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Cognate picture naming in bilingual aphasia

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ABSTRACT

Cognate vs. non-cognate words have been utilised to understand the impact of shared structures in bilinguals' lexical organisation and processing. Despite clinical and theoretical importance of understanding the influence of shared structures, there remains limited research in bilingual aphasia. We investigated cognate effects in bilingual aphasia; determined if these effects are modulated by bilingualism profiles and executive control abilities. Picture naming data for cognates vs. non-cognate words were collected from seven Bengali-English bilinguals with aphasia (BWA) and matched controls in both languages, along with executive control measures. At the group level, BWA showed significant cognate facilitation in the non-dominant language. Individual level analyses revealed cognate facilitation in only two of the seven BWA. Specifically, BWA with relatively preserved executive control abilities did not show cognate facilitation. The findings highlight that cognate facilitation is not universal and can be influenced by individual differences in language dominance and executive control abilities.

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Cognate; naming; executive control; bilingual; Bengali; aphasia

Introduction

A quick literature search in PubMed for the last five years (from 2019 to 2024) with words 'aphasia' and 'bilingual aphasia' appearing in the title/abstract generated 4,056 and 33 published studies in English, respectively. Despite the large number of published studies on aphasia, the number of studies reporting bilingual aphasia remains limited. This limitation is even more pronounced when considering bilingualism beyond European languages. Recent reviews have put forward persuasive arguments to improve the linguistic diversity in research of neurological conditions (see Beveridge & Bak, 2011 for aphasia; García et al., 2023 for neurodegenerative conditions). In this research, we studied under-explored bilingual populations – specifically, speakers of South Asian languages (e.g. Bengali-English bilinguals) – to determine whether shared linguistic structures between languages (i.e. cognates) facilitate language production, and which participant-related factors (e.g. language dominance, executive control abilities) might modulate such facilitatory effects.

Research on the processing of shared linguistic structures has provided us with important insights into bilingual language processing and its organisation (Costa et al., 2000). At

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the lexical level, researchers have used cognate versus non-cognate words to understand the impact of shared structures in bilinguals. Cognates are words that have the same meaning and a similar phonological form in both languages (e.g. English-Bengali cognate pair: *doctor* in English, /*dakt̪ar*/ in Bengali); non-cognate words have the same meaning in both languages but different forms (e.g. English-Bengali non-cognate pair: *lip* in English, /*ʈʰoʈ*/ in Bengali).

Cognate effects in neurologically unimpaired bilingual population have been extensively studied using a range of tasks, including simple picture naming (Costa et al., 2000; Hoshino & Kroll, 2008), picture naming with language switching (Broersma et al., 2016), reading aloud (Filippi et al., 2014; Linck et al., 2008), lexical decision (Dijkstra et al., 1999; Van Hell & Dijkstra, 2002), repetition priming (Gollan et al., 2007), translation (Kroll & Stewart, 1994), and word association (Van Hell & De Groot, 1998; Van Hell & Dijkstra, 2002). The majority of studies have shown cognate facilitation – cognates are processed and produced faster and more accurately than non-cognates – in neurologically unimpaired bilingual populations (Costa et al., 2000; Dijkstra et al., 2010; Hoshino & Kroll, 2008). However, opposing findings also have been reported, particularly in tasks with higher cognitive demands, ranging from no effect to cognate interference or inhibition, that is, cognates being processed and produced more slowly and less accurately than non-cognates (Broersma et al., 2016; Filippi et al., 2014; Li & Gollan, 2018). These opposing findings are not surprising as *cognate effects*, that is, differences in performance (accuracy or reaction time, or both) between cognate and non-cognate words, have been shown to be mediated by individuals' executive control abilities (Linck et al., 2008), relative proficiency and dominance across their languages (Gollan et al., 2007), and task demands (Broersma et al., 2016; Costa et al., 2000; Filippi et al., 2014).

Establishing the interaction amongst shared linguistic structures, bilingualism profiles (e.g. language dominance), and executive control abilities in bilingual aphasia is essential, as the benefits of shared structures are not universal. This line of work provides crucial clinical knowledge for assessment and management of language impairment, as well as data to test theoretical assumptions regarding bilingual lexical organisation. Despite these important implications, there remains limited research about cognates versus non-cognates in bilingual aphasia, with existing research mostly consisting of case studies from Germanic and/or Romance language combinations, and lacking detailed characterisation of participants' bilingualism profiles and executive control abilities. In the present study, we examine the cognate effects using a picture naming task in a group of Bengali-English bilinguals with aphasia and matched controls, and investigate if the effects are modulated by language dominance and executive control abilities. In addition to extending our understanding of bilingual aphasia, reporting data from Bengali speakers with aphasia increases the diversity of published aphasia research, which still predominantly presents data from English and European languages (Beveridge & Bak, 2011).

Theoretical explanation of cognate facilitation effects in neurologically unimpaired bilingual population

Depending on the researcher's perspectives, cognate facilitation effects have been explained using various theoretical models, such as cascaded activation models of lexical selection (Costa et al., 2000), the weaker links hypothesis (Gollan et al., 2005), the inhibitory control model (Green, 1998), and response conflict theories (Acheson et al., 2012). For example, based on the cascaded activation models of lexical selection, cognate facilitation in picture naming can be explained as follows. When a Bengali-English bilingual speaker is required to name a picture in English, there is *some* activation of the phonological properties of the translation equivalent word in Bengali and *strong* activation of the phonological properties of the target word in English. Therefore, cognate words, which share phonological features between the languages, receive activation from both languages, resulting in a higher activation at the phonological level compared to non-cognates, which do not share their phonological form. Accordingly, the locus of cognate facilitation has been attributed at the phonological level (Costa et al., 2000). Cognate facilitation can also be explained by the weaker links hypothesis, which proposes that cognates receive greater activation compared to non-cognates because cognates are used more frequently (due to their form being similar in both languages) and have higher levels of recency (Gollan et al., 2005).

Factors modulating cognate effects in neurologically unimpaired bilingual population

As mentioned earlier, cognate effects can be modulated by various factors, such as individual differences in executive control abilities and bilingualism profiles (e.g. relative proficiency and dominance across languages). In this section, we briefly discuss the influence of each of these factors.

Role of executive control

Executive control (also known as cognitive control) refers to the capacity to manage and adjust one's behaviour based on the demands of the current situation and personal objectives. According to Miyake et al. (2000), executive control consists of three components, namely inhibitory control (the ability to suppress automatic, dominant, or prepotent responses when needed), mental set-shifting (the ability to switch between different tasks), and working memory (the ability to update and manipulate task-relevant information). Previous studies involving neurologically unimpaired bilingual populations have suggested a relationship between cognate effects and individual differences in executive control abilities. For example, Linck et al. (2008) tested two groups of bilingual adults on a picture naming task in their L2 (English) involving cognate and non-cognate words. The participants' executive control abilities were measured by employing working memory (operation span) and inhibitory control (Simon task) tasks. Results revealed that bilinguals with better inhibitory control abilities showed a lesser cognate facilitation effect. No such relationship was observed between working memory and the cognate facilitation effect. The authors suggested that individuals with stronger inhibitory control can better suppress the interference from the non-target language during L2 picture naming, resulting in smaller cognate facilitation effects. Linck et al'.s findings align with Green's (1998) inhibitory control model, which suggests that bilingual individuals suppress the non-target language to facilitate language production in the target language, and that this suppression can be more demanding when both languages are strongly activated (as is the case with cognates). To benefit from cognates, this cross-linguistic activation must be allowed. However, individuals with stronger inhibitory control may suppress the non-target language more effectively, resulting in reduced cognate facilitation (Green, 1998).

Role of bilingual language profile (language proficiency and dominance)

In addition to executive control, studies have shown that cognate facilitation is modulated by various bilingualism factors, including language proficiency (Andras et al., 2022; Ito et al., 2025) and dominance (Costa et al., 2000; Gollan et al., 2007). Language proficiency is defined as the degree of competence a bilingual individual possesses in effectively communicating across various domains, such as speaking, listening, reading, and writing. Studies have found cognate facilitation to depend on L2 proficiency (see Van Hell & Tanner, 2012 for a review). For example, only low proficiency bilinguals (but not high proficiency bilinguals) showed a cognate facilitation effect when asked to listen to either a cognate or a non-cognate noun and select the corresponding picture as quickly as possible (Andras et al., 2022). Similarly, Ito et al. (2025) did not observe any cognate facilitation effect in more proficient L2 speakers. In another study, Libben and Titone (2009) found an inverse relationship between the cognate facilitation effect and L2 proficiency, that is, the cognate facilitation effect decreases as L2 proficiency increases. The reduced/no cognate facilitation effect in more proficient L2 speakers can be explained by the Revised Hierarchical Model (Kroll & Stewart, 1994), which posits that the connection between L1 and L2 weakens as L2 proficiency increases. As a result, the ability to benefit from cross-linguistic activation – a key mechanism underlying the cognate facilitation effect – diminishes.

Language dominance is defined as the relative ease or efficiency with which each of a bilingual's languages is accessed and utilised during language processing. In a recent editorial, Hamann et al. (2019) proposed that language dominance should be conceptualised as a multidimensional construct, shaped by factors such as language proficiency, frequency of language use, and environmental exposure.

Costa et al. (2000) suggested that the links between the semantic system and the lexical nodes are stronger for a word in the dominant language compared to a word in the non-dominant language, resulting in higher activation of the lexical node in the dominant language. Therefore, when naming a cognate word in the non-dominant language, the greater activation from the translation-equivalent word in the dominant language provides a boost for the shared target phonological units, resulting in greater cognate facilitation in the non-dominant language. However, when an individual names a cognate word in the dominant language, the translation-equivalent word in the non-dominant language provides a relatively smaller boost (compared to the previous case) for the shared target phonological units, due to weaker links between the semantic system and the lexical nodes in the non-dominant language. This results in weaker cognate facilitation in the dominant language. For example, in a picture naming task, Costa et al. (2000) observed a cognate facilitation effect in both languages, but the magnitude was greater in the non-dominant language compared to the dominant language. In another picture naming study, Gollan et al. (2007) observed similar cognate facilitation in both languages for balanced bilinguals, but only in the non-dominant language for unbalanced bilinguals. The authors classified balanced vs. unbalanced bilinguals based on the performance in the Boston Naming Test. Therefore, while cognate facilitation is typically stronger in the non-dominant language, it may also be present in the dominant language (Costa et al., 2000; Gollan et al., 2007).

Previous studies have shown that bilinguals are good at self-reporting their dominant language, but are relatively less reliable when it comes to evaluating the extent of difference in proficiency between their two languages (Gollan et al., 2012). Further, as discussed earlier, dominance is a composite measure that accounts for language proficiency along with other bilingualism variables (Hamann et al., 2019). Therefore, for the present study, language dominance (rather than language proficiency) is treated as the primary variable for examining the relationship between cognate effects and bilingual language profile.

To conclude, a robust investigation of cognate effects in bilinguals should examine the interaction among various factors, such as language dominance and executive control abilities of individuals, when interpreting cognate effects.

Cognates effects in bilingual aphasia

Despite progress in understanding cognate effects and the factors that can modulate these in neurologically unimpaired speakers, there remain only a handful of studies that have investigated cognate effects in bilingual aphasia. Supplementary File 1 (see Supporting Information section) provides a summary of the studies that have experimentally[1] investigated cognate processing or production in stroke-induced bilingual aphasia either in an assessment or therapy context. There are 14 studies with results remaining equivocal and ranging from facilitation in specific conditions (Detry et al., 2005; Ferrand & Humphreys, 1996; Kohnert, 2004; Lalor & Kirsner, 2001; Marte et al., 2023; Roberts & Deslauriers, 1999; Siyambalapitiya et al., 2013; Van der Linden, Dricot, et al., 2018; Van der Linden, Verreyt, et al., 2018) to no effect (Grasso et al., 2019; Hameau & Köpke, 2015; Kendall et al., 2015; Lalor & Kirsner, 2001; Van der Linden, Dricot, et al., 2018; Verreyt et al., 2013) or interference (Kurland & Falcon, 2011; Siyambalapitiya et al., 2013; Verreyt et al., 2013). More specifically, only five out of these 14 studies have investigated cognate effects in aphasia using a picture naming paradigm. Out of these five studies, three found cognate facilitation (Kohnert, 2004; Marte et al., 2023; Roberts & Deslauriers, 1999), one found cognate interference (Kurland & Falcon, 2011), and one reported no cognate effect (Hameau & Köpke, 2015).

There is some evidence in the bilingual aphasia literature suggesting a role for executive control deficits in cognate effects. Van der Linden, Verreyt, et al. (2018) tested seven bilingual patients with differential aphasia, eight with parallel aphasia, and 19 matched controls on a lexical decision task to examine the cognate effect in these groups. Additionally, executive control was assessed using a non-linguistic flanker task. The authors observed cognate facilitation for all three groups, with larger cognate facilitation for the differential aphasia group compared to the parallel aphasia group and controls. On the flanker task, the differential group made more errors on the incongruent trials compared to the congruent trials. Greater cognate facilitation effects and poorer performance on the executive control task were attributed to a control deficit in bilinguals with differential aphasia. The results from this study concur with the findings of Linck et al. (2008), where better executive control abilities were associated with smaller cognate facilitation effects in the neurologically unimpaired bilingual population. However, it was not clear from Van der

[1]We have only included bilingual post-stroke aphasia studies that have used cognate status variation as an experimental manipulation.

Linden, Verreyt et al'.s study whether the magnitude of cognate facilitation effects was modulated by differences in executive control abilities, as the authors did not correlate the findings from the executive control measures with the magnitude of cognate facilitation effects. Additionally, the authors did not account for language dominance, used non-equivalent test batteries across languages, and included aphasia participants who were in their acute stage of recovery (i.e. 2–4 weeks post-stroke). The present study directly addresses these key limitations of previous research by employing equivalent test batteries across both languages, systematically accounting for language dominance, and excluding participants in the acute recovery stage. Additionally, by incorporating a comprehensive set of executive control measures, we aim to more precisely investigate how cognate effects interact with bilingual profiles and executive control abilities.

To summarise, the research that has experimentally examined cognate effects in bilingual aphasia has reported mixed results. Moreover, these studies have involved participants with Germanic and/or Romance languages (e.g. Spanish-English, French-English, Dutch-English, Italian-English, German-French) and most of these studies were single case reports. Critically, several of these studies did not include an extensive measure of language background or measures of executive control, which have been shown to be important determinants in teasing out the specifics of cognate effects in bilingual word production.

The current study

The present study addresses the above-mentioned outstanding methodological issues in the research on cognate effects in bilingual aphasia by including a range of measures to characterise participants' bilingualism, executive control abilities and studying an under-explored language. We compared differences in performance in picture naming accuracy between cognates and non-cognate words in seven Bengali-English bilinguals with non-fluent aphasia (BWA) and eight age-, gender-, education-matched neurologically unimpaired bilinguals. For brevity, we will use the term bilingual controls (BC) to refer to neurologically unimpaired bilingual participants from here on. Each participant was characterised in detail using relevant bilingualism variables, such as language history and acquisition patterns, usage patterns, proficiency, and dominance (pre-stroke for the BWA group). To explore the relationship between language dominance and cognate effects, we used the language dominance score (obtained from the language dominance questionnaire, Dunn & Tree, 2009) to identify the dominant and non-dominant language.

In addition, each participant was tested on three extensively tested measures of executive control (Miyake et al., 2000): Stroop test (measuring selective inhibition), Trail Making Test (TMT, measuring shifting between mental sets) and backward digit span test (measuring working memory) to explore the relationship between executive control and cognate effects. The choice of these tasks was primarily determined by the feasibility of using them with the neurologically impaired population and the availability of existing literature on these tasks for comparisons (Bose et al., 2022; Patra et al., 2020a). Finally, to capture the heterogeneity of aphasia performance, we implemented individual as well as group level analyses.

This study fills an important research gap in bilingual aphasia and extends the diversity of the literature, especially by including an under-researched population, Bengali-English speakers (Lahiri et al., 2020). Bengali (also known as Bangla) belongs to the Indo-Iranian branch of the Indo-European group of languages. Bengali is the seventh most spoken language in the world and has over 242 million speakers globally. It is the national language of Bangladesh (first language of 142 million speakers, 98.8% of the total population, Bangladesh Census, 2011), the official language of three states of India, West Bengal, Tripura, and Assam (first language of 97 million speakers, 8.3% of the total population, India Census, 2011); and it is the 8th most spoken language in the UK (main language of 199,000 speakers, UK Census, 2021).

The research aims and predictions were as follows:

1. To determine cognate effects in picture naming accuracy and whether these effects were modulated by language dominance.
   We expect cognate facilitation effects in both groups (BWA and BC) based on previous literature on simple picture naming (Costa et al., 2000; Roberts & Deslauriers, 1999). In terms of language dominance, we expect the magnitude of cognate facilitation to be greater in the non-dominant language in both BWA (Roberts & Deslauriers, 1999) and BC groups (Costa et al., 2000; Gollan et al., 2007).
2. To determine the relationship between executive control abilities and the magnitude of cognate effects.
   Based on the inhibitory control model (Green, 1998), we expect a relationship between cognate effects and executive control abilities. Specifically, we expect individuals with better inhibitory control abilities to show less cognate facilitation, and this relationship to be true in both groups (Linck et al., 2008; Van der Linden, Dricot, et al., 2018). We do not make any differential prediction for this relationship in terms of language dominance.

Methods

Participants

Participants were seven Bengali-English bilinguals with aphasia (BWA) and eight Bengali-English bilingual controls (BC). The groups were matched on age (BWA, $M = 47.43$ years, SD = 12.88; BC, $M = 43.13$ years, $SD = 15.30$; $t(13) = 0.58$, $p = 0.57$), gender distribution (BWA: 5 male, 2 female; BC: 6 male, 2 female; $\chi^2(1) = 0.02$, $p = 0.88$), and years of education (BWA, $M = 16.57$ years, SD = 2.51; BC, $M = 16.88$ years, $SD = 1.88$, $t(13) = -0.27$, $p = 0.79$). These participants were part of a larger research program on bilingualism and language production in aphasia (Patra et al., 2020a). All participants provided informed consent under a protocol approved by the Institutional Research Ethics Committee (Ethical approval code: 2014/060/AB). They were recruited via contacts with certified speech and language therapists from Kolkata, India.

Inclusion criteria for BWA were: a single left hemisphere cerebrovascular accident (CVA) as determined by medical and neurological reports; a diagnosis of post-stroke aphasia at least 6 months post-stroke on standardised clinical tests (WAB-R in English, Kertesz, 2007 and its adapted version in Bengali; Keshree et al., 2013); absence of other neurological conditions, neuropsychiatric disorders or substance abuse; no visual field, sensory perceptual (e.g. colour vision), or cognitive deficits.

The demographic and neurological characteristics of the BWA group are reported in Table 1. In addition to WAB-R, all BWA participants completed a test battery (Croft et al., 2011) in both languages for picture naming, spoken word-to-picture matching, word

Table 1. Demographic profile, dominance profile, aphasia type and severity, and test scores in the Croft's naming subtest of each bilingual with aphasia (BWA).

Variables	BWA1	BWA2	BWA4	BWA5	BWA6	BWA7	BWA8
Age/Gender	50/M	58/F	54/M	35/F	35/M	34/M	66/M
Highest degree	Postgraduate	High school	Graduate	Postgraduate	Graduate	Graduate	Graduate
Time post onset (months)	17	58	12	27	40	22	27
Bilingual language dominance profile (pre-stroke)[a]							
Dominant	Bengali	Bengali	Bengali	Bengali	Balanced	English	Bengali
Non-dominant	English	English	English	English		Bengali	English
Aphasia type[b]							
Bengali	Broca's	Broca's	TMA[c]	Broca's	NAT[d]	Broca's	Broca's
English	Broca's	NAT[d]	TMA[c]	Broca's	Broca's	Broca's	NAT[4]
Severity[b]							
Bengali	Moderate	Moderate	Mild	Mild	NAT[d]	Mild	Moderate
English	Moderate	NAT[d]	Mild	Moderate	Severe	Mild	NAT[d]
AQ[e]							
Bengali	68.6	75	83.6	76.8	NAT[d]	77.2	68.6
English	64.4	NAT[d]	79.8	74.2	48	76.4	NAT[d]
Croft's naming test (% accuracy)							
Bengali	93.3	76.7	96.7	96.7	33.3	96.7	73.3
English	73.3	6.7	96.7	80	76.7	96.7	50

BWA: Mean $_{Bengali}$ = 77.1% (SD = 24.1); Mean $_{English}$ = 70.9% (SD = 29.9)
Bilingual Controls: Mean $_{Bengali}$ = 100%, Mean $_{English}$ = 100%

[a]Dominance profile was based on the language dominance questionnaire (Dunn & Tree, 2009). [b]Type and severity of aphasia were classified based on WAB-R (Kertesz, 2007) in English and the adapted version in Bengali (Keshree et al., 2013); [c]Transcortical Motor Aphasia; [d]Not Available for Testing; [e]Aphasia Quotient (AQ) was calculated by using the following formula {AQ = (SS score + AVC score + Repetition score + Naming score) ×2}, AQ ratings = Mild (76 and above), Moderate (51 – 75), Severe (26 – 50), Very severe (0 – 25).

repetition, and reading aloud (see Patra et al., 2020a for further description). Results from WAB-R and Croft et al'.s naming subtest are summarised below. BWA participants showed characteristics of mild to moderate non-fluent aphasia: slow effortful speech, limited prosody and suprasegmentals, short or fragmentary utterances, simplified syntax, relatively good auditory comprehension in both languages (except for BWA6, who was unavailable for testing in Bengali and demonstrated severe aphasia in English). In Croft et al'.s picture naming task, BWA1, BWA2, BWA5 and BWA8 performed better in their dominant language, with the exception of BWA6, who was a balanced bilingual but performed better in English than Bengali. Despite Bengali dominance, BWA4 showed comparable performance in both languages. Similarly, BWA7, although English-dominant, demonstrated equivalent performance in both languages.

Bilingualism measures

We assessed the bilingualism profile of all participants by administering a set of subjective language background questionnaires, with support from their caregiver or family members as needed. A modified version of Muñoz et al. (1999) questionnaire was administered to measure language acquisition history, instruction of language during education, self-rated language proficiency, and language usage patterns. The language dominance questionnaire (Dunn & Tree, 2009) was used to measure language dominance (pre-stroke for BWA) in both groups. Adapted versions of all these questionnaires are available for interested readers in Patra et al. (2020b). Language proficiency and usage questionnaires were administered twice to BWA participants to assess their pre- and post-stroke language abilities. Results of the bilingualism measures are presented in Supplementary File 2 in the Supporting Information section. All participants reported to acquire Bengali before English (age of language acquisition for English is 5 years or more) and had English as the language of instruction during higher education. On the language dominance questionnaire, prior to stroke, all BWA had Bengali as their dominant language except BWA6 and BWA7. BWA6 had equal level of dominance in both languages, whereas BWA7 was English dominant. In the BC group, all were Bengali dominant except BC1 and BC4, who were English dominant. We used this language dominance classification (Dunn & Tree, 2009) for all our analyses in the present study.

Executive control measures

Inhibitory control (Stroop test)

All participants took part in a computerised verbal Stroop test which was adapted from Scott and Wilshire (2010). Previous studies have shown this test to successfully measure inhibitory control in different populations (Patra et al., 2020a, 2020b; Bose et al., 2022). The test consisted of an incongruent condition and a neutral condition. In the incongruent condition, participants saw a series of 50 coloured words (red, green, blue, yellow, orange, and purple) on the computer screen in different font colours (e.g. red in green colour). Participants were instructed to name the font colour of the coloured words as quickly and accurately as possible. In the neutral condition, participants saw a series of 50 coloured rectangles in one of the six colours and named the colour of the rectangles as quickly and accurately as possible. In both conditions, stimuli were presented in a random order and no two successive trials had the same stimulus. Prior to the actual test, participants received practice with 12 trials (6 incongruent, 6 neutral) along with feedback until they achieved 100% accuracy. All participants completed the neutral condition first followed by the incongruent condition in a single session. A beep indicated the onset of each stimulus, and a digital voice recorder was used to record the responses. RT for the correct trials were measured to derive the Stroop ratio. The Stroop ratio was calculated using the following equation (Patra et al., 2020a):

$$\text{Stroop ratio}(\%) = \left[\frac{RT_{INCONGRUENTTRIAL} - RT_{NEUTRALTRIAL}}{\frac{RT_{INCONGRUENTTRIAL}+RT_{NEUTRALTRIAL}}{2}}\right] X100$$

The Stroop ratio was preferred as a dependent variable over the traditional Stroop difference to account for overall slowness in response speed in the aphasia group (Bose et al., 2022). A smaller Stroop ratio indicates better inhibitory control (Bose et al., 2022).

Shifting between task-sets (Trail Making test)

To assess mental set-shifting ability, we administered the Trail Making Test (TMT, Reitan, 1986), one of the most widely used neuropsychological tests (Sánchez-Cubillo et al., 2009). All participants completed two parts of this test on paper. BWA used their non-paralytic hand for both parts. Part A consists of 25 circled numbers and participants were asked to connect the circled numbers using a pen/pencil as quickly and accurately as possible. Part

B consists of circled numbers and letters and participants were instructed to connect the circles alternating between numbers and letters (e.g. 1, A, 2, B, 3, C, and so on). RT were measured for both parts of the test and the dependent variable was the TMT ratio. The TMT ratio was calculated by using the following equation:

$$\text{TMT ratio} = \frac{RT_B}{RT_A}$$

A smaller TMT ratio indicates better mental set-shifting or switching abilities (Salthouse, 2011).

Working memory (backward digit span)

Backward digit span from the Wechsler Memory Scale-3 (Wechsler, 1997) was used to assess working memory ability. Participants heard a sequence of digits that increased in length with every presentation and were required to repeat the sequence of digits in reverse order. The test was terminated when participants failed to recall the complete sequence of digits on two consecutive trials or when the maximum list length was reached (7 digits). The dependent variable was the backward digit span score, which is the total number of lists reported correctly.

Participants completed the executive control measures in their language of preference, typically in their dominant language. BWA6 (balanced bilingual) preferred to perform the tasks in English. Below we have summarised the main findings from the executive control measures. At the group level, a significant difference was observed only for the TMT ratio. Compared to BC, BWA showed significantly larger TMT ratio (Mann-Whitney U = 10, p = 0.04). To reiterate a larger TMT ratio is indicative of poorer switching abilities. However, both groups performed similarly on the Stroop ratio (Mann-Whitney U = 15, p = 0.13) and the backward digit span (Mann-Whitney U = 26, p = 0.81). Individual level analyses were performed to measure the individual level variation in the BWA group. Using Crawford and Howell's (1998) method, we compared each BWA's score with the BC group. BWA2 and BWA8 showed impairment in both Stroop ratio and TMT ratio; BWA6 showed impairment in Stroop ratio only. BWA1, BWA4, BWA5, and BWA7 showed no executive control impairment across the three domains.

Cognate picture naming task

Stimuli

Stimuli were nouns, consisting of black-and-white line drawings of 38 cognates and 38 non-cognates. Images were taken from various picture databases, such as the Philadelphia Naming Test database (PNT; Roach et al., 1996), the International Picture Naming Project database (IPNP; Szekely et al., 2004), the Bank Of Standardized Stimuli database (BOSS; Brodeur et al., 2010), the picture database by Snodgrass and Vanderwart (1980), and internet resources. Both subjective and objective methods were used to determine the cognate status of the stimuli, and the word lists were matched for available psycholinguistic properties. See Supplementary File 3 for details on stimuli development and the final stimuli list with their psycholinguistic properties.

Procedure

Participants completed the picture naming task in each language on two separate days (with an average gap of at least 4 days between administrations). On each day, participants were familiarised with all the stimuli. Familiarisation is a commonly used approach in picture naming studies to avoid errors due to unfamiliarity (Acheson et al., 2012). During the familiarisation, participants saw the stimuli at the centre of the screen with the written name of the object at the bottom of the screen. The experimenter read aloud the correct name of the stimuli, and participants were encouraged to repeat the word after the experimenter. Following the familiarisation, a short break was given before the picture naming task.

For the picture naming task, participants were shown the picture stimuli (without the written name) in random order one at a time on a computer screen using E-Prime software. Each trial started with a fixation cross for 250 ms, followed by a 100 ms blank screen, then the target stimuli for 4000 ms. Each target stimulus was accompanied by a 150 ms short beep sound. A blank screen appeared following the target stimulus for 2000 ms before the beginning of a new trial. Participants were asked to name the images as quickly and accurately as they could. No feedback was provided, except for occasional encouragement. Responses were voice recorded and transcribed manually.

Scoring and analyses

All participants completed the picture naming task in both languages except participants BWA2, BC2, and BC4. BWA2 was not available for English (the non-dominant language). BC2 and BC4 were not available for completing the task in Bengali (the dominant language for BC2 and the non-dominant language for BC4). Overall, the picture naming task produced 988 trials in the dominant language (38 stimuli ×2 conditions ×13 participants) and 912 trials in the non-dominant language (38 stimuli ×2 conditions ×12 participants).

Naming responses were coded for accuracy and error types. Accuracy was based on the first complete, non-fragmented naming attempt within 4-seconds after the stimulus presentation (Roach et al., 1996). Responses were classified as correct if participants produced the intended target word without any phonological errors. Plural forms of the target and correct response following hesitations, fragments, or distortions were also classified as correct. From the total number of accurate responses, percentage correct value was calculated. In addition to accuracy measures, we classified the errors into semantic, formal, mixed, non-word, no response, unrelated, and descriptive. We provide a detailed error classification code and its results in Supplementary File 4 and File 5 in the Supporting Information section for interested readers to explore the data.

The raw scores and percentage correct for each BWA in each condition (cognate, non-cognate) and in each language (Bengali, English) are presented in Supplementary File 6 in the Supporting Information section.

Statistical analyses

The following analyses were undertaken to address the research questions. To determine the cognate effects, mixed-effects models were implemented (described below), followed by an individual analysis of cognate effects for BWA. To determine the relationship between cognate effects and executive control measures, correlational analyses were performed.

Cognate effects at the group level

We performed mixed logistic regression using the glmer function in R version 3.6.0 (R Core Team, 2021) with alpha = 0.05 for tests of significance. To examine whether cognate effects were different based on language dominance and group, we assessed a potential three-way interaction of condition (cognate vs non-cognate), language dominance (dominant vs. non-dominant), and group (BWA vs BC) on naming accuracy with random intercepts for participants. We were unable to fit intercepts for items and slopes for both items and participants due to convergence errors. A significant three-way interaction was followed by simple-effects models to inspect whether each group showed significant cognate effects in their dominant and non-dominant languages (see Supplementary File 7 in the Supporting Information section for the complete model equations). BWA6 was excluded from this analysis due to having equal dominance in both languages (pre-stroke). However, BWA6 was included in the individual analysis.

Treatment coding was applied to the condition (reference: non-cognate), group (reference: BC), and dominance (reference: dominant language) factors. Results from the analyses are presented in Supplementary File 8 in the Supporting Information section.

Cognate effects at the individual level

Separate analyses at the individual level were performed for all BWA participants to address the following issues: 1) to capture the heterogeneity of cognate effects in aphasia, 2) because most of the cognate studies are case reports, 3) access to individual data analyses is helpful for future data extraction and meta-analyses. Cognate effects in each language were analysed for each BWA using the chi-square goodness-of-fit test. Results from the individual level analyses are summarised in Table 2; statistical analyses are reported in Supplementary File 6 in the Supporting Information section.

Table 2. Summary of individual level findings for each bilingual with aphasia (bwa) and group level (bwa, bc) findings in the context of cognate facilitation effect (accuracy), language dominance and executive control measures.

	BWA1	BWA2	BWA4	BWA5	BWA6[a]	BWA7	BWA8	Group effect	
Cognate facilitation effect								BWA	BC
Dominant	No (p = 0.89)	No (p = 0.78)	No (p = 0.90)	No (p = 0.62)	No (p = 0.59)	No (p = 0.1)	No (p = 0.75)	No (p = 0.91)	**Yes** (p = 0.002)
Non-dominant	No (p = 0.58)	NAT[b]	No (p = 0.81)	No (p = 1)	**Yes** (p = 0.03)	No (p = 0.30)	**Yes** (p = 0.01)	**Yes** (p = 0.002)	No (p = 0.06)
Executive control measures								*M(SD)*	*M(SD)*
Stroop ratio	36	76	33	4	80	19	85	47.6 (32.5)	24(11.2)
TMT ratio	2.8	8	1.6	2.8	2.8	2.7	6.7	3.9(2.4)	2(0.6)
Digit span	4	3	4	4	5	5	3	4(0.8)	4.5(1.6)

[a]BWA6 evidenced a balanced bilingual dominance. BWA6 showed cognate facilitation effect in Bengali but not in English.
[b]Not Available for Testing. please see Supplementary File 8 in the Supporting Information section. Crawford and Howell's (1998) statistical test was used to compare each BWA's executive control score with the BC group mean. Singlism.exe program (2002) was used to compute the statistics; text in shaded cells represent a significant difference ($p < 0.05$) between an individual BWA's score compared to the BC group mean.

Table 3. Correlation coefficients between the executive control measures and the cognate effects (i.e. difference in accuracy scores between cognate and non-cognate items) according to language dominance for two participant groups (bwa, bc) while controlling for naming severity for BWA. bold font with asterisk indicates significant correlation.

Executive control measures		Cognate effects (naming difference between cognate and non-cognates)	
		Bilingual with Aphasia (BWA)	
		Dominant ($N = 6$)	Non-dominant ($N = 5$)
Stroop ratio	rs^a	−0.70	0.46
TMT ratio	rs^a	0.07	**0.85***
		Bilingual Controls (BC)	
		Dominant ($N = 7$)	Non-dominant ($N = 7$)
Stroop ratio	rs^b	**0.89***	0.27
TMT ratio	rs^b	**0.76***	**0.74***

[a]– Spearman's partial correlation controlling for naming severity, [b]Spearman's bivariate correlation; For significant correlations in the dominant language, in the group of BWA ($n = 6$) effect size r needs to be .78 to obtain sufficient power (1-β of .8) at α = .05, for BC ($n = 7$), r needs to be .74. For significant correlations in the non-dominant language, in the group of BWA effect size r needs to be .83 to obtain sufficient power (1-β of .8) at α = .05, for BC ($n = 7$), r needs to be .74.

Relationship between cognate effects and executive control

To examine the relationship between the executive control measures and cognate effects, Spearman's correlations were performed separately for each group in each language (dominant and non-dominant). For BWA, we performed partial correlation by controlling for naming severity in the dominant and non-dominant language (based on Croft's naming subtest). Specifically, we were interested in examining the correlation between the magnitude of cognate effects (i.e. accuracy difference score between cognate and non-cognate conditions) and the two executive control measures (Stroop ratio, TMT ratio). We decided to exclude backward digit span from the correlation analysis as there was no difference observed either between groups or at the individual level. We also excluded BWA6 from this analysis as BWA6 was a balanced bilingual (pre-stroke). Although our sample size is typical in clinical studies, to minimise false positive rates (Bose et al., 2022), we calculated effect size r to obtain sufficient power (1-β of .8) at α = .05 using G*Power (Faul et al., 2007) and interpreted correlations only when the effects sizes were large enough to show sufficient power. For the correlation analyses (accuracy) in the dominant language, in the group of BWA ($N = 6$) effect size r needs to be ≥.78; for BC ($N = 7$), r needs to be ≥.74. For the correlation analyses in the non-dominant language, in the group of BWA effect size r needs to be ≥.83 for accuracy ($N = 5$); for BC ($N = 7$), r needs to be ≥.74 for accuracy. Results from the correlation analyses are presented in Table 3.

Results

Results are mapped onto the two main research questions: 1) Cognate effects on naming performance and how such effects are modulated by language dominance; 2) The relationship between cognate effects and executive control.

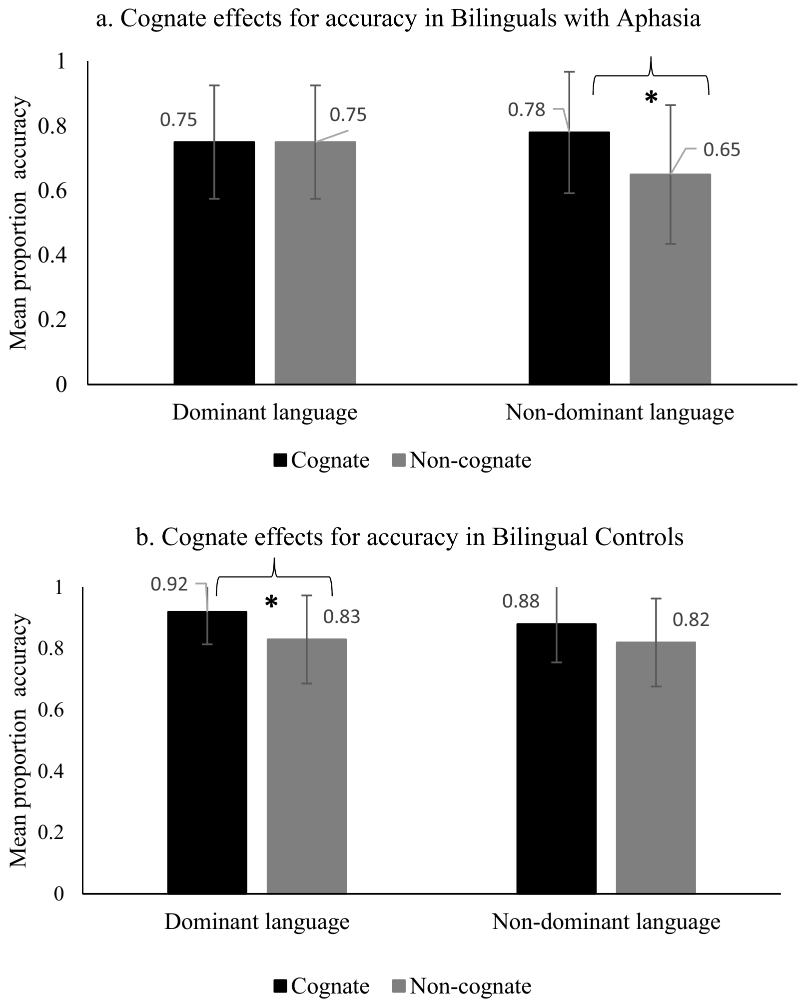

Figure 1. Cognate effects in the dominant and non-dominant language for accuracy in bilinguals with aphasia (a) and bilingual controls (b) Error bars represent standard error of the means. *$p \leq 0.05$.

Cognate effects at the group level

We observed a main effect of condition (cognate vs. non-cognate) (estimate = 0.85, SE = 0.28, Z = 3.02, $p = 0.003$), suggestive of cognate facilitation. As expected, we observed a main effect of group (BWA vs. BC) (estimate = −0.75, SE = 0.24, Z = −3.07, $p = 0.002$), that is BWA participants were less accurate compared to the BC group. There was no main effect of language dominance (estimate = 0.07, SE = 0.24, Z = 0.28, $p = 0.78$).

Results showed a significant three-way interaction (estimate = 1.05, SE = 0.50, Z = 2.12, $p = 0.03$) between condition (cognate vs. non-cognate), group (BWA vs. BC), and language dominance (dominant vs. non-dominant). For BWA, the simple-effects model revealed a significant cognate facilitation effect in the non-dominant language (estimate = 0.77, SE = 0.26, Z = 3.06, $p = 0.002$) but not in the dominant language (estimate = 0.03, SE = 0.22, Z = 0.11, $p = 0.91$). For BC, the simple-effects model revealed no cognate facilitation effect in the non-dominant language (estimate = 0.46, SE = 0.25, Z = 1.85, $p = 0.06$) but a significant cognate facilitation effect in the dominant language (estimate = 0.86, SE = 0.28, Z = 3.06, $p = 0.002$). See Supplementary File 8 in the Supporting Information section for model output. Figure 1 presents mean naming accuracy for both groups in the cognate and non-cognate conditions in their dominant and non-dominant language.

Cognate effects at the individual level

In the individual level analysis (see Table 2), not all BWA participants showed cognate facilitation. Only two out of seven BWA participants showed cognate facilitation.

Relationship between cognate effects and executive control

Table 3 presents the correlation coefficients between the cognate effects (difference in accuracy scores between cognate and non-cognate items) and executive control measures for BWA and BC in their dominant and non-dominant language. For both groups, we observed a significant correlation between cognate effects and executive control abilities. For BWA, better switching abilities (indicated by a smaller TMT ratio) were associated with a smaller cognate facilitation effect ($r = 0.85$), and this effect was observed only in the non-dominant language. For BC, we observed significant correlations between executive control abilities and cognate facilitation effects in both languages. Specifically, smaller cognate facilitation effects in the dominant language were associated with better inhibitory control abilities (indicated by a smaller Stroop ratio, $r = 0.89$) and better switching abilities (indicated by smaller TMT ratio, $r = 0.76$). In the non-dominant language, better switching abilities were associated with smaller cognate facilitation effects ($r = 0.74$).

Discussion

The primary aim of this research was to investigate cognate effects in bilingual aphasia, and how those effects are modulated by language dominance and executive control abilities.

Our analysis revealed a significant three-way interaction between group, cognate status, and language dominance. For BWA, cognate facilitation was significant only in the non-dominant language, whereas the controls showed significant cognate facilitation in the dominant language only. The findings support the cascaded activation model of lexical selection (Costa et al., 2000), which proposes that cognates receive convergent activation from their shared semantic and phonological representations across languages, whereas non-cognates receive activation only from the shared semantic representations. Further, our results are consistent with alternative explanations of cognate facilitation effects, such as cognates being used more frequently compared to non-cognates (Gollan et al., 2005); cognates being easier to learn, and therefore having stronger representations compared to non-cognates (Costa et al., 2017).

In terms of language dominance and cognate effects, findings from the BWA group are consistent with previous studies that have shown stronger cognate facilitation effects in the non-dominant language (Costa et al., 2000; Gollan et al., 2007; Roberts & Deslauriers, 1999). However, among the controls, the significant cognate facilitation in the dominant language, and the absence of an effect in the non-dominant language, is inconsistent with findings from the cognate literature (Costa et al., 2000). At the moment, we can only provide speculation for this finding. Although the controls identified themselves as Bengali dominant, the dominance measure is a composite construct of several bilingualism behaviours, while picture naming is a constrained and specific linguistic task. It is feasible that a higher level of education in our control participants (graduates or postgraduates), and substantial exposure to English (particularly in academic and professional contexts), compared to Bengali, enabled English to be dominant in structured linguistic contexts, such as experimental picture naming.

According to Siyambalapitiya et al. (2009), increased exposure to a language can influence in which language the cognate advantage occurs. This suggests that, despite Bengali being identified as the dominant language through the questionnaire, participants' actual language dominance may have shifted towards English, at least for a structured task. To better understand such shifts, future studies would benefit from incorporating more nuanced and dynamic measures of language dominance that account for current patterns of language exposure.

Although the group level findings of bilingual aphasia concur with three (Kohnert, 2004; Marte et al., 2023; Roberts & Deslauriers, 1999) of the five picture naming studies in bilingual aphasia, two existing single-case studies did not observe cognate facilitation (no effect, Hameau & Köpke, 2015; interference, Kurland & Falcon, 2011). Our individual level analyses in Table 2 provide a nuanced insight into the variable nature of the cognate effect in BWA; how such variability can be explained by differences in bilingualism-related variables (such as language dominance, relative language impairment between the two languages), and executive control abilities. For example, BWA1 and BWA8 were comparable in aphasia severity (moderate), and had relatively similar naming impairments in both languages, but showed differential cognate effects. BWA1 showed no cognate effect and exhibited comparable executive control abilities to the controls; whereas BWA8 showed cognate facilitation in the non-dominant language, and exhibited impaired inhibitory control and switching abilities (compared to the controls). Similarly, BWA6 and BWA8 were the only two participants who showed cognate facilitation at the individual level. Both exhibited greater language impairment (as can be seen from Croft's naming test and WAB AQ scores) compared to the other bilingual participants with aphasia (with the exception of BWA2, for whom we do not have data on cognate task in their most impaired language). Additionally, BWA6 and BWA8 performed significantly worse than the controls on the executive control measures. Overall, the individual level analyses highlight the fact that *cognate facilitation effects are not universal*. Instead, they appear to be influenced by individual differences in executive control abilities and the severity of language impairment.

Further support for the relationship between cognate facilitation effects and executive control measures in BWA comes from the correlation findings. We found that the magnitude of cognate facilitation effect in the non-dominant language was significantly correlated with executive control (mental set-shifting) abilities. Specifically, individuals with poorer executive control abilities showed a greater cognate facilitation effect. This effect was observed even after controlling for the severity of naming impairments in the aphasia group. These findings are consistent with the inhibitory control model of language production (Green, 1998). According to the inhibitory control model, at the lexical level, greater activation of the cognate word in the non-target language may lead to increased cross-language competition while naming the word in the target language. It can be argued that participants with better executive control abilities can suppress that cross-language interference and may not be able (or may not need) to use any advantage of the cognate word. This is in line with Linck et al'.s (2008) study involving controls, which reported greater cognate facilitation for participants with poorer inhibitory control abilities. Our findings are also consistent with the only group study that has examined executive control abilities and cognate facilitation effects in bilinguals with aphasia (Van der Linden, Verreyt, et al., 2018). The authors attributed an executive control deficit to the greater cognate facilitation shown by bilinguals with differential aphasia. However, they neither performed individual level analyses nor related the performance on these tasks to each other (i.e. the magnitude of cognate facilitation and executive control abilities). The findings from this study provide evidence for a potential link between the magnitude of cognate facilitation effects and executive control abilities in BWA. Findings from the correlation analysis involving controls provide further support for this statement, where controls with poorer executive control abilities (inhibitory control and mental set-shifting) showed greater cognate facilitation effects.

Finally, we acknowledge the limitations of the present study, and the outstanding questions that should be addressed in future research. Our study sample size ($N = 7$) is respectable for clinical research in bilingual aphasia (which is still emerging), but small compared to standard cognitive psychology studies that address individual differences. Similarly, the number of items in the present study is rather small, therefore we could not add an intercept for the items in our regression models. We wish to highlight that one reason for the underrepresentation of South Asian languages in aphasiology is the lack of existing lexical and psycholinguistic databases. This poses a significant challenge in developing well-controlled experimental stimuli and methodologies, which are more readily available for English and other well-studied European languages. It is our hope that this study encourages future researchers and clinicians to undertake investigations in under-researched languages and clinical populations, and not be deterred by the lack of psycholinguistic measures. In light of these challenges, until better databases and corpora become available, future research in under-represented languages will need to undertake significant preliminary work to generate at least subjective norms for their stimuli on relevant variables (e.g. name agreement), which are expected to influence study outcomes. Therefore, as research on under-researched languages progresses, future studies would benefit from having a large number of items and carefully controlling for relevant psycholinguistic variables in order to examine cognate effects in aphasia. Another methodological limitation of the present study is the use of a familiarisation procedure, which may lead to priming or learning. However, the familiarisation process was applied consistently across all participants and conditions. Future studies may examine whether priming or learning mechanisms contribute to cognate effects.

Finally, all of our executive control measures were verbal, and it could be said that the correlation between the cognate facilitation effects and executive control abilities may reflect the nature of the task (i.e. verbal) rather than the underlying executive control abilities. However, in a recent study, Kendrick et al. (2019) showed that verbal load was not a significant predictor in the performance of executive control tasks in both aphasia and control groups. A recent review article highlighted the extreme difficulty in addressing the 'task impurity' problem in existing executive control measures, and suggested the use of a variety of executive control measures to address this challenge (Tessaro et al., 2024). Therefore, future research with larger sample sizes, along with different measures of verbal and non-verbal executive control, would further inform how individual differences in the executive control abilities of people with aphasia relate to the cognate facilitation effects.

Importantly, aphasia studies involving participants from an underrepresented group are almost non-existent. Therefore, the data from this research adds to the much-needed breadth in the bilingual aphasia literature. In clinical settings, it is possible that targeting cognates would be beneficial, especially for individuals with weaker executive control abilities and differential language impairment. Therefore, during the assessment period, clinicians should consider several factors, including language dominance, severity of aphasia, and the individual's executive control abilities. However, these speculations need to be tested with a range of language combinations, and various aphasia severities and profiles.

Conclusion

To the best of our knowledge, this is the first study to examine the relationship between cognate effects, language dominance, and executive control in bilingual aphasia using a picture naming task. The present study highlights that, to explain cognate facilitation, it is necessary to use a multi-pronged approach, including detailed bilingualism measures and a range of executive control measures (inhibitory control, mental set-shifting, and working memory). Further, we point to the importance of individual level analyses in aphasia, due to the high variability in performance in this population. The key findings of this research are that cognate facilitation is observed in bilinguals with aphasia in their non-dominant language, even when the language combinations are structurally and typologically different. Bilinguals with aphasia with poorer executive control abilities demonstrated larger cognate facilitation effects. Our research makes a significant contribution to the limited literature in the domain of cognate production in bilingual aphasia, especially in an underreported language (Bengali). This study contributes to the knowledge of bilingual language processing and its organisation, and emphasises the importance of understanding word production in bilingual aphasia in the context of executive control and bilingualism variables.

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Author contributions

CRediT: **Abhijeet Patra:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing; **Arpita Bose:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing; **Theodoros Marinis:** Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing.

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Data availability statement

Deidentified participant data can be available 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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