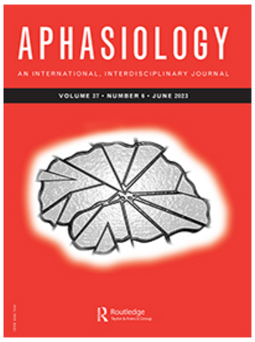


Aphasiology

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/paph20

Noun and Verb Impairment in Single-Word Naming and Discourse Production in Mandarin-English Bilingual Adults with Aphasia

Ran Li & Swathi Kiran

APHASIOLOGY
https://doi.org/10.1080/02687038.2023.2189994

Noun and Verb Impairment in Single-Word Naming and Discourse Production in Mandarin-English Bilingual Adults with Aphasia

Ran Li[a] and Swathi Kiran[b]

[a]Human Communication, Development, and Information Sciences, Faculty of Education, The University of Hong Kong, Hong Kong; [b]Department of Speech, Language, and Hearing Sciences, Boston University, Boston, USA

ABSTRACT

Background: Previous studies on bilingualism and aphasia have identified a similar pattern of verb-noun dissociation in single-word naming (i.e., lower accuracy for verbs than nouns) in both languages. However, whether a similar pattern of verb and noun dissociation emerges in discourse production remains unknown, particularly in typologically dissimilar languages.

Aims: This study investigated patterns of verb and noun impairment in both single-word naming and discourse production, and whether naming was associated with lexical retrieval in discourse production in Mandarin-English bilingual adults with aphasia (BWA).

Methods: Twelve Mandarin-English bilinguals with chronic aphasia completed standardized assessments on object and action naming, and three discourse tasks from the AphasiaBank (i.e., sequential pictures, single-picture, storytelling) in both L1 (Mandarin) and L2 (English). Item-level accuracy of object and action naming was fit into a generalized mixed-effects model to estimate single-word naming ability as a function of grammatical category. The proportion of verb and noun production and the number of verbs and nouns per utterance were fit into multivariate linear regression models to assess lexical retrieval in discourse. Finally, another linear regression was performed to examine the association between naming and lexical retrieval in discourse production.

Results: The naming accuracy for verbs was lower than for nouns in both L1 and L2. Mandarin-English BWA also demonstrated less production of verbs than nouns in discourse. However, depending on the type of the task, the effect of word category was greater in L2 than in L1. This cross-linguistic difference of the verb-noun dissociation was diminished in individuals with lower aphasia severity. Our results further showed a direct relationship between naming and lexical retrieval in discourse, irrespective of the language.

Conclusions: Our findings suggest an overall similar pattern of verb and noun dissociation across different linguistic contexts. However, depending on the cognitive-linguistic demands of the task, the

ARTICLE HISTORY
Received 18 Mar 2022
Revised 05 Mar 2023
Accepted 07 Mar 2023

KEYWORDS
verb and noun retrieval; naming; discourse; bilingual aphasia

CONTACT Ran Li rli92@hku.hk Speech, Language, and Reading Lab, 8/F, Meng Wah Complex, Human Communication, Development, and Information Sciences, Faculty of Education, The University of Hong Kong, Pokfulam, Hong Kong.

verb-noun dissociation may emerge in L1 and L2 to varying degrees in individuals with different levels of aphasia severity. This study facilitates better understanding of verb and noun retrieval in Mandarin-English BWA.

Introduction

The growing bilingual population coincides with an overall increase of older people at risk for neurogenic disorders, i.e., stroke and dementia (Hoeffel et al., 2012). In bilingual adults, aphasia may occur in one or both languages and demonstrate diverse patterns of language impairment due to complex cross-linguistic interactions (Fabbro, 2001; Lorenzen & Murray, 2008; Paradis, 2001). Evidence of language recovery in bilingual adults with aphasia (BWA) is mostly derived from individuals speaking Indo-European languages (e.g., Spanish-English). Given the increase in the number of Chinese-speaking individuals in the U.S. (Zeigler & Camarota, 2019), there is an urgent need for future research to uncover the patterns of language impairment in Chinese-English BWA.

Anomia, or trouble retrieving words and/or naming objects and actions, is a hallmark symptom in aphasia. Studying anomia in BWA enables a direct cross-linguistic comparison of language recovery patterns, and provides insight into models of both bilingual language processing and language impairment (Nadeau, 2019). Lexical retrieval in individuals with aphasia can be differentially impacted based on specific grammatical class, i.e., nouns and verbs (Berndt et al., 1997; Kim & Thompson, 2000; Miceli et al., 1984; Zingeser & Berndt, 1990). Several studies so far have attempted to compare lexical-retrieval ability between nouns and verbs in BWA (Kremin & De Agostini, 1995; Sasanuma & Park, 1995; Kambanaros & van Steenbrugge, 2006; Poncelet et al., 2007; Faroqi-Shah & Waked, 2010; Kambanaros, 2010; Dai et al., 2012). Among these previous studies, some have reported no noticeable difference between verb and noun retrieval (Kremin & De Agostini, 1995; Sasanuma & Park, 1995), whereas others have found a verb-noun dissociation with higher accuracy for object naming when compared to action naming (Kambanaros, 2010; Kambanaros & van Steenbrugge, 2006; Poncelet et al., 2007). The term "dissociation" here refers to any significant differences between noun and verb processing in individuals with aphasia. The same verb-noun difference has been previously identified in healthy bilinguals (Li et al., 2019), suggesting that verbs are more difficult to produce than nouns in neurotypical adults. Prior aphasia studies examining verb and noun retrieval have consistently reported lower naming performance in individuals with aphasia relative to healthy controls (Sung et al., 2016; Kambanaros & van Steenbrugge, 2006; Poncelet et al., 2007; Faroqi-Shah & Waked, 2010; Kambanaros, 2010; Dai et al., 2012), in support of a word category dissociation in aphasic patients.

Different psycholinguistic accounts have been posited to explain the verb-noun dissociation in individuals with aphasia. Among many other lexical-semantic variables that may impact lexical processing (e.g., frequency, familiarity; Cuetos et al., 2002; Kemmerer & Tranel, 2000; Luzzatti et al., 2002), *imageability* has been identified as a strong predictor of verb and noun naming (Kambanaros, 2010; Kiran & Tuchtenhagen, 2005; Luzzatti et al., 2002). In general, verbs are semantically less imageable than nouns because verbs often denote abstract events and actions that are temporarily transient (Bird et al., 2003; Gentner, 2006; Vigliocco et al., 2011). This account has been corroborated by studies that did not find a dissociation between nouns and verbs after imageability was controlled for (Bird et al., 2001; Shapiro & Caramazza, 2003). From a morphological perspective, some studies have argued that verbs are more difficult to retrieve than nouns as verbs in many languages carry rich morphological markings, i.e., third-person singular, tense markers (Caramazza & Berndt, 1985). However, this may not be true as verb-retrieval deficits have also been identified in languages with less complex verb morphology, i.e., Chinese (Bates et al., 1991) and in languages with similar morphological inflections between nouns and verbs, i.e., Greek (Tsapkini et al., 2002). From a syntactic standpoint, verbs play a crucial role in sentence processing as they may require thematic roles (i.e., agent, patient) assigned to each argument (Vigliocco et al., 2011). Hence, verbs may be difficult to retrieve due to syntactic deficits in individuals with aphasia (Ferretti et al., 2001). These accounts altogether inform us that the differences between verb and noun processing are an artifact of the many processing dimensions that separate these two grammatical categories (Szekely et al., 2005).

In addition to single-word processing, a few studies in bi/multilingual adults with aphasia have conducted spoken discourse analysis to investigate patterns of verb and noun production in connected speech (Dai et al., 2012; Faroqi-Shah & Waked, 2010; Kambanaros, 2007). One study examined verb and noun retrieval in picture naming and narrative speech in a highly proficient Arabic-French-English trilingual patient (Faroqi-Shah & Waked, 2010). This individual showed more impairment for verbs than nouns in both tasks (i.e., lower verb naming accuracy and less verb production in discourse), indicating a similar pattern of verb-noun processing regardless of the linguistic context. Another study investigated lexical retrieval in both naming and connected speech in 12 late Greek-English BWA (Kambanaros, 2007). Results also revealed a verb-noun dissociation in picture naming with lower accuracy for verbs than nouns. In contrast to Faroqi-Shah & Waked (2010), this study found that patients who had difficulty with action naming could retrieve verbs during connected speech, whereas those who could name objects had difficulty with noun production in connected speech, suggesting an inconsistent pattern of verb and noun impairment across different linguistic contexts. The third study examined verb and noun retrieval in a late Cantonese-Mandarin bilingual with mild anomic aphasia (Dai et al., 2012), who exhibited better naming of objects than actions only in Mandarin (L2). Additionally, this study reported noticeable differences between naming and discourse production with few occurrences of word-finding difficulties in discourse, but no direct comparison was carried out. Results from these studies are mixed regarding the verb and noun dissociation across linguistic contexts. These complex findings are likely due to the inconsistency in assessment, analysis, or individual variations (Linnik et al., 2016; Stark et al., 2021). Examining the relationship between naming and lexical retrieval in discourse in BWA would help identify the cross-linguistic differences in verb and noun processing across different linguistic contexts.

Patterns of verb and noun retrieval in BWA provide further evidence of whether the verb-noun dissociation is similar in both languages (i.e., language non-dependent) or different between languages (i.e., language-dependent). Results from most bilingual aphasia studies have pointed to a trend of language non-dependency, that is, verbs were less accurate than nouns in naming tasks in both first (L1) and second (L2) languages (Kambanaros & van Steenbrugge, 2006; Poncelet et al., 2007; Miozzo et al., 2010). Note that L2 language proficiency and age of acquisition (AoA) varied across these studies. Hence, the verb-noun dissociation may not arise from an unbalanced language proficiency between L1 and L2, but instead from the conceptual or linguistic properties that differ between grammatical categories (i.e., difficulty accessing the semantic or morphological representation of verbs; Kambanaros, 2010).

Although patterns of the verb-noun dissociation are similar in L1 and L2 in most previous bilingual aphasia studies, the evidence has been limited to Indo-European languages. The same patterns of verb and noun impairment may not be observed in languages that are typologically different. One example is Mandarin Chinese, which is a 'verb-friendly' language (Gentner, 1981). Unlike verbs in many Indo-European languages that carry complex morphological inflections (e.g., Greek, English), verbs in Mandarin Chinese are not morphological inflected for numbers, gender, etc. (Gentner, 1981). At the sentence level, verbs in Mandarin can be more salient than nouns. Specifically, Mandarin is a pro-drop language in certain contexts (Huang, 1989), allowing verbs themselves or along with their objects to formulate a complete and grammatical sentence. For instance, the subject "我" (*I*) can be dropped from the sentence "我吃了一个苹果" (*I ate an apple*) if followed by a question, such as "what did you eat?" Thus, verbs in pro-drop sentences carry high informational values as they may be the first or the only overtly produced words (Sung et al., 2016). Evidence from child language research further supports a verb-saliency account, since Mandarin-speaking children tend to acquire verbs earlier than nouns (Huang, 1989). Given these cross-linguistic variations in verb morphology and verb salience, patterns of verb and noun deficits may be different in Mandarin English BWA.

Since verb morphology is more complicated in English than in Mandarin, one would expect verbs to be more difficult to produce than nouns in English at the single-word level, leading to a verb-noun dissociation (Caramazza & Berndt, 1985). However, if a verb-noun dissociation is identified in Mandarin (Bates et al., 1991), then the verb-noun dissociation may be attributed to any lexical-semantic differences between word categories (Bird et al., 2003; Gentner, 2006; Vigliocco et al., 2011). At the syntactic level, verbs in English require thematic roles and are morphologically inflected to a larger extent than nouns, making verbs more difficult to retrieve. The same verb-noun dissociation may be expected in Mandarin Chinese, as the basic syntactic structure is subject-verb-object (SVO) and verbs also require thematic roles assigned to arguments (Vigliocco et al., 2011). Alternatively, verbs in Mandarin may not be as difficult to produce as in English due to their salience in pro-drop sentences (Huang, 1989). To test this hypothesis, measurements such as the amount of noun and verb production would allow us to directly compare noun and verb retrieval in discourse. Using the same measures, one study examined verb and noun production in connected speech in Korean speakers with aphasia, another verb-salient language (Sung et al., 2016). Findings showed that Korean speakers with aphasia produced more verbs per utterance than English speakers with aphasia in spontaneous speech, whereas English speakers produced more nouns than Korean speakers. Hence, if the cross-linguistic variation in verb salience plays a role at the syntactic level, a verb-noun dissociation would more likely emerge in English but not Mandarin.

In sum, while most previous studies have identified a verb-noun dissociation in single-word naming, whether a similar pattern of this dissociation emerges across different linguistic contexts remains unclear. Patterns of verb and noun retrieval in BWA may arise from a complex interaction among factors including the conceptual and linguistic properties of grammatical categories, cross-linguistic features, and individual heterogeneity (Kambanaros, 2010). In BWA, a similar pattern of verb-noun impairment in L1 and L2 has been consistently reported regardless of premorbid language proficiency. This finding suggests that the verb-noun dissociation primarily arises from the semantic representation level, which is shared between L1 and L2 in bilingual lexical processing (Kambanaros, 2010). Nevertheless, evidence so far has been limited to languages that carry rich verb morphology (i.e., Greek, English), and whether the same patterns of the verb-noun dissociation emerge in languages that have different verb morphological structures or syntactic features remains unclear (i.e., Mandarin; Bates et al., 1991; Vigliocco et al., 2011). Therefore, it is important to investigate verb and noun impairment across languages that vary in verb and noun characteristics, i.e., Mandarin-English, and thereby to better understand patterns of lexical impairment in BWA.

Current study

This study aimed to investigate patterns of verb and noun impairment in both naming and discourse production in Mandarin-English BWA. Specifically, we addressed the following research questions:

(1) Does a verb and noun dissociation emerge at the *single-word* level in Mandarin-English BWA?
(2) Does a verb and noun dissociation emerge at the *discourse* level in Mandarin-English BWA?
(3) Does a similar pattern of verb and noun dissociation emerge across single-word naming and discourse production in Mandarin-English BWA?

According to more recent bilingual studies that directly compared verb and noun retrieval in naming tasks (Kambanaros, 2010; Kambanaros & van Steenbrugge, 2006; Poncelet et al., 2007), it was hypothesized that Mandarin-English BWA would show a verb-noun dissociation with lower naming accuracy for verbs than nouns in both L1 and L2. Alternatively, the verb-noun dissociation would only be observed in the language that carries richer morphosyntactic structures for verbs (i.e., English), as posited by the morphological account (Bates et al., 1991; Caramazza & Berndt, 1985). Since a previous study has already examined verb and noun retrieval in Mandarin-English healthy bilinguals (Li et al., 2019), the current study aimed to focus on the effect of word class in Mandarin-English BWA. Additionally, we expected a verb-noun dissociation in discourse production in both Mandarin and English with more production of nouns than verbs (Faroqi-Shah & Waked, 2010). This performance in discourse would mirror the naming performance of nouns and verbs. Alternatively, if the cross-linguistic variation in verb salience matters (Huang, 1989), it was hypothesized that Mandarin-English BWA would demonstrate a verb-noun dissociation in English but not Mandarin discourse tasks (Dai et al., 2012; Kambanaros, 2007; Sung et al., 2016).

Method

Participants

Twelve Mandarin-English bilinguals with chronic aphasia (11 due to left-hemisphere single stroke, 1 due to traumatic brain injury) were enrolled in the current study (Table 1; 6 females, mean age = 52.6 ± 18.5 years, mean years of education = 17.7 ± 3.4, mean months post-onset = 51.4 ± 48.4). These participants were all late bilinguals and L1-Mandarin speakers. Note that our participants included a few young adults, who had aphasia due to either heart/vascular disease (i.e., P3, P6) or car accident (i.e., P4). These individuals met the following inclusion criteria: (1) frequently used Mandarin and English before onset, (2) diagnosed with aphasia based on the Western Aphasia Battery-Revised (WAB-R; Kertesz, 2007) for English and the Aphasia Battery in Chinese (ABC; Gao, 1993, 1996) for Mandarin, (3) were between 18 and 85 years old, (4) presented with normal/near normal or corrected-to-normal hearing and vision, (5) were premorbid right-handed, and (6) had no other neurological condition (i.e., dementia) or learning disorders. Participants were recruited from rehabilitation centers and hospitals around Boston as well as remotely from other places in the U.S. All enrolled participants were consented according to the Boston University Institutional Review Board (IRB) protocol.

Individual differences in lexical processing can be influenced by developmental and contextual factors such as L2 AoA, the degree of life-time exposure and the frequency of use in each language (Kastenbaum et al., 2019). Therefore, information about second language acquisition and language proficiency of each language was collected via the Language Use Questionnaire (LUQ; Kastenbaum et al., 2019; Table 1). Specifically, *language usage* measured the proportion of time participants and their conversation partners spent using Mandarin and English during weekdays and weekends. *Lifetime exposure* captured the average proportion of time that participants heard, spoke, and read each language. *Language ability rating (LAR)*

Table 1. Demographics and language use background.

						Usage %		Exposure %		LAR %	
ID	Sex	Age	Edu (yr)	MPO	AoA	L1	L2	L1	L2	L1	L2
P1	F	75.2	18.0	110.8	16.0	4.4	95.6	32.9	67.1	100.0	100.0
P2	M	72.7	20.0	165.2	10.0	33.4	66.6	19.5	80.5	100.0	100.0
P3	M	31.5	25.0	45.0	10.0	43.9	56.1	63.3	36.7	100.0	80.0
[a]P4	F	29.3	17.0	19.2	8.0	0.0	100.0	39.2	60.8	100.0	100.0
P5	F	67.9	13.0	20.8	17.0	22.5	77.5	47.0	53.0	100.0	68.6
P6	F	25.2	20.0	8.2	9.0	56.6	43.4	74.1	25.9	100.0	68.6
P7	M	57.9	20.0	77.3	10.0	19.5	80.5	70.7	29.3	100.0	80.0
P8	M	42.8	16.0	17.4	12.0	50.0	50.0	80.2	19.8	100.0	60.0
P9	F	61.7	19.0	75.5	13.0	36.9	63.1	50.9	49.1	100.0	100.0
P10	F	53.0	15.0	20.5	12.0	29.2	70.8	43.6	56.4	88.6	82.9
P11	M	38.7	16.0	50.1	12.0	32.0	68.0	23.1	76.9	90.0	100.0
P12	M	74.7	13.0	6.2	20.0	50.0	50.0	80.8	19.2	100.0	48.6
Mean		52.6	17.7	51.4	12.4	31.5	68.5	52.1	47.9	98.2	82.4
SD		18.5	3.4	48.4	3.6	17.7	17.7	21.5	21.5	4.2	18.1

[a]This patient had aphasia due to traumatic brain injury. L1: Mandarin, L2: English, Edu: education, MPO: months post-onset, AoA: age of acquisition, LAR: language ability rating.

indicated the average self-rated scores of premorbid abilities to listen, speak, read, and write in each language. Most participants reported higher usage of L2 English given that they currently live in the U.S. for work or study. Although they were relatively proficient in both languages, their premorbid LARs were slightly higher in L1 than in L2.

Standardized assessment and scoring

Participants were administered a battery of standardized language assessments and discourse tasks that were counterbalanced by language across testing sessions. All the assessments in this study were conducted remotely via Zoom (https://zoom.us/) during the COVID-19 pandemic. According to previous studies comparing in-person and teleassessment, no significant difference in performance between these two modalities has been reported (Dekhtyar et al., 2020; Theodoros et al., 2008). Responses in each assessment were calculated based on guidelines within each test manual and aimed to comprehensively characterize language impairment in both languages. Measures of naming (i.e., Boston Naming Test, Northwestern Naming Battery, Northwestern Assessment of Verbs and Sentences) and discourse tasks (i.e., AphasiaBank) served as primary outcome measures for this study.

WAB-R and ABC

The WAB-R (Kertesz, 2007) and the ABC (Gao, 1993, 1996) were administered to measure the overall aphasia severity in English and Mandarin, respectively, as characterized by the Aphasia Quotient (AQ). The ABC is a Chinese-adapted version of the WAB-R. Previous studies have indicated its high reliability and validity based on assessment outcomes from 199 post-stroke patients with aphasia and 165 post-stroke patients without aphasia (Gao, 1993, 1996).

Boston Naming Test

Single-word lexical retrieval in English was evaluated with the Boston Naming Test Long Form (BNT; Goodglass et al., 2001), which contains pictures of 60 common objects. A 30-item version for the Chinese BNT (Chen et al., 2014; Cheung et al., 2004) was administered to assess the noun-retrieval ability in Mandarin Chinese. This 30-item BNT has been culturally adapted and validated in Chinese speakers. A cut-off score of 24 in spontaneous naming generated a sensitivity of 73.1% and specificity of 75.3% in differentiating normal from participants with brain injury (Cheung et al., 2004), suggesting that the 30-item BNT is applicable to the Chinese-speaking population. Instructions in both Mandarin and English were provided in Appendix C. An accurate response was given one credit based on the BNT scoring criteria, that is, any spontaneous responses produced in the target language and accurate responses following a semantic cue.

Northwestern Naming Battery & Northwestern Assessment of Verbs and Sentences

Confrontation naming of nouns and verbs was additionally administered using the Northwestern Naming Battery (NNB; Thompson et al., 2012) and the Verb Naming Test (VNT) from the Northwestern Assessment of Verbs and Sentences (NAVS, Thompson, 2012). The same subtests were administered using the Chinese NNB (Liao & Thompson, 2017) and NAVS (Wang & Thompson, 2016), which have been adapted and validated in Chinese-speaking individuals with aphasia. Instructions in both

Mandarin and English were provided in Appendix C. A response was accurate if an item was produced spontaneously in the target language without any phonemic paraphasia.

Pyramids and Palm Trees Test

A three-picture version of the Pyramids and Palm Trees Test (PPT; Howard & Patterson, 1992) was administered to evaluate semantic processing in Mandarin-English BWA. Participants were asked to select one from two pictures at the bottom that was semantically associated with the top picture. This test was administered in the dominant or preferred language given that bilinguals have a shared semantic system across languages (Kroll & Stewart, 1994). Verbal instructions were provided in the administered language (Appendix C).

Cognitive Linguistic Quick Test

Executive functions were assessed using the Cognitive Linguistic Quick Test (CLQT; Helm-Estabrooks, 2001). This domain included three non-linguistic tasks (i.e., symbol trails, mazes, design generation) and one linguistic task (i.e., animal and letter fluency). In that previous studies suggest different mechanisms in processing language control and general cognitive control in BWA (Gray & Kiran, 2016), all of the non-linguistic tasks were assessed in the dominant or preferred language, and the linguistic tasks were assessed in both languages.

Discourse

Connected speech samples from all twelve participants were collected in Mandarin and English in separate sessions using sequential-picture, single-picture, and storytelling tasks from the AphasiaBank (https://aphasia.talkbank.org/), which have been commonly implemented for assessing spontaneous speech for both clinical and research purposes (Chen et al., 2018; MacWhinney et al., 2011). Performance may highly vary across these tasks as they elicit distinctive linguistic and cognitive demands (Brady et al., 2005; Nicholas & Brookshire, 1993). The sequential pictures included a six-frame strip ("*Umbrella*") that depicts the story of a young boy who refuses to take an umbrella from his mother when he leaves for school; on his way to school it starts raining so he returns home to take the umbrella. The single picture was *"Cat Rescue"* (Nicholas & Brookshire, 1993). In this picture, a girl's cat is on a tree and her dad has tried to rescue the cat but is stuck on the tree; so, the fire department comes to rescue the cat and the girl's father. The single- and sequential-picture stimuli were included in Appendix A and can be found at: www.talkbank.org/AphasiaBank/protocol/pictures.html. Storytelling was assessed using *"The Tortoise and the Hare"* which is about a hare who falls asleep while running a race with a tortoise, then the tortoise wins the race. The rationale for choosing this story was because it is more culturally relevant to the Chinese population as compared to other stories such as *"Cinderella"* (Kong, 2017). Participants were tested in a quiet environment. Verbal instructions and prompts were provided in both languages (Appendix D). Responses in these discourse tasks were audio and video recorded on Zoom and transcribed by the first author using Computerized Language ANalysis (CLAN) program (MacWhinney, 2000).

Connected speech in both languages was analyzed using the Computerized Quantitative Production Analysis (C-QPA) command (Berndt et al., 2000; Saffran et al., 1989). Our outcome measures for spoken discourse included a total of four continuous variables: (1) proportion of nouns (equation 1), (2) proportion of verbs (equation 2), (3) number of nouns per utterance (equation 3), and (4) number of verbs per utterance (equation 4). According to the C-QPA rules (Berndt et al., 2000; Saffran et al., 1989), nouns included common nouns and proper nouns, and verbs included common verbs, copulas and participles. The same rules applied in both Mandarin and English. The proportion of verbs or nouns has been used in a previous bilingual aphasia study to compare verb and noun retrieval in spoken discourse (Dai et al., 2012). This measure allows us to directly examine lexical retrieval in both languages as a function of word category. In addition, the numbers of nouns and verbs were normalized by the total number of utterances to minimize the influence of the amount of discourse production on critical linguistic units in this analysis (Sung et al., 2016). As mentioned earlier, if lexical properties of verbs make them more difficult to produce than nouns, then these measures would capture a verb-noun dissociation across languages. But if the cross-linguistic variation in verb salience matters, these measures would reveal a smaller effect of word category in Mandarin than in English (Sung et al., 2019).

$$\frac{\#\ of\ nouns}{\#\ of\ nouns + \#\ of\ verbs} \tag{1}$$

$$\frac{\#\ of\ verbs}{\#\ of\ nouns + \#\ of\ verbs} \tag{2}$$

$$\frac{\#\ of\ nouns}{\#\ of\ total\ utterances} \tag{3}$$

$$\frac{\#\ of\ verbs}{\#\ of\ total\ utterances} \tag{4}$$

Naming stimuli and psycholinguistic variables

Noun stimuli were composed of the same items in both Mandarin and English BNTs (n = 30 per language) and items that contributed to the noun-verb ratio on the NNB (n = 16 per language). Likewise, verb stimuli were composed of non-redundant items from the NNB and NAVS (n = 21 for Mandarin, n = 31 for English). See Appendix B for the stimuli.

Furthermore, psycholinguistic measures of nouns and verbs were obtained to examine their potential influence on naming performance. Specifically, frequency-per-million was extracted from the Subtlex-US (Brysbaert & New, 2009) for English and from the Subtlex-CH (Cai & Brysbaert, 2010) for Mandarin. Additionally, imageability and familiarity ratings were obtained from the Glasgow Norms (Scott et al., 2019) and the MRC Psycholinguistic Database (Coltheart, 1981), which both are based on 7-point scales (lower means less familiar or imageable). Since values of most stimuli are unavailable in the existing Chinese databases (Liu et al., 2007; Wang & Chen, 2020; Xu et al., 2021), imageability and familiarity ratings in English were used as measures for all the Mandarin items. Previous studies have reported high

Table 2. Psycholinguistic values of noun and verb stimuli by language.

	Log frequency		Familiarity		Imageability	
[a]L1						
	Noun	Verb	Noun	Verb	Noun	Verb
Mean	0.67	1.59	5.42	6.05	6.52	5.19
SD	0.80	0.70	0.91	0.37	0.43	0.87
t-value	-15.66**		-12.33**		20.28**	
L2						
	Noun	Verb	Noun	Verb	Noun	Verb
Mean	0.57	1.59	5.44	5.88	6.49	5.14
SD	0.72	0.69	0.91	0.57	0.43	0.84
t-value	-20.73**		-7.97**		25.37**	

Note: L1: Mandarin, L2: English; [a]Familiarity and imageability ratings in L2 were used as approximate measures for L1. **: p-value < 0.01.

correlations of imageability ratings across languages, suggesting that lexical-semantic ratings may be used cross-linguistically (Blomberg & Öberg, 2015; Rofes et al., 2018). Independent *t*-tests showed a significant difference between verbs and nouns for all variables in both Mandarin and English (Table 2).

Data analysis

Data analysis was conducted in R Studio (Version 4.1.0). To address the first research question, a linear mixed-effects model were fitted to the data using the *lmerTest* package (Kuznetsova et al., 2017) to examine the effect of word class on item-level response accuracy (0 = inaccurate, 1 = accurate). The fixed factors included word class (i.e., nouns, verbs), language (i.e., Mandarin, English), and the class*language interaction term. Random intercepts for subject and item were included to account for additional variance. Additionally, WAB-AQ and log frequency were included as the covariates. Two additional models were performed to control for imageability and familiarity ratings (Appendix E). However, results were interpreted with caution since ratings in English were used as approximate measures for Mandarin. To estimate the main effects, sum-to-zero contrasts were coded for the categorical fixed factors (i.e., word class, language). Statistical significance was set at $p < 0.05$.

For the second research question, linear regression was conducted to examine the effect of word class on each of the dependent variables: the proportion of lexical production and the number of words per utterance. For each model, the fixed factors were word class (i.e., nouns, verbs), language (i.e., Mandarin, English), discourse task (i.e., *Umbrella, Cat Rescue, The Tortoise and the Hare*), and their three-way interaction. WAB-AQ was included as the covariate to account for the overall aphasia severity. Sum-to-zero contrasts were coded for the categorical fixed factors (i.e., word class, language, discourse task).

To answer the last research question, linear regression was performed to examine the relationship between single-word naming and lexical retrieval in discourse. To promote a comparable measure to discourse production, a proportion of accurate object vs. action naming was calculated using equation (5) to capture the pattern of verb and noun impairment in single-word naming. Hence, a higher proportion of accurate nouns means a lower proportion of accurate verbs. In the model, the proportion of noun vs. verb production across all discourse tasks was the dependent variable (equation 1). The fixed factors included the proportion of accurate object vs. action naming, language (i.e., Mandarin, English), and the naming*language interaction. WAB-AQ was entered as the covariate.

$$\frac{\#\ of\ accurate\ nouns}{\#\ of\ accurate\ nouns\ +\ \#\ of\ accurate\ verbs} \tag{5}$$

Reliability measure

Twenty percent of the discourse production was randomly selected and transcribed by a trained student. Inter-rater reliability was then calculated for the C-QPA measures (i.e., total number of narrative words, total number of nouns, total number of verbs, total number of utterances) using *Pearson's* correlations.

Table 3. Standardized language measures and naming performance.

ID	WAB AQ	WAB Type	ABC AQ	ABC Type	EN BNT[a] %	CH BNT %	CLQT EF-NV	PPT %	EN NNB obj %	EN NNB act %	EN VNT %	CH NNB obj %	CH NNB act %	CH VNT %
P1	47.6	B	34.1	B	18.3	3.3	23.0	76.6	62.5	6.3	13.6	12.5	0.0	0.0
P2	92.3	A	86.9	A	80.0	73.3	17.0	96.9	100.0	87.5	86.4	100.0	87.5	80.0
P3	78.7	A	86.5	A	38.3	86.7	31.0	95.3	93.8	62.5	72.7	100.0	81.3	80.0
P4	68.6	C	51.2	B	26.7	16.7	28.0	93.8	81.3	25.0	45.5	25.0	6.3	5.0
P5	82.9	A	77.7	A	46.7	53.3	7.0	84.4	75.0	81.3	45.5	87.5	68.8	65.0
P6	82.8	A	87.6	A	31.7	73.3	25.0	98.4	75.0	68.8	72.7	100.0	87.5	95.0
P7	39.2	B	51.9	B	3.3	13.3	18.0	60.9	6.3	6.3	0.0	6.3	25.0	15.0
P8	13.3	G	50.0	B	0.0	3.3	16.0	75.0	0.0	0.0	0.0	12.5	25.0	15.0
P9	69.0	C	78.4	A	23.3	63.3	25.0	96.9	75.0	50.0	40.9	75.0	81.3	65.0
P10	93.8	A	88.3	A	53.3	53.3	29.0	98.4	93.8	93.8	81.8	93.8	93.8	90.0
P11	77.7	C	78.4	A	30.0	26.7	27.0	98.4	62.5	37.5	45.5	50.0	43.8	55.0
P12	82.9	A	90.9	A	33.3	93.3	23.0	95.3	87.5	43.8	50.0	93.8	62.5	60.0
Mean	69.1		71.8		32.1	46.7	22.4	89.2	67.7	46.9	46.2	63.0	55.2	52.1
SD	24.0		19.5		21.7	32.7	6.8	12.3	32.4	32.8	29.6	38.9	33.8	34.3

[a]Thirty of the total 60 items were included in the data analysis. CH: Mandarin Chinese; EN: English; WAB-AQ: Western Aphasia Battery Aphasia Quotient (total = 100); ABC-AQ: Aphasia Battery in Chinese Aphasia Quotient (total = 100); Aphasia Type: A = Anomic, B = Broca's, C = Conduction, G = Global; EN BNT = English Boston Naming Test (total = 60); CH BNT = Chinese Boston Naming Test (total = 30); CLQT EF-NV: Cognitive Linguistic Quick Test Executive Function Non-verbal (total = 31); PPT: Pyramids and Palm Trees (total = 64); NNB obj: Northwestern Naming Battery Object Naming (total = 16 in CH and EN); NNB act: Northwestern Naming Battery Action Naming (total = 16 in CH and EN); VNT: Verb Naming Test (total = 22 in EN; total = 20 in CH).

Table 4. Regression results of noun and verb naming.

	Estimate	SE	Z-value	*p-value*
Model 1: Accuracy ~ word class * lang + AQ + *log freq* + (1|item) + (1|subj)				
class (noun)	0.512	0.162	3.161	0.002**
lang (L1)	0.288	0.104	2.755	0.006**
class*lang	0.097	0.103	0.934	0.350
log freq	0.913	0.178	5.119	3.08e-07**
AQ	0.119	0.009	13.695	< 2e-16**

Note: lang: language, L1: Mandarin, log freq: log frequency, subj: subject, SE: standard error, AQ: Aphasia Quotient; *p*-value: ** = $p < 0.01$.

Results

Individual naming ability on each task is shown in Table 3. The mixed model results (Table 4) showed that lexical frequency was a significant predictor of the overall naming performance (i.e., higher naming accuracy for items with higher frequency; $p < 0.01$). There was also a significant main effect of word class (β = 0.512, SE = 0.162, $p < 0.01$), suggesting that naming accuracy was higher for nouns than verbs across languages. Further, a significant main effect of language above and beyond lexical frequency (β = 0.288, SE = 0.104, $p < 0.01$) indicated lower naming accuracy in L2 (English) than in L1

Table 5. Group-level measures of discourse production in L1 and L2.

	L1				L2			
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
Number of narrative words								
Cat	38.83	28.49	0.00	82.00	40.00	25.82	0.00	86.00
Tortoise	50.33	38.37	2.00	125.00	50.33	42.33	1.00	136.00
Umbrella	42.17	27.36	2.00	77.00	42.08	27.04	4.00	99.00
Number of nouns								
Cat	9.50	6.54	0.00	21.00	10.42	6.36	0.00	21.00
Tortoise	10.67	6.75	0.00	21.00	12.17	9.84	0.00	33.00
Umbrella	9.75	6.28	0.00	21.00	9.17	6.07	0.00	21.00
Noun proportion (%)								
Cat	61.07	16.08	50.00	100.00	63.77	16.48	47.06	100.00
Tortoise	49.43	16.82	0.00	66.67	61.38	15.78	44.00	100.00
Umbrella	48.29	22.04	0.00	87.50	56.13	18.13	35.00	100.00
Number of nouns per utterance								
Cat	1.59	0.53	0.57	2.14	1.71	0.74	0.40	2.40
Tortoise	1.21	0.45	0.00	1.67	1.21	0.70	0.00	2.00
Umbrella	1.11	0.63	0.00	2.11	1.27	0.80	0.00	2.80
Number of verbs								
Cat	6.92	5.79	0.00	17.00	7.50	6.05	0.00	20.00
Tortoise	10.00	7.26	1.00	22.00	9.25	8.30	0.00	25.00
Umbrella	9.17	6.19	1.00	21.00	8.42	6.73	0.00	23.00
Verb proportion (%)								
Cat	38.93	16.09	0.00	50.00	36.23	16.48	0.00	52.90
Tortoise	50.58	16.81	33.30	100.00	38.63	15.78	0.00	56.00
Umbrella	51.70	22.04	12.50	100.00	43.88	18.14	0.00	65.00
Number of verbs per utterance								
Cat	1.21	0.68	0.00	2.14	1.26	0.77	0.00	2.40
Tortoise	1.14	0.34	0.60	1.75	0.88	0.59	0.00	1.50
Umbrella	1.13	0.52	0.13	2.10	1.17	0.88	0.00	2.60
Number of utterances								
Cat	5.75	3.22	0.00	10.00	6.42	3.26	0.00	11.00
Tortoise	7.83	4.20	2.00	16.00	9.00	5.05	2.00	20.00
Umbrella	7.50	2.50	3.00	11.00	6.83	2.52	3.00	12.00

L1: Mandarin; L2: English; SD: standard deviation; Min.: minimum; Max.: maximum; Cat = Cat Rescue; Tortoise: The Tortoise and the Hare; Noun proportion (%): # Nouns / (# Nouns + # Verbs); Verb proportion (%): # Verbs / (# Nouns + # Verbs); Number of nouns per utterance: # Nouns / # Utterances; Number of verbs per utterance: # Verbs / # Utterances.

Table 6. Inter-rater reliability measures (Pearson's *r*) of discourse production.

	Total # of Narrative Words	Total # of Utterances	Total # of Nouns	Total # of Verbs
L1	0.95**	0.91**	0.95**	0.99**
L2	0.95**	0.90**	0.89**	0.96**

L1: Mandarin, L2: English; **: *p*-value < 0.01.

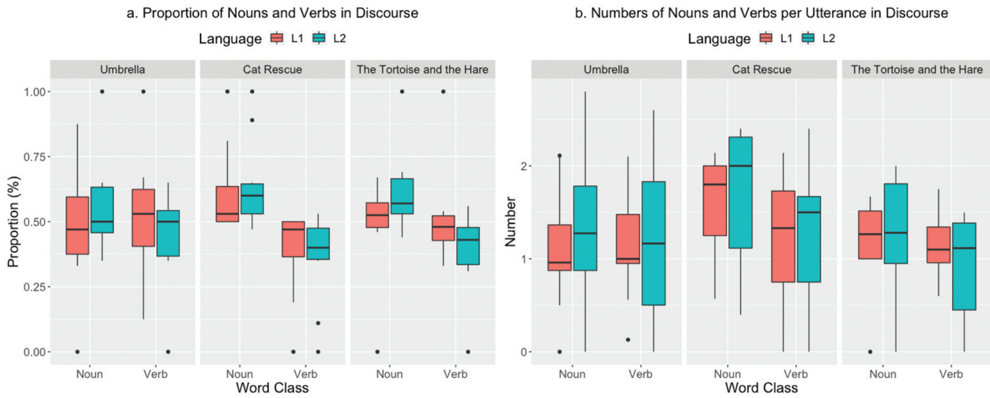


Figure 1. (a) A boxplot showing the average proportion of verb and noun production by the target language (L1 vs. L2) in each discourse task (i.e., *Umbrella, Cat Rescue, The Tortoise and the Hare*); Y-axis: Proportion of lexical production (1.00 = 100%); Noun Proportion: # Nouns / (# Nouns + # Verbs); Verb Proportion: # Verbs / (# Nouns + # Verbs). (b) A boxplot capturing the average number of verbs and nouns per utterance in the target language (L1 vs. L2) in each discourse task. Y-axis: Number of verbs or nouns per utterance; Nouns: # Nouns / # Total Utterances; Verbs: # Verbs / # Total Utterances. A significant main effect of word class was found on both the proportion of lexical production ($p < 0.01$) and the number of lexical items ($p < 0.01$). A significant difference between the proportion of nouns and verbs was found in L1 ($p < 0.05$) and L2 ($p < 0.01$) in *Cat Rescue*, and in L2 in *The Tortoise and the Hare* ($p < 0.05$).

(Mandarin). The results did not show a significant class*language interaction, that is, the effect of word class on naming was similar in both languages. Further, a significant main effect of AQ (p-value < 0.01) suggested higher naming accuracy in individuals with higher AQ, i.e., lower aphasia severity.

Group-level measures of Mandarin and English discourse tasks are illustrated in Table 5. Inter-rater reliability for these measures showed significant correlations in both L1 and L2 (Table 6). Figure 1 captures the average proportion of verbs and nouns (a) and the number of verbs and nouns per utterance (b) by the target language (i.e., L1, L2) in each discourse task (i.e., *Cat Rescue, Umbrella, The Tortoise and the Hare*). The regression results revealed a significant main effect of word class on both the proportion of lexical production (β = 0.067, SE = 0.016, $p < 0.01$) and the number of lexical items per utterance (β = 0.109, SE = 0.037, $p < 0.01$), suggesting a verb-noun dissociation across languages and tasks, i.e., higher production of nouns than verbs. The model predicting the proportion of lexical production also showed a significant class*task interaction (*Cat Rescue*: β = 0.057, SE = 0.022, $p < 0.05$) and a significant class*language interaction (L1: β = -0.038, SE = 0.016, $p <$ 0.05). *Post-hoc* pairwise comparisons were performed using the *emmeans* package in R Studio (tukey method). Results showed that the proportion of noun production was significantly higher than verb production in English ($p < 0.05$) but not in Mandarin ($p >$ 0.05). For the discourse tasks, there was a higher proportion of nouns than verbs in both L1 ($p < 0.05$) and L2 ($p < 0.01$) in *Cat Rescue*, and in L2 in *The Tortoise and the Hare* ($p <$ 0.05). These findings suggested that the verb-noun dissociation emerged in L1 and L2 to varying degrees, depending on the type of task.

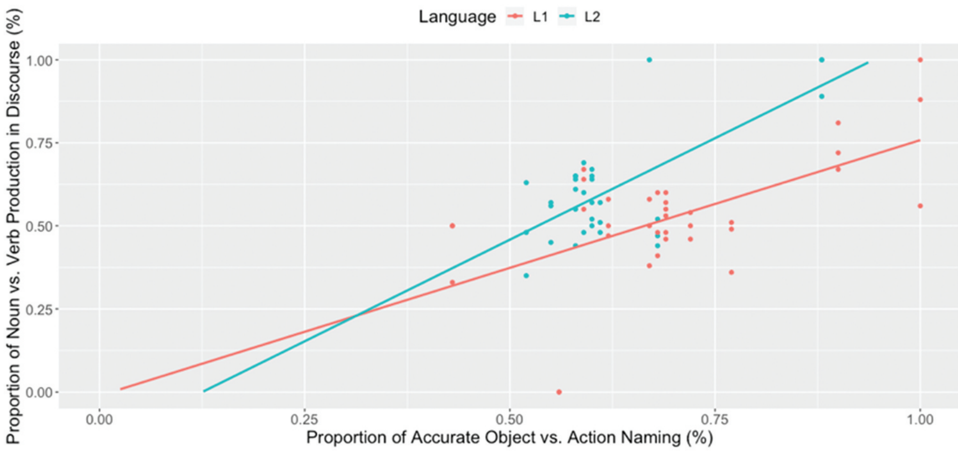


Figure 2. X-axis: the proportion of accurate object vs. action naming (equation 5; 1.00 = 100%); 100% of accurate object naming means 0% of accurate action naming. Y-axis: the proportion of nouns vs. verbs across all three discourse tasks (equation 1; 1.00 = 100%); 100% of noun production means 0% of verb production. A positive relationship was identified between naming and discourse ($p < 0.01$). No significant class*language interaction was found ($p > 0.05$).

To further examine factors that might have affected the cross-linguistic differences in the verb and noun dissociation (i.e., a significant class*language interaction effect on the proportion of lexical production), linear regression was carried out to assess the effect of aphasia severity (i.e., WAB-AQ) and premorbid proficiency (i.e., LAR) across all three discourse tasks. The model estimating the modulating effect of aphasia severity captured a significant AQ*class interaction (β = -0.005, SE = 0.001, $p < 0.01$), a significant class*language interaction (β = -0.273, SE = 0.067, $p < 0.01$), and a significant AQ*class*language three-way interaction (β = 0.003, SE = 0.001, $p < 0.01$), suggesting that the cross-linguistic difference of the verb-noun dissociation in discourse was smaller in individuals with higher AQ, i.e., lower aphasia severity. The model estimating the modulating effect of premorbid proficiency did not reveal any significant effect (p-values > 0.05), indicating that the cross-linguistic difference of the verb-noun dissociation was not driven by bilingual language history.

The relationship between naming and lexical retrieval in discourse is illustrated in Figure 2. The regression results revealed that lexical retrieval in discourse was significantly predicted by single-word naming after accounting for aphasia severity (β = 0.90, SE = 0.18, $p < 0.01$), suggesting that a higher proportion of accurate nouns (i.e., a lower proportion of accurate verbs) in naming was associated with a higher proportion of noun production (i.e., a lower proportion of verb production) in discourse. In addition, there was not a significant interaction between the target language (i.e., L1, L2) and naming performance ($p > 0.05$). These findings altogether indicated a similar pattern of verb and noun dissociation across single-word naming and discourse production irrespective of the target language. In addition, naming performance could be a significant indicator of lexical retrieval in discourse in Mandarin-English BWA.

Discussion

The current study aimed to investigate patterns of verb and noun impairment in Mandarin-English BWA. Specifically, we examined if: (1) a verb and noun dissociation emerged at the *single-word* level, (2) a verb and noun dissociation emerged at the *discourse* level, and (3) a similar pattern of verb and noun dissociation emerged across single-word naming and discourse production. The study to our knowledge is the first one that systematically examined word-retrieval abilities for verbs and nouns in a group of Mandarin-English BWA. Results partially support previous studies that investigated verb and noun impairment in BWA. In general, Mandarin-English BWA performed better in their L1 (Mandarin) than in L2 (English) in single-word naming. Across L1 and L2, naming accuracy for nouns was higher than for verbs. The magnitude of the verb-noun dissociation did not vary by language, suggesting that the differences between verbs and nouns might be instead attributed to their lexical-semantic properties.

In discourse production, Mandarin-English BWA demonstrated better performance in lexical retrieval of nouns than verbs across languages and tasks, as evidenced by a larger proportion of nouns and higher production of nouns per utterance. These findings corroborated previous evidence of a verb-noun dissociation in lexical retrieval. In addition, the proportion of noun production was significantly higher than that of verb production in both L1 and L2 in single-picture description and in L2 storytelling. These results suggest that depending on the discourse task, the effect of word class was larger in L2 than in L1. This cross-linguistic difference of the verb-noun dissociation was diminished in individuals with higher AQ, i.e., lower aphasia severity. Finally, our linear regression results showed that irrespective of the language, a higher proportion of accurate nouns (i.e., a lower proportion of accurate verbs) in naming was associated with a higher proportion of noun production (i.e., a lower proportion of verb production) in discourse. These results altogether pointed to a similar pattern of verb and noun dissociation across different linguistic contexts. However, depending on the cognitive-linguistic demands of the context/task, the verb-noun dissociation may emerge in L1 and L2 to varying degrees in individuals with different levels of aphasia severity. Findings in our study help uncover the cross-linguistic variations in lexical retrieval of verbs and nouns in Mandarin-English BWA. In the discussion that follows, we elaborate on these findings.

Verb-noun dissociation in naming

Consistent with our predictions, the findings revealed a pattern of verb-noun dissociation in single-word naming (i.e., lower naming accuracy for verbs than nouns) after controlling for lexical frequency. While the patterns of verb-noun impairment varied across previous studies (Kremin & De Agostini, 1995; Sasanuma & Park, 1995; Kambanaros & van Steenbrugge, 2006; Poncelet et al., 2007; Faroqi-Shah & Waked, 2010; Kambanaros, 2010; Dai et al., 2012), the current finding of a verb and noun dissociation is in-line with more recent studies that have reported a similar pattern in BWA (Kambanaros, 2010; Kambanaros & van Steenbrugge, 2006; Poncelet et al., 2007). Even in healthy bilinguals, verbs are more difficult to access than nouns due to a weaker cross-linguistic connection at the conceptual level, as posited by the *Distributed Feature Model* (Van Hell & De Groot, 1998). This model assumes that bilinguals would perform worse on tasks involving verb access as compared to noun access. Hence, the dissociation between action and object naming in this study suggests that these weaker connections at the semantic representation level affect verbs more following brain damage in BWA. This presumption warrants future analysis with a well-matched group of healthy bilinguals.

Although the current study did not aim to investigate the linguistic mechanisms underlying the verb-noun dissociation, we noticed that the effect of word class disappeared after *imageability* was controlled for (Appendix E). Previous research has posited that imageability has strong effects on object and action naming because concrete words benefit from conceptual specificity and redundancy between concepts, whereas the conceptual connections between abstract words are relatively loose (Kiran & Tuchtenhagen, 2005). Given that verbs were significantly less imageable than nouns in this study (Table 2), our finding supports this hypothesis and suggests that the dissociation between verbs and nouns may arise at the semantic/conceptual level of lexical processing (Bird et al., 2001; Poncelet et al., 2007; Shapiro & Caramazza, 2003). However, while this finding resonates with previous studies examining the effect of imageability in verb and noun processing (Kambanaros, 2010; Kiran & Tuchtenhagen, 2005; Luzzatti et al., 2002), we recognize that it needs to be interpreted with caution given that imageability ratings in English were used as approximate measures for Mandarin in our study.

Mandarin-English BWA also performed better in their L1 than in L2, as evidenced by higher naming accuracy across verbs and nouns in L1 (Mandarin). This L1 advantage could be due to individual aphasia severity and language proficiency. According to the standardized assessment scores, most of our participants demonstrated higher WAB-AQ and language ability ratings (LAR, Table 1) in L1 than in L2. Previous bilingual aphasia studies including individuals with differential recovery patterns have shown better performance in the language with less impairment and higher premorbid proficiency (Paradis, 2001). This finding supports the growing body of evidence suggesting that the severity of language impairment and premorbid language proficiency may be strong predictors of bilingual aphasia recovery (Kuzmina et al., 2019; Lorenzen & Murray, 2008; Peñaloza et al., 2019; Gray & Kiran, 2013).

Although the overall naming performance across verbs and nouns was better in L1 than in L2, the verb-noun dissociation discussed above was similar in both languages. The majority of previous research also identified a similar pattern of verb-noun dissociation in L1 and L2 (Kambanaros & van Steenbrugge, 2006; Poncelet et al., 2007; Miozzo et al., 2010). Our study successfully replicated this finding when extended to languages with different verb typologies (i.e., Mandarin and English). In English, verbs are marked by grammatical morphology, such as number, person, and tense markers, whereas verbs in Mandarin Chinese do not carry these linguistic markers (Gentner, 2006). Given these cross-linguistic variations in verb morphology, the morphological account of the verb-noun dissociation has posited that the effect of word class would emerge in English but not in Mandarin at the single-word level (Bates et al., 1991; Caramazza & Berndt, 1985). Nevertheless, our findings showed a similar verb-noun dissociation in both languages, suggesting that the source of the grammatical category differences may not be attributed to the cross-linguistic differences in morphology. According to a previous neurophysiological account, verbs and nouns of both languages are processed in a similar manner by the same neural substrates (Miozzo et al., 2010). Hence, our findings support this account and indicate that the organization of verbs and nouns may be shared across languages.

Verb-noun dissociation in discourse and its relationship with naming

In discourse production, Mandarin-English BWA exhibited higher production of nouns than verbs across languages and tasks, suggesting a verb-noun dissociation. More interestingly, the verb-noun dissociation emerged in L1 (Mandarin) and L2 (English) to varying degrees. Our *post-hoc* analysis showed that the proportion of verb production was significantly lower than noun production only in L2. This finding was consistent with the prediction that verbs in Mandarin may not be more difficult than nouns given that Mandarin is a pro-drop and verb-salient language (Huang, 1989). Previous studies have corroborated the verb-saliency hypothesis as evidence has suggested an earlier age of acquisition and a larger lexical inventory of verbs than nouns in Mandarin-speaking children. As pointed out earlier, Sung et al. (2016) found that Korean individuals with aphasia produced more verbs per utterance than English speakers with aphasia. They argued that the cross-linguistic differences in verb production support the idea of cue validity in the competition model (Bates et al., 1988), that is, linguistic features with more informative cues (i.e., verb salience) are more resilient to language impairments in aphasia. Therefore, our findings in Mandarin-English bilinguals with aphasia support this assumption and suggest that patterns of verb and noun retrieval in discourse may be due to the cross-linguistic differences in verb salience.

This cross-linguistic variation in the verb-noun dissociation was also dependent on the task. Specifically, the proportion of nouns was higher than that of verbs in both L1 and L2 in single-picture description, whereas the proportion of nouns was higher than the proportion of verbs in L2 in storytelling. Taken together, these findings can be explained by a combination of task- and individual-related factors, including: (1) cognitive-linguistic demands of language contexts, (2) premorbid language proficiency in L1 and L2, and (3) individual aphasia severity. While the verb-noun dissociation in discourse emerged in languages and tasks to different degrees, our regression results revealed an overall positive relationship between naming and lexical retrieval in discourse irrespective of the target language. We unpack each of these points in the following paragraphs.

In comparison with naming, discourse production involves more activation and interaction of both cognitive and linguistic subsystems, which are commonly affected in individuals with aphasia (Linnik et al., 2016). The effect of linguistic context, i.e., single-word naming vs. connected speech, on lexical retrieval has been previously investigated in aphasia studies, but mainly focused on monolinguals with aphasia (Law et al., 2015; Mayer & Murray, 2003; Pashek & Tompkins, 2002; Wilshire & McCarthy, 2002). Some of these studies suggest that linguistic context highly influences lexical retrieval due to different processing demands. In discourse production, there tend to be more semantic alternatives to the target competing for lexical selection, whereas lexical selection in naming is relatively more context-constrained as the target word is the preferred choice for production (Law et al., 2015; Wilshire & McCarthy, 2002). Hence, while the verb-noun dissociation was found in both naming and discourse, the processing demand might be higher for discourse production.

Different types of discourse tasks also impose distinctive cognitive-linguistic demands, which may differentially impact lexical retrieval in individuals with aphasia (Brady et al., 2005; Nicholas & Brookshire, 1993). In our study, a verb-noun dissociation was found in both single-picture description and storytelling, but to a larger extent in the former. In conversation, speakers usually establish main ideas via communicating the relations and causal links among units of information (van Dijk & Kintsch, 1983). This claim is supported by previous research in both healthy adults and individuals with aphasia (Capilouto et al., 2005; Fergadiotis & Wright, 2014). In general, these studies found less production of main events from the single pictures versus sequential pictures and storytelling, suggesting that single pictures convey less temporal and causal information about a story. As a result, participants may simply list the objects without considering the events or underlying relationships, leading to less production of verbs than nouns (Fergadiotis & Wright, 2014). Our results corroborate this account and further suggest that irrespective of the language, verb retrieval in BWA is particularly sensitive to discourse tasks that include fewer causal links among information. However, these presumptions should be investigated in future research targeting different bilingual populations with aphasia.

Relative to L1 (Mandarin), Mandarin-English BWA demonstrated a verb-noun dissociation to a greater extent in their L2. One explanation of this finding is the variability in language history. Among many other individual factors that impact bilingual language impairment, a lower L2 proficiency and a late AoA have been consistently associated with poorer language performance across studies (Kuzmina et al., 2019; Peñaloza & Kiran, 2019). Given that our participants had a late L2 AoA (mean = 12.4 years) and a relatively lower premorbid LAR for L2 (mean = 82.4%) as compared to L1 (mean = 98.2%), verb production in discourse might be more impaired in the less proficient language, i.e., L2. This finding can also be explained by the *Revised Hierarchical Model* (Kroll & Stewart, 1994), which assumes a stronger link between the conceptual system and lexical system of L1 than between the conceptual system and lexical system of L2. Hence, accessing the semantics of verbs in the less proficient language may be affected to a larger extent than in the more proficient language. This presumption can be tested in future research via an error analysis to examine whether there are more semantic errors for verbs than noun in L2.

We further found that the cross-linguistic difference of the verb-noun dissociation was smaller in individuals with higher WAB-AQ (i.e., lower aphasia severity). The effect of aphasia severity/type on the verb and noun impairment in connected speech is still unclear across previous bilingual aphasia studies (Dai et al., 2012; Faroqi-Shah & Waked, 2010; Kambanaros, 2007). Two of these studies did not identify a verb-noun dissociation in connected speech in either language of bilinguals with mild aphasia (Dai et al., 2012; Kambanaros, 2007). However, they did not include individuals with more severe aphasia for comparison. One account claimed that individuals with mild aphasia tend to have less difficulty with verb retrieval relative to those with more severe aphasia, leading to a smaller or even no grammatical category dissociation in connected speech (Berndt et al., 1997). However, evidence supporting this account has mainly come from monolinguals with aphasia (Law et al., 2015; Mayer & Murray, 2003; Pashek & Tompkins, 2002; Wilshire & McCarthy, 2002).

One may further link the role of aphasia severity with bilingual language history (Paradis, 2001), that is, individuals with lower aphasia severity in one language may have higher premorbid proficiency in the same language. However, results from the model examining the modulating effect of language proficiency did not support this assumption, possibly due to a small variation in proficiency ratings (Table 1). Although most of our participants with lower L2 language ability ratings also demonstrated lower

L2 AQ scores, these participants on average were relatively proficient in both Mandarin and English. Future studies can include individuals with a greater variation in premorbid language proficiency to investigate the joint effect of bilingual language history and aphasia severity on verb and noun retrieval in spoken discourse.

Notwithstanding the above factors that may affect verb and noun impairment in discourse, our results pointed to a similar pattern of verb-noun dissociation in single-word naming and discourse production in Mandarin-English BWA. In both linguistic contexts, the effect of word category was consistently observed across languages, suggesting that verbs were more difficult to produce than nouns regardless of the variation in task demands. Most previous bilingual aphasia studies examining verb and noun retrieval in naming and connected speech have either revealed the opposite (i.e., superior verb impairment in naming than discourse) or no direct relationship (Dai et al., 2012; Kambanaros, 2007). Several key methodological differences might have caused the disparity in findings. For example, the stimuli and patient samples varied across studies, which might have affected the underlying relationship between naming and discourse. Also, the previous studies either did not carry out a direct comparison between naming and discourse (Dai et al., 2012) or only examined the relationship using correlational analysis without accounting for individual factors, such as aphasia severity (Kambanaros, 2007). As highlighted in previous reviews (Armstrong, 2000; Linnik et al., 2016), future research can benefit from comparative evaluation of existing methods to better reproduce results of earlier studies. Findings from our study indicate that quantitative measure of verbs and nouns in discourse production can help capture patterns of lexical impairment in BWA and may identify the cross-linguistic variations in verb and noun processing.

Limitations and future implications

Despite the findings discussed above in support of a verb-noun dissociation in both naming and discourse production in Mandarin-English BWA, there are several limitations in this study. First, the lack of a Mandarin-English bilingual control group made it difficult to identify between-group differences in verb and noun retrieval. While previous aphasia studies including both healthy controls and patients have consistently reported a group-level difference, i.e., lower performance in patients than controls, a well-matched control group would help us better understand the grammatical category dissociation in BWA. Second, we had a heterogenous group with different levels of aphasia severity and premorbid language proficiency, which both could be factors impacting language performance in L1 and L2 (Kuzmina et al., 2019; Lorenzen & Murray, 2008; Peñaloza et al., 2019). Hence, it is important for future research to increase the sample size with different language profiles to examine the effect of these factors. Third, we used imageability and familiarity ratings in English as measures for Mandarin stimuli because values would be missing for most items if they were extracted from the existing Chinese databases (Liu et al., 2007; Wang & Chen, 2020; Xu et al., 2021). Even though previous studies have argued that same lexical-semantic values could be used cross-linguistically (Blomberg & Öberg, 2015; Rofes et al., 2018), results would be more informative if values for each language were available. Hence, there is an urgent need for future studies to develop larger databases for use in bilingual language research. Forth, future research could examine error patterns in both naming and discourse production to better understand the linguistic mechanisms underlying the verb-noun dissociation across different contexts. Finally, the current study focused specifically on verb and noun production in spoken discourse. Future studies could expand the analysis and help better understand the cross-linguistic variations in lexical retrieval from both micro-linguistic (i.e., word retrieval) and macro-linguistic perspectives (i.e., coherence).

Conclusion

This study aimed to investigate patterns of verb and noun impairment in single-word naming and discourse production in Mandarin-English BWA. Our results showed a verb and noun dissociation in single-word naming, which was similar in L1 (Mandarin) and L2 (English). Another pattern of verb and noun dissociation was captured in discourse production. However, depending on the task, the effect of word class was significantly larger in L2 than in L1. This cross-linguistic difference of the verb-noun dissociation in discourse production was diminished in individuals with lower aphasia severity. Although the verb-noun dissociation in discourse emerged in L1 and L2 to varying degrees, our results pointed to an overall direct relationship between naming and lexical retrieval in discourse. Our results added to the growing body of literature concerning a verb and noun dissociation in bilingual aphasia when extended to typologically dissimilar languages, i.e., Mandarin-English. Results may facilitate greater understanding of bilingual lexical impairment and highlight the value of using discourse production to identify the cross-linguistic variations in verb and noun processing in BWA.

Acknowledgements

The authors would like to thank the individuals who participated in this study. We also thank the members of the Aphasia Research Laboratory for their support throughout the development and execution of this study. Special thanks to Hongli Zheng, who transcribed the discourse data for fidelity check. Also, many thanks to Michael Scimeca and Jee Eun Sung for their constructive feedback on this manuscript.

Disclosure statement

No potential conflict of interest was reported by the first author. The second author is a scientific consultant for The Learning Corporation (FKA Constant Therapy) but there is no scientific overlap with the work in this project.

Funding

This work was supported by the Boston University Sargent Student Research Grant [number 9250001170]; Authors were funded by the NIH/NIDCD under Grant [number 1U01DC014922].

ORCID

Ran Li http://orcid.org/0000-0002-5034-7294
Swathi Kiran http://orcid.org/0000-0003-1586-8913

References

Armstrong, E. (2000). Aphasic discourse analysis: The story so far. *Aphasiology*, *14*(9), 875–892.

Bates, E., Chen, S., Tzeng, O., Li, P., & Opie, M. (1991). The noun-verb problem in Chinese aphasia. *Brain and language*, *41*(2), 203–233. 10.1016/0093-934X(91)90153R90153R

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. 10.1016/0093-934X(88)900727900727

Berndt, R. S., Haendiges, A. N., & Wozniak, M. A. (1997). Verb retrieval and sentence processing: Dissociation of an established symptom association. *Cortex*, *33*(1), 99–114. 10.1016/S0010-9452(97)80007X80007X

Berndt, R. S., Wayland, S., Rochon, E., Saffran, E., & Schwartz, M. (2000). *Quantitative production analysis: A training manual for the analysis of aphasic sentence production*. Hove, UK: Psychology Press.

Bird, H., Howard, D., & Franklin, S. (2001). Noun-verb differences? A question of semantics: A response to Shapiro and Caramazza. *Brain and Language*, *76*(2), 213–222. 10.1006/brln.2000.2432

Bird, H., Howard, D., & Franklin, S. (2003). Verbs and nouns: The importance of being imageable. *Journal of Neurolinguistics*, *16*(2–3), 113–149. 10.1016/S0911-6044(02)00016-7

Blomberg, F., & Öberg, C. (2015). Swedish and English word ratings of imageability, familiarity and age of acquisition are highly correlated. *Nordic Journal of Linguistics*, *38*(3), 351–364. 10.1017/S0332586515000220

Brady, M., Armstrong, L., & Mackenzie, C. (2005). Further evidence on topic use following right hemisphere brain damage: Procedural and descriptive discourse. *Aphasiology*, *19*(8), 731–747. 10.1080/02687030500141430

Brysbaert, M., & New, B. (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods*, *41*(4), 977–990. 10.3758/BRM.41.4.977

Cai, Q., & Brysbaert, M. (2010). SUBTLEX-CH: Chinese word and character frequencies based on film subtitles. *PLoS ONE*, *5*(6), e10729. 10.1371/journal.pone.0010729

Capilouto, G., Wright, H. H., & Wagovich, S. A. (2005). CIU and main event analyses of the structured discourse of older and younger adults. *Journal of Communication Disorders*, *38*(6), 431–444. 10.1016/j.jcomdis.2005.03.005

Chen, Z., Lin, F., & Deng, B. (2018). Construction of Chinese Mandarin corpus with anomic aphasia. *Chinese Journal of Rehabilitation Medicine*, *33*(6), 669–674. 10.3969/j.issn.1001-1242.2018.06.010

Chen, T.-B., Lin, C.-Y., Lin, K.-N., Yeh, Y.-C., Chen, W.-T., Wang, K.-S., & Wang, P.-N. (2014). Culture Qualitatively but Not Quantitatively Influences Performance in the Boston Naming Test in a Chinese-Speaking Population. *Dementia and Geriatric Cognitive Disorders Extra*, *4*(1), 86–94. 10.1159/000360695

Cheung, R. W., Cheung, M.-C., & Chan, A. S. (2004). Confrontational naming in Chinese patients with left, right or bilateral brain damage. *Journal of the International Neuropsychological Society*, *10*, 46–53. 10.1017/0S1355617704101069

Coltheart, M. (1981). The mrc psycholinguistic database. *The Quarterly Journal of Experimental Psychology Section A*, *33*(4), 497–505. 10.1080/14640748108400805

Cuetos, F., Aguado, G., Izura, C., & Ellis, A. W. (2002). Aphasic naming in Spanish: Predictors and errors. *Brain and Language*, *82*(3), 344–365. 10.1016/S0093-934X(02)00038X00038X

Dai, E. Y. L., Kong, A. P. H., & Weekes, B. S. (2012). Recovery of naming and discourse production: A bilingual anomic case study. *Aphasiology*, *26*(6), 737–756. 10.1080/02687038.2011.645013

Dekhtyar, M., Braun, E. J., Billot, A., Foo, L., & Kiran, S. (2020). Videoconference administration of the western aphasia battery–revised: Feasibility and validity. *American Journal of Speech-Language Pathology*, *29*(2), 673–687. 10.1044/2019_AJSLP-19-00023

Fabbro, F. (2001). The bilingual brain: Bilingual aphasia. *Brain and Language*, *79*(2), 201–210. 10.1006/brln.2001.2480

Faroqi-Shah, Y., & Waked, A. N. (2010). Grammatical category dissociation in multilingual aphasia. *Cognitive Neuropsychology*, *27*(2), 181–203. 10.1080/02643294.2010.509340

Fergadiotis, G., & Wright, H. H. (2014). Lexical diversity for adults with and without aphasia across discourse elicitation tasks. *Bone*, *23*(1), 1–7. 10.1038/jid.2014.371

Ferretti, T. R., McRae, K., & Hatherell, A. (2001). Integrating Verbs, Situation Schemas, and Thematic Role Concepts. *Journal of Memory and Language*, *44*(4), 516–547. 10.1006/jmla.2000.2728

Gao, S. (1993). 失语症 [Aphasia]. Peking Union Medical College and Peking Union Medical College.

Gao, S. (1996). Clinical diagnosis of aphasia in Chinese. *Stroke and Nervous Diseases*, *3*, 57–59.

Gentner, D. (2006). Why Verbs Are Hard to Learn. In K. Hirsh-Pasek & R. Golinkoff (Eds.), *Action Meets Word: How Children Learn Verbs*. 544–564. Oxford University Press. 10.1093/acprof:oso/9780195170009.003.0022

Gray, T., & Kiran, S. (2013). A theoretical account of lexical and semantic naming deficits in bilingual aphasia. *Journal of Speech, Language, and Hearing Research*, *56*(4), 1314–1327. 10.1044/1092-4388(2012/12-0091)

Gray, T., & Kiran, S. (2016). The relationship between language control and cognitive control in bilingual aphasia. *Bilingualism*, *19*(3), 433–452. 10.1017/S1366728915000061

Helm-Estabrooks, N. (2001). Cognitive linguistic quick test: CLQT. Psychological Corporation.

Hoeffel, E. M., Rastogi, S., Kim, M. O., & Hasan, S. (2012). The asian population: 2010. US Department of Commerce, Economics and Statistics Administration, US Census Bureau.

Howard, D., & Patterson, K. E. (1992). The pyramids and palm trees test.

Huang, C.T.J. (1989). Pro-Drop in Chinese: A Generalized Control Theory. In: Jaeggli, O.A., Safir, K.J. (eds) The Null Subject Parameter. Studies in Natural Language and Linguistic Theory, vol 15. Springer, Dordrecht. 10.1007/978-94-009-2540-3_6

Kambanaros, M. (2007). Action naming versus verb retrieval in connected speech: Evidence from late bilingual Greek–English fluent, anomic aphasic speakers. *Brain and Language*, *103*(1–2), 73–74. 10.1016/j.bandl.2007.07.051

Kambanaros, M. (2010). Investigating grammatical word class distinctions in bilingual aphasic individuals. In G. Ibanescu & S. Pescariu (Ed.), *Aphasia*: *Symptoms, Diagnosis and Treatment* (pp. 1-59). Nova Science Publishers, Inc.

Kambanaros, M., & van Steenbrugge, W. (2006). Noun and verb processing in Greek-English bilingual individuals with anomic aphasia and the effect of instrumentality and verb-noun name relation. *Brain and Language*, *97*(2), 162–177. 10.1016/j.bandl.2005.10.001

Kaplan, E., Goodglass, H., & Weintraub, S. (2001). Boston naming test.

Kastenbaum, J. G., Bedore, L. M., Peña, E. D., Sheng, L., Mavis, I., Sebastian-Vaytadden, R., Rangamani, G., Vallila-Rohter, S., & Kiran, S. (2019). The influence of proficiency and language combination on bilingual lexical access. *Bilingualism: Language and Cognition*, *22*(2), 300–330. 10.1017/S1366728918000366

Kemmerer, D., & Tranel, D. (2000). Verb retrieval in brain-damaged subjects: 1. Analysis of stimulus, lexical, and conceptual factors. *Brain and Language*, *73*(3), 347–392. 10.1006/brln.2000.2311

Kertesz, A. (2007). *Western aphasia battery: Revised*. Pearson.

Kim, M., & Thompson, C. K. (2000). Patterns of comprehension and production of nouns and verbs in agrammatism: implications for lexical organization. *Brain and language*, *74*(1), 1–25. 10.1006/brln.2000.2315

Kiran, S., & Tuchtenhagen, J. (2005). Imageability effects in normal Spanish-English bilingual adults and in aphasia: Evidence from naming to definition and semantic priming tasks. *Aphasiology*, *19*(3–5), 315–327. 10.1080/02687030444000778

Kong, A. P. (2017). Speech-Language Services for Chinese-Speaking People With Aphasia (C-PWA): Considerations for Assessment and Intervention Anthony. *Perspectives of the ASHA Special Interest Groups*, *2*(Part 3), 100–109.

Kremin, H., & De Agostini, M. (1995). Impaired and preserved picture naming in two bilingual patients with brain damage. *Aspects of Bilingual Aphasia. New York: Elsevier*, 101–110.

Kroll & Stewart, 1994. (1994). Category Interference in Translation and Picture Naming. *Journal of Memory and Language*, *33*(2), 149–174.

Kuzmina, E., Goral, M., Norvik, M., & Weekes, B. S. (2019). What Influences Language Impairment in Bilingual Aphasia? A Meta-Analytic Review. *Frontiers in Psychology*, *10*(April), 1–22. 10.3389/fpsyg.2019.00445

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software*, *82*, 1–26. 10.18637/jss.v082.i13

Law, S. P., Kong, A. P. H., Lai, L. W. S., & Lai, C. (2015). Effects of context and word class on lexical retrieval in Chinese speakers with anomic aphasia. *Aphasiology*, *29*(1), 81–100. 10.1080/02687038.2014.951598

Liao M., & Thompson, C. K. (2017). 《中国失语症语言评估量表》的设计原理 [Principles of the design of the Chinese Aphasia Language Assessment Battery]. *Chinese Scientific Journal of Hearing and Speech Rehabilitation*, *15*(5), 336–341

Li, R., Faroqi-Shah, Y., & Wang, M. (2019). A comparison of verb and noun retrieval in Mandarin–English bilinguals with English-speaking monolinguals. *Bilingualism: Language and Cognition*, *22*(5), 1005–1028. 10.1017/S1366728918000913

Linnik, A., Bastiaanse, R., & Höhle, B. (2016). Discourse production in aphasia: a current review of theoretical and methodological challenges. *Aphasiology*, *30*(7), 765–800. 10.1080/02687038.2015.1113489

Liu, Y., Shu, H., & Li, P. (2007). Word naming and psycholinguistic norms: Chinese. *Behavior Research Methods*, *39*(2), 192–198. 10.3758/BF03193147

Lorenzen, B., & Murray, L. L. (2008). Bilingual aphasia: A theoretical and clinical review. *American Journal of Speech-Language Pathology*, *17*(3), 299–317. 10.1044/1058-0360(2008/026)

Luzzatti, C., Raggi, R., Zonca, G., Pistarini, C., Contardi, A., & Pinna, G. D. (2002). Verb-noun double dissociation in aphasic lexical impairments: The role of word frequency and imageability. *Brain and Language*, *81*(1–3), 432–444. 10.1006/brln.2001.2536

MacWhinney, B. (2000). The CHILDES project: Tools for analyzing talk: Volume I: Transcription format and programs, volume II: The database.

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

Mayer, J. F., & Murray, L. L. (2003). Functional measures of naming in aphasia: Word retrieval in confrontation naming versus connected speech. *Aphasiology*, *17*(5), 481–497. 10.1080/02687030344000148

Miceli, G., Silveri, M. C., Villa, G., & Caramazza, A. (1984). On the Basis for the Agrammatic's Difficulty in Producing Main Verbs. *Cortex*, *20*(2), 207–220. 10.1016/S0010-9452(84)800386800386

Miozzo, M., Costa, A., Hernández, M., & Rapp, B. (2010). Lexical processing in the bilingual brain: Evidence from grammatical/morphological deficits. *Aphasiology*, *24*(2), 262–287. 10.1080/02687030902958381

Nadeau, S. E. (2019). Bilingual aphasia: Explanations in population encoding. *Journal of Neurolinguistics*, *49*, 117–143. 10.1016/j.jneuroling.2018.10.002

Nicholas, L. E., & Brookshire, R. H. (1993). A system for quantifying the informativeness and efficiency of the connected speech of adults with aphasia. *Journal of Speech and Hearing Research*, *36*(2), 338–350. 10.1044/jshr.3602.338

Paradis, M. (2001). Bilingual and polyglot aphasia. In R. S. Berndt (Ed.), *Handbook of neuropsychology*, *2nd* ed.: Vol *3 Language and aphasia* (pp. 69-91). Elsevier Science Publishers B. V.

Pashek, G. V., & Tompkins, C. A. (2002). Context and word class influences on lexical retrieval in aphasia. *Aphasiology*, *16*(3), 261–286. 10.1080/02687040143000573

Peñaloza, C., Barrett, K., & Kiran, S. (2019). The influence of prestroke proficiency on poststroke lexical-semantic performance in bilingual aphasia. *Aphasiology*, *34(*10), 1223–1240. 10.1080/02687038.2019.1666082

Peñaloza, C., & Kiran, S. (2019). Recovery and Rehabilitation Patterns in Bilingual and Multilingual Aphasia. In W. J. Schwieter & M. Paradis (Ed.), *The Handbook of the Neuroscience of Multilingualism* (pp. 553-571). 10.1002/9781119387725.ch27

Poncelet, M., Majerus, S., Raman, I., Warginaire, S., & Weekes, B. S. (2007). Naming actions and objects in bilingual aphasia: A multiple case study. *Brain and Language*, *103*(1–2), 158–159. 10.1016/j.bandl.2007.07.078

Rofes, A., Zakariás, L., Ceder, K., Lind, M., Johansson, M. B., de Aguiar, V., Bjekić, J., Fyndanis, V., Gavarró, A., Simonsen, H. G., Sacristán, C. H., Kambanaros, M., Kraljević, J. K., Martínez-Ferreiro, S.,

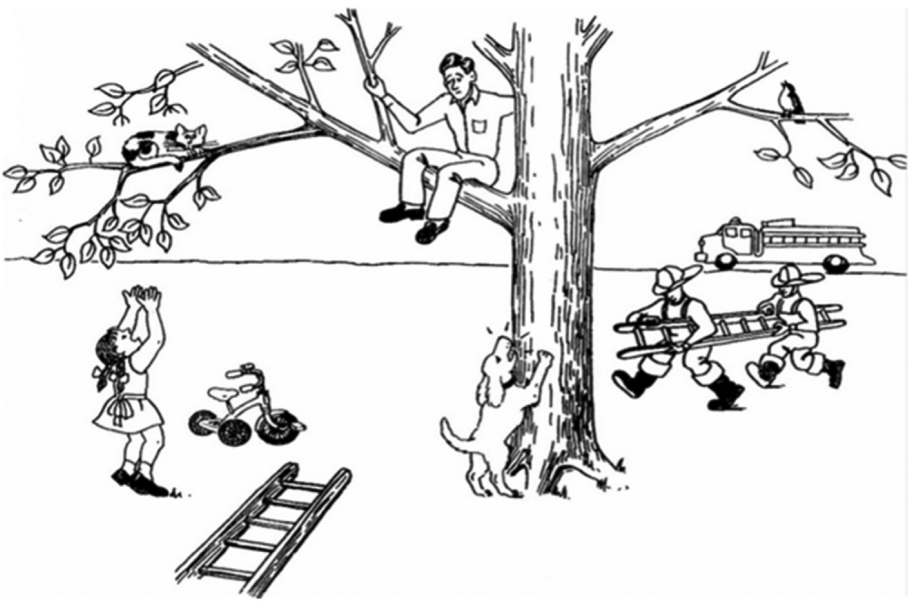
Mavis, İ., Orellana, C. M., Sör, I., Lukács, Á., Tunçer, M., . . . Howard, D. (2018). Imageability ratings across languages. *Behavior Research Methods*, *50*(3), 1187–1197. 10.3758/s13428-017-0936-0
Saffran, E. M., Berndt, R. S., & Schwartz, M. F. (1989). The quantitative analysis of agrammatic production: Procedure and data. *Brain and Language*, *37*(3), 440–479. 10.1016/0093-934X(89)900308900308
Sasanuma, S. (1995). Patterns of language deficits in two korean-japanese bilingual aphasic patients-a clinical report. *Aspects of bilingual aphasia*, 111–122.
Shapiro, K., & Caramazza, A. (2003). The representation of grammatical categories in the brain. *Trends in Cognitive Sciences*, *7*(5), 201–206. 10.1016/S1364-6613(03)000603000603
Stark, B. C., Dutta, M., Murray, L. L., Fromm, D., Bryant, L., Harmon, T. G., Ramage, A. E., & Roberts, A. C. (2021). Spoken discourse assessment and analysis in aphasia: an international survey of current practices. *Journal of Speech, Language, and Hearing Research*, *64*(11), 4366–4389.
Sung, J. E., Dede, G., & Lee, S. E. (2016). Cross-linguistic differences in a picture-description task between Korean- and English-speaking individuals with aphasia. *American Journal of Speech-Language Pathology*, *25*(4S), S813–S822. 10.1044/2016_AJSLP-15-0140
Tardif, T. Z. (1994). *Adult-to-child speech and language acquisition in Mandarin Chinese*. [Doctoral dissertation, Yale University].
Theodoros, D., Hill, A., Russell, T., Ward, E., & Wootton, R. (2008). Assessing acquired language disorders in adults via the Internet. *Telemedicine and E-Health*, *14*(6), 552–559. 10.1089/tmj.2007.0091
Thompson, C. K., Lukic, S., King, M. C., Mesulam, M. M., & Weintraub, S. (2012). Verb and noun deficits in stroke-induced and primary progressive aphasia: The Northwestern Naming Battery. *Aphasiology*, *26*(5), 632–655. 10.1080/02687038.2012.676852
Tsapkini, K., Jarema, G., & Kehayia, E. (2002). Regularity revisited: Evidence from lexical access of verbs and nouns in Greek. *Brain and Language*, *81*(1–3), 103–119. 10.1006/brln.2001.2510
van Dijk, T. A., & Kintsch, W. (1983). *Strategies of Discourse Comprehension*. New York: Academic Press. 10.2307/415483
Van Hell, J. G., & De Groot, A. M. B. (1998). Conceptual representation in bilingual memory: Effects of concreteness and cognate status in word association. *Bilingualism: Language and Cognition*, *1*(3), 193–211. 10.1017/s1366728998000352
Vigliocco, G., Vinson, D. P., Druks, J., Barber, H., & Cappa, S. F. (2011a). Nouns and verbs in the brain: A review of behavioural, electrophysiological, neuropsychological and imaging studies. *Neuroscience and Biobehavioral Reviews*, *35*(3), 407–426. 10.1016/j.neubiorev.2010.04.007
Wang, J., & Chen, B. (2020). A Database of Chinese-English Bilingual Speakers: Ratings of the Age of Acquisition and Familiarity. *Frontiers in Psychology*, *11*(September), 1–12. 10.3389/fpsyg.2020.554785
Wang, H., & Thompson, C. K. (2016). Assessing syntactic deficits in Chinese Broca's aphasia using the Northwestern Assessment of Verbs and Sentences-Chinese (NAVS-C). *Aphasiology*, *30*(7), 815–840. 10.1586/14737175.2015.1028369.Focused
Wilshire, C. E., & McCarthy, R. A. (2002). Evidence for a context-sensitive word retrieval disorder in a case of nonfluent aphasia. *Cognitive Neuropsychology*, *19*(2), 165–186. 10.1080/02643290143000169
Xu, X., Li, J., & Guo, S. (2021). Age of acquisition ratings for 19,716 simplified Chinese words. *Behavior Research Methods*, *53*(2), 558–573. 10.3758/s13428-020-01455-8
Zingeser, L. B., & Berndt, R. S. (1990). Retrieval of nouns and verbs in agrammatism and anomia. *Brain and Language*, *39*(1), 14–32. 10.1016/0093-934X(90)90002X90002X

Appendix

Appendix A. Picture stimuli for the discourse tasks. (a) *Umbrella* (sequential-picture), (b) *Cat Rescue* (single-picture).

(a)

(b)



Appendix B. Verb and noun naming stimuli in English and Mandarin with psycholinguistic values

Item	Language	Source	Category	Freq	Fam	Image
abacus	C	BNT	Noun	0.95		
accordion	C	BNT	Noun	0.83	3.794	6.273
broom	C	BNT	Noun	1.25	5.515	6.455
cactus	C	BNT	Noun	2.68	4.324	6.771
camel	C	BNT	Noun	6.86	4.793	6.633
compass	C	BNT	Noun	0.15	4.968	6.324
dart	C	BNT	Noun	4.11	4.96	5.97
escalator	C	BNT	Noun	0.72		
flower	C	BNT	Noun	266.7	6.6	6.788
funnel	C	BNT	Noun	0.86		
hanger	C	BNT	Noun	22.76		
harmonica	C	BNT	Noun	1.31	4.794	6.647
harp	C	BNT	Noun	1.34	4.603	6.613
igloo	C	BNT	Noun		3.844	6.548
mushroom	C	BNT	Noun	6.68	6.063	6.849
pencil	C	BNT	Noun	7.27	6.231	6.92
protractor	C	BNT	Noun	0.06		
pyramid	C	BNT	Noun	3.96	5.875	6.879
racquet	C	BNT	Noun	0.98	4.8	5.22
rhinoceros	C	BNT	Noun	2.71	5.061	6.818
saw	C	BNT	Noun	1.37	5.52	5.31
scissors	C	BNT	Noun	11.6	5.909	6.543
seahorse	C	BNT	Noun	0.8	5.265	6.686
snail	C	BNT	Noun	1.58	5.125	6.815
stethoscope	C	BNT	Noun	0.45	4.4	6.321
tongs	C	BNT	Noun	2.33		
tree	C	BNT	Noun	64.09	6.5	6.69
trellis	C	BNT	Noun	0.09	2.546	5.087
tripod	C	BNT	Noun	0.72	4.303	6.177
wheelchair	C	BNT	Noun	11.3		
bear	C	NNB	Noun	43.82	5.61	6.57
belt	C	NNB	Noun	8.38	6.19	6.34
camel	C	NNB	Noun	6.86	4.79	6.63
dress	C	NNB	Noun	34.67	6.71	6.73
elephant	C	NNB	Noun	12.4	5.9	6.86
frog	C	NNB	Noun	10.11	5.43	6.89
glove	C	NNB	Noun	20.15	6.19	6.68
hat	C	NNB	Noun	46.29	6.25	6.79
pants	C	NNB	Noun	55.77	5.75	6.3
rabbit	C	NNB	Noun	23.76	6.29	6.79
shirt	C	NNB	Noun	25.28	6.44	6.69
shoe	C	NNB	Noun	69.52	6.49	6.79
snake	C	NNB	Noun	30.49	5.65	6.66
sock	C	NNB	Noun	15.65	6.16	6.65
squirrel	C	NNB	Noun	7.18	5.52	6.68
tiger	C	NNB	Noun	10.97	6.21	6.73
abacus	E	BNT	Noun	0.24		
accordion	E	BNT	Noun	1.31	3.794	6.273
broom	E	BNT	Noun	4.76	5.515	6.455
cactus	E	BNT	Noun	2.9	4.324	6.771
camel	E	BNT	Noun	5.02	4.793	6.633
compass	E	BNT	Noun	4.06	4.968	6.324
dart	E	BNT	Noun	1.92	4.96	5.97
escalator	E	BNT	Noun	1.29		
flower	E	BNT	Noun	22.76	6.6	6.788
funnel	E	BNT	Noun	1.1		
hanger	E	BNT	Noun	1.35		
harmonica	E	BNT	Noun	1.75	4.794	6.647

(*Continued*)

Item	Language	Source	Category	Freq	Fam	Image
harp	E	BNT	Noun	2.63	4.603	6.613
igloo	E	BNT	Noun	0.29	3.844	6.548
mushroom	E	BNT	Noun	2.14	6.063	6.849
pencil	E	BNT	Noun	9.86	6.231	6.92
protractor	E	BNT	Noun	0.06		
pyramid	E	BNT	Noun	4	5.875	6.879
racquet	E	BNT	Noun	0.33	4.8	5.22
rhinoceros	E	BNT	Noun	0.75	5.061	6.818
saw	E	BNT	Noun	6.92	5.52	5.31
scissors	E	BNT	Noun	6.69	5.909	6.543
seahorse	E	BNT	Noun	0.14	5.265	6.686
snail	E	BNT	Noun	1.76	5.125	6.815
stethoscope	E	BNT	Noun	0.94	4.4	6.321
tongs	E	BNT	Noun	0.78		
tree	E	BNT	Noun	65	6.5	6.69
trellis	E	BNT	Noun	0.27	2.546	5.087
tripod	E	BNT	Noun	0.9	4.303	6.177
wheelchair	E	BNT	Noun	6.2		
apple	E	NNB	Noun	23.67	6.72	6.91
belt	E	NNB	Noun	24.35	6.19	6.34
broom	E	NNB	Noun	4.76	5.52	6.46
cat	E	NNB	Noun	66.33	6.38	6.77
corn	E	NNB	Noun	14.22	5.29	6.29
elephant	E	NNB	Noun	11.37	5.9	6.86
glove	E	NNB	Noun	10.1	6.19	6.68
hammer	E	NNB	Noun	12.47	5.47	6.63
mouse	E	NNB	Noun	19.12	6.06	6.69
onion	E	NNB	Noun	4.24	6.71	6.64
pepper	E	NNB	Noun	8.8	6.46	6.68
scissors	E	NNB	Noun	6.69	5.91	6.54
snake	E	NNB	Noun	22.35	5.65	6.66
sock	E	NNB	Noun	8.98	6.16	6.65
suit	E	NNB	Noun	68.61	5.7	6.24
tie	E	NNB	Noun	44.43	6.23	6.68
gift	C	VNT	Verb	2.86	6.3	5.58
give	C	VNT	Verb	3494.19	6.57	3.65
sell	C	VNT	Verb	222.82	6.15	4.26
squat	C	VNT	Verb	25.76	5.76	5.65
teach	C	VNT	Verb	152.83	6.14	3.55
arrest	C	NNB	Verb	62.72	5.58	5.4
award	C	NNB	Verb	20.45	5.91	5.65
cut	C	NNB	Verb	30.82	6.13	6.13
drunk	C	NNB	Verb	75.24	6.58	5.86
fall	C	NNB	Verb	41.2	5.79	5.03
feed	C	NNB	Verb	336.43		
inquire	C	NNB	Verb	18.63		
kick	C	NNB	Verb	67.55	6.29	5.83
kneel	C	NNB	Verb	9.78	5.71	5.74
praise	C	NNB	Verb	3.82	5.76	4.11
ride	C	NNB	Verb	42.42	5.61	5.42
shower	C	NNB	Verb	28.26		
sleep	C	NNB	Verb	119.21	6.84	5.94
spray	C	NNB	Verb	7.33	5.58	5.29
swim	C	NNB	Verb	26.59	6.41	6.41
visit	C	NNB	Verb	4.98	5.81	3.85
bark	E	NNB	Verb	5.49	5.47	5.09
climb	E	NNB	Verb	19.75	5.82	5.41
crawl	E	NNB	Verb	12.04	5.52	5.5
cry	E	NNB	Verb	65.65	6.44	5.88
jump	E	NNB	Verb	69.82	5.51	5.06
pour	E	NNB	Verb	15.12	5.45	4.95
pray	E	NNB	Verb	36.22	4.73	5.17

(*Continued*)

Item	Language	Source	Category	Freq	Fam	Image
pull	E	NNB	Verb	146.45	5.97	4.42
read	E	NNB	Verb	241.22	6.57	5.88
spill	E	NNB	Verb	8.47		
stir	E	NNB	Verb	5.9	5.88	5.44
sweep	E	NNB	Verb	9.51	5.06	5.52
swim	E	NNB	Verb	31.8	6.41	6.41
throw	E	NNB	Verb	128.82	6	5.09
write	E	NNB	Verb	126.8	6.53	5
zip	E	NNB	Verb	7.63		
bite	E	VNT	Verb	40.78	5.93	5.53
cut	E	VNT	Verb	229.76	6.13	6.13
deliver	E	VNT	Verb	28.35	5.29	3.88
drive	E	VNT	Verb	153.14	6.1	5.25
give	E	VNT	Verb	1167.82	6.57	3.65
howl	E	VNT	Verb	2.06	4.47	5.36
laugh	E	VNT	Verb	62.86	6.65	5.62
pinch	E	VNT	Verb	6.12	5.75	5.56
put	E	VNT	Verb	828.45	5.39	2.63
send	E	VNT	Verb	179.78	6.47	3.61
shave	E	VNT	Verb	13.76	6.06	5.54
shove	E	VNT	Verb	13.22		
tickle	E	VNT	Verb	4.8	6.23	5.09
wash	E	VNT	Verb	40.73		
watch	E	VNT	Verb	330.02	6.42	6.19

Note: C: Mandarin Chinese, E: English. BNT: Boston Naming Test, NNB: Northwestern Naming Battery, VNT: Verb Naming Test. Freq: frequency (word/million), Fam: familiarity (7-pt scale, lower point = less familiar), Image: imageability (7-pt scale, lower point = less imageable). Familiarity and imageability ratings in English were used as approximate measures for Mandarin. Blank cells represent NA (not available) values.

Appendix C: Verbal instructions for naming tasks

Boston Naming Test: "Tell me the name of each of these pictures" or "告诉我每一幅图片的名称".

Northwestern Naming Battery and Verb Naming Test of the Northwestern Assessment of Verbs and Sentences: "Tell me the name of each object/action" or "告诉我每一个物体或者动作的名称".

Appendix D: Verbal instructions for discourse tasks

Umbrella: "Here are some more pictures that tell a story. Take a look at all of them, and then I'll ask you to tell me the story with a beginning, a middle, and an end. Again, you

can look at the pictures as you tell the story."

"这里额外有一些可以叙述成一个故事的图片。看一下全部图片, 然后我会请你告诉我一个包含开头, 过程, 以及结尾的故事。同样的, 您可以边看图片边说故事。"

Cues: "Take a look at this picture (point to first picture) and tell me what you think is happening." If needed, point to each picture sequentially, giving the prompt: "And what happens here?"

"看一下这张图片(point to first picture) 然后告诉我您觉得发生了什么。"If needed, point to each picture sequentially, giving the prompt: "然后这里发生了什么?"

For each panel, if no response, provide the prompt (P):

"Can you tell me anything about this picture?"

"您能否告诉我关于这张图片上的任何东西?"

Cat Rescue: "Here is another picture. Look at everything that's happening and then tell me a story about what you see. Tell me the story with a beginning, a middle, and an end."

"这里有另一张图片。看一下上面所有发生的事情, 然后告诉我一个关于您看见的故事。这个故事要包含开头, 过程, 以及结尾。"

If no response in 10 seconds, give second prompt (P):

"Take a look (point to picture) and tell me any part of the story."

"看一下 (point to picture) 然后请告诉我任何关于这个故事的一部分"

*The Tortoise and the Hare: "*Do you remember much about it? These pictures might remind you of how it goes. Look at the pictures and then I'll put the pictures away and ask you to tell me the story in your own words."

"您还记得这个故事吗?这些图片可以提醒您故事是怎么发生的。看一下这些图片, 然后我会把图片拿开, 并且请您用自己的话告诉我这个故事。"

Appendix E: Additional regression results of noun and verb naming

	Estimate	SE	Z-value	p-value
Model 2: Accuracy ~ word class * lang + AQ + *fam* + (1|item) + (1|subj)				
class (noun)	0.569	0.153	3.716	2.03e-4**
lang (L1)	0.191	0.108	1.762	0.078
class*lang	0.187	0.107	1.740	0.082
fam	1.467	0.204	7.178	7.06e-13**
AQ	0.116	0.009	13.309	< 2e-16**
Model 3: Accuracy ~ word class * lang + AQ + *image* + (1|item) + (1|subj)				
class (noun)	-0.111	0.268	-0.416	0.677
lang (L1)	0.231	0.121	1.912	0.056
class*lang	0.172	0.120	1.442	0.149
image	0.577	0.284	2.031	0.042*
AQ	0.116	0.009	13.396	< 2e-16**

Note: additional regression results examining noun and verb naming in Mandarin-English BWA. Familiarity and imageability were significant predictors of the overall naming accuracy; A significant main effect of word class was found after controlling for familiarity but not after controlling for imageability; No significant language*class interaction; lang: language, L1: Mandarin, fam: familiarity, image: imageability, subj: subject, SE: standard error, AQ: Aphasia Quotient; p-value: ** = $p < 0.01$, * = $p < 0.05$.