retrieval remained consistently impaired in English across tasks. RZ frequently but rigidly code-switched, mainly inserting English nouns within Hindi matrix structure and used bilingual compound verbs, suggesting a strategy to compensate for lexical deficits in Hindi and morphosyntactic challenges in English. These findings underscore the importance of language typology and task demands in shaping aphasic symptomatology in bilinguals.

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Bilingual aphasia; noun; verb; code-switching; agrammatism

Introduction

Following are a few utterances from the Frog Story narrative produced by RZ, a Hindi-English bilingual with Broca's aphasia.

"sun six o clock seven o clock time होगया तो

IPA: /sən 6 o klok 7 o klok təəym hogəyɑ t̪oh/

Translation tier: /sun 6 0 clock 7 0 clock time happened then/ [The time was 6 0 clock or 7 0 clock then]

boy और dog frog गायब होगया है

IPA: /boj ɒr ɖɔg frɔg gɑjəb hogəjɑ hɛ/

Translation tier: /boy and dog frog disappear-ed has/ [Boy and dog frog has disappeared.]

तो boy था hello कर रहा था

IPA: /t̪oh bɔj tʰɑ hɛllɔ kər rəhɑ tʰɑ/

Translation tier: /then boy was hello do-ing was/ [the boy was doing hello]

frog गायब होगया है"

IPA: /frɔg gɑjəb hɔgəjɑ hɛ/

Translation tier: /frog disappear-ed has/ [frog has disappeared]

RZ's narrative sample offers several key insights. First, his short, fragmentary utterances with limited syntax align with Broca's aphasia, likely indicating agrammatism. Second, the narrative reveals language-specific asymmetries in grammatical versus lexical abilities and word class production. Third, frequent code-switching is evident. This study aims to describe and investigate the underlying causes of these asymmetries, focusing on task differences and extensive code switching, and explores what these patterns reveal about aphasic impairments in bilingual speakers of typologically distinct languages – Hindi and English. We compared RZ's performance on a narrative task with a series of single word production tasks and contrasted his results with those of a non-brain damaged bilingual control (BC). The narrative task provided a broader linguistic context for assessing both lexical retrieval and morphosyntactic abilities, allowing for the identification of potential dissociations between lexical and grammatical processing. In contrast, the single-word production tasks – comprising noun naming, verb naming, and repetition

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– offered a more controlled lexical environment with well-controlled stimuli sets, making them suitable for detecting specific word class retrieval differences across languages.

Beyond its theoretical and clinical relevance, this research provides valuable data on Hindi, the third most spoken language globally, with approximately 609.5 million speakers (Eberhard et al., 2024). As one of India's official languages, Hindi is also widely spoken across the Indian diaspora globally. Despite its global presence, Hindi remains significantly underrepresented in aphasia research (Beveridge & Bak, 2011), with only a handful of studies to date (e.g., Bhatnagar et al., 2002; Bhatnagar & Whitaker, 1984; Ramoo et al., 2024; Vaid & Pandit, 1991; Venkatesh et al., 2012). This research addresses that gap and advances our understanding of aphasia in a major world language.

Cross-linguistic differences between Hindi and English and possible influence on linguistic deficits

RZ's narrative sample featured short, simplified, and fragmentary utterances, with minimal syntactic and morphological markings, a few function words, and a predominance of content words. These are characteristic features of agrammatism (Bastiaanse & Thompson, 2012; Menn et al., 1990). While documenting agrammatism is not the primary aim of this study, RZ's output offers valuable insight into language-specific patterns in lexical and grammatical abilities. His bilingualism appeared to support code-switching, likely used to overcome lexical or grammatical difficulties. Before exploring the causes of language-specific asymmetries and extensive code-switching, it is important to consider the cross-linguistic differences between Hindi and English and their potential impact on aphasic symptoms.

Hindi and English are typologically distinct languages. Hindi, a synthetic language from the Indo-Iranian branch of the Indo-European family, features rich morphology, flexible word order (typically SOV), and allows subject pronoun omission (pro-drop) (Agnihotri, 2022; Shapiro, 2003). In contrast, English is an analytic language with simpler morphology, rigid SVO word order, and obligatory subject pronouns. Flexible word order is often closely tied to rich morphology of languages.

Hindi also has fewer closed-class words compared to English, which includes a broader range such as determiners, modals, auxiliaries, and conjunctions (Comrie, 1998). In Hindi, open-class words often carry grammatical functions typically handled by closed-class words in English. Nouns inflect for number, gender, case, and particles, while verbs inflect for person, number, gender, tense, aspect, mood, and honorification. Verb agreement in Hindi is extensive, bare verb forms are rare. In contrast, English nouns inflect only for number and possession, and verbs inflect primarily for tense, aspect, and mood, with limited agreement (mainly third-person singular present). English also allows many words to function as both nouns and verbs (e.g., *book*, *notice*), a flexibility largely absent in Hindi.

These differences could likely shape how lexical and grammatical elements are produced in each language by RZ. The pattern of his performance can align with one (or more) of the following possibilities: (1) Noun and verb production are influenced by similar cross-linguistic factors, regardless of morphological complexity. (2) In morphologically rich languages like Hindi, verb retrieval may be facilitated by agreement cues, particularly in narrative contexts. (3) Alternatively, the same morphological complexity may hinder verb production due to the increased linguistic demands of achieving accurate agreement. This study contributes to the limited body of research on typologically distinct languages by examining whether differences in morphological richness between Hindi and English influence the relative preservation of nouns and verbs in bilingual aphasia.

Grammatical class dissociation and utility of task comparisons

There exists substantial literature on grammatical class dissociation in both monolingual and bilingual aphasia (Bates et al., 1991; Luzzatti et al., 2002; Crepaldi et al., 2006; Kambanaros, 2008; Nilipour et al., 2017; Kambanaros & van Steenbrugge, 2006; Faroqi-Shah & Waked, 2010; Kambanaros, 2010; Li & Kiran, 2023). Numerous factors influence grammatical class production in aphasia, including neural mechanisms, linguistic structure, psycholinguistic properties of stimuli as well as the type of tasks. Although a detailed discussion of these factors is beyond the scope of this paper, in the following section we focus on the influence of linguistic features on noun and verb production literature in monolingual and bilingual aphasias. We highlight how comparison of narrative and single word tasks enables researchers to determine the interaction of lexical and grammatical processing in bilingual aphasia.

While debate continues over whether lexical retrieval depends on grammatical category, a consensus holds that verbs are more frequently impaired than nouns (Kambanaros, 2010; Luzzatti et al., 2002). For instance, Kambanaros (2008) found greater verb impairment in five Greek speakers with anomic aphasia; Nilipour et al. (2017) reported verb deficits in 95% of 52 Persian-

speaking individuals with aphasia. Conversely, some studies show verbs being better preserved. Sung et al. (2016) using a picture description task, found that Korean speakers produced more verbs per utterance than English speakers attributing this to Korean being a verb salient and a pro-drop language. The authors suggested that noun-verb deficits may be shaped by language-specific features.

Findings on grammatical class dissociation in bilingual aphasia remain mixed (Kremin & De Agostini, 1995; Sasanuma & Park, 1995; Kambanaros & van Steenbrugge, 2006; Faroqi-Shah & Waked, 2010; Kambanaros, 2010; Abuom & Bastiaanse, 2012; Law et al., 2015; Li & Kiran, 2023). Appendix A summarizes studies comparing noun and verb performance in bilingual aphasia. While results vary, some patterns emerge: in four of 11 studies, nouns and verbs were similarly affected across languages; in seven, verbs were more impaired; and in only one study, nouns were more impaired in a participant. Two studies reported task-dependent dissociations, for example, better noun performance in naming but better verb use in connected speech (Kambanaros, 2010) and a better performance on single word naming compared to connected speech (Law et al., 2015). Notably, some studies tested only one language despite participants being bilingual (e.g., Kambanaros & Grohmann, 2015) and research in typologically distinct languages remains limited, with only a few exceptions (Faroqi-Shah & Waked, 2010; Li & Kiran, 2023; Venkatesh et al., 2012).

An underexplored area in this literature is the comparison between narrative production and structured single-word production tasks, with only a limited number of studies addressing this distinction (e.g., Kambanaros, 2010; Venkatesh et al., 2012; Law et al., 2015; Li & Kiran, 2023). A narrative task is broader in scope and places higher demands integrating several linguistic domains including lexicon, syntax and morphology, while single word production requires lexical retrieval and articulation. It is possible that cues from surrounding lexical items support verb retrieval in narrative speech, though some might argue that integrating various linguistic cues imposes a retrieval difficulty. For example, complex verb morphology makes verbs harder to retrieve, as seen in English and Mandarin (Li & Kiran, 2023). However, studies in morphologically rich languages like German, Hebrew, and Bengali suggest that complexity does not necessarily lead to greater difficulty or more errors, instead verbs in these languages are more resilient to neurological impairment (Bose et al., 2021; Kavé & Levy, 2003; Nedergaard et al., 2019; Penke, 2012). This apparent contradiction may be reconciled by considering the nature of morphological complexity. In synthetic languages such as Hindi and Bengali, inflectional systems are complex yet highly regular and systematic. These systems often exhibit a one-to-one correspondence between meaning and form, thereby reducing ambiguity in meaning-form mapping and leading to better preservation of verbs.

This study examines noun and verb production across different tasks, testing whether verbs are more vulnerable in narrative tasks due to their reliance on agreement, tense, and other morphosyntactic features, demands that are absent in single-word naming tasks. Alternatively, if lexical retrieval is pervasively impaired, similar patterns of difficulty would be expected across tasks.

Code-switching in bilinguals with aphasia

Code-switching is a fundamental aspect of bilingual communication often employed to emphasize, to fill lexical gaps or to enhance communicative effectiveness (Gafaranga, 2005; Grosjean, 2013). While it is a natural and strategic behaviour among neurotypical bilinguals, it's role in bilingual aphasia has been debated. The term *pathological code-switching* was initially used to describe uncontrolled language switching leading to communicative breakdowns (Fabbro et al., 2000). However, this view has evolved. Code-switching in bilinguals with aphasia is now often seen as a compensatory strategy to manage linguistic difficulties, rather than a sign of impaired control (Goral et al., 2019; Muñoz et al., 1999).

Neurotypical bilingual speech features a range of qualitatively distinct code-switching types, namely insertion, alternation and dense code-switching (Muysken, 2000; see Table 2 presenting examples of different types of code-switching produced by RZ and BC in methods). Despite its relevance, research on code-switching in bilingual aphasia is limited and has primarily focused on typologically similar languages, emphasizing frequency over type or quality (Ansaldo & Marcotte, 2007; Muñoz et al., 1999; Neumann et al., 2016). For example, Muñoz et al. (1999) found that Spanish-English bilinguals with aphasia code-switched more frequently than controls, suggesting they draw on both languages to support communication. A detailed code-switching analyses including both quantity (frequency) and quality (type) allows us to disentangle code-switching tendencies across grammatical classes, thereby offering a deeper insight into the nature of RZ's impairment. For example, if RZ consistently used Hindi as the matrix language, that would support that he used Hindi verbs and sentence structure to generate an utterance,

which could be better preserved due to its morphological richness. In a context like this, insertion of English nouns would then imply that he is potentially overcoming noun retrieval difficulties in Hindi.

The current study

RZ was recruited for a larger study investigating language production in bilingual aphasia. Initial screening assessments had revealed cross-linguistic asymmetries in narrative speech with extensive code-switching patterns. Typological and structural distinction between Hindi and English provided us the opportunity to test if cross-linguistic asymmetrical performance reflects constraints imposed by linguistic properties of the given languages. To investigate cross-linguistic asymmetries and task effects in RZ, we employed both narrative (broader linguistic scope) and single word production tasks (focused linguistic scope, including noun-verb naming and noun-verb repetition). A repetition task was included to assess whether RZ's difficulties persisted when phonological forms were provided. We also conducted code-switching analyses to examine whether switching patterns differed between nouns and verbs.

Aphasia assessments typically administer narrative tasks in a unilingual mode. We employed a narrative elicitation based on "*Frog, Where Are You?*", in both unilingual and bilingual modes. "Bilingual mode" refers to communicative contexts where interlocutors who share the same language pair naturally engage in code-switching, a common practice in multilingual societies (Gafaranga, 2005; Muysken, 2000). We introduced a bilingual mode for three key reasons. First, screening assessments suggested that RZ might struggle to produce a narrative in a unilingual context. Second, we aimed to provide a more ecologically valid opportunity for narrative production, reflecting typical bilingual communication. Third, we anticipated that the bilingual mode would elicit code-switching, allowing us to examine it as a natural communicative strategy rather than a pathological symptom. To assess whether RZ's code-switching was atypical, we collected narrative data from a matched non-brain damaged bilingual control (BC), analysing both the frequency and type of code-switches. To summarise, we analysed RZ and BC's performances in the following domains: (1) count and proportion of nouns and verbs in the narrative task; (2) percentage accuracy from single-word production tasks (noun-verb naming, and noun-verb repetition); (3) frequency and type of code-switching patterns. Research questions and associated predictions are listed below:

1) Cross-linguistic comparison of grammatical class production and task influence-

Does variation in morphological complexity between Hindi and English and task differences influence RZ's production of nouns and verbs between narrative and single word production tasks?

Predictions: A consistent use of Hindi morphosyntax in RZ's narrative output would suggest that his production is influenced by the structural properties of Hindi. In Hindi, where verb morphology is rich and inflected forms are the norm, verbs are expected to be better preserved than English verbs (Penke, 2012). In contrast, no significant cross-linguistic differences are anticipated for nouns. The presence of task difference in grammatical class production, especially verbs would point towards utilisation of various agreement and morphosyntactic cues to facilitate production. The lack of task difference would imply a pervasive difficulty in grammatical class production. No differences are expected in noun and verb repetition as the phonological form would be provided to him.

2) Comparison of quantity and quality of code-switching-

Does RZ's code-switching patterns differ in quantity (frequency) and quality (type) from that of BC?

Predictions: We predict to observe differential patterns in the frequency and type of code-switching, which may reflect asymmetrical impairment patterns and compensation strategies. Specifically, a consistent use of one matrix language either English or Hindi would suggest limited flexibility and use of insertions in other language as compensatory for lexical retrieval difficulties. Similarly, type of code-switches, that is, amount of insertion and alternation in RZ's narrative would provide evidence of preference for use of one language over the other. Specifically, use of both insertion and alternation would indicate flexibility in use of both languages; contrastingly, low frequency of alternation would indicate a preference of one language over the other.

Methods

Participants

RZ was a 32-year-old right-handed bilingual (Hindi-English) male who had sustained a traumatic brain injury in a road traffic accident at age 27. He held a degree in Mechanical Engineering and was highly proficient in both Hindi (first language) and English (second

language) prior to the injury. RZ was raised in Bihar, North India, where Hindi is the dominant language, RZ received primary education in both Hindi and English. His secondary and higher education were primarily in English. At 18, he moved to Bangalore, Karnataka, for his engineering studies. Despite Kannada being the local language, he continued to use Hindi and did not acquire Kannada. Following graduation, RZ relocated to the UK for employment. At the time of the accident, he had been living there for six months and was working for a multinational IT company.

Following the accident, RZ presented with a Glasgow Coma Score of 3/15, indicating a severe traumatic brain injury. A CT scan revealed a comminuted fracture of the left calvarium, involving the frontal and parietal bones and extending through the mastoid air cells. He underwent an emergency left-sided frontotemporal decompressive craniectomy. One-year post-injury, RZ returned to India and received speech-language therapy. At the time of assessment, four and a half years post-onset, he was residing in Delhi, North India, in a predominantly Hindi-speaking environment with his parents and extended family.

To enable comparative analysis, we also collected data from a bilingual control participant (BC) using a pairwise matching approach. Pairwise matching has been shown to effectively address the complexity of bilingualism, enhancing the validity of comparative studies (Czapka et al., 2020), and improving participant comparability by minimizing inter-individual variability (Si & Mark Ellison, 2023). BC was carefully selected to match RZ on key variables known to influence code-switching and bilingual language use, including age, gender, education, profession, language pair, language dominance, age of acquisition, and proficiency in each language. BC was a 32-year-old male with an engineering background, employed in the IT sector, and proficient in both Hindi and English. Both participants provided informed consent under a protocol approved by the Institutional Research Ethics Committee (Ethical approval code: 2015-071-AB).

Bilingual profile

Table 1 summarizes RZ's language acquisition history, proficiency, and patterns of language use pre- and post-trauma. A comprehensive overview of his performance on various bilingualism measures is available in Supplementary Material Table S1. To assess RZ's bilingual profile, we employed multiple measures, including an adapted version of the questionnaire by Muñoz et al. (1999). This tool evaluated his language acquisition timeline, educational language exposure, self-rated proficiency across speaking, comprehension, reading, and writing, as well as current language usage patterns.

Prior to his brain injury, RZ was equally proficient in Hindi and English. However, Hindi was used more frequently in daily life, both before the trauma and at the time of assessment. Professionally, he primarily communicated in English, while Hindi was used in personal and social contexts. This was reflected in his self-rated oral proficiency scores (listening and speaking), which were equal for both languages (Hindi: 6.25; English: 6.25). His literacy skills were stronger in English (6.25) than in Hindi (5), and he regularly read newspapers and magazines in both languages (see Supplementary Material Table S1). Post-injury, RZ's language use shifted significantly. He relied predominantly on Hindi for verbal communication, while English use became limited to digital communication (e.g., text messaging, social media), as he had discontinued employment and returned to India.

Aphasia assessment

RZ's aphasia profile in both Hindi and English was assessed using the Western Aphasia Battery in Hindi (Karanth, 1980) and the Western Aphasia Battery–Revised (WAB-R; Kertesz, 2006). Assessments were conducted by the first author, who is fluent in both languages. Table 1 presents scores from WAB subtests and a narrative speech sample elicited through the Picnic picture description task.

RZ demonstrated moderate Broca's aphasia in both languages, with Aphasia Quotients of 60.2 in Hindi and 55.1 in English. Detailed domain scores are provided in Supplementary Material Table S1. Overall, none of the WAB subtests showed statistically significant differences between the two languages, although descriptively certain scores were higher in English and others in Hindi. RZ showed higher scores in Hindi on auditory verbal comprehension, but this did not reach statistical significance ($t = 1.097, p = 0.38$). In naming tasks, English scores were higher but not statistically significant ($t = -2.72, p = 0.07$), particularly in object naming (Hindi = 29/60; English = 48/60) and verbal fluency (Hindi = 3/20; English = 7/20). His spontaneous speech was also more productive in Hindi but this difference was not statistically significant (Hindi = 12/20; English = 9/20; $t = 3.0, p = 0.20$).

Notably, the narrative speech sample revealed language-specific differences in noun and verb production. In English, the output was restricted to primarily nouns (e.g., /tree is leaf/; /ship boat/); whilst in Hindi the output included both nouns and verbs (e.g., /tʃʰoːɽaː bə͡tʃə pət̪ən t͡ʃəlaː rəɦaː

Table 1. RZ's bilingual profile detailing his language acquisition history, proficiency (pre-trauma and current), frequency of usage (pre-trauma and current), and language scores on Western Aphasia Battery in Hindi (Karanth, 1980) and English (Kertesz, 2006).

	Languages	
Bilingualism profile	**Hindi**	**English**
Language acquisition history[1,2]	19 (20)	1 (20)
Language proficiency pre-trauma[1,3,4]	5.62 (7)	6.25 (7)
Current language proficiency[1,3,4]	2.5 (7)	2.12 (7)
Frequency of usage pre-trauma[1,5,6]	4.6 (5)	2.5 (5)
Current frequency of usage[1,5,6]	5 (5)	2 (5)
WAB assessment		
Spontaneous Speech (SS)[7]		
Information Content	8 (10)	7 (10)
Fluency	4 (10)	2 (10)
SS Score[7]	12 (20)	9 (20)
Auditory Verbal Comprehension (AVC)		
Total[8]	178 (200)	157 (200)
AVC Score[9]	8.9	7.85
Repetition	52 (100)	42 (100)
Repetition Score[10]	5.2	4.2
Naming		
Total[11]	40 (100)	65 (100)
Naming Score[12]	4	6.5
Aphasia quotient (AQ)[13]	60.2	55.1
Aphasia severity [14]	Moderate	Moderate
Aphasia type[15]	Broca's	Broca's
Description of the Picnic picture[16]	'**pɑːrk** hɛ' */Park is there/* '**tri**: ətʃa hɛ' */Tree is good/* '**hoʊm** kɑːr tʰɑː **saɪd** hɛ' */Is doing (going) home, is sad/* 'ɔːr kɔːn hɛ' */and who is there?/* '**dæd mɒm** hɛnə baɪl̪ʰa huːn' */Dad and mom are there no? I am sitting/* 'tʃʰoːɻaː bət͡ʃə pət̪əŋ t͡ʃəlaː rəɦaː ɦɛː' */A small boy is flying a kite/*	'aɪ æm ˈsɪtɪŋ' */I am sitting/* 'mɒm' */Ma'am/* 'triː ɪz liːf' */Tree is life/* 'bɔɪ ɪn ɪz **pətʌŋg** ɪŋglɪʃ **hɛ hɪndi hɛ**?' */Boy in is kite, English or Hindi?/* 'kaɪt' */kite/* 'ʃɪp boʊt **pətɑ**ː **nəhi**' */ship, boat don't know/*

Notes: Values in brackets denote the maximum possible score for each variable. 1-adapted from Munoz, Marquardt & Copeland (1999), 2-greater score in one language means greater immersion in that language during childhood; 3- a higher score means greater proficiency(1 = very poor; 7 = native like); 4- Average rating score across the four modalities: listening, speaking, reading, and writing; 5-Average frequency of usage across settings such as at home, at work, telecommunication etc; 6-a higher score means greater frequency of usage (1 = not at all; 5 = very often); 7-sum of information content and fluency score; 8-sum of all auditory verbal comprehension subtest scores; 9-total score divided by 20; 10-repetition score divided by 10; 11-sum of all the naming subtests scores; 12- total divided by 10; 13- AQ = [(SS score+ AVC score+ Repetition score+ Naming score)*2]; 14-Severity rating scale: Mild (76 and above), Moderate(51–75), Severe(26–50), Very severe(0–25);15- Type of aphasia were classified based on WAB-R (Kertesz, 2006) in English and WAB-Hindi (Karanth, 1980); 16- Font highlighted in bold indicates words used from the non-target language.

ɦɛ/ [Small boy is flying kite]). There was frequent code-switching: RZ used English nouns in the Hindi narrative (e.g., /tree ə͡tʃʰaː ɦɛ/ [tree is good]).

Experimental tasks

Narrative task

Narrative speech samples were elicited using the wordless picture book *Frog, Where Are You?* (Mayer, 1969). RZ was instructed to review the images and narrate a story based on them. The task was administered in both unilingual (Hindi or English) and bilingual modes. In the unilingual mode, RZ was asked to narrate the story in only one language, without time constraints. In the bilingual mode, he was free to use either language, with no restrictions on time or language choice. Occasional prompts were provided when RZ did not respond. Consistent with previous observations, RZ was unable to produce a narrative in the unilingual mode. However, in the bilingual mode, he produced a narrative comprising 107 utterances (451 words), lasting 11 min and 30 s, though the utterances were short and fragmented. For the control participant (BC), data were collected only in the bilingual mode. BC produced a bilingual narrative of 99 utterances (731 words), lasting 4 min and 56 s.

All responses were audio-recorded and transcribed for analysis. Two analytical approaches were applied: lexical analysis and code-switching analysis. Glossed full transcripts are provided in Supplementary Material S2. Below are excerpts from the first 10 utterances of RZ and BC, with code-switching instances indicated in bold.

First ten utterances of RZ

1. **home** मे ं था |
   /hoʊm meɪn t̪ʰɑ/
   'He was at home'
2. **boy** और **dog** बैठा था |

/bɔɪ ɔːr dɒg baɪˈʈʰa ʈʰɑ/
'Boy and dog was sitting'
3. और **monkey** नहीं |
/ɔːr ˈmʌŋki nəhiːŋ/
'and not monkey'
4. **frog** बंद बैठा |
/frɒg bənɖ baɪˈʈʰɑ/
'frog closed sitting'
5. **frog** बैठा था |
/frɒg baɪˈʈʰa ʈʰɑ/
'frog was sitting'
6. **frog** ताला बंद था बैठा था |
/frɒg ˈʈaːla bənɖ ʈʰa baɪˈʈʰa ʈʰɑ/
'frog lock closed was sitting'
7. होगया |
/ hogaːjə/
'done'
8. रात था |
/ɾaːʈ ʈʰɑ/
'was night'
9. **stars** रात कर रहा था |
/stɑːrz ɾaːʈ kər rəhɑː ʈʰɑ/
'was night star'
10. रात **star** था |
/ɾaːʈ stɑːr ʈʰɑ/
'was night star'

First ten utterances of BC

1. कसिी घर में एक लड़का रहता था |
kɪsi gʱər meːn eːk lʌɽkaː ɾɛːɳʈa ʈʰɑ/
'Once upon a time, there lived a boy in a house'
2. उसके पास दो दोस्त थे |
/ʊsˈke paːs ɖoː ɖoːsʈ ʈʰeː/
'He had two friends'
3. एक था कुत्ता दूसरा था मेंढ़क |
/eːk ʈʰɑ kʊʈʈaː duːsraː ʈʰɑ meːɳɖək/
'One was dog, the other was frog'
4. मेंढ़क को एक **glass bowl** में रखता था |
/meːɳɖək koː eːk glɑːs boʊl meːn rəkʈa ʈʰɑ/
'He was keeping the frog in a glass bowl'
5. कुत्ता घूमने के लिए आज़ाद था |
/kʊʈʈaːgʱuːmneː keː liːjeː ɑːzɑːd ʈʰɑ/
'The dog was free to roam'
6. लड़का कुत्ते से खेलता मेंढ़क को देखता,
/lʌɽkaː kʊʈʈe seː kʰeːlʈa meːɳɖək koː deːkʈa/
'The boy plays with the dog and watches the frog
7. उसने यह नहीं सोचा कि मेंढ़क को कैसा लगेगा |
/ʊsˈneː jə nahi soːʧa kɪ meːɳɖək koː kɛːsa ləˈgeːga/
'He didn't think how the frog would feel'
8. एक रात जब मेंढ़क त्रस्त होगया लड़के के अत्याचार से |
/eːk ɾaːʈ ʤəb meːɳɖək ʈrəsʈ hogaːjə lʌɽke keː ʌʈjaːˈʧɑːr seː/
'One night, when the frog was distressed by the frog's atrocity/cruelty'
9. उसने बोला 'अब तो मुझे निकलना ही है |
/ʊsˈneː boːla ab ʈo mʊˈʤeː nɪˈkəlnaː hiː haɪ/
He said 'Now, I really have to leave'
10. **He climbed out of the bowl.**
/hiː klaɪmd aʊt ʌv ðə boʊl/
'He climbed out of the bowl'

Lexical analysis. Lexical content was analysed to determine the count of lexical items in each language. The Quantitative Production Analysis (QPA, Berndt et al., 2000) was used to extract the narrative words (i.e., number of meaningful words used to tell the story) irrespective of the language. Words that did not contribute to the narrative (i.e., repetitions, repairs, examiner's prompts, discourse markers, nonwords) were removed. For example, in the sentence /frɒg .. baɪˈʈʰa ʈʰɑ/("frog was sitting"), the number of narrative words in English would be one (/frɒg/); the number of narrative words in Hindi would be two /baɪˈʈʰa ʈʰɑ/('was sitting'); total number of narrative words for this utterance would be three.

From the extracted narrative corpus, a set of count variables was computed for each language based on the frequency of lexical categories. Specifically, we quantified the total number of nouns, verbs, adjectives, adverbs, auxiliary verbs, interrogative adverbs, conjunctions, prepositions/postpositions, pronouns, as well as open- and closed-class words. To capture verb morphology, bare verbs and inflected verbs were coded separately. Additionally, a distinct category was introduced for verbs inflected in combination. For example, in the sentence /bɔɪ slɪp hogaːjə/('boy slipped'), /bɔɪ/ was coded as noun in English; /slɪp hogaːjə/('slip-ed':past tense) was coded as a bilingual compound verb. For succinctness, we derived proportional measures for key lexical categories. Specifically, proportions were calculated for nouns, verbs (bare, inflected, total), and open- and closed-class words by dividing the frequency of each category by the total number of narrative words in the respective language. For example, the proportion of nouns in Hindi was calculated as 13/300 = 0.04. Table 3 presents the formulas used to calculate proportional measures for various lexical categories from the narrative corpus.

Code-switching analyses. Since this study aimed to examine RZ's code-switching in relation to aphasia-related processing and retrieval issues, the analysis focused on ad-hoc code-switches, excluding loanwords. Code-switching occurs during real-time language production, while borrowing reflects long-term language contact, where elements from one language become integrated into another. Given the prevalence of English loanwords in Hindi (Chandola, 1963), distinguishing between the two was essential. Research

Table 2. Examples of different code-switching types from RZ and BC.

Code-switching type	Participant	Example #	Example
Alternation	BC	1	First thing he did, उसने boot उलटी की
			/fɜrst θɪŋ hi dɪd, ˈʊsne but ʊlˈti ki/
		1	/first thing he do (past tense), he boot reverse do (past tense)/
		1	The first thing he did, he reversed the boot".
Alternation	BC	2	कुत्ता नीचे गिरि गया and and dropped the bowl
		2	toʊ kʊ̱tta niːtʃeː gir gəjaː ænd ænd drɒpt ðə boʊl/
		2	/then dog down fall (past tense) and and drop (past tense) the bowl/
		2	"then the dog fell down and dropped the bowl"
	RZ	n/a	None
Insertion of English word into Hindi matrix	RZ	3	और gate खुला हुआ था।
		3	/ɔːr geɪt khʊ̱laː hʊaː thaː/
		3	/and gate open (past participle form) was/
		3	"and the gate was open"
	RZ	4	home में था
		4	/hoʊm meɪn θaː/
		4	/home in was/
		4	"He was at home"
	RZ	5	Vase throw करो
		5	/veɪs θroʊ kəroʊ/
		5	/vase throw do (imperative form)/
		5	"Throw the vase".
Insertion of English phrase into Hindi matrix	BC	6	तो उसने देखा कि glass bowl is empty
			/toʊ ˈʊsne ˈdekʰə ki glaːs boʊl ɪz ˈɛmpti/
		6	/then he see (past tense) that glass bowl is empty/
		6	So he saw that the glass bowl is empty.'
Insertion of Hindi words into English Matrix	BC	7	The उल्लू came out
		7	/ðə ˈʊlu keɪm aʊt/
		7	/The owl come (past tense) out (adv)/
	BC	7	"The owl came out".
	RZ	n/a	None
Bilingual Compound Verbs	RZ	8	Slip हो गया था
		8	/slɪp hoˈgaːjə θaː/
		8	/slip happen (v, past tense) was (past tense)/
		8	"It slipped"
	RZ	9	Jump कर रहा था
		9	/ d͡ʒʌmp kər rəhaː t̪ʰɑ/
		9	/jump do(v, present continuous tense) was (past tense)/
		9	"He was jumping"
	BC	10	और कुत्ते को chase करने लगे
		10	/ɔːr kʊ̱tte ko tʃeɪs kərne ləge/
		10	/and dog to chase (v) to doing (v) started(v)
		10	"and started chasing the dog"

Note: RZ = Bilingual with Broca's aphasia; BC = Bilingual control.

shows code-switching and borrowing exist on a continuum, some switches become conventionalized as loans over time (Backus, 2015; Gardner-Chloros, 2009). This is especially relevant here, as English-Hindi contact has led to extensive borrowing, particularly of English lexemes into Hindi (Bhatia, 1967; Kachru, 1978).

To ensure accurate analysis, potential English loanwords in Hindi utterances were identified and excluded. Loanwords often replace existing terms in the host language, so the first criterion was whether a Hindi translation equivalent existed, its presence indicated code-switching rather than borrowing (Muysken, 2000). The second criterion involved frequency analysis using the hiTenTen13 (Hindi) and enTenTen13 (English)[1] corpora via SketchEngine. If an English lexeme was common in English but rare or absent in Hindi, it was classified as a code-switch. Comparable frequencies in both corpora suggested the lexeme was a likely loanword.

Based on a range of criteria, code-switching was classified into three categories: dense code-switching, alternation and insertion (Deuchar et al., 2007; Muysken, 2000). Table 2 presents examples of code-switching in the narratives.

Dense Code-Switching: This involves extensive blending of grammar and lexicon typologically related languages. As no instances were found in RZ or BC's narratives, it is not discussed further.

Alternation: Alternational code-switches occur at sentence boundaries or peripheries, often marked by pauses or commas (examples 1 and 2). These typically involve longer adverbial phrases.

Insertion: Insertion refers to embedding lexical items or constituents from one language (embedded) into the syntactic structure of another (matrix). These can be single words or larger constituents (e.g., complements). A hierarchical relationship must exist between the two languages, with the matrix language providing the

sentence's morpho-syntactic structure. In this study, the matrix language was identified for each utterance using criteria from Deuchar et al. (2007), and could be either Hindi (examples 3–6) or English (example 7).

As a first step, each utterance was examined to identify a clear matrix language. The matrix language, which provides the utterance's structural framework, was identified based on its morpho-syntactic features. Following Deuchar et al. (2007), we applied four criteria to determine the hierarchical relationship between the two languages and the matrix language for each utterance.

1) Word Order: English follows SVO, while Hindi uses SOV. An SOV structure indicated a Hindi matrix (example 5).
2) Morphology: Consistent use of Hindi inflectional morphemes or postpositions suggested a Hindi matrix (examples 3-6). In example 4, the English word *home* was integrated into Hindi via the postposition *meɪn* ("in"). Similarly, example 3, English word *gate* functioned as a obligatory subject complement selected by the Hindi verb *kʰulə huːa ʈʰa* ("was opened").
3) Word Class: The language membership of closed-class function words (e.g., determiners, pronouns, auxiliaries) indicated the matrix language. Hindi's pro-drop and zero-determiner nature meant their absence pointed to Hindi; their presence suggested English.
4) Verb: The language of the main verb was a strong indicator. In example 4, Hindi verb and SOV order confirmed Hindi matrix. In example 7, English determiners and structure indicated an English matrix, with the Hindi noun *ʊllu:* ("owl") inserted. Contrary to examples 3,4, 5 and 6, the determiners in example 7 are overtly marked, following the English pattern.

Bilingual Compound Verbs in RZ's Code-Switching. A common feature in RZ's code-switching was the use of bilingual compound verbs (examples 5, 8, 9), where an English verb (e.g., *throw*) was combined with a Hindi auxiliary (e.g., *karo* "do") within a Hindi matrix. This code-switching pattern is typical between English and Indo-Iranian languages allowing semantically rich English verbs or nouns to be integrated into Hindi using semantically light[2] Hindi auxiliary verbs (do, make, etc) that carry grammatical features, such as tense or aspect (Edwards & Gardner-Chloros, 2007; Khan, 2015; Muysken, 2000). While monolingual Hindi permits noun–auxiliary compounding, bilingual compound verbs often involve two verb forms, blurring the line between insertion and alternation (Muysken, 2000). In this study, they were classified as insertions, as the English verb was non-finite or nominalized and structurally dependent on the Hindi auxiliary. These constructions may serve as a compensatory strategy for semantic or lexical retrieval difficulties. To explore this, we compared the frequency of compound verbs in RZ's and BC's narratives.

Aphasia-related challenges in classifying types of code switching. Applying Deuchar et al.'s (2007) criteria requires identifiable morpho-syntactic features. However, aphasic speech, especially in RZ's case of severe agrammatism, often lacks such structure (Muñoz et al., 1999). RZ's utterances were typically short (MLU = 4.29), often limited to subjects and verbs, making it difficult to apply criteria like word order. Despite this, the framework remained useful due to its range of classification tools. For instance, in one utterance, all function words [/ɔːr/ (and), nəhiːŋ/(not)] were in Hindi, allowing classification of the English content word /monkey/ as an insertion into a Hindi matrix.

Noun-verb naming task

Noun and verb naming were assessed using the stimuli set developed for Hindi-English bilinguals with aphasia (Venkatesh et al., 2012). The task included 30 nouns (e.g., /haʈʰ/-hand, /gɛnd/-ball,/gʊbbara/-balloon) and 24 verbs (e.g., /rona/- crying,/piːna/- drinking,/kʰana/-eating), presented as black-and-white line drawings from the Object and Action Naming Battery (Druks & Masterson, 2000). All items had direct translation equivalents across Hindi and English and were non-cognates. The stimuli were matched across languages on key psycholinguistic variables, including picture-name agreement (for verbs) and familiarity ratings (see Supplementary Materials Table S3 for details). One verb ("flow") was excluded due to image ambiguity, resulting in a final set of 23 verbs. The stimuli, detailed instructions and response type of both RZ and BC are provided in Appendix B.

Procedure. Testing in Hindi and English was conducted on two separate days. Participants were instructed to name each picture as quickly and accurately as possible. Stimuli were presented individually using PowerPoint slides. Verbs were elicited in the present continuous (*-ing*) form in both languages. All responses were audio-recorded and subsequently transcribed for analysis.

Analyses of responses. Responses were analysed for accuracy, calculated as the percentage of correct responses. Only the first complete response was considered. A response was deemed correct if it matched the target word or was an acceptable alternative. For example, if the Hindi target was */puʂtak/* (book), both */puʂtak/* or */kiʈab/* were accepted. For verbs, both the present continuous (*-ing* form) and the infinitive form

Table 3. Analyses of proportion of different class of words in the narrative production of RZ and BC.

		RZ (Bilingual with Broca's aphasia)			**BC** (Bilingual control)		
Word Class		Hindi	English	Total	Hindi	English	Total
Narrative words	# narrative words	300	151	451	521	210	731
Count variables	**Formula**						
Open class words							
Nouns	# nouns	13	96	109	91	64	155
Total Verbs	# bare verbs and # inflected verbs	63	4	67	92	27	119
Bare verbs	# bare verbs	6	4	10	1	4	5
Inflected verbs	# inflected verbs	57	0	57	91	23	114
Adjectives	# adjectives	9	5	14	26	11	37
Adverbs	# adverbs	43	2	45	54	20	74
	Total # Open class words	**128**	**107**	**235**	**263**	**122**	**385**
Closed class words							
Auxiliary verbs	# auxiliary verbs	113	0	113	83	10	93
Interrogative adverbs	# interrogative adverbs	7	0	7	6	0	6
Conjunction	# conjunctions	28	2	30	30	12	42
Prepositions/postpositions	# prepositions/postpositions	3	2	5	65	19	84
Pronouns	# pronouns	1	0	1	54	18	74
Determiners	# determiners	0	0	0	2	26	26
	Total # Closed class words	**152**	**4**	**156**	**240**	**85**	**325**
Additional lexical variables							
Bilingual Compound Verbs	# English verbs imported into the Hindi matrix by using Hindi auxiliary verbs	20	20	40	1	1	2
Interjections	interjections	0	20	20	1	2	3
Emphatic particles	emphatic particles	0	0	0	16	0	16
	Total # Additional lexical variables	20	40	60	18	3	21
	Total Narrative words	**300**	**151**	**451**	**521**	**210**	**731**
Proportional variables	**Formula**						
Proportion of Open class words							
Proportion of Nouns	# nouns /# narrative words	0.04	0.64	0.24	0.17	0.30	0.21
Proportion of Total Verbs	# total verbs/# narrative words	0.21	0.03	0.15	0.18	0.13	0.16
Proportion of Bare verbs	# bare verbs /# narrative words	0.02	0.03	0.02	0.00	0.02	0.01
Proportion of Inflected verbs	# inflected verbs /# narrative words	0.19	0.00	0.13	0.17	0.11	0.16
Proportion of Adjectives	# adjectives /# narrative words	0.03	0.03	0.03	0.05	0.05	0.05
Proportion of Adverbs	# adverbs/# narrative words	0.14	0.01	0.10	0.10	0.10	0.10
	Total	**0.43**	**0.71**	**0.52**	**0.50**	**0.58**	**0.53**
Proportion of Closed Class words							
Proportion of Auxiliary verbs	# auxiliary verbs/# narrative words	0.38	0.00	0.25	0.16	0.05	0.13
Proportion of Interrogative Adverbs	# interrogative adverbs/# narrative words	0.02	0.00	0.02	0.01	0.00	0.01
Proportion of Conjunctions	# conjunctions/ # narrative words	0.09	0.01	0.07	0.06	0.06	0.06
Proportion of Preposition/ postpositions	# prepositions or postpositions/# narrative words	0.01	0.01	0.01	0.12	0.09	0.11
Proportion of Pronouns	# pronouns/ # narrative words	0.00	0.00	0.00	0.10	0.09	0.10
Proportion of Determiners	#determiners/ # narrative words	0.00	0.00	0.00	0.00	0.12	0.04
	Total	**0.51**	**0.03**	**0.35**	**0.46**	**0.40**	**0.44**
Proportion of additional lexical variables							
Proportion of bilingual compound verbs	# Bilingual compound verbs/# narrative words	0.07	0.13	0.09	0.00	0.00	0.00
Proportion of Interjections	# interjections/# narrative words	0.00	0.13	0.04	0.00	0.01	0.00
Proportion of Emphatic particles	# emphatic particles/# narrative words	0.00	0.00	0.00	0.03	0.00	0.02
	Total	**0.07**	**0.26**	**0.13**	**0.03**	**0.01**	**0.03**

were considered correct (e.g., "eating" or "to eat" for the English target "eating").

Noun-verb repetition task

Repetition was tested using the same noun-verb naming stimuli on a separate day from the naming task.

Procedure. Repetition testing in Hindi and English was conducted on separate days. Participants were instructed to listen carefully to each word and repeat it immediately after the examiner. To minimize reliance on visual or facial cues, participants were seated beside the examiner during the task.

Analyses of responses. Responses were scored for accuracy, defined as the percentage of responses that exactly matched the target word.

Statistical analysis

The following analyses were undertaken to answer the two broad research aims:

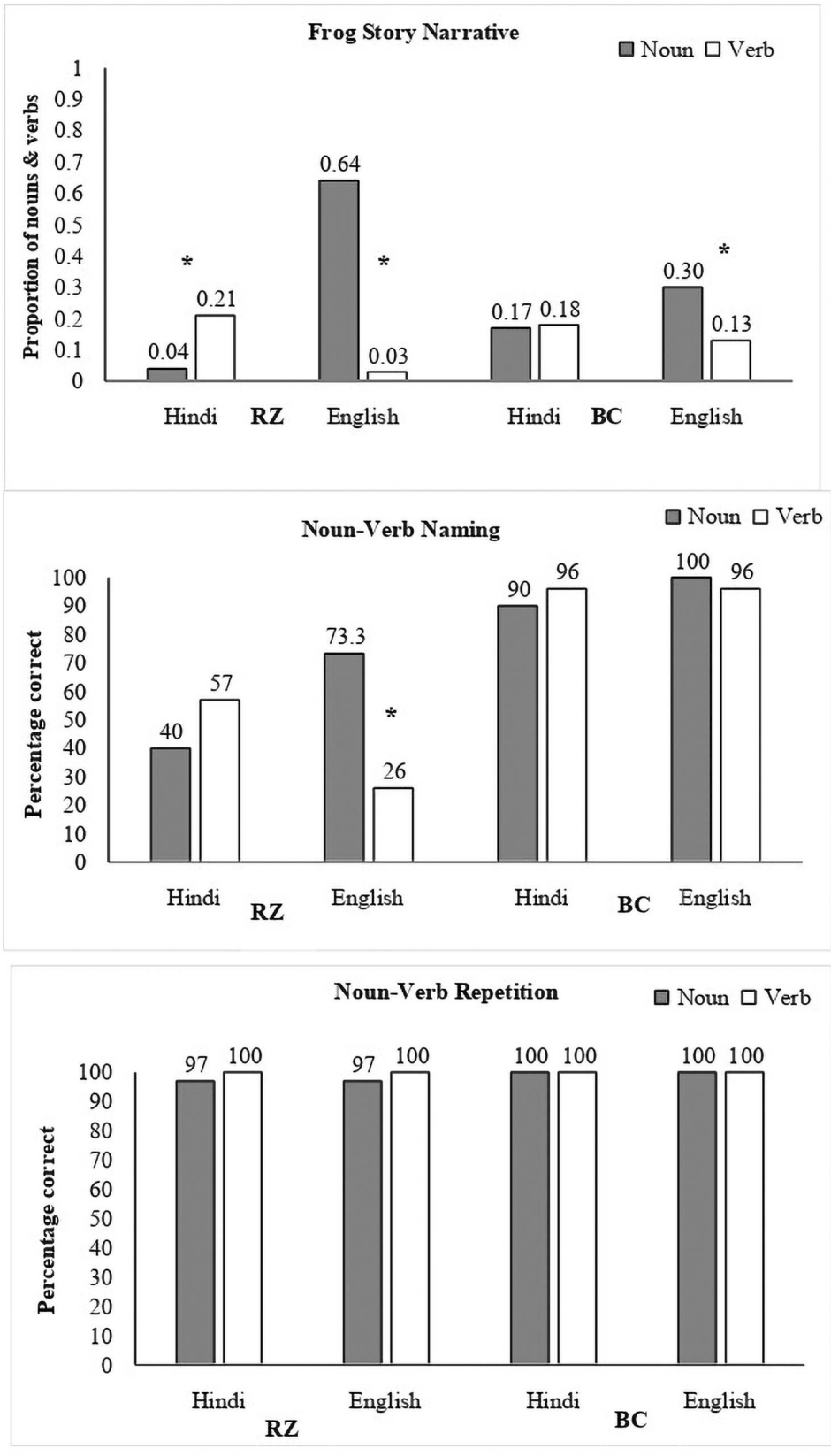

Figure 1. Proportions of nouns and verbs in a narrative task and percentage correct in single-word production tasks (noun-verb naming and noun-verb repetition) for RZ and BC.

Note: An asterisk indicates a significant difference between nouns and verbs within each language. Abbreviations: RZ = Bilingual with Broca's aphasia; BC = Bilingual control.

Table 4. Code-switching analyses in RZ and BC narrative samples.

Code Switching	**Formula**	**RZ** (Bilingual with Broca's aphasia)	**BC** (Bilingual Control)
Code-switching (CS) ratio	# of CS/# of utterances	1.2 (128/107)	0.26 (61/236)
Predominant code-switching type		Insertion	Insertion and Alternation
Proportion of insertional code-switches	# of insertions/# of total CS	**0.78**** (N=99)	**0.58**** (N=35)
Proportion of alternational code-switches	# of alternation/# of total CS	**0.22****(N=29)	**0.42**** (N=25)
Matrix language of insertions		Hindi	Hindi and English
Proportion of Hindi matrix language	# Hindi matrix/# of total insertions	**1.00**** (N=128)	**0.70 **(N=27)
Proportion of English matrix language	# English matrix/# of total insertions	**0.00**** (N=0)	**0.23****(N=8)
Predominant word class of insertion		Noun	Noun
Proportion of noun insertions	# of noun insertions/# of total insertions	0.76 (N=60)	0.93 (N=31)
Proportion of verb insertions	# of verb insertions/# of total insertions	0.24[1] (N=19)	0.07 (N=2)

Note: Bold font indicates significant difference between RZ and BC. (**p<.01;***p<.001). N = number of occurrences.[1]- All verbs inserted by RZ were bilingual compound verbs.

Cross-linguistic comparison of grammatical class production and task influence: Chi-square tests of independence were conducted on narrative speech to compare: (1) Proportions of nouns and verbs across languages for each participant; (2) Proportions of nouns vs. verbs within each language for each participant; (3) Proportions of open-class vs. closed-class words across languages for each participant. Additionally, chi-square tests were applied to single-word production tasks to compare: (1) the proportions of nouns and verbs across languages, and (2) the proportions of nouns and verbs within each language, for each participant. *Comparison of quantity (frequency) and quality (type) of code-switching:* Chi-square tests were also conducted to compare patterns of code-switching between participants. Specifically, we examined differences in: (1) Proportions of insertional vs. alternational code-switching; (2) Matrix language (Hindi vs. English); (3) Predominant word class involved in code-switching (nouns vs. verbs). These comparisons were made between RZ and BC to identify participant-specific patterns in code-switching behaviour.

Results

Table 3 and Figure 1 illustrate noun and verb performance across tasks for RZ and BC and map on to the first research question of cross-linguistic comparison of grammatical class production and task influence. Table 4 presents the results of the code-switching analyses.

Differences between grammatical categories within the same language across tasks

The narratives for both RZ and BC were elicited in bilingual mode and the lexical analyses primarily focused on nouns and verbs. Recall that the attempt to elicit narratives in unilingual mode for RZ did not yield productive output. Table 3 and top panel of Figure 1 illustrate the following performance. Within language grammatical class analyses showed that RZ produced a lower proportion of nouns in Hindi compared to verbs (nouns = 0.04; verbs = 0.21; $\chi2(1) = 32.89$, $p < .001$); whilst BC produced equal proportion of nouns and verbs in Hindi (nouns = 0.17; verbs = 0.18; $\chi2(1) = .005$, $p = 0.94$). Contrastingly, in English both RZ and BC produced a higher proportion of nouns than verbs (RZ: nouns = 0.64; verbs = 0.03; $\chi2(1) = 84.64$, $p < .001$; BC: nouns = 0.30; verbs = 0.13; $\chi2(1) = 15.04$, $p < .001$), an effect that was exaggerated for RZ in comparison to BC. Additionally, RZ produced a significantly higher number of bilingual compound verbs compared to BC (RZ = 20; BC = 1; $\chi2(1) = 25.68$, $p < .001$). Figure 1 middle and bottom panels show participants performance on single word production tasks. RZ's performance on nouns and verbs naming differed significantly in English (nouns = 73.3%; verbs = 26%; $\chi^2(1) = 9.84$; $p = .002$) suggesting dissociation between these grammatical classes. This differential performance replicates the pattern observed in his narrative production for English. However, in Hindi naming, he showed statistically comparable performance for verbs and nouns (nouns = 40%; verbs = 57%; $\chi^2(1) = 0.84$, $p = .35$). While, in his narrative production he produced a significantly greater proportion of Hindi verbs compared to nouns (nouns = 0.04; verbs = 0.21; $\chi2(1) = 11.56$, $p = .001$) (see top panel of Figure 1). RZ did not have any difficulty in repeating the nouns and verbs in either language and showed comparable performance to BC (see bottom panel of Figure 1).

Differences between languages within grammatical class

As can be seen in Table 3, RZ had lower productivity in his narrative sample compared to BC (RZ: 451 words, BC: 731 words). Within participant cross-linguistic analysis of nouns revealed that both participants produced higher proportion of nouns in English compared to Hindi with the difference being notably exaggerated

for RZ (RZ: Hindi noun = 0.04; English noun = 0.64, $\chi^2(1) = 192.79$, $p < .001$; BC: Hindi noun = 0.17; English noun = 0.30; $\chi2(1) = 15.12$, $p < .001$). To rule out the influence of word frequency[3] for nouns in Hindi and English, we compared the log frequencies (Zipf scores) of both Hindi and English noun tokens produced by RZ. He predominantly produced high frequency nouns (Hindi: 6/7; English: 23/24), with no significant difference in Zipf scores between the two languages (Hindi: M = 5.05, SD = 0.73; English: M = 5.00, SD = 0.87; t (29) = 0.13, p = .896). Analysis of verbs revealed that RZ produced a significantly higher proportion of verbs in Hindi compared to English (Hindi verbs = 0.21; English verbs = 0.03; χ^2 (1) = 25.56, $p < .001$). However, there was no significant difference for BC (Hindi verbs = 0.18; English verbs = 0.13; χ^2 (1) = 2.70, p = .09).

Table 3 also provides distribution of other word classes. RZ produced a higher proportion of open class words in English than Hindi (RZ: Hindi open class words=0.43, English open class words=0.71; $\chi2(1) = 30.87$, $p < .001$) However, there was no significant difference for BC (BC: Hindi open class words=0.50, English open class words=0.58; $\chi2(1) = 3.183$, p = .07). The proportion of closed class words was higher in Hindi for RZ (Hindi closed class words= 0.51, English closed class words= 0.03; $\chi^2(1) = 100.24$, $p < .001$), while there was no significant difference for BC (BC: Hindi closed class words=0.46, English closed class words=0.40; $\chi2(1) = 1.67$, p = .19).

We implemented a log-linear analysis with a Poisson distribution to ascertain if there was an interaction of Participant and Word class (nouns and verbs). The results showed a significant interaction of Participant and Word class ($\beta = -2.31$, $p<.001$) indicating that RZ produced fewer verbs than BC. There was a significant three-way interaction between Participant, Word Class, and Language ($\beta = 3.88$, $p < .001$), because RZ produced fewer verbs than nouns in English, but more verbs than nouns in Hindi ($\beta = 4.76$, $p<.001$). However, BC produced more nouns than verbs in English while in Hindi, nouns and verbs occurred in a similar proportion ($\beta = 0.87$, $p = .001$).

In summary, RZ was significantly poorer in naming than BC for both nouns and verbs in both languages (see Figure 1, middle panel). However, his performance evidenced cross-linguistic grammatical class asymmetries depending on the task. RZ demonstrated a pervasive noun and verb dissociation for both narrative and naming tasks in English, with verbs being significantly lower than nouns in both tasks. While in Hindi, nouns and verbs were similarly affected in the naming task, the narrative task led to a significantly higher proportion of verbs than nouns.

Comparison of quantity and quality of code-switching analysis in narrative task

Establishing code-switching versus loan/borrowed words

As argued in the methods, prior to the code-switching analysis, it was important to differentiate spontaneous code-switches from established loan words. All English words inserted into Hindi sentences had productively used Hindi translation equivalents (e.g., /boy/ /ləṛkɑ:/, /monkey/ /bəndər/). Hence, they had not "replaced" the Hindi lexeme or filled in a lexical gap, as is often the case in borrowing. A Wilcoxon signed rank test was used to compare the frequency of the English lexemes in the Hindi corpus (hiTenTen13) and to their frequency in the English corpus (enTenTen13). The comparison revealed that the English insertions occurred significantly more frequently in the English corpus (Mean frequency per 1 million words = 94.67, SD = 121.83) than in the Hindi corpus (M = 0.10, SD = 0.11, Z (1, 124) = −9.71, p<.000). In fact, none of the inserted English lexemes occurred with a frequency greater than 0.6 words per million in the Hindi corpus. On average, they had an occurrence frequency of 0.1 per million tokens, which is very low. This suggested that the observed insertions were indeed spontaneous code-switches, rather than loan words incorporated into the Hindi lexicon.

Quantitative (frequency) and qualitative (type) nature of code-switching

Table 4 presents the results of code-switching for both RZ and BC. The classification of code-switching patterns revealed both similarities and differences between RZ and BC. In terms of similarities, both RZ and BC showed instances of insertion and alternation but no instance of dense code-switching. Moreover, the majority of insertions involved single content words, most of which were nouns.

In contrast, there were both quantitative and qualitative differences between RZ's and BC's code-switching patterns. RZ displayed an unusually high frequency of code-switching. Whilst BC produced on average 0.26 code-switches per utterance, RZ produced 1.2 code-switches per utterance, meaning that each utterance contained at least one code-switch. This difference is particularly salient considering RZ's short MLU. Second, RZ produced a significantly different distribution of code-switching types (see Table 4 for statistical results). Whilst BC engaged almost equally frequently in insertion (0.58) and alternation (0.42), RZ's code-switching was more weighted towards insertion (0.78) than alternation (0.22). As the most frequent code-switching type in both

participants' narratives was insertion, the nature of insertional code-switching was explored in further detail.

RZ and BC differed in their choice of matrix language during insertional code-switching. While both speakers used a Hindi matrix language in more than 0.70 (70%) of insertion cases, BC also adopted an English matrix language in 0.23 (23%) of insertion cases (see Table 4). In contrast, RZ stuck exclusively to Hindi as the matrix language.

Nature of insertional code-switches

Further analysis of the nature of insertional code-switching was investigated by comparing the nature of the inserted items. Whilst BC's insertions sometimes involved whole clauses, such as the inserted subordinate clause in object complement function in example 5 in Table 3, RZ's insertions were limited to single content words (examples 2, 3). This was unsurprising because the embedding of whole clauses is grammatically more complex. Hence, the two speakers could only be compared with regards to inserted single content words. Qualitatively, BC's insertions involved semantically-specific nouns, such as, /beehive/, /antlers/, /burrow/. In contrast, RZ's insertions were semantically lighter words, such as /boy/, /gate/, /home/. Moreover, BC's insertions included only nouns and verbs, whilst RZ's insertions also comprised of adjectives. The occurrence of inserted word classes common to both narratives—nouns and verbs—was compared between RZ and BC. Although the results were not statistically significant (see Table 4), they indicated that nouns comprised the majority of inserted content words in both narratives. RZ showed a higher proportion of inserted verbs (0.24) than BC (0.07).

The nature of verb insertions was further investigated. For both RZ and BC, the inserted verbs were English verbs used in a Hindi matrix utterance. All inserted verbs were bilingual compound verbs (examples 5, 8, 9, 10), that is, non-inflected English verb forms integrated into the Hindi matrix through an inflected Hindi auxiliary (Khan, 2015). The difference between RZ and BC was the frequency and nature of the bilingual compound verbs. Whilst BC imported only one English verb (/chase/ in example 10) in 61 code-switching instances, RZ employed the bilingual compound verb strategy 31 times in 128 code-switches (examples 5,8,9). This means that 0.24 of RZ's code-switches were bilingual compound verbs. Moreover, the bilingual compound verbs in RZ's narrative were not only composed of auxiliaries and inserted English verbs (examples 5,8,9) but also contained inserted English adjectives. Overall, RZ produced 17 verb-based compounds and 14 adjective-based compounds. BC did not produce any adjective-based bilingual compound verbs.

Table 5. Summary of results comparing noun (N) and verb (V) performance and code-switching analyses between RZ and BC.

	RZ (Bilingual with Broca's aphasia)	**BC** (Bilingual Control)	Interpretation
Research question 1: Cross-linguistic comparison of grammatical class production and task influence			
Narrative Task			RZ had lesser productivity than BC.
By Language			
Nouns	Hindi << English*	Hindi < English*	Similar qualitative pattern between RZ and BC; quantitatively exaggerated pattern in RZ.
Verbs	*Hindi > English	Hindi = English	Differential qualitative pattern between RZ and BC.
By Word Class			
Hindi	N < V*	N = V	Differential qualitative pattern between RZ and BC.
English	*N >> V	*N > V	Similar qualitative pattern between RZ and BC; quantitatively exaggerated for RZ.
Open class words	Hindi < English*	Hindi = English	Differential qualitative and quantitative patterns for RZ and BC.
Closed class words	*Hindi >> English	Hindi = English	Differential qualitative and quantitative patterns for RZ and BC.
Single Word Production Tasks			RZ showed poorer naming performance for both N and V in both languages; comparable performance to BC for repetition.
Hindi (Naming)	N = V	N = V	Similar qualitative pattern for RZ and BC; although accuracy scores were lower for RZ.
English (Naming)	*N >> V	N = V	RZ showed significantly better N production than V production.
Hindi (Repetition)	N = V	N = V	Similar qualitative and quantitative pattern for RZ and BC.
English (Repetition)	N = V	N = V	Similar qualitative and quantitative pattern for RZ and BC.
Research question 2: Comparison of quantity and quality of code-switching			
Code-switching Analyses			
Frequency	Higher	Lower	Differential frequency between RZ and BC; RZ had higher frequency of code-switching compared to BC.
Predominant code-switching type	Insertion	Insertion and alternation	Differential code-switching pattern; RZ mostly used insertions while BC used both insertions and alternations.
Matrix language of insertions	Hindi	Hindi and English	Differential pattern of matrix language use. RZ used only Hindi matrix language, while BC used both Hindi and English matrix language
Predominant word class of insertions	Noun	Noun	Similar word class of insertions for RZ and BC

Note: *indicates statistically significant difference.

Although adjective-based compound verbs exist as a derivational method in monolingual Hindi, previous studies of Hindi-English code-switching report mostly verb-based or noun-based bilingual compound verbs (Khan, 2015). Hence, RZ's frequent employment of bilingual compound verbs, as well as his frequent use of adjective-based bilingual compound verbs, diverged from common socio-linguistic code-switching practices.

Discussion

This research investigated the underlying causes of cross-linguistic asymmetries in noun and verb production across narrative and single word production tasks in a Hindi-English bilingual with Broca's aphasia, RZ. Specifically, we examined if the performances across grammatical classes can be explained based on differences in morphological complexity between Hindi and English and task demands. Further, frequency and type of code-switching were analysed to decipher if difficulties with specific grammatical classes were overcome by strategic code-switching. Table 5 summarizes the findings. The key messages of this research are the following: (1) RZ's evidenced features of agrammatism both in Hindi and English, with a more pronounced manifestation in English. (2) RZ demonstrated a marked cross-linguistic asymmetry in lexical retrieval, with better verb production in Hindi and comparatively better noun production in English. (3) RZ demonstrated a grammatical class asymmetry in Hindi, producing a higher proportion of verbs than nouns suggesting a potential advantage for verb retrieval in Hindi, possibly due to Hindi's rich morphological complexity. Contrastingly, English showed the opposite pattern, with significantly fewer verbs than nouns, highlighting a cross-linguistic divergence based on morphological richness of the languages. (4) In Hindi, grammatical class production was significantly influenced by task: narratives elicited a higher proportion of verbs, while naming tasks yielded comparable rates of noun and verb production. This suggests that task demands modulate lexical access differently depending on the language and its morphological characteristics. Consistent noun–verb asymmetries were observed in English across narrative and naming tasks, indicating a persistent difficulty in retrieving English verbs. This may be attributed to the relatively limited morphological richness of English. (5) The absence of a noun–verb asymmetry in either language on the repetition task suggests that providing the phonological form of the stimuli mitigates the effects of task demands and morphological richness. (6) RZ exhibited more prevalent code-switching, characterized by reduced flexibility, limited to English noun insertions within a Hindi matrix. The greater use of bilingual compound verbs indicates a structured compensatory strategy rather than random switching. The preference for Hindi as the matrix language, combined with the selective insertion of English nouns, reflects a lexico-semantic deficit in Hindi noun access and a potential morphosyntactic difficulty with English verbs.

Before delving deeper into the cross-linguistic asymmetries observed in RZ's performance and their relation to morphological richness and task differences, it is important to first examine his narrative production through the lens of agrammatism. RZ's output was characterized by fragmentary, short, and simplified utterances with minimal syntactic structure. His speech was weighted toward open-class words, with notable difficulty in producing closed-class words and marked challenges with inflectional morphology in English. Owing to the absence of unilingual narratives, our observations are solely limited to RZ's production in bilingual mode. Agrammatic features were evident in both languages but were pronounced in English. This was reflected in his limited production of verbs and their inflections in the narrative task, a significantly reduced number of closed-class words, and lower accuracy in verb naming during the naming task. These difficulties align with established findings that verb and inflectional impairments are core features of agrammatism, particularly in English speakers (Faroqi-Shah, 2023).

The impact of morphological richness on grammatical class asymmetries in RZ's production is evident in both his higher proportion of verbs in narrative output and his code-switching patterns. RZ consistently relied on Hindi morphosyntax, producing Hindi verbs with inflectional features and using Hindi as the matrix language during code-switching. These patterns suggest that Hindi's morphological complexity may support verb retrieval and structural scaffolding.

We argue that such findings require a nuanced interpretation grounded in language typology, particularly the role of morphological richness in shaping language-specific impairments. Prior cross-linguistic research on morphologically rich languages has shown that inflectional difficulties in such languages often manifest not as errors but as a reduced variety and range of inflections, in contrast to the omission patterns typically observed in English (e.g., Bose et al., 2021; Kavé & Levy, 2003; Nedergaard et al., 2019; Penke, 2012). It has been proposed that morphologically rich languages offer greater morphological transparency, which may facilitate earlier acquisition and more robust retention of inflectional morphology (Bates & MacWhinney, 2014; Dressler, 2010; Penke, 2012). Contrary to the assumption that greater complexity leads to greater difficulty,

studies have shown that languages with complex morphology such as Korean, Greenlandic, and Bengali, often show better verb preservation in terms of lack of inflectional errors in clinical populations (Bose et al., 2021; Nedergaard et al., 2019; Sung et al., 2016). RZ's ability to retain Hindi verbs may thus reflect the stability of morphologically rich inflectional systems.

This dissociation between the narrative and naming tasks further provides credence to the notion that RZ's verb production in narrative discourse is influenced by the contextual and structural scaffolding, which may activate morphosyntactic frameworks that are less accessible in isolated word retrieval tasks (Kambanaros, 2010). The linguistic properties of Hindi may have supported the retention of verbs and some morphological features, thereby enabling RZ to maintain a Hindi matrix frame. Notably, all of RZ's morphology and function words were in Hindi. Following Hindi grammatical patterns, he omitted determiners and subject pronouns in his narrative. Hindi verbs inherently exhibit morphological complexity, being inflected for person, number, tense, gender, aspect, mood, and honorification (Agnihotri, 2022). In contrast, English verbs are morphologically simpler, typically inflected only for number, tense, and aspect. Such findings underscore the importance of language characteristics as well as task demands in revealing underlying linguistic abilities in bilingual individuals with agrammatism.

In addition to the above findings, the RZ's performance points to a severe, language-specific impairment affecting Hindi nouns. This is evidenced by RZ's proportionally greater difficulty in naming nouns during the naming task, as well as his lower performance on the WAB naming subtest and the animal fluency task, both of which rely heavily on semantic processing. Further support for a semantically mediated deficit comes from the qualitative analysis of his code-switching behaviour.

When comparing RZ's code-switching behaviour to that of BC, RZ demonstrated more frequent code-switching and rigid matrix language use, consistently favouring Hindi, while BC switched flexibly. Using Muysken's (2000) typology, we found no instances of dense code-switching, which is characterized by extensive blending of grammar and lexicon. This finding aligns with his observation that such patterns are rare in typologically distant languages. RZ's code-switching was atypical and directly informed our second research question. We interpret the findings as Hindi provided the grammatical frame and English supplying lexico-semantic content. This was particularly evident in disproportionately high number of English noun insertions into Hindi sentences. Additionally, frequent use of bilingual compound verbs indicated that English lexical stems were embedded within Hindi verb frames to convey semantic content. This pattern reflects a compensatory strategy arising from selective lexico-semantic and grammatical impairments shaped by typological contrasts, reinforcing our view that RZ's differential deficits are influenced by cross-linguistic typology. The following paragraphs will expand upon these observations.

A comparison of BC and RZ's code-switching in the Frog Story reveals distinct patterns. BC inserted semantically specific English terms (e.g., *antlers*, *burrow*), typical of natural code-switching to express precise meanings. In contrast, RZ inserted more general English words with Hindi equivalents (e.g., *boy*, *frog*), indicating that his insertions were not for specificity but to compensate for semantic retrieval difficulties in Hindi. This reflects RZ's reliance on English to convey basic content within Hindi grammatical frames, pointing to a language-specific lexico-semantic impairment. RZ's predominance of English insertions and greater use of bilingual compound verbs, embedding English lexical stems into Hindi verb frames, further supports this compensatory strategy. Although RZ struggled with English verb naming, he accessed English verb stems as nominal, non-finite forms, consistent with better noun production in English. These grammatical class asymmetries shaped his code-switching behaviour.

To explore whether compound verbs function as a compensatory strategy, we compared their frequency in the narratives of RZ and BC. RZ used bilingual compound verbs in 24% of code-switching instances, compared to just 1.6% in BC, suggesting a language-specific lexical retrieval difficulty. RZ's atypical use of adjective insertions in these constructions further indicates a reluctance to use English verb forms, reflecting an interaction between grammatical class and processing asymmetries, namely, impaired lexico-semantic retrieval in Hindi alongside stronger noun than verb production in English.

Future directions and conclusions

Our study contributes to the field of bilingual aphasia research by examining noun and verb production in Hindi and English, two typologically distinct languages with differing morphological complexities. To generalize these findings, future research should replicate them in a larger cohort of bilingual individuals with diverse aphasia types and severities. Cross-linguistic studies, especially between typologically distinct language families (e.g., Indo-Aryan vs. Dravidian), can shed light on grammatical class impairments. A key limitation of this study is the incomplete assessment of RZ's cognitive

abilities, despite known links between code-switching and executive functions (Hofweber & Marinis, 2023). Future work should include comprehensive evaluations of verbal and non-verbal executive functions, and examine the impact of bilingual versus monolingual modes in both assessment and intervention. Comparing task types (e.g., single-word retrieval vs. sentence production) will help clarify how language mode and task demands interact with underlying impairments.

This study demonstrates that cross-linguistic asymmetries in noun and verb production in a Hindi-English bilingual with Broca's aphasia are shaped by language-specific morphological richness and task demands. RZ's preservation of verb morphology in Hindi suggests that verbs may be more resilient in morphologically rich languages like Hindi compared to English. This finding underscores the role of typological features in shaping lexical–grammatical interactions and supports models that view the interface between the lexicon and grammar as dynamic and language-specific, rather than uniform across languages (De Bot, 2007; Dijkstra & van Heuven, 2002; Wei, 2006). RZ's code-switching was marked by rigid use of Hindi grammar and English noun insertions which reveal how a bilingual speaker may strategically compensate for lexico-semantic deficits, particularly in Hindi. Our research highlights the importance of considering language typology, task demands, and communicative context in documenting and assessing linguistic impairments in under-researched languages.

Notes

1. The link to the Hindi and English corpora can be found here: https://www.sketchengine.eu/hitenten-hindi-corpus/
2. Semantically light describes a word, usually a verb, that lacks significant or specific meaning by itself and instead depends on pairing with other words—often nouns—to express the primary semantic content of a phrase. In English, verbs such as do, make, have, take, and give frequently function as light verbs in expressions like "take a shower".
3. Frequency analyses of the noun tokens were performed using log frequencies (Zipf scores) derived from established corpora: SUBTLEX-UK for English (van Heuven et al., 2014) and the Shabd Psycholinguistic Database for Hindi (Verma, Sikarwar, Yadav, Jaganathan, & Kumar, 2022). The Zipf value ranges from 1 to 7 (Zipf values 1–3: low-frequency words; 3.1–3.4: low-mid frequency words; 3.5–3.9: high-mid frequency words; 4–7: high-frequency words).

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Data availability statement

In the spirit of transparency and open science practices, we provide item level data from the object and action naming tasks in Appendix B, response analyses of naming in Supplementary Table S4 and the full transcripts of the narrative data from RZ and BC in the supplementary material S2. We urge readers to explore their performances and possibly undertake further analyses to answer their specific research questions. We are also happy to share any other data collected for this study (i.e., deidentified participant data) under a signed data access agreement, after the online publication date, in response to reasonable requests from academic researchers emailed to the corresponding author.

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Appendices

Appendix A

Summary of literature on noun (N) and verb (V) production in bilingual aphasia.

S.No.	Study	Number of participants, Gender (M/F)	Age in years (age range)	Clinical population/ lesion	Aphasia type or predominant aphasic symptom	Languages	Age of acquisition of L2 and L3	Language proficiency	Tasks, Language tested	Dependent variables; Main analysis	Findings
1	Kremin and De Agostini (1995)	1 F	35	Left CVA	Anomic	Bergamasc (L1); Italian (L2); German (L3)	Early	High	Picture naming (Bergamasc, Italian, German)	Accuracy (%correct) L1 vs. L2 vs. L3; N vs.V	Naming performance in L1: 80% correct; L2: 65% correct; L3: 26% correct. N = V in all three languages
2	Sasanuma and Park (1995)	1 M	62	Left CVA	Anomic	Korean (L1); Japanese (L2)	Early	High	Picture naming, spontaneous speech (Korean, Japanese)	Accuracy (% correct)	N = V in L1 & L2; poorer performance in L2 on picture naming.
3	Kambanaros and van Steenbrugge (2006)	8 M; 4 F	60–84	Left CVA	Anomic	Greek (L1); English (L2)	Late	High	Picture naming (Greek, English)	Accuracy (% correct); N vs.V; Error pattern	N > V in both L1 & L2; Effect higher in L2; V > N in L2 (for one participant); Most frequent errors- semantic substituitions for both nouns & verbs. % errors higher for verbs.
4	Kambanaros (2010)	12 (8 M; 4 F)	60–84	Left CVA	Anomic	Greek (L1); English (L2)	Late	High	Action and object naming (Single word level), spontaneous speech (Greek, English)	Single word level: Accuracy (% correct) Spontaneous speech: No. of types & tokens of N and V	Single word naming: N > V (L1 & L2); Spontaneous speech: V > N (L1 & L2)
5	Faroqi-Shah and Waked (2010)	1 M	43	Left CVA	Broca's	Arabic (L1); French (L2); English (L3)	Early (L2); Late (L3)	High	Picture naming, narrative speech (Arabic, French, English)	Accuracy (% correct); N vs.V; N:V ratio; Error pattern	N > V (all 3 languages & across picture naming & narrative speech)
6	Abuom and Bastiaanse (2012)	6 (3M; 3F)	20–49	Left CVA	Agrammatic	Bantu/Nilotic (L1); Swahili (L2a); English (L2b)	Early	High	Narrative and spontaneous speech (Swahili, English)	Number & diversity of N and V; use of copula & auxiliaries; number of V inflections	N=V(in Swahili & English); No significant differences between two languages on any of the parameters except some individual variations. Verb inflections:over occurrence of infinite & gerund form of verbs (English); Tense inflections: Swahili>English
7	Venkatesh et al. (2012)	2 F	70; 75	Left CVA	Transcortical	Gujarati (L1); English (L2); Hindi (L3); Swahili (L4)	Late (L2, L3 & L4)	L1>L2>L3>L4	Object and action naming, picture description (English, Hindi)	Accuracy (% correct); Error types; N:V ratio for connected speech	Naming: N > V(in both languages); No consistent error pattern. Connected speech: N > V(in both languages); N:V ratio – English>Hindi
8	Kambanaros and Grohmann (2015)	24 (15 M; 9 F)	30–68	Left CVA	Broca's (n=7 monolingual) Anomic (n=12 bilingual; n=5 monolingual)	Greek (L1); English (L2)	Late	-	Object and action naming (Greek)	Accuracy (% correct); N vs.V	N > V(tested in L1 only). All three groups of aphasics showed similar performance.

(*Continued*)

Continued.

S.No.	Study	Number of participants, Gender (M/F)	Age in years (age range)	Clinical population/ lesion	Aphasia type or predominant aphasic symptom	Languages	Age of acquisition of L2 and L3	Language proficiency	Tasks, Language tested	Dependent variables; Main analysis	Findings
9	Law et al. (2015)	19 (17 M; 2 F)	41–85	Left CVA	Anomic	Cantonese(L1); English (L2) 15 monolinguals & 4 bilinguals	Early	-	Picture naming; connected speech from picture description, procedural description and storytelling (Cantonese)	Accuracy (Proportion of correct); N vs.V; Naming vs. connected speech.	Controlled for AoA & familiarity: N > V & Task effect: Single word naming > connected speech; Controlled for Imageability: N = V & Task effect: Single word naming > connected speech
10	Kambanaros (2016)	1 M	25	Left CVA	Anomic	Greek (L1); English (L2); Arabic (L3)	Simultaneous	Greek (Native-like); English (very good); Arabic (good)	Spoken and written naming; spelling to dictation and oral reading of nouns and verbs (Greek, English)	Accuracy (% correct); Error pattern; N vs. V; Modality contrast	Spoken naming: N = V (both L1 and L2)
11	Li and Kiran (2023)	12 (6M; 6F)	25–75	11 Left CVA; 1 TBI	Chronic	Mandarin (L1); English (L2)	Late	L1=L2 (with L2 usage > L1)	Object and action naming; 3 discourse tasks (sequential pictures, single picture and story telling) (Mandarin, English)	Accuracy; N vs. V	Naming & discourse tasks: N > V (L1 & L2) with severity of aphasia impacting N-V performance.

Appendix B This appendix includes responses from noun naming (B1) and verb naming (B2) tasks.

Table B1. Noun naming stimuli, instructions and responses in Hindi and English of RZ (Bilingual with Broca's aphasia).

	Noun Naming (Hindi)				Noun Naming (English)			
S.No	Hindi Target	RZ	Response type	Scoring	English Target	RZ	Response type	Scoring
1	ɦaːtʰ	ɦaːtʰ	C	1	arm	hand	C	1
2	gɐːnd	ball	CLT	0	ball	ball	C	1
3	gubbara	gubbara	C	1	balloon	balloon	C	1
4	daʈʰi	daʈʰi	C	1	beard	moustache	S	0
5	paːlaŋg	cot	CLT	0	bed	bed	C	1
6	gʰəʈi	gʰəʈi	C	1	bell	gʰəʈi..tell bell	CLT	0
7	ciṛiya/pəkṣi	crow	CL	0	bird	pigeon hai animal	S	0
8	pustək/kitab	kitab	C	1	book	book	C	1
9	pul	siidi (step)	S	0	bridge	flyover	S	0
10	mombətti	candle	CLT	0	candle	candle	C	1
11	billi	cat	CLT	0	cat	cat	C	1
12	kursi	chair table	CLT	0	chair	chair	C	1
13	gʰəʈi	watch	CLT	0	clock	clock	C	1
14	gay	gay	C	1	cow	cow	C	1
15	hatʰi	elephant	CLT	0	elephant	elephant	C	1
16	məcʰli	fish	CLT	0	fish	fish	C	1
17	pʰu l	pʰu l	C	1	flower	flower	C	1
18	bal	bal	C	1	hair	baal baal hair	CLT	0
19	gʰoṭa	elephant	CL	0	horse	horse	C	1
20	gʰər	gʰər	C	1	house	home	C	1
21	cabi	cabi	C	1	key	key	C	1
22	pətta	ped (tree)	S	0	leaf	feather	S	0
23	pɛr	hath (hand)	S	0	leg	leg	C	1
24	gʰosla	nest hai gʰosla	CLT	0	nest	ghost bird ka (bird's ghost)	CL	0
25	kəmiz	shirt	CLT	0	shirt	shirt	C	1
26	juta	juta	C	1	shoe	shoe	C	1
27	mez	chair table	CL	0	table	table	C	1
28	peṭ	darakth (tree in Urdu)	CLT	0	tree	tree	C	1
29	cʰata/ cʰətəri	cʰata	C	1	umbrella	umbrella	C	1
30	kʰiṭki	door	CL	0	window	door	S	0
		No. of correct		12/30		No. of correct		22/30

Instructions for noun naming: "I am going to show you some pictures of objects, one at a time. Please look at the pictures carefully and then, name the object in one word. For example, this is a picture of a door, so you would say door. Now I will present some more pictures, remember to use one word to name the object in the picture".

Note: Text in parentheses are English translations. C = correct response; S = semantic error; CL = cross-linguistic error; CLT = cross-linguistic translational equivalent; NR = no response. BC performed at ceiling in noun naming in both Hindi (27/30) and English (30/30).

Table B2. Verb naming stimuli, instructions and responses in Hindi and English of RZ (Bilingual with Broca's aphasia).

	Verb Naming (Hindi)					Verb Naming (English)				
S.No	Hindi Target	RZ	English translation of responses	Response type	Scoring	English Target	RZ	English translation of responses	Response type	Scoring
1	ʈu ʈna	/ləd.kiː glaːs ʈuːʈ kəɾ ɾə.hiː hɛ/	girl glass break doing	C	1	break	crack | coffee /crack hoː gəja: hɛ/	crack/ coffe has cracked	S	0
2	jəlna	/aːg ləːgaː hɛ/ | /aːg/	fire there is/fire	S	0	burn	fire /hoː gəjaː hɛ/	fire has happened	CL	0
3	pʰu ʈna	/bɔɪ bloʊ.ɪŋ kəɾ ɾə.hiː hɛ/ | /tʃuː ɾə.haː hɛ/	boy blowing doing/ is touching	CL	0	blow	Boy is blowing	–	C	1
4	cəʈʰna	/bət.tʃʰaː tʃɛːɾ ʌp kəɾ ɾə.haːhɛ/	kid chair up doing	S	0	climb	table /ʌp kəɾ ɾə.haː hɛ/	Table up is doing	CL	0
5	rona	/ləd.kiː ʊ.daːs hɛ/ | /ɾoː ɾə.haːhɛ/	girl is sad/he is crying	C	1	cry	crying | I am crying | Boy is crying | Girl is crying	–	C	1
6	pi na	/ləd.kaː tʃaɪ piː ɾə.haː hɛ/	boy is drinking tea	C	1	drink	boy is coffee coffee | boy is coffee /kʰaː ɾə.haː hɛ/	Boy is eating coffee	S	0

(*Continued*)

Table B2. Continued.

	Verb Naming (Hindi)					Verb Naming (English)				
S.No	Hindi Target	RZ	English translation of responses	Response type	Scoring	English Target	RZ	English translation of responses	Response type	Scoring
7	kʰana	/ləd.kaː kʰaː.naː kʰaː ɾə.haː hɛ/	boy is eating food	C	1	eat	boy is fooding	Boy is fooding	S	0
8	girna	/ɻuːɻ gə.jaː hɛ/ | /slɪp kəɾ ɾə.haːhɛ/	broken/ is slipping	S	0	fall	Bottle /slɪp kəɾ ɾə.haː hɛ/	Bottle slip is doing	S	0
9	uɻna	/tʃɪ.ɻjaː aː.kaːʃ flaɪ.ɪŋ kəɾ ɾə.hiːhɛ/ | /bə.dəl ʊɖ ɾə.hiː hɛ/	bird sky flying doing/cloud flying	C	1	fly	flying | /aː.kɑːʃ kəɾ ɾə.haː hɛ/ | Boy is flying	–	C	1
10	utərna	NR	NR	NR	0	get down	NR	NR	NR	0
11	ku dna	/ləd.kaː bət.tʃʰaː dʒʌm.pɪŋ kəɾɾə.haː hɛ/ | /kʰʊd ɾə.haː hɛ/	boy/kid is jumping/he is jumping	C	1	jump	Boy jumping	–	C	1
12	hə sna	*ləd.kaː ʈʰə.ʈʰə.kə kəɾ ɾə.hiː hɛ*	boy doing (unclear)	S	0	laugh	Boy is fun ha ha | Boy is happy | Boy is funny	–	S	0
13	sunna	/sʊn ɾə.haː hɛ/	Is listening	C	1	listen	ear | Boy is ear		S	0
14	pigəlna	/kʰə.ɾaːb kəɾ ɾə.haː hɛ/	spoiling it	S	0	melt	/ɖʱuːp hɛ/ | /kʰə.ɾaːb hoː ɾə.haː hɛ/	Sun is there/it's spoiling	CL	0
15	kʰulna	/ɖuːɾ kʰʊ.laː ʊ.aː hɛ/ | /ləd.kaːɖuːɾ kʰoːl ɾə.haː hɛ/	door is open/ boy is opening the door	C	1	open	Boy door /kʰoːl ɾə.haː hɛ/	Boy is opening the door	CLT	0
16	pəʈʰna	/ləd.kiː kɪ.taːb kəɾ ɾə.hiː hɛ/ | /lɪkʰ ɾə.hiː hɛ/ | /nə.hiː ɾiː.dɪŋ kəɾ ɾə.hiː hɛ/	girl book doing/ whe is writing/no is doing reading	S	0	read	Girl is reading | girl is book reading	–	C	1
17	uʈʰna	/ləd.kaː sʊ.bʰaː hoː.gə.jiː/ | /ləd.kaː soː ɾə.haː ʈʰaːhoː.gə.jaː/ | /ʊʈʰ ɾə.haː hɛ/	boy morning happened/boy was sleeping/is waking up	C	1	rise, get up	Boy /ʊʈʰ ɾə.haː hɛ/	Boy is getting up	CLT	0
18	dɔɻna	/ləd.kiː ɖoːɖ kəɾ ɾə.hiː hɛ/ | /ɖoːɖ ɾə.hiː hɛ/	girl is making run/ is running	C	1	run	Girl is running	–	C	1
19	dekʰna	/ləd.kiː ɟiː.viː ɖeːkʰ ɾə.hiː hɛ/	girl is watching TV	C	1	see(look)	Girl sitting	–	S	0
20	ɖu bna	/dʒə.ɦaːz ɖuːb gə.jaː hɛ/	ship has sunk	C	1	sink	ship /ɖaʊn ɖaʊn kəɾ ɾə.haː hɛ/ | ship is collapse	Ship doing down down/ ship is collapse	S	0
21	sona	/ləd.kaː soː ɾə.haː hɛ/	boy is sleeping	C	1	sleep	boy is /soː ɾə.haː hɛ/	Boy is sleeping	CLT	0
22	pʰəɻna	/peɪ.p̃əɾ/	paper	CL	0	tear	boy is throwing	–	S	0
23	cʰu na	/mʊ.dʒ̃ʰe pə.ʈaː nə.hiː/	I don't know	NR	0	touch	up down	–	S	0
		No. of correct			13/23		No. of correct			6/23

Instructions for verb naming: "I am going to show you some pictures, one at a time. These pictures depict actions or activities being carried out by someone. Please look at each picture carefully, then describe the main action you see. For example, if you see a picture of a girl writing, you would describe the action as writing. Now, I will present more pictures; remember to describe the main action in each picture".

Note. C = correct response; S = semantic error; CL = cross-linguistic error; CLT = cross-linguistic translational equivalent; NR = no response. BC performed at ceiling in verb naming in both Hindi (22/23) and English (22/23).