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Word Production and Executive Control in Bilingual Aphasia

Thesis submitted for the degree of Doctor of Philosophy

School of Psychology and Clinical Language Sciences

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DECLARATION OF ORIGINAL AUTHORSHIP

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

Abhijeet Patra

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Abstract

Word production is an essential feature of successful communication where semantic information (meaning) of a word is activated first, and this representation then activates the corresponding phonological form followed by the articulation of the target word. However, the production of words becomes effortful and impaired following neurological impairments (e.g., aphasia). The nature of word production impairments in aphasia is poorly understood and inadequately treated. In healthy monolingual speakers, word production involves selection of target word from competing lexical items within the target language. The situation becomes complicated for bilinguals with two sets of lexical systems leading to enhanced lexical competition. Research has shown different executive control processes are involved while resolving lexical competition. There is currently not a consensus in the literature as to whether this lexical competition is resolved in the same way by monolingual and bilingual speakers. Moreover, research on the nature of word production deficits in bilinguals with aphasia (BWA) and their relationship to executive control mechanism is not established in the literature, especially in Indian languages. In this project, we investigate the relationship between word production and executive control in a systematic and stepwise exploration in two phases (Phase I in UK and Phase II in India) by using different participant groups, wide range of linguistic measures, and separate executive control measures.

Participants in Phase I were 25 healthy Bengali-English bilinguals and English monolinguals who were matched on age, gender, years of education, non-verbal intelligence, and vocabulary. Participants completed two linguistic experimental tasks (verbal fluency in Chapter 2 and blocked-cyclic naming in Chapter 3) in English and three executive control tasks (inhibitory control: Stroop task, mental-set shifting: colour-shape switch task, working memory: backward digit span test). Results revealed bilinguals performed at par with the monolinguals in some linguistic measures (semantic fluency and heterogenous context in blocked-cyclic naming) and outperformed monolinguals in certain linguistic measures (e.g. letter fluency and homogenous context in blocked-cyclic naming). Therefore, bilingual disadvantage in the linguistic domain can be negated if vocabulary is controlled for. Also, bilingual advantage in the non-linguistic domain can be extended to the linguistic domain if the linguistic tasks were made more challenging by increasing the executive control demands.

Bilingual Participants in Phase II were eight Bengali-English BWA and eight Bengali-English bilingual healthy adults (BHA) who were matched on age, gender, years of education, and measures of bilingualism. Participants completed two linguistic tasks (verbal fluency in Chapter 4 and picture naming involving cognates and non-cognates in Chapter 5) in both languages and same executive control tasks as in Phase I, except for mental-set shifting (Trail Making Test). As expected, we found evidence of linguistic and executive control impairments at the group level for BWA individuals. Similar to the monolingual group in Phase I, we found BWA had more difficulty in the linguistic

measures (e.g. fluency difference score, number of switches, between-cluster pause) where executive control demands were higher. However, the underlying executive control deficits in the linguistic tasks may not be visible with the usual analysis techniques. Therefore, we argued in favor of including a more fine-grained analysis of linguistic tasks. In terms of cross-linguistic impairment following a stroke, our results showed similar impairment in both the languages and the post-stroke language ability (e.g. better performance in Bengali) mirrored their pre-stroke language ability (Bengali dominant). Findings from the linguistic tasks revealed that despite showing deficits in lexical access, BWA still mirrored the BHA in terms of the underlying language processing mechanism which is required to perform in the linguistic tasks.

In summary, performance differences on the linguistic measures were mediated by various factors such as the participant groups, nature of the task, language proficiency, and executive control abilities. We emphasise the importance of characterising the BWA participants in terms of their linguistic impairments in both languages, bilingualism related variables, separate linguistic and executive control measures and involved analysis approaches. We provide a foundation for future research on understanding the interplay of linguistic and executive control processes during word production in healthy bilinguals as well as in BWA population.

Chapter 1. General Introduction

1.1 Introduction

Producing words accurately, in isolation and sentences, is an essential feature of successful and fluent communication in everyday life which enables speakers to map conceptual representations onto words and to refer to objects in the outside world. Knowing the names of objects (as well as of abstract entities) and being able to retrieve these names, therefore, is a central aspect of successful verbal communication. However, when illness or injury interferes with verbal communication, the impact can be severe, affecting our social and work life, and our emotional well-being. A universal difficulty for People with Aphasia (PWA) is the failure to produce intended words, which severely limit the success of their verbal communication. The nature of word production impairments in aphasia is poorly understood and inadequately treated.

The effortless production of words is achieved through a complex interplay of several processes, including the retrieval of semantic information (meaning), phonological information (word sounds) and articulation (moving lips, jaw and tongue to make the chosen sequence of sound). Even in monolinguals, naming is a competitive process. Importantly, a speaker must select the target word from several other competing lexical items, e.g., if the target is *dog*, items such as *cat* and *horse* might also be activated and compete for selection. Research indicates that of a set of higher order cognitive skills known as executive control mechanisms are crucial for successful retrieval of words, and resolution of the competition. Studies have suggested that executive control mechanism, primarily inhibitory control helps to resolve this lexical competition (Crowther & Martin, 2014; Shao, Roelofs, Martin, & Meyer, 2015). However, the situation gets more complicated for bilinguals, i.e., speaker of two languages. Bilinguals not only have to resolve the lexical competition from their target language but also must prevent the interference from the non-target language.

There is currently not a consensus in the literature as to whether this lexical competition is resolved in the same way by monolingual and bilingual speakers. Moreover, research on the nature of word production deficits in bilingual aphasia and their relationship to executive control mechanism is not well-established in the literature.

This PhD research sets out to investigate some of the outstanding issues in the bilingual word production literature in the context of aphasia and healthy participants. Specifically, the project aims to understand the relationship between word production and executive control in a systematic and stepwise exploration in two phases (Phase I and Phase II). We approach these research aims by using: (1) different participant groups (healthy monolingual versus bilingual; neurologically impaired bilingual aphasia versus bilingual healthy control); (2) a wide range of linguistic measures such as tasks which tap into both linguistic and executive control aspects (verbal fluency), paradigms where lexical activation can be increased or decreased (blocked-cyclic naming task), or changing stimuli characteristics that can manipulate lexical activation (picture naming involving cognates and non-cognates); and (3) separate executive control measures such as inhibitory control (Stroop test), mental-set shifting (colour-shape switch and Trail Making Test), and working memory (backward digit span).

In Phase I (Chapters 2 and 3), we aim to inform the debate on performance differences between healthy monolingual and bilingual speakers on linguistic and executive control processes. We determined differences between healthy monolingual and bilingual speakers on word production by using task and experimental manipulations that can tap both into the linguistic and executive control abilities. We also determined if different bilingualism related variables (vocabulary, proficiency, dominance etc.) and executive control performances could explain differences between the groups. We compared healthy Bengali-

English bilinguals and English monolinguals residing in Berkshire, the UK on verbal fluency and blocked-cyclic naming tasks.

In Phase II (Chapters 4 and 5), we investigate the relationship between word production and executive control processes in bilingual aphasia with an aim of identifying and describing how the two languages break down, how the impairments are manifested and whether linguistic and executive control processes mediate these manifestations. In addition, we compared cross-linguistic performance between the languages and determined if bilingualism variables, executive control and/or profile of linguistic deficits can explain the performance pattern between the groups. We compared Bengali-English bilinguals with aphasia (BWA) and Bengali-English bilingual healthy adults (BHA) residing in West Bengal, India on verbal fluency and picture naming (cognate and non-cognate) tasks. Participants across all the studies also performed the same set of executive control tasks (except for mental-set shifting).

On the next section, first we will briefly provide motivations and rationale for the experiments in Phase I and Phase II . Second, we will provide an introduction to the Bengali language followed by the linguistic differences between Bengali and English and the implications for the present project. At the end, we will provide a summary table for all the experimental chapters with its specific research questions, and methods.

1.1.1 Phase I (healthy bilinguals versus monolinguals)

In Phase I, we aim to examine the relative contribution of linguistic and executive control processes during word production in healthy bilinguals and monolinguals by using a linguistic task (verbal fluency) and a linguistic paradigm (blocked-cyclic naming) where executive control demands are varied, from low (e.g. semantic fluency condition in verbal fluency task, heterogenous context in blocked-cyclic naming paradigm) to high (e.g. letter fluency in verbal fluency task, homogenous context in blocked-cyclic naming paradigm). We also aim to investigate whether the performance differences in the linguistic measures between the two groups can be explained by the differences in their executive control abilities. In the following section, first we will introduce the differences in the language production system between healthy bilingual and monolingual speakers, followed by a literature review on the present debate to the differences between these two groups on various linguistic and executive control tasks, and how the present study will aim to address these debates. At the end, we will provide the methodological challenges to consider while studying bilingual population and how the present study will address these challenges.

1.1.1.1 Differences in word production mechanisms. Bilingual speakers' word production mechanism differs from monolingual speakers' due to having a single conceptual representation linked to two different lexical items belonging to two different languages (Kroll & Stuart, 1994). *Figure 1.1* shows the revised hierarchical model given by Kroll and Stuart, where a single concept is linked to two different languages. Hence, monolinguals face only within language competition, whereas bilinguals must resolve both within and between language competitions during the lexical selection of the target word (Lee & Williams, 2001).

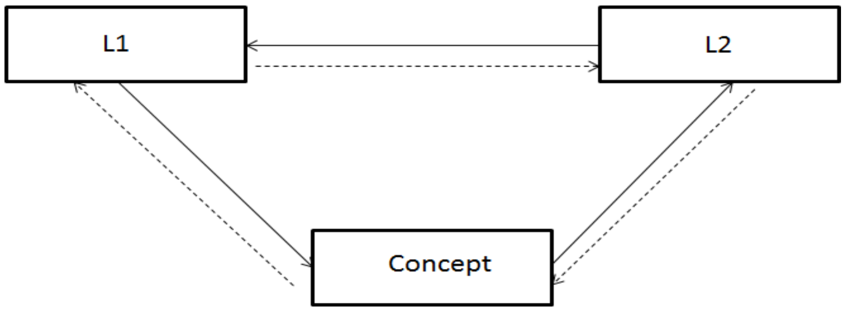


Figure 1.1 Revised hierarchical model (Kroll and Stuart, 1994) where single concept is linked to two different languages (L1 and L2). Thickness of the line indicates the strength of the relationship.

To simplify the concept of different lexical competition in monolingual and bilingual populations, let's take an example from Costa's model (Costa, 2005). *Figure 1.2* shows the schematic representation of monolingual and bilingual lexical representations. Seeing a picture of '*deer*', conceptual representations of the target item (*deer*) and other related concepts (*elephant, antler*, etc.) get activated. However, in bilinguals, lexical selection mechanism has to deal with the activation of lexical items belonging to two different languages in addition to the activation of the lexical items within a language.

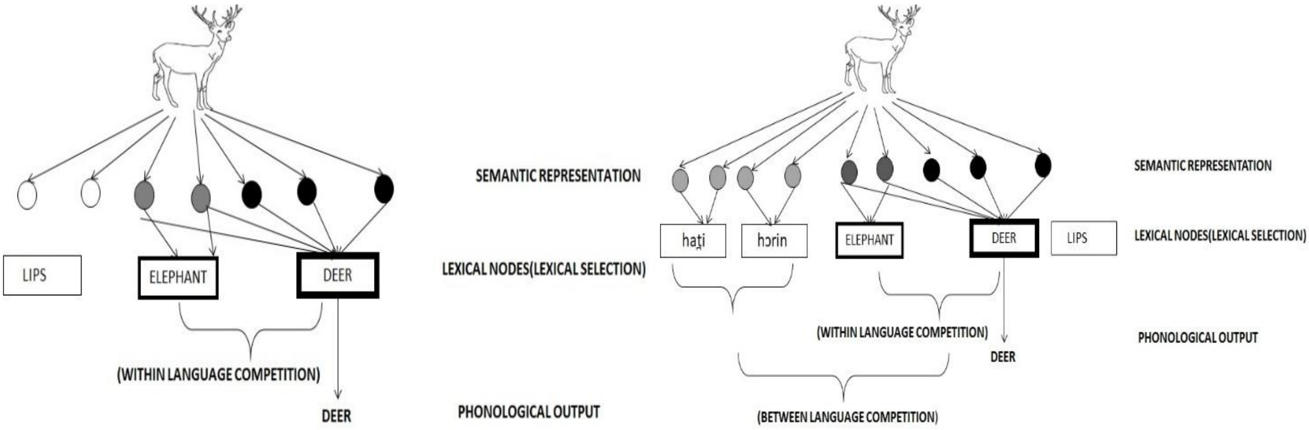


Figure 1.2 Schematic representation of the monolingual (left panel) and bilingual (right panel) system. Circles and squares represent lexical nodes of language in use (English) and language not in use (Bengali in IPA) respectively. Thickness of the circles indicates level of activation of the lexical nodes (Adapted from Costa, 2005).

1.1.1.2 Experimental findings on linguistic measures. In the literature, studies have shown bilingual disadvantages in language processing using a variety of psycholinguistics tasks (e.g. picture naming, verbal fluency, etc.) and across groups of bilinguals who vary in their languages, age and bilingual status (Bialystok, Craik & Luk, 2008; Gollan et al., 2005; Gollan, Montoya & Werner, 2002; Rogers, Lister, Febo, Besing, & Abrams, 2006). For example, bilinguals have been shown to be slower in picture naming tasks (Roberts, Garcia, Desrochers & Hernandez, 2002; Gollan et al., 2005), produced fewer number of correct responses in verbal fluency tasks (Rosselli et al., 2000; Gollan et al., 2002; Portocarrero et al., 2007), come across more tip-of-the tongue phenomenon (Gollan & Acenas, 2004), perform poorer in word identification through noise task (Rogers et al., 2006), as well as in lexical decision tasks (Ransdell & Fischler, 1987). Bialystok, Craik, and Luk (2008) compared younger and older monolinguals and bilinguals on an English vocabulary test (PPVT-III), Boston naming test, and two tests of verbal fluency (semantic and letter). They found bilinguals to obtain lower scores compared to monolinguals across all the age groups.

There are various explanations for bilingual disadvantage in the language processing. According to the weaker link hypothesis, bilinguals use each of their languages less frequently as compared to the monolinguals resulting in weaker link between the connections crucial for rapid speech production (Michael & Gollan, 2005). This hypothesis follows the connectionist model which assumes there are networks between the words and concepts in each language and rapid production of speech depends on the strength of these networks (Dijkstra, 2005). Alternatively, sensorymotor account (Hernandez & Lee, 2007) suggests age of acquisition as one of the key factor for developing vocabulary in each language and the delay in second language acquisition hampers the language processing abilities in that language for bilinguals.

The other viewpoints are based on the assumption that bilinguals' both languages are active during language production and comprehension and the language co-activation is a consistent phenomenon (Costa & Caramazza, 1999; Guo & Peng, 2006; Wu & Thiery, 2010). According to the inhibitory control model (Green, 1998), bilinguals solve the lexical competition by inhibiting the active, non-target language competitors. However, bilinguals face greater lexical competition than monolinguals, and the slower picture naming performances in bilinguals (Gollan, Montoya, Fennema-Notestine, & Morris, 2005) as compared to monolinguals can be attributed to this increased lexical competition (Green, 1998). Consequently, bilinguals have to inhibit one language while speaking another language and this exercise of inhibition reflects bilingual's superiority in non-linguistic executive control tasks over monolinguals (Bialystok, 2009). Therefore, bilinguals face greater lexical competition compared to monolinguals during language production but show improved executive control in the non-verbal domain.

1.1.1.3 Experimental findings on executive control measures. In contrast to the disadvantages of being bilingual in the verbal domain, effect of bilingualism on executive control mechanism is more hotly debated. Researchers have shown advantages (Bialystok et al., 2008; Prior & MacWhinney, 2010) as well as no differences across various executive control tasks (Kousaie & Philips, 2012; Paap & Greenberg, 2013; Paap et al., 2017). Specific of what entails within the executive control processes is still debated in the literature (Harnishfeger, 1995; Miyake et al., 2000; Nigg, 2000), however, for the present study we emphasise on the three most frequently hypothesised components of executive control (Miyake et al., 2000) in the literature–inhibitory control, mental set-shifting and working memory–to explore the executive control processes underlying language production in bilinguals. Miyake et al.´s framework allow us to compare our results to the existing literature as well as testing different components of executive control with specific tasks.

Bilingual research exploring inhibitory control has used tasks such as the Simon task, the Flanker task, and the Stroop test. Although many studies have reported bilingual advantage on inhibitory control for these tasks (e.g., Bialystok et al., 2004; Emmorey, Luk, Pyers, & Bialystok, 2008; Bialystok et al., 2008), no difference or similar performance between monolingual and bilinguals has also been noted (e.g., Gathercole et al., 2014; Kousaie & Philips, 2012; Paap & Greenberg, 2013; Paap & Sawi, 2014). Similarly, on mental set shifting measured using task switching paradigm have reported divergent findings ranging from advantage for bilinguals (Prior & Gollan, 2011; Prior & MacWhinney, 2010) to no differences between the two groups (Paap & Greenberg, 2013; Paap & Sawi, 2014; Paap et al., 2017; Prior & Gollan, 2013). For example, Prior and MacWhinney (2010) tested 45 English young monolinguals (M = 18.7 years, SD = .9) and 47 young bilinguals (M = 19.5, SD =1.5) on a colour-shape non-verbal switch test. This test measures the response time difference (switch cost) between repeat (colour to colour or shape to shape) and switch (colour to shape or shape to colour) trials. They found that bilinguals had a smaller switch cost than monolinguals, suggesting a bilingual advantage in mental set shifting. However, Paap and his colleagues (Paap & Greenberg, 2013; Paap & Sawi, 2014; Paap et al., 2017) did not find any switch cost difference between bilinguals and monolinguals using the same colour-shape switch test.

Similarly, literature on working memory (WM) and bilingualism remains equivocal, with results ranging from no working memory differences between bilinguals and monolinguals (Bialystok et al., 2008; Lu et al., 2010) to disadvantage for bilinguals (Fernandes, Craik, Bialystok, & Kreuger, 2007) or advantage for bilinguals (Bialystok et al., 2004; Blom, Küntay, Messer, Verhagen, & Leseman, 2014; Morales, Calvo, & Bialystok, 2013).

Although the dominant view in the literature is that bilinguals have an “advantage” of executive control, as could be seen from the ongoing review, it is still unresolved whether bilinguals would show specific advantages on certain domains of executive control. In a review article by Paap, Johnson, & Sawi (2014), there are various confounds which may be the reason of bilingual advantages in executive control measures. Some of them are the immigration status of the bilinguals, cultural differences, small sample size, inappropriate statistical analysis, and measures of executive control abilities.

We chose three executive control tasks to test the domains of inhibition, shifting between mental sets, and working memory. Specifically, we use the Stroop task to measure the selective inhibition (Stroop, 1935), backward digit span test to measure the working memory, and colour-shape switch task to measure the shifting ability (Prior & MacWhinney, 2010).

1.1.1.4 Motivation for choosing the linguistic tasks. As can be seen from the literature review above, bilinguals and monolingual speakers have shown to demonstrate differences in performance on both language production and executive control processes. On one hand, bilinguals show a disadvantage on language production tasks (e.g., slower reaction time, a higher number of errors on picture naming task), whilst on the other hand, they demonstrate an "advantage" on executive control tasks, especially in the non-verbal domain (e.g., lower interference on conflict resolution task). Evidence from these two lines of research has come from using separate measures of language production and executive control mechanisms; linguistic tasks tapping into language production, and non-linguistic tasks tapping into executive control processes. With the exception of a handful of studies, the role of executive control during language production amongst bilinguals and monolinguals has not been explored (e.g. Bialystok et al., 2008; Friesen et al., 2015). A better approach to inform the debate on – disadvantage or advantage – amongst language and executive control processes for bilingual and monolingual speakers would be to use tasks (e.g. verbal fluency task) or paradigms (e.g. blocked-cyclic picture naming paradigm) that simultaneously draw upon both these processes.

In a typical verbal fluency test, speakers are asked to generate words belonging to a certain semantic category in the semantic fluency condition (e.g., *animals*) or beginning with a specific letter in the letter fluency condition (e.g. *letter F*). The linguistic and executive contribution for semantic and letter condition are different. The simplicity and nature of the verbal fluency tasks make it an important measure to understand the relationship between word production and executive control.

In this research, we harness the power of this simple test to determine the interaction of linguistic and executive control processes using a broad range of measures (quantitative, time-course, and qualitative) by comparing healthy bilingual and monolingual speakers in Chapter 2. In addition, we complement our verbal fluency data with specific measures of executive control functioning to establish the relationship amongst specific performance parameter on verbal fluency and executive mechanisms.

In a typical blocked-cyclic experiment, there are two types of context – homogeneous context (semantically related) and heterogeneous context (semantically unrelated). In homogenous context, participants name pictures from the same semantic category (e.g. *duck, fish, horse, mouse, cat*). Similarly, in the heterogeneous trials, participants name pictures from semantically unrelated categories (e.g. *duck, beard, vest, pear, lock*). RT and accuracy are observed to be longer and poorer in the homogeneous context as compared to the heterogeneous context due to increased semantic interference at the lexical selection level (Belke, Meyer, & Damian, 2005). As previously mentioned, executive control, especially inhibitory control helps to resolve this interference (Crowther & Martin, 2014). Keeping the two differences in mind, that is differences in lexical competitions, and differences in executive control abilities among monolinguals and bilinguals, the question arises how executive control and lexical context interacts in monolingual and bilingual populations in a blocked-cyclic picture naming paradigm?

Now, three conditions can arise:

Condition 1: Compared to monolinguals, bilingual's executive control advantage outweighs the bilingual's increased lexical competition (disadvantage). Therefore, bilinguals will have lesser semantic context effect than monolinguals.

Condition 2: Compared to monolinguals, bilingual's increased lexical competition (disadvantage) outweighs the bilingual's executive control advantage. Therefore, bilinguals will have greater semantic context effect than monolinguals.

Condition 3: Bilingual's increased lexical competition (disadvantage) and the executive control advantage are of similar magnitude. Therefore, both groups will have comparable semantic context effects.

To summarise, the differences in blocked-cyclic picture naming task between bilinguals and monolinguals can be attributed to the interaction between the executive control and lexical competition during word production. Therefore, in this research, we aim to investigate the relationship between word production and executive control in bilingual speakers by taking blocked-cyclic picture naming as an experimental paradigm in Chapter 3.

We will provide the detailed literature review specific to this task (verbal fluency) and paradigm (blocked-cyclic picture naming) in Chapter 2 and 3, respectively.

1.1.2 Phase II (bilinguals with aphasia versus bilingual healthy adults)

Bilingual aphasia is defined as an impairment in one or both languages of a bilingual individuals following a stroke**.** The study of bilingual aphasia provides an opportunity to examine the break down of two languages following a brain damage. However, in contrast to research on linguistic and executive control processes in healthy bilinguals, studies investigating linguistic manifestation of a breakdown in the two languages in bilinguals with aphasia (BWA) are limited (see Kiran & Gray, 2018 for a review). Therefore, in Phase II, we aim to identify and describe the nature and extent of language breakdown following a brain stroke in bilingual individuals. While Phase I was conducted in Berkshire, UK, Phase II was conducted in West Bengal, India. Further we aim to investigate if bilingualism related variables (pre- and post-stroke) and executive control profile of individuals can explain the linguistic manifestation of a breakdown in the two languages in BWA.

According to data from World Population Prospects: the 2015 Revision (United Nations, 2015), there is a substantial increase in the ageing population. It has been projected that by 2030 there will be 56 percent growth rate of people older than 60 years and by 2050 there will be in total 2.1 billion people aged above 60 years in the world. As aphasia is more prevalent in older population compared to younger (Ellis & Urban, 2016) and very little is known about the linguistic and executive control impairment in bilinguals with aphasia, this becomes a significant and timely area to investigate. In addition, there are very few studies in healthy as well as aphasia population in Indian languages and as suggested by Bak (2015) “India offers an enormous potential for bilingual research” (pp. 332). The present project provides the opportunity to examine the effect of bilingualism and neurological status on linguistic and executive control processes in Indian languages which is currently lacking in the literature. In the following section, we will review the findings pertinent to this project involving BWA on various linguistic and executive control tasks.

1.1.2.1 Experimental findings on linguistic measures. There are limited studies which have examined lexical access and word retrieval in BWA (Faroqi-Shah, Sampson, Pranger, & Baughman, 2016; Gray & Kiran, 2013; Kiran, Balachandran, & Lucas, 2014; Roberts & Deslauriers, 1999). BWA has shown difficulties in picture naming (Kiran, Balachandran, & Lucas, 2014; Roberts & Deslauriers, 1999), verbal fluency (Kiran et al., 2014; Faroqi-Shah, Sampson, Pranger, & Baughman, 2016), and lexical decision (Green et al., 2010; Verreyt et al., 2013) tasks.

Kiran et al. (2014) tested 10 Spanish-English BWA and 12 bilingual healthy adults (BHA) on two picture naming tasks: Boston Naming Test (BNT) and Bilingual Picture Naming Task (BPNT); and on a semantic fluency task (*animals, food, and clothing*). On the two picture naming tasks, BWA produced significantly fewer correct responses compared to BHA. BWA did not show any cross-linguistic difference. However, BHA group performed significantly better in their dominant language. On the semantic fluency task, BWA produced fewer correct responses, smaller cluster sizes, and fewer numbers of switches compared to BHA. In terms of correct responses and cluster size, BHA group performed significantly better in their most currently used language (English). However, there were no cross-linguistic differences in any of the measures mentioned above for BWA. On individual analysis, the majority of the patients performed better in their most proficient and currently used language (Spanish). The author concluded that the differences in both the groups arise from the lexical retrieval deficits in BWA and can be linked to their language proficiency in the two languages. Although BHA outperformed BWA on the naming and verbal fluency task, both groups made similar types of errors on naming tasks (e.g. circumlocutions) in both languages and used similar clustering strategies in the verbal fluency task. Overall, the results indicate that despite showing deficits in lexical access, BWA still mirrors the BHA in terms of the underlying language processing mechanism which is required to perform in the naming and verbal fluency task.

Gray and Kiran (2013) examined the pattern of lexical and semantic deficits between the two languages in 19 Spanish-English bilingual adults with aphasia by using standardized measure of diagnostic testing in Spanish and English. The researchers found pre-stroke language ability to be a significant predictor of post-stroke language ability. They also found two distinct patterns of impairment, one group showed similar impairment in both languages whereas the other group showed differential pattern of impairment in Spanish and English. Overall, the result showed evidence for both parallel and differential impairment following a brain stroke in a large sample of patients.

In addition to the experimental tasks, various assessment tools also have been developed in various languages to better understand the language impairment in BWA, such as Aachen Aphasia Test (Huber, Poeck, Weniger, & Willmes, 1983), Western Aphasia Battery (Kertesz, 1982), Boston Diagnostic Aphasia Examination (Goodglass, Kaplan, & Barresi, 2000), Bilingual Aphasia Test (Paradis, 1989), etc. These assessment tests allow cross-linguistic comparisons of language impairment across various domains (comprehension, production, reading, writing, etc).

1.1.2.2 Experimental findings on executive control measures. In contrast to the studies involving healthy bilinguals, there are only a handful of studies that have investigated the executive control abilities in BWA. The situation gets complicated when we need to work with persons with aphasia (PWA), because of short attention span, difficulty in comprehension, fatigue and other physical factors. Despite the challenges in implementing sophisticated task, executive control deficits in PWA has been documented across different experimental tasks, such as tasks that require resolution of response conflict (Dash & Kar, 2014; Gray & Kiran, 2015; Kuzmina & Weekes, 2017), inhibition of dominant responses (Faroqi-Shah et al., 2016; Green et al., 2010; Kuzmina & Weekes, 2017), switching between tasks sets or rules (Chiou & Kennedy, 2009), and working memory (Salis, Kelly, & Code, 2015).

Gray and Kiran (2015) examined ten Spanish-English BWA and 30 age-matched Spanish-English BHA on two tasks tapping into resistance to distractor interference - a non-linguistic flanker task and a linguistic task. They found BWA were impaired only on the linguistic task (as evidenced by individual analysis) but not on the non-linguistic flanker task indicative of domain specific executive control impairment.

In another study, Green et al (2010) examined two BWA (French-English and Spanish-English), 12 BHA, and 14 MHA on a lexical decision task, verbal Stroop task, and non-linguistic flanker task. Compared to monolinguals, healthy bilinguals performed better on the verbal Stroop task (smaller interference effect), poorer on the lexical decision task (greater interference effect), and similarly on the flanker task. However, results were different for each BWA. Compared to BHA, Patient 1 performed poorly on the lexical decision task and Stroop task, but performed similarly on the flanker task. Compared to BHA, Patient 2 performed poorly on all the three measures. The results indicate the complexity of interpreting the executive control abilities in BWA individuals. In the above study, Patient 1 showed domain specific executive control deficit whereas Patient 2 exhibited domain general executive control deficit.

Kuzmina and Weekes (2017) tested a group of fluent monolingual PWA and non-fluent monolingual PWA on a non-verbal flanker task, verbal Stroop task, and a domain general Auditory Control and Rule Finding task (Russian version of Birmingham Cognitive Screen, Humphreys, Bickerton, Samson, & Riddoch, 2012). They found impaired performance for all the PWA compared to healthy controls on the verbal Stroop, but no impairment on the verbal flanker task. Both the fluent and non-fluent groups recruited non-verbal executive control during language comprehension and verbal executive control during picture naming. Further, non-fluent group showed greater deficit in the verbal Stroop suggestive of greater deficits in the inhibitory control for the non-fluent group as compared to the fluent group.

Faroqi-Shah et al. (2016) compared monolingual PWA and BWA groups with monolingual heathy adults and BHA on a verbal Stroop task and found both PWA produced more errors compared to healthy adults across all trial types. However, Scott and Wilshire (2010) did not find any difference on accuracy between a monolingual PWA speaker and healthy adults group on the same Stroop task but the response times were significantly slower in the conflict condition for the PWA compared to the healthy. PWA also has been shown to perform poorer where they have to shift between tasks or rules (Chiou & Kennedy, 2009). Chiou and Kennedy (2009) compared a group of monolingual PWA and healthy adults on a Go/No-Go task and found PWA group were less accurate and slower compared to healthy adults while switching from one rule to another. Salis, Kelly and Code (2015) in a comprehensive review on working memory assessment in aphasia have argued in favour of a close link between working memory and aphasia. Working memory impairments have also been seen irrespective of the severity of aphasia in tasks even where the verbal demand is low (Martin & Gupta, 2004; Martin & Ayala, 2004).

The outcomes of the above studies are contradictory, and this inconsistent finding highlight the complex interplay between executive control and language processing in bilinguals, especially in bilinguals with aphasia. Further research to assess the executive control abilities in BWA is warranted because it has the potential to provide crucial insights into how linguistic and executive control mechanisms operate in the brain. Therefore, present study aimed to assess the executive control abilities of BWA by using three extensively tested measures of executive control (Miyake et al., 2000) – inhibitory control (Stroop test), task switching (Trail Making Test), and working memory (Backward digit span).

1.1.2.3 Motivation for choosing the linguistic tasks. The simplicity and nature of the verbal fluency tasks make it an important measure to understand the relationship between word production and executive control not only for healthy speakers but also in the aphasia population (Please refer to section 1.1.1.4 for detail). It is well established that aphasia speakers produce fewer number of correct responses than healthy adults and the productivity reduces as a function of time (e.g., Adams, Reich, and Flowers, 1989; Arroyo-Anlló, Lorber, Rigaleau and Gil, 2011; Baldo, Schwartz, Wilkins, and Dronkers, 2010; Bose, Wood, & Kiran, 2017; Helm-Estabrooks, 2002; Kiran, Balachandran, and Lucas, 2014; Roberts and Le Dorze, 1994; Sarno, Postman, Cho, and Norman, 2005). However, there are only a few studies which have investigated both the linguistic (i.e. number of correct words, initiation, cluster size and within-cluster pauses) and executive control (slope, response latency, number of switches, and between-cluster pauses) contribution of this task to understand the performance differences between BWA and healthy adults (e.g. Kiran et al., 2014). Similar to Chapter 2, we aim to understand the relationship between linguistic and executive control processes in BWA by using verbal fluency task (semantic and letter) with a broad range of variables (quantitative, time-course, and qualitative).

Another linguistic manipulation which has been used in the literature to understand the lexical activation/competition process in bilingual individuals during word production is the use of cognate and non-cognate words. Cognates are words that share the same meaning, and similar phonology across the two languages (e.g., /bʌtən/ in English and /bɔtʌm/ in Bengali) compared to non-cognate words that share only the meaning but not the phonology (e.g., /haʊs/ in English and /bʌri/ in Bengali). Majority of the studies have shown cognate facilitation that is better performance in the cognate words compared to non-cognates in both healthy and BWA (Costa, Caramazza, & Sebastian-Galles, 2000; Hoshino & Kroll, 2008; Roberts & Deslauriers, 1999). However, other studies have shown cognate inhibition as well as no difference between cognate and non-cognates in healthy as well as BWA (Broersma, Carter, & Acheson, 2016; Filippi, Karaminis, & Thomas, 2014; Tiwari & Krishnan 2015).

Cognate facilitation effect can be supported by the language non-selective hypothesis (Abutalebi & Green, 2007) which assumes the facilitation effects to arise from the shared phonological segments in both languages resulting in higher activation for the cognate words, whereas the non-cognate words receive activation only from the target language. No difference between cognates and non-cognates or cognate inhibition can be supported by the inhibitory control model of lexical access. According to the inhibitory control model (Green, 1998), the cross-language competition leads to the inhibition of the non-target word and the inhibition is required more for the cognate words as compared to non-cognates resulting in interference for the cognate words (Declerck & Philipp, 2015). Further, studies have shown executive control components, especially inhibitory control and working memory modulates the cross-language activation in healthy bilinguals during cognate production (Linck, Hoshino, & Kroll., 2008) but it is unclear which executive control components modulates the cross-language activation in BWA. Present project aims to examine the relationship between executive control and cross-linguistic activation/competition by including cognate and non-cognate words in a picture naming task.

We will provide the detailed literature review specific to these tasks task (verbal fluency and cognate/non-cognate picture naming) in Chapter 4 and 5, respectively

1.1.3 Methodological Consideration

Marian (2008) has outlined various methodological factors while considering research involving bilinguals. In the following section, we will discuss those methodological factors and their impact on the performance of bilinguals on both linguistic and executive control measures.

A probable reason for differences in linguistic performance in healthy as well BWA literature can be attributed to the combination of languages that the bilingual group speaks. Neighbour languages in a language family tree, share origin, vocabulary, phonological qualities, and orthographic features. There are different language families such as Central American, Dravidian, Sino-Tibetan, Austro-Asian etc., therefore, bilinguals who speak two similar languages, for example, English and German (both from Germanic language tree) may show different performance in a study of spoken or written language processing as compared to speakers of two languages that belong to different branches of the language family, such as English and Bengali (English comes from Germanic language tree whereas Bengali comes from Indo-Aryan language tree; Marian, 2008).

Recent studies which have investigated the relationship between linguistic and executive control mechanism have often ignored the importance of including a homogeneous group of bilinguals in terms of the first and second language they speak. For example, Luo, Luk, and Bialystok (2010) compared monolinguals and bilinguals on a verbal fluency test. However, their bilingual participants have only English language in common, and the other language was a mixed of different languages (e.g., 9 French speakers, 7 Cantonese, 4 Hebrew etc.). Similarly, bilinguals tested by Friesen, Luo, Luk, and Bialystok (2015), spoke English as one language and another language. Paap and Shawi (2014) tested 54 bilinguals who in addition to English were fluent speakers of Spanish, Vietnamese, French, Cantonese, Hindi and others. However, including a homogenous group of bilinguals will decrease the within-group variability amongst bilingual participants. The present study included a homogenous group of bilinguals with respect to their language combination, i.e., all the bilingual participants were speakers of English and Bengali in their day to day life.

Factors such as vocabulary knowledge may also influence performance in the linguistic and executive control tasks. Bialystok et al. (2008) have shown that bilinguals with lower vocabulary score do not demonstrate the advantage in the linguistic tasks involving greater executive control demands, but bilinguals with matched vocabulary score to monolinguals performed significantly better in the linguistic tasks with greater executive control demands (e.g. letter fluency). Thus, the bilingual advantage in linguistic tasks may not show if not controlled for vocabulary knowledge.

Age of second language acquisition and language proficiency have shown to influence the performance of bilinguals in linguistic as well as executive control measures. In the literature, based on the age of acquisition, bilinguals have been mostly classified into two groups namely, early bilinguals and late bilinguals. Early bilinguals are bilinguals who acquired both their languages since early childhood and late bilinguals are who learned their second language at a later stage of their life. Previous studies have shown better performance in both linguistic and executive control measures for early bilinguals as compared to late bilinguals (Bialystok, Craik, Klein, Viswanathan, 2004; Bialystok et al., 2008; Pelham & Abrams, 2014). Based on proficiency, bilinguals are classified into high-proficient and low-proficient bilinguals. Studies have shown performance difference between these two groups on both linguistic and executive control measures (Bialystok et al., 2008; Perani et al., 2003; Rosselli et al., 2002; Singh & Mishra, 2014).

In addition to the age of second language acquisition and proficiency, number of years of education is another crucial factor while selecting bilingual participants during psycholinguistic experiments. Ratcliff et al. (1998) have found that years of education have a significant effect on the performance in linguistic tasks. Participants with higher education performed better in linguistic and executive control measures than the participants with a lesser number of years of education. In addition to that, Marian has argued that psycholinguistic studies with bilinguals may also need to account for differences in language dominance, current usage of language, language switching habits, and IQ scores. Therefore, we have taken all these factors into account while characterising and selecting our bilingual participants.

1.1.3.1 Implications for aphasia. When it comes to studies involving BWA, most of the studies are single case studies (Detry, Pillion, & de Partz, 2005; Kambanaros, 2016; Kiran & Iakupova, 2011; Kohnert, 2004; Kurland & Falcon, 2011; Scott & Wilshire, 2010; Tiwari & Krishnan, 2015; Verreyt, De Letter, Hemelsoet, Santens, & Duyck, 2013) and involve speakers with Germanic languages, especially English (Beveridge & Bak, 2011). Beveridge and Bak (2011) published a comprehensive review article on the bias and diversity of aphasia research in terms of languages spoken by participants. Beveridge and Bak reviewed 1184 unique articles on aphasia from four journals published in between 2000-2009 inclusive. They found only 65 studies with speakers who spoke more than one language and out of 65 studies, only 18 were cross-linguistic comparison studies.

At present cross-linguistic studies involving aphasia patients are very limited. In addition, Beveridge and Bak found strong research bias towards Germanic and Romance languages (96.29% of all the articles) in aphasia research. The most under represented languages in the aphasia research were Arabic, Hindi, Bengali, Portuguese, and Russian. In summary, Beveridge and Bak suggested that the research on aphasia can make a significant contribution to the debate on language universals versus language variation, "however, in order to do so it needs to make cross-linguistic studies of aphasia one of its research priorities" (p. 1465). According to the 2001 Census of India, 255 million speakers in India speak more than one language in their day-to-day life and according to World Atlas of Language Structures (Haspelmath, Dryer, Gil, & Comrie, 2005), there are approximately 180.5 million native Bengali speakers (6th most spoken language) in the world (Ethnologue: Languages of the World, 2005). Yet, as can be seen from the review article by Beveridge and Bak, there is only one study with Bengali aphasia speakers. The present project address this research bias in aphasia by conducting a cross-linguistic comparison to understand the language breakdown in a group of speakers who spoke Bengali, a language of Indo-Aryan family.

In addition to the research bias and smaller sample size in studies involving BWA, there are various complexities to consider while studying BWA population. Studies have shown that patients with different pre-stroke language profile can present with similar post-stroke language impairment profile and patients with similar pre-stroke language profile can present with different post-stroke language profile (Gray & Kiran, 2013). As discussed earlier, age of acquisition, language proficiency, language dominance, language usage pattern, number of years of education are important factors that influence the language processing in healthy bilinguals. Therefore, while studying aphasia, these factors also need to be taken into account in addition to the site and size of lesion that are specific to aphasia (Fabbro, 2001; Lorenzen & Murray, 2008). Kiran and Gray (2018) noted that "it is important to understand bilingual aphasia in the context of relative impairment and relative recovery in determining whether both/all the clients' languages were similarly affected and consider pre-morbid proficiency when determining parallel patterns of impairment post-stroke" (pp. 381). To address the methodological issues involving BWA individuals, we have made a detail language profile in each language for each of our BWA participants by using demographic questionnaire (age, gender, site and extent of lesion, occupational history, literacy), language background questionnaire (acquisition history, language proficiency, usage, dominance), WAB in Bengali and English, and Croft's tests (naming, picture-to-word matching, reading, and writing) in Bengali and English.

In the following section, we will provide an introduction to Bengali, the differences with English at various linguistic levels, and the implications for the present study.

1.1.4 Linguistic Differences between Bengali and English and the Implications

Bengali (also known as Bangla) is the national language of Bangladesh (144 million speakers, 98% of total population, Bangladesh Census, 2001) and official language of the three states of India – West Bengal, Tripura and Assam (80 million speakers, 8.3% of total population, India Census, 2001). There are more than 224 million Bengali speakers in the world (speak Bengali as their first or second language in their day to day life) and is currently ranked as sixth most spoken language in the world (Comrie, 2005). Bengali is a member of Indo-European language family and many of its words are descendent of Sanskrit (Dil, 1991). However, despite the large number of Bengali speakers there are very few studies involving Bengali speakers, especially in aphasia (see Beveridge & Bak, 2011, for a review). Therefore, understanding the nature of language deficits, development of proper assessment tools, and therapeutic intervention is currently lacking.

In this PhD thesis, we have recruited healthy Bengali-English bilinguals as well as Bengali-English bilinguals with aphasia to provide an understanding to the nature of language abilities and deficits in Bengali-English bilingual speakers with aphasia. In the following section, we will provide the social and demographic picture of Bengali immigrants in

Berkshire, UK (recruited in Phase I) and native Bengali speakers residing in West Bengal, India (recruited in Phase II), followed by the linguistic nature of Bengali and how that may influence the current project.

The UK has the largest Bengali community (341,000 speakers according to the Joshua Project, US Center for World Mission, 2018) living outside of Bangladesh and West Bengal. Due to the long history of (1858-1947) British rule in India, there are many similarities between Bengali and English as well as many borrowed words in Bengali from English (Wright, 1991). However, at the structural level, there are distinct differences between these two languages. English has a Subject-Verb-Object word order whereas Bengali has a Subject-Object-Verb word order. As verbal fluency task especially, the letter fluency depends on the phonology of the language, therefore it is informative to describe the phonemes and the prosodic nature of Bengali.

Bengali sound inventory consists of 43 phonemes (Radice, 2007) – 29 consonants and 14 vowels (7 vowels and 7 nasalized counterparts). Table 1.1 illustrates the Bengali consonants. As can be seen from Table 1.1, Bengali has a larger range of consonants compared to English, however there is higher degree of phonological overlap between these two languages. Native Bengali words rarely have consonant clusters and the CVC (Consonant-Vowel-Consonant) is the most common syllabic structure. However, words borrowed from Sanskrit and English contain consonant clusters at the beginning or at the end (e.g. /*mrittü/* meaning death; /lɪft/ meaning lift or elevator).

Table1.1

Inventory of Bengali Consonants

	Labial	Dental/Alveolar Alveolar	Retroflex	Palatoalveolar	Velar	Glottal
Nasal	ম mɔ	ঞ ~ ণ ~ ন nɔ			ঙ ŋɔ	
Plosive						
Voiceless	প pɔ	ত t̪ɔ	ট ʈɔ	চ tʃɔ	ক kɔ	
Aspirated	ফ pʰɔ	থ t̪ʰɔ	ঠ ʈʰɔ	ছ tʃʰɔ	খ kʰɔ	
Voiced	ব bɔ	দ d̪ɔ	ড ɖɔ	জ ~ য dʒɔ~dzɔ	গ gɔ	
Aspirated	ভ bʱɔ	ধ d̪ʱɔ	ঢ ɖʱɔ	ঝ dʒʱɔ	ঘ gʱɔ	
Fricative		শ ~ স sɔ		শ ~ ষ ~ স ʃɔ		হ hɔ
Liquid		ল lɔ				
Rhotic		র rɔ	ড় ~ ঢ় ɽɔ			

Table1.2

Inventory of Bengali Vowels

	Front	Central	Back
Close	ই~ঈ i		উ~ঊ u
Close-mid	এ e		ও ʊ~o
Near open	এ্যা/অ্যা æ or ε		অ ɔ
Open		আ a	

Table 1.2 outlines the vowels in Bengali and it is important to note that /o/ is the inherent vowel in Bengali in contrast to /ə/ in English. This has an influence on the current project as letter fluency description will be realized slightly different for English phonemes as

opposed to Bengali phonemes, i.e. phoneme /p/ will be realized in English as [pə] but as [po] in Bengali. In terms of prosody, stress is usually placed on the initial syllable in Bengali. Intonation does not impact Bengali words in general, but at the sentence level, intonation plays an important role. Bengali words have a rising tone in simple declarative sentences except for the last word which is marked with low tone. This alternating high and low tones creates a musical intonational pattern to the typical Bengali sentence. Another major distinction between Bengali and English is the script that is the Bengali script has a one-to-one correspondence between the phonemes and the letters.

In terms of gender, there is no gender specification for Bengali nouns and verbs. Bengali nouns are inflected for case and numbers. The case marking for each noun depends on the animacy of the noun. Another distinctive feature of Bengali nouns is that during counting, Bengali nouns must be accompanied by appropriate measure word. The measure word must be in between the numeral and the noun word. In Bengali, measuring nouns without measure words are considered ungrammatical. In summary, the similarities and differences between Bengali and English language and the lack of studies in this language group especially in the aphasia population make this project a timely investigation.

Finally, using these various approaches, the research investigated the relationship between word production and executive control through four systematic experiments reported in Chapter 2 to 5. Table 1.3 presents a summary of all the experimental Chapters with its specific research questions and the methodology.

Table1.3

Summary of the Experimental Chapters with the Research Questions and Methodology

Chapter 2. Verbal fluency and executive control in healthy monolingual and bilingual speakers	
Specific research questions	**Methodology**
To determine the relative contribution of linguistic and executive control processes during word production in healthy monolingual and bilingual speakers by using verbal fluency task	*Participants*: 25 healthy young adult Bengali-English bilinguals and 25 healthy young adult English monolinguals. Groups were matched on age, years of education, and receptive vocabulary. Balanced bilinguals in terms of language of instructions during education, subjective language proficiency, and language dominance. During childhood, bilinguals had significantly greater Bengali exposure than English. Current usage of language was predominantly English; they were more prone to switch from Bengali to English than the reverse during day-to-day communication. *Linguistic tasks:* Verbal fluency tasks in English, two conditions - semantic (animals, fruits and vegetables, and clothing) and letter (F, A, S). *Variables*: Quantitative: (number of correct responses, fluency difference score), time-course (1st RT, sub-RT, initiation, slope), qualitative (cluster size, number of switches, within-cluster pauses, between-cluster pauses) *Executive control measures*: Inhibitory control (Stroop test: Stroop ratio), mental set-shifting (colour-shape task switch: switch cost for accuracy and RT), working memory (backward digit span test: backward digit span)
Chapter 3. Semantic contexts effects and executive control in healthy monolingual and bilingual speakers	
Specific research questions	
To determine the relative contribution of linguistic and executive control processes during word production in healthy monolingual and bilingual speakers by using a paradigm where executive control demands can be varied from low to high.	*Participants*: Same as Chapter 2. *Linguistic tasks*: Blocked cycling picture naming task. 25 black and white line-drawings of nouns across five semantic categories (animals, body parts, clothing, fruits and vegetables, and tools). Contexts (homogeneous, i.e., items are from same semantic category and heterogeneous, i.e., items are from different semantic categories) and five presentation cycles. *Variables:* Context effect (RT difference between the homogeneous and heterogeneous context) for all cycles, excluding first presentation cycle, and excluding cycle 2-4. Slope (changes in RT across cycles) *Executive control measures*: Same as Chapter 2

Chapter 4. Verbal fluency and executive control in bilingual aphasia (BWA) and bilingual healthy adults (BHA).	
Specific research questions	**Methodology**
To determine the relative contribution of linguistic and executive control processes during word production in bilinguals with aphasia and bilingual healthy adults by using verbal fluency task	*Participants:* Eight Bengali-English BWA and eight Bengali-English BHA. All BWA speakers sustained a single left hemisphere CVA and had mild to moderate non-fluent type aphasia in both languages and were matched with BHA on age, sex, and years of education, language acquisition history, language of instruction during education, self-rated language proficiency, language usage and language dominance. *Linguistic tasks:* Verbal fluency tasks in both languages, two conditions - semantic (animals, fruits and vegetables) and letter (*F, A, S* in English; *P, K, M* in Bengali) *Variables*: Same as in Chapter 2. *Executive control measures*: Inhibitory control (Stroop test: Stroop ratio), mental set-shifting (Trail Making Test: RT difference between trial B and A that is TMT B-A), working memory (backward digit span test: backward digit span)
Chapter 5. Cognate production and executive control in bilinguals with aphasia (BWA) and bilingual healthy adults (BHA).	
Specific research questions	**Methodology**
To examine the cross-linguistic interference/activation using a picture naming task with cognates and non-cognates in BWA and BHA. In addition, we also aimed to investigate whether the differential cognate/non-cognate naming abilities were influenced by their executive control.	*Participants:* Same as in Chapter 4 *Linguistic tasks*: Picture naming tasks in both languages. Black-and-white line drawings of 38 cognates and 38 non-cognates nouns matched for syllable length and subjective familiarity across word types and languages. *Variables*: Accuracy and RT for cognate and non-cognate pictures. *Executive control measures*: Same as Chapter 4.

Chapter 2. Verbal Fluency and Executive Control in Healthy Monolingual and Bilingual Speakers

2.1 Abstract

Background. Research has shown that bilinguals can perform similarly, better or poorly on verbal fluency task compared to monolinguals. These mixed results have been mainly attributed to the differences in vocabulary between the two groups. Although it is widely accepted that bilinguals have better non-verbal executive control, research is limited in exploring the relationship of executive control, vocabulary measures and verbal fluency to explain the mixed findings in the literature.

Aims. The overarching aim of this study was to determine the contribution of linguistic and executive control processes to word retrieval in bilingual and monolingual participants.

Methods & Procedure. Verbal fluency data for semantic (*animals*, *fruits and vegetables,* and *clothing*) and letter fluency (*F, A*, *S*) were collected from 25 Bengali-English bilinguals and 25 English monolinguals in English. The two groups were matched for age, English receptive vocabulary tests scores, years of education, non-verbal intelligence, and sex. Traditional analysis (e.g., number of correct responses) along with involved analysis techniques – such as fluency difference scores (FDS) between semantic and letter fluency conditions, time course analysis (1st RT, sub-RT, initiation, and slope), and qualitative analysis (e.g. clustering, switching, within-cluster pause and between-cluster pause) were performed. Participants also completed three executive control measures tapping into inhibitory control processes (Stroop task: Stroop ratio), mental-set shifting (colour-shape switch task: switch cost for accuracy and RT) and working memory (backward digit span test: backward digit span).

Outcomes & Results. Bilinguals and monolinguals showed differences in both linguistic and executive control domains. Specifically, differences were observed where executive control demands were higher such as number of correct responses (CR) in the letter fluency, FDS, mean response latency, slope, cluster size for letter fluency and BCP for letter fluency. On the

separate executive control measures, compared to the monolinguals, bilinguals showed significantly better inhibition and mental shifting skills but a comparable working memory. The verbal fluency slope correlated significantly with the inhibitory control measure for the bilinguals but not for the monolinguals.

Conclusions & Implications. Bilinguals, when matched for vocabulary, performed similarly to monolinguals in semantic fluency where the demand of linguistic processes were higher but performed better in the difficult letter fluency where executive control demands were higher. Findings from the correlational analysis suggest that superior executive control abilities of bilinguals helped them to perform better than monolinguals only where the task difficulty is higher (i.e. letter fluency slope). Findings also highlight the importance of using separate measures of executive control abilities to explore the bilingual advantage and disadvantages reported in the literature.

2.2 Introduction

The verbal fluency task requires speakers to produce as many unique words as possible within a limited amount of time, usually 60 seconds, according to a given criterion (e.g., semantic or category; letter or phonemic). Successful performance requires the use of specific cognitive strategies, such as initiation, inhibition, monitoring, set-shifting to perform systematic search and retrieve words within the mental lexicon. The integrity of both linguistic and executive control abilities is essential for productive performance. However, respective contribution of linguistic and executive components for semantic and letter fluency condition is differential; higher demands are placed on executive control mechanisms in letter fluency; while a larger role is placed on linguistic abilities in the semantic fluency (Delis, Kaplan, & Kramer, 2001). This feature has made it an appealing task to explore differences in linguistic and executive processes between monolinguals and bilinguals.

Verbal fluency research comparing bilingual and monolingual performance have shown mixed results (Bialystok et al., 2008; Lu et al., 2010; Paap et al., 2017; Sandoval, Gollan, Ferreira, & Salmon, 2010). In semantic fluency, monolinguals generate more number of correct responses than bilinguals (Gollan et al., 2002; Rosselli et al., 2000; Sandoval et al., 2010). However, this bilingual disadvantage disappeared when the groups were matched on receptive vocabulary (Bialystok et al., 2008; Luo et al., 2010). For letter fluency, findings have been wide ranging from lesser to equivalent to greater number of correct responses by bilinguals (Bialystok et al., 2008; Kormi-Nouri, Moradi, Moradi, Akbari-Zardkhaneh, & Zahedian, 2012; Rosselli et al., 2000; Luo et al., 2010; Paap et al., 2017; Sandoval et al., 2010). Luo et al. (2010) found that their vocabulary matched bilinguals outperform monolinguals on letter fluency condition, proposing that it is suggestive of better executive control in bilinguals. Although the approach to inform the debate of bilingual advantage/disadvantage in executive and linguistic processes using verbal fluency task is promising, the number of empirical research has been limited, and there is a dire need for replication. Paap et al. (2017) suggested that “relatively better performance by a group on letter fluency compared to category fluency cannot be taken as evidence that the group has superior executive functions. Rather such a claim must be backed up by independent and direct test of EF ability” (p.108). Moreover, research that has attempted to link direct measure of executive control to verbal fluency performance (at least in monolinguals) did not find that executive control had a stronger effect on performance in the letter than in the category fluency task (Shao et al., 2014). Thus, it remains an open question to determine whether bilinguals and monolinguals perform differentially in semantic and letter fluency task and whether their performance differences are mediated by specific aspects of executive control abilities.

In this research, using both semantic and letter fluency as well as independent measures of executive control we investigate the interaction of linguistic and executive control processes for bilingual and monolingual speakers. Moving beyond the number of correct responses, we used a wide range of methods to characterize verbal fluency performance, such as time-course analysis, and clustering and switching analysis (Luo et al., 2010; Troyer, Moscovitch, & Winocur, 1997). These measures were chosen as they better reflect the contribution of linguistic and the executive components of the fluency performance. Table 2.1 provides description of these variables and the components of verbal fluency they are assumed to be indexing. To our knowledge, no study has systemically compared healthy bilinguals and monolinguals on this full range of measures. Moreover, to establish, if bilinguals are indeed better in letter fluency due to superior executive control, we included independent measures of executive processes (i.e., inhibition, shifting, and memory) to compare performance differences between bilinguals and monolinguals, and their relationship to verbal fluency performance.

Table2.1

Contribution of Verbal Fluency Variables to the Linguistic and Executive Control Components

Parameters	Definition	Significance	**Linguistic process**	**Executive control processes**
Quantitative				
1. Number of correct responses	Number of responses produced in one minute excluding any errors (e.g. cross-linguistic, words from different category for semantic fluency and different letters for letter fluency, repetition, non-word etc).	Measures word retrieval abilities.	√	√
2. Fluency difference score	Differences in the number of correct responses between semantic and letter fluency conditions as a proportion of correct responses in the semantic fluency condition.	Measures the ability to maintain the performance in the difficult condition.		√
Time course				
1. 1st RT	Time duration from the beginning of the trial to the onset of first response.	Preparation time to initiate the response.	√	
2. Sub-RT	Average of time intervals from the onset of first response to the onset of each subsequent response.	Measures the word retrieval latency.		√
3. Initiation	Starting point of the logarithmic function that is the value of y when $t = 1$ or $In(t) = 0$ (e.g. initiation parameter for the above mentioned logarithmic function is $y = 4.31 - 1.312\ In(1) = 4.31 - 0 = 4.31$).	Measures the initial linguistic resources or vocabulary available to perform the task.	√	
4. Slope	Shape of the curve (e.g. slope value for the logarithmic function $y = 4.31 - 1.312\ In(1)$ is -1.312).	Measures the word retrieval speed across the time duration of the task.		√
Qualitative				
1. Cluster size	Number of successive words produced within a semantic subcategory (e.g. African animals, Pets, etc.) or number of successive words which fulfil certain criteria (e.g. begin with first two letters, rhyme words, etc.) in the letter fluency condition.	Strategy to perform efficiently by searching the available linguistic resources in the present subcategory.	√	
2. Number of switches	Number of transitions between two clusters, one cluster to a single word, one single word to another cluster, or between two single words.	Strategy to perform efficiently by switching into a newer subcategory when the search process is exhausted for the present subcategory.		√
3. Within-cluster pauses	Mean time differences between each successive word within the same cluster	Time to access new words within a cluster.	√	
4. Between-cluster pauses	Mean time difference between the onset time of the last word of a cluster and first word of the consecutive cluster.	Time to switch between clusters.		√

As verbal fluency tasks place a premium on rapid search and retrieval, temporal measures of the performance (i.e., time interval required to produce each word as a function of its position in the sequence) provide insights into the linguistic and executive control strategies (e.g., Crowe, 1998; Tröster et al., 1998). Techniques such as time-course analysis have provided ways to assess the role of linguistic knowledge and executive control in verbal fluency performance (Luo et al., 2010; Sandoval et al., 2010). In time-course analysis, the number of words generated over the 60 second time interval is grouped into 5-second time bins; with declining pattern presented by plotting the number of words produced against time.

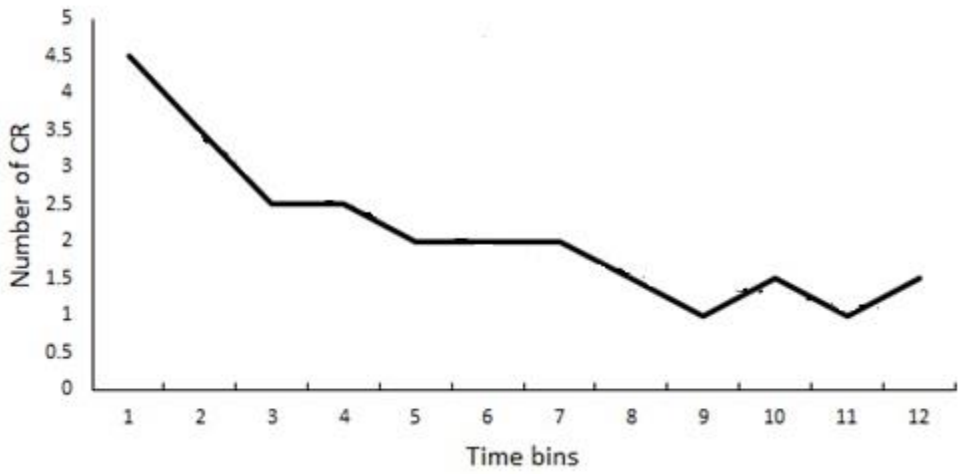


Figure 2.1 Time course of correct responses over twelve 5-sec bins.

Figure 2.1 allows generating various parameters that tap into the linguistic and executive processes involved in the retrieval of words: First response time (1^{st}-RT), subsequent response time (sub-RT); initiation parameter; and slope (See Table 2.1). Luo et al. (2010) compared semantic and letter fluency performance for a group of young monolinguals vs. two groups of young bilinguals (high-vocabulary who were matched with monolinguals; low-vocabulary bilinguals). Their results revealed that in the letter fluency condition, high-vocabulary bilinguals generated more number of correct responses and demonstrated a longer Sub-RT and a flatter slope than the monolinguals.

Similar results have been obtained by Friesen et al (2015). Friesen et al (2015) tested four groups of participants – two groups of 7-year old and 10-year old monolingual and bilingual children, one group of younger monolingual and bilingual adults, and one group of older monolingual and bilingual adults – on a verbal fluency test. All monolinguals were native English speakers and bilinguals spoke English and another language fluently. Friesen et al found no main effect of age but the main effect of language group and a marginal age by language group interaction. There were no differences between bilinguals and monolinguals on the semantic fluency condition, but bilinguals produced more number of correct responses (CR) on the letter fluency condition suggestive of executive control advantage for bilinguals on the difficult letter fluency condition.

In contrast, studies have also shown that bilinguals produced longer sub-RT along with fewer number of correct responses compared to monolinguals in the letter fluency condition (Sandoval et al., 2010). These authors argued that the bilingual disadvantage results from the cross-linguistic interference which slows down their word retrieval process, as denoted by longer sub-RT. As vocabulary-matched bilinguals produced more number of correct responses compared to monolingual, it is unlikely that retrieval slowing hypothesis can explain the bilingual advantage (Friesen et al., 2015; Luo et al., 2010). Instead, bilingual's better performance in the letter fluency in conjunction with the longer sub-RT have been argued to be result of bilingual's superior executive control abilities. This has been proposed to be a by-product of constant cross-linguistic interference faced by bilinguals.

Fluency difference score (FDS) has been suggested to capture the role of executive control in fluency task (Friesen et al., 2015). FDS is the differences in the number of correct responses between semantic and letter fluency conditions as a proportion of correct responses in the semantic fluency condition. Therefore, individuals who can maintain better performance in the difficult letter fluency condition would show smaller FDS score; indicative of better executive control abilities (Friesen et al., 2015).

The production of words during verbal fluency performance are not evenly distributed over time, but tend to be produced in “spurts”, or temporal clusters, with a short time interval between words in a cluster and a longer pause between clusters (Gruenewald & Lockhead, 1980; Troyer et al., 1997). On semantic fluency tasks, the words that comprise these temporal clusters tend to be semantically related (e.g., first name farm animals, then switch to pets, then to birds); on letter fluency tasks, the words tend to be phonologically related (e.g., words that start with same first two letters, then switch to words that rhyme, then to words that has same ending). Clustering is the strategic process that helps to generate words within a subcategory and utilizes the speaker’s ability to access words within subcategories. A breakdown in the lexical system or difficulty to access the lexical system could lead to the reduction in cluster size (Troyer, Moscovitch, Winocur, Alexander, & Stuss, 1998).

Switching is the ability to shift efficiently to a new subcategory when a subcategory is exhausted; reduced switching has been linked to executive control difficulty (Troyer et al., 1997; Tröster et al., 1998). Research has shown that both clustering and switching abilities contribute to the total number of correct responses; however, in category fluency, clustering accounts for more of the variance for number of correct; whilst in letter fluency, switching accounts for more of the variance for number of correct. Thus, clustering and switching analysis provides another well-established mean to further inform the linguistic and executive debate for bilinguals vs. monolinguals.

It has been proposed that bilinguals’ both languages are active during language tasks, and they need a control mechanism that suppresses the interference from the other language while performing a task in the target language (for review, see Kroll et al., 2012). Researchers have claimed that bilinguals can resolve the interference from the non-target language by their constant engagement with the executive control processes (Abutalebi & Green, 2008). The specific of the executive processes that distinguishes bilinguals and monolinguals is a hotly debated area in the literature (Bialystok, 2011; Hilchey & Klein, 2011).

For this research, we aimed to establish the executive control processes that underpin verbal fluency differences between the monolinguals and bilinguals, especially to allow us to determine which aspects of executive control contribute to the superior performance of letter fluency task for bilinguals. We measured three components of executive control – inhibitory control, mental set-shifting and working memory – modelling on Miyake et al.´s framework of the three domains of executive control (Miyake et al., 2000).

Inhibitory control in bilingual research has been assessed using the Simon task, the Flanker task, and the Stroop test. Although many studies have reported bilingual advantage on these tasks (e.g., Bialystok et al., 2004; Bialystok et al., 2008), no difference or similar performance between monolingual and bilinguals have also been noted (e.g., Kousaie & Philips, 2012; Paap & Greenberg, 2013). Similarly, on mental set-shifting measured using task switching paradigms have reported divergent findings (Paap & Greenberg, 2013; Prior & MacWhinney, 2010). For example, Prior and MacWhinney (2010) compared English young monolinguals and bilingual speakers on a colour-shape non-verbal switch task. This task measures the difference in response time (switch cost) between non-switch trials and the switch trials. They found that bilinguals had a smaller switch cost than monolinguals, suggesting a bilingual advantage in mental set-shifting. However, other studies did not find any switch cost difference between bilinguals and monolinguals using the same colour-shape switch task (Paap & Greenberg, 2013; Paap & Sawi, 2014). Literature on the working memory and bilingualism also remains equivocal, with results ranging from either advantage or disadvantage as well as no working memory differences between bilinguals and monolinguals (Bialystok et al., 2004; Bialystok et al., 2008; Blom et al., 2014; Fernandes et al., 2007; Luo et al., 2010).

Since verbal fluency performance rely both on linguistic and executive control, it is imperative to explore which component of executive control mediates verbal fluency performance (see Paap et al., 2017). No research has reported the relationship of executive control measures to the bilingual vs. monolingual performance difference on verbal fluency. There exists only one study with healthy monolingual adults that investigated the verbal fluency performance with measures of executive control (Shao et al., 2014). Shao et al. had assessed older Dutch speakers on both semantic and letter fluency conditions and related their performance with the measures of executive control (i.e., shifting between mental-sets, operation span; inhibitory control, stop-signal task). Results revealed that only shifting ability predicted the number of correct responses in both fluency conditions. Shao et al. noted that "there was no evidence that executive control had a stronger effect on performance in the letter than in the category fluency task" (p.8). The authors cautioned that the inhibitory control task (i.e., stop-signal task) used in their study may not have represented the inhibitory control required for the verbal fluency task. The stop-signal task measures how fast an individual can stop a planned response, whereas, in verbal fluency, participants need to suppress the activation of competitor lexical items (selective inhibition) to come up with the target word. For this research, we use the Stroop task to measure the selective inhibition (Stroop, 1935), the colour-shape switch task to measure the shifting ability (Prior & MacWhinney, 2010), and the backward digit span test to measure the working memory (Wechsler, 1997).

There remain other important considerations in bilingual experimental research. Recent literature has emphasized the need of including homogeneous bilinguals, as unable to control the different language combinations results in wide range of performance that could be attributed to typological and structural differences amongst the languages (Marian, 2008). Language proficiency of bilinguals has shown to be a significant contributor for verbal fluency performance (Bialystok et al., 2008; Gollan et al., 2002; Luo et al., 2010). When bilinguals were matched with monolinguals in terms of language proficiency, they either outperform (Luo et al., 2010) or perform at par with the monolinguals (Bialystok et al., 2008; Paap et al., 2017). In contrast, low proficient bilinguals perform poorly (Gollan et al., 2002) compared to the monolinguals. Therefore, including a homogenous group of bilinguals in terms of language combination and proficiency would decrease the within-group variability amongst participants and findings could be attributed to the processes that are tested.

2.3 The Current Investigation, Research Questions and Predictions

We compared the differences in verbal fluency performance in two groups of young healthy participants; 25 English monolinguals and 25 Bengali-English bilinguals. The groups were matched on receptive vocabulary, years of education, age and non-verbal intelligence. We collected semantic (animals, fruits, vegetables) and letter (F, A, S) fluency data for 60 s in English. We provided detailed characterization of our bilingual participants on relevant variables for bilingualism: language history and acquisition patterns, usage patterns, proficiency and dominance, switching habits, immigration history, and occupational status. Our bilingual participants formed a relatively homogenous group of balanced bilinguals in terms of language of instruction during education, self-rated language proficiency and language dominance. All bilingual participants were born in Bengali speaking region in India and acquired Bengali as their first language. However, they used English more in their day to day life and switched more from Bengali to English as they were living in the UK at the time of this research.

We quantified the verbal fluency performance in terms of quantitative (number of correct responses, fluency proportion difference score); time-course (1st-RT; Sub-RT;

initiation; slope); and qualitative (cluster size; number of switches). Executive control processes were measured using the Stroop (measured selective inhibition), the colour-shape switch task (measured shifting between mental sets) and the backward digital span (measured working memory) tasks.

The overarching aim of this study was to determine the contribution of linguistic and executive control processes to word retrieval in bilingual and monolingual participants. To address this overall aim, we used verbal fluency task and specific research questions and predictions were the following:

1. To determine differences in verbal fluency performance (quantitative, time course, and qualitative analysis) between bilingual and monolingual participants.

   As the groups were matched on vocabulary, we predict bilinguals to perform similarly to monolinguals on semantic fluency condition but potentially more number of words in letter fluency condition. In similar vein, we do not expect differences in cluster size. If bilinguals were to show superior executive control, then compared to monolinguals we would expect bilinguals to demonstrate; smaller FDS; more number of switches, and shorter between-cluster pauses; and in the time-course analysis, longer Sub-RT and flatter slope in letter fluency.

2. To determine measures of executive control (inhibitory control, mental set shifting, and working memory) that mediate verbal fluency performance difference between the groups.

   We expect that if bilinguals are to show advantage in letter fluency condition, then executive control measures would have a stronger correlation with performance measures that related to the executive control abilities (i.e., FDS, slope, number of switches, and between-cluster pauses).

2.4 Methods

2.4.1 Participants

Twenty-five Bengali-English bilingual healthy adults (*M* = 32.84, *SD* = 4.78) and 25 English monolingual healthy adults (*M* = 30.4, *SD* = 8.2) residing in the town of Reading, and Slough of Berkshire county, United Kingdom participated in this study. A screening questionnaire was used to gather information about their handedness, auditory and visual ability, and history of any neurological illness. All the participants reported themselves to be right-handed, normal or corrected to normal vision, no history of hearing impairment and no history of any neurological illness. Monolingual participants were recruited from the university student population (received course credit for participation) and local community (Reading, Berkshire, UK). Bilingual participants were recruited from the local Bengali community (e.g., Bengali Cultural Society of Reading, Berkshire, UK).

A background questionnaire was used to collect information about the demographic details (age, gender, years of education, current occupation status, and immigration history) of all the participants. The participants in both groups had a wide range of occupations. Monolingual participants were university student (14), engineer (3), manager (2), accountant (1), businessman (1), technician (1), administration (1), maintenance (1), and support worker (1). Bilingual participants were home maker (7), engineer (6), university student (5), businessman (2), accountant (1), doctor (1), clerk (1), lecturer (1), and sales (1). Bilinguals were immigrants who have lived in the Berkshire county (Reading, Slough) of the UK, ranging from 1 year to 15 years (*M* = 7.48, *SD* = 3.58). Bilingual participants spoke Bengali and English fluently; had minimal or no knowledge of any other language. Bilinguals were biliterate, that is, they were able to read and write in both languages. In a 7-point self-reported rating scale (where 1 is no or minimum knowledge and 7 is native like ability), reading and writing ability of bilinguals were similar in both languages (Reading: Bengali, *M*

= 6.7, *SD* = .6; English, *M* = 6.7, *SD* = .5; Writing: Bengali, *M* = 6, *SD* = .5; English, *M* = 6.4, *SD* = .6). Participation in this study was voluntary and participants provided written consent (see Appendix 2.1 for an example of information sheet and consent form) prior to participation. All the procedures in this study were approved by the University of Reading Research Ethics Committee (Ethical approval code: 2014/060/AB).

Demographic details (age, gender, and years of education) and scores for nonverbal IQ from Raven's standard progressive matrices *plus* version (SPM *Plus*, Raven, 2008) are presented in Table 2.2. Appendix 2.5 provides raw score of each individual for all the background measures (age, gender, years of education, IQ, years of immigration, occupation) and the objective language tests (OPT, BPVS-III). Independent sample t-tests were performed where data was normally distributed and Mann-Whitney U tests were performed where data was not normally distributed. The groups did not differ significantly on age, gender, years of education and non-verbal IQ.

Table2.2

Mean (M), Minimum (Min) and Maximum (Max) values, Standard Deviations (SD), and Statistical Results of the Demographic Variables and Raven's SPM-plus.

	Bilingual (N =25)			Monolingual (N = 25)			Statistical results
Measures	*M*	*Min-Max*	*SD*	*M*	*Min-Max*	*SD*	
Age (years)	32.8	27-45	4.8	30.4	22-45	8.2	$t(48) = 1.3, p = .21$
Years of education	18.1	16-20	1.6	17.1	15-20	1.2	$U^1 = 311.5, p = .98$
Raven's IQ[2]	43.5	38-51	3.8	43	33-54	5.4	$U^2 = 275.5, p = .47$
Gender	*N*			*N*			
Female	11			12			$\chi 2\ (1) = .08, p = .78$
Male	14			13			

[1] – Mann-Whitney U test; [2] - Raven's Standard Progressive Matrices Intelligence Quotients (Raven, 2008), maximum score possible 60, greater score indicates higher non-verbal intelligence; * $p \leq .05$.

2.4.2 Background and Executive Control Measures

In this section, we will discuss the language background measures and the executive control measures. First, we will describe the subjective measures used for characterising our bilingual participants followed by the objective vocabulary tests. At the end, we will discuss the three executive control measures.

2.4.2.1 Bilingualism measures. Bilinguals were assessed using various measures to document their characteristics of bilingualism. We adapted and modified the questionnaire developed by Muñoz, Marquardt & Copeland (1999). This questionnaire (see Appendix 2.2) assessed language acquisition history, instruction of language during education, self-rated language proficiency across speaking, comprehension, reading and writing, and current language usage pattern. Language dominance was measured using the language dominance questionnaire (Dunn & Fox Tree, 2009), and language switching habits in both of their languages were assessed using language switching questionnaire (Rodriguez-Fornells, Krämer, Lorenzo-Seva, Festman, & Münte, 2012).

2.4.2.2 Vocabulary tests. To assess participants' receptive vocabulary, all participants were assessed on two standardised tests: Oxford Placement Test (Oxford University Press and Cambridge ESOL, 2001) and the British Picture Vocabulary Scale III (Dunn & Dunn, 2009).

2.4.2.3 Inhibitory control (Stroop task). The Stroop task (Stroop, 1935) is one of the most widely used and best-known procedures to study response interference and selective inhibition (Bialystok et al., 2008). In the classic Stroop task, participants are shown a patch of colour in one condition (neutral) and they identify the colour. In another condition (incongruent), colour words are written in a contrasting print colour (e.g., 'red') and participants are asked to say the name of the print colour (response would be 'green'). Participants produce more errors and have longer latencies in the incongruent condition as compared to the neutral condition. The difference in accuracy and latency between the incongruent condition and the neutral condition is referred to as Stroop effect (for review, see MacLeod, 1991).

In present study, the stimulus consisted of six basic colours/colour word names: red, green, blue, yellow, orange, and purple. In the neutral condition, participants named the colour of differently coloured rectangles. A series of 50 coloured rectangles, each in one of the six colours were presented in a random order such that two successive trials never had the same colour. In the incongruent condition, participants had to name the font colour of the colour words as quickly and accurately as possible. A series of 50 colour words were shown one at a time on the screen in a random order, each of which was presented in a colour other than the word's name (e.g., 'red' in 'green' colour). Both conditions were completed during a single session with the neutral condition first followed by the incongruent condition. All responses were recorded with a digital voice recorder. The onset of each stimulus was accompanied by a beep, which allowed latency measurement. The latency for each naming response was measured from the onset of the beep to the onset of the naming.

The interference effect or the Stroop difference was scored by subtracting the reaction time in the neutral condition from the incongruent condition (Scott & Wilshire, 2010). A lower Stroop difference indicated better inhibitory control. However, calculating the Stroop difference in this way sometimes yield similar results even when the interference effects are not similar. For example, a reaction time of 800 msec in the incongruent condition minus a reaction time of 400 msec in the neutral condition will give a Stroop interference effect of 400 msec (Example 1 in Appendix 2.3). Again, a reaction time of 1200 msec in the incongruent condition minus a reaction time of 800 msec in the neutral condition will also give a Stroop interference effect of 400 msec (Example 2 in Appendix 2.3). However, the difference score does not take overall slowness into account which is a crucial factor while assessing Stroop interference (Green et al., 2010). Therefore, we measured Stroop ratio as our dependent variable to measure the interference effect in relation to the participant's performance in both neutral and incongruent condition. However, we do provide the mean and sd for all both conditions (i.e., neutral and incongruent). Stroop ratio was calculated by dividing the Stroop difference with the overall mean latency. The ratio was then converted to a percentage score. Stroop ratio in example 1 and 2 is 66.67 and 40, respectively (see Appendix 2.2 for a worked-out example). A lower Stroop ratio indicated better inhibitory control.

2.4.2.4 Mental-set shifting (colour-shape switch task). In a colour-shape switch task, participants had to switch between colour judgement and shape judgements trials (Prior & MacWhinney, 2010). We adapted Prior and MacWhinney's (2010) colour-shape switch task. Target stimuli consisted of filled red triangle, red circle, green triangle and green circle. Participants had to judge the colour or shape of the stimuli based on a cue. There were two types of cues: colour cue (colour gradient) and shape cue (row of small black shapes). If the cue was a colour cue, participants had to judge the colour of the stimulus (red or green) and if the cue was a shape cue, participants had to judge the shape of the stimulus (circle or triangle). Cue was followed by the target stimulus which appeared at the centre of the screen while the cue remained on the screen above the target stimulus.

The task was presented via E-Prime (Psychology Software Tools, Pittsburgh, PA). Each trial started with a fixation cross for 500ms after which the cue appeared on the screen for 250ms, 2.8° above the fixation cross followed by a blank screen for about 300ms. The targets were red or green circles (2.8°*2.8°) and red or green triangles (2.3°*2.3°). The cue and target remained on the screen until response or for a maximum duration of 2000ms. This was followed by a blank screen for about 1000ms before the onset of the next trial. Participants were required to press the key on a computer corresponding to red/green colour or triangle/circle shape.

In this task, half of the trials were switch trials and half were non-switch trials. In the switch trial, a colour stimulus preceded the shape stimulus (colour to shape switch) or a shape preceded the colour stimulus (shape to colour switch). In the non-switch trial, a colour stimulus always preceded another colour stimulus (colour to colour) and a shape stimulus always preceded another shape stimulus (shape to shape). There were 20 practice trials followed by 3 blocks of 48 experimental trials each. There were total 72 switch trials and 72 non-switch trials. Reaction time and accuracy were measured for switch trials and non-switch trials, separately. We derived two dependent variables – switch cost for reaction time (SC_{RT}) and switch cost for accuracy (SC_{ACC}).

$$SC_{RT} = RT_{SWITCH\ TRIAL} - RT_{NON-SWITCH\ TRIAL}$$

$$SC_{Accuracy} = \%Accuracy_{NON-SWITCH\ TRIAL} - \%Accuracy_{SWITCH\ TRIAL}$$

Smaller switch cost meant participants had smaller difference (i.e., equivalent performance) between the easier (non-switch trial) and the difficult condition (switch trial). This would suggest efficient shifting ability (Prior & MacWhinney, 2010).

2.4.2.5 Working memory (backward digit span). We used the subtest from the Wechsler Memory Scale (WMS 3, Wechsler, 1997) to measure the backward recall of digit sequences. This is thought to reflect working memory performance (Wilde, Strauss, & Tulsky, 2004). Participants were verbally presented an increasingly longer series of digits, 2 to 9, and then were asked to repeat the sequence of the digits in reverse order. The rate of presentations was one digit per second. The test terminated failing two consecutive trials at any one span size or when the maximum trial size was reached. Backward digit score was the total number of lists reported correctly in the backward digit span test.

2.4.3 Verbal Fluency Measures

2.4.3.1 Trials and procedures. All the participants completed two verbal fluency conditions − semantic and letter – in English. They were asked to produce as many words as possible in 60 s. In semantic fluency condition, participants produced words in three categories− animal, fruits and vegetables, and clothing items. In letter fluency condition, participants were asked to produce words that start with letters *F, A,* and *S*. The restrictions for the letter conditions were to produce unique words that are not proper names or not numbers (e.g., Singapore, seven), and to not produce variants of the same words (e.g., shop, shopper, shopping). The orders of the fluency conditions were randomized across participants; however, the trials were blocked by condition. Each participant was tested individually. After providing the instruction, the participant started a trial only when the tester said “start”. This ensured that there was a definitive starting point for each trail. Responses were recorded with a digital voice recorder and later analysed for the following variables.

2.4.3.2 Data coding and analysis. All responses (including repetition and errors) were transcribed verbatim. Each correct response was time-stamped using PRAAT (Boersma & David, 2015). The time-stamping enables to index the onset of a response from the onset of the trail (i.e., “start”). That is, it is the time that has elapsed from the beginning of the trial until the onset of the response, which allowed us to calculate the variables in time-course analysis. We measured the following variables for each trial:

2.4.3.2.1 Total number of correct responses (CR). CR was calculated after excluding the errors. In semantic fluency, errors were repetition of same words, words that were not from the target category (e.g., *cat* as a response for clothing category), or cross-linguistic intrusions. In letter fluency, CR was calculated after excluding repetition of same words, words that began with a different letter (e.g., *pig* as a response for letter *F*), proper nouns (e.g., *France* as a response to letter *F*), same word but with different endings (e.g. *fast, faster, fastest* were counted as single CR), and cross-linguistic intrusions.

2.4.3.2.2 Fluency difference score (FDS). The FDS was calculated first by subtracting the mean of letter fluency score ($CR_{\text{letter fluency}}$) from the mean semantic fluency score ($CR_{\text{semantic fluency}}$) and then dividing the difference by the mean semantic fluency score ($CR_{\text{semantic fluency}}$) for each participant.

$$FDS = (CR_{\text{semantic fluency}} - CR_{\text{letter fluency}}) / CR_{\text{semantic fluency}}$$

2.4.3.2.3 Time-course analysis variables. Four variables were analysed following Luo et al.’s (2010) recommendation: 1^{st} RT; Sub-RT; initiation parameter; and slope. Based on the time tag, CRs were grouped into 5-sec bins over each 60-sec trial, resulting in 12 bins. The group means of CR in each of the twelve bins were calculated for each semantic and letter fluency trial. The means of CRs for each trial were plotted using a line graph (x variable, bins; y-variable, mean CR). This graph was then fitted with logarithmic function. An example of a logarithmic function (see *Figure 2.2*) is $y = 4.31 - 1.312\ In(t)$, where y

is the estimated value of the function at different points of time(t). Two central measures derived from this plot were: initiation parameter and slope.

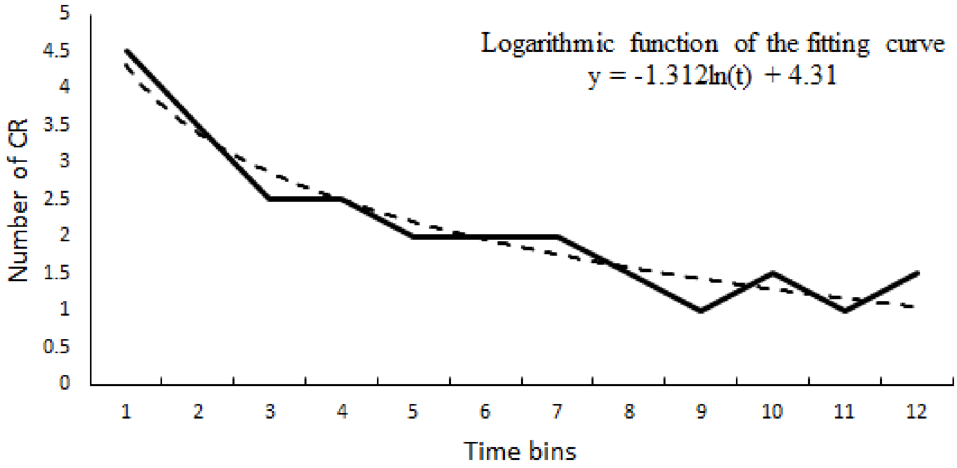


Figure 2.2 Time course of correct responses over twelve 5-sec bins. Best-fit line is logarithmic functions.

2.4.3.2.3.1 1st-RT. The 1st-RT is the time interval from the beginning of the trial to the onset of first response. The first response usually takes longer than the subsequent responses and this delay in first response has been linked to the task preparation (Rohrer, Wixted, Salmon, & Butters, 1995).

2.4.3.2.3.2 Sub-RT. Subsequent-RT (Sub-RT) is the average value of the time intervals from the onset of first response to the onset of each subsequent response. Thus, Sub-RT provides a good estimate for mean retrieval latency and represents the time point at which half of the total responses have been generated (Sandoval et al., 2010) . A longer mean Sub-RT indicates that performance extends later into the time course, but interpretation of this variable depends on the total number of correct (Luo et al., 2010). If one group produces more correct responses than another group and has longer mean Sub-RT, then the interpretation is that the group has superior control (and equivalent or better vocabulary) and could continue generating responses longer. If one group produces fewer or equivalent correct responses but has longer mean Sub-RT, then the interpretation is that the control is more effortful as it took longer to generate the same or a fewer number of items. In contrast, a shorter mean Sub-RT would indicate a faster declining rate of retrieval because a large proportion of the responses were produced early during the trial.

2.4.3.2.3.3 Initiation parameter. This parameter is the starting point of the logarithmic function that is the value of y when $t = 1$ or $In(t) = 0$ (e.g., initiation parameter for the above mentioned logarithmic function is $y = 4.31 - 1.312\,In(1) = 4.31 - 0 = 4.31$). Initial parameter indicates the initial linguistic resources/breath of lexical items available for the initial burst when the trail begins and is largely determined by vocabulary knowledge.

2.4.3.2.3.4 Slope. Slope of the plot is determined by the shape of the curve and refers to the rate of retrieval output as a function of the change in time over 60-sec. Slope for the above example would be 1.31. It reflects how the linguistic resources are monitored and used over time and is largely determined by executive control. Flatter slope indicates that participants were able to maintain their performance across the response period despite greater lexical interference (e.g. avoiding repetition, searching for words from the already exhausted vocabulary source) towards the end of the trial, reflecting better executive control.

2.4.3.2.4 Qualitative analysis. We closely followed the methods used by Troyer et al.'s (1997) to perform our clustering and switching analysis. Repetitions were included for clustering and switching analysis. Semantic fluency clustering was defined as successively produced words that shared a semantic subcategory. Letter fluency clustering was defined as successively generated words which fulfil any one of the following criteria (Troyer et al., 1997): words that begin with the same first two letters (*stop* and *stone*); words that differ only by a vowel sound regardless of the actual spelling (*son* and *sun*); words that are rhyme (*stool* and *school*); or words that are homonyms (*sheep* and *ship*). Appendix 2.3 provides the details of the subcategories. Two variables were generated subsequent to clustering the responses:

2.4.3.2.4.1 Mean cluster size. Cluster size was calculated beginning with the second word in each cluster. A single word was given a cluster size of zero (e.g. *crocodile*), two words cluster was given a cluster size of one (e.g. *bear, fox* belong to North American animal cluster and cluster size of one), three words cluster was given a cluster size of two (e.g. *rhinoceros*, *hippopotamus*, *deer* belong to African animal cluster and cluster size of two) and so on. Mean cluster size for a trial was calculated by adding the size of each cluster and dividing the total score by the number of clusters.

2.4.3.2.4.2 Number of switches. Number of switches was the number of transitions between clusters. For example, *dog, cat; snake, lizard; horse, cow, goat* contain two switches – before snake and before horse. *Leopard, cheetah; kangaroo, koala bear; robin, sparrow, crow; chimpanzee, orang-utan, baboon* has three switches – before kangaroo, robin and chimpanzee. Similarly, in letter fluency – *fragile, fraught, fray; fan, fat; fly, flower, flute* contain two switches – before *fan* and before *fly*.

2.4.3.2.4.2 Within-cluster pauses. Within cluster pauses (WCP) was the mean time differences between each successive word within the same cluster. For example, *cat*, *dog* is a pet cluster and onset time of *cat* is 3 sec and onset time of *dog* is 4 sec. WCP time for this cluster is (4-3) = 1 sec. A three-word cluster example can be *pig, cow, horse* and suppose the onset time for *pig*, *cow*, and *horse* is 5, 7, and 8 respectively within trial. WCP time for this farm animal cluster will be ({(7-5) + (8-7)}/2 = 1.5 sec).

2.4.3.2.4.2 Between-cluster pauses. Between cluster pauses (BCP) refer to the time difference between the onset time of the last word of a cluster and first word of the consecutive cluster. Let’s take the same example from the pauses within cluster explanation. The two consecutive clusters are *cat, dog* and *pig, cow, horse*. The pause time between these clusters will be the difference between the onset time of *dog* and *pig* that is (5-4) = 1 sec.

2.5 Statistical Analysis

Normality checks were performed for all the variables using Shapiro-Wilk test. For the normally distributed data set, we performed parametric statistical tests and for the data set which was not normally distributed, we performed non-parametric statistical tests. The vocabulary measures and working memory span were not normally distributed. Therefore, Mann-Whitney U test was performed for all the above-mentioned variables. For Stroop ratio and switch cost accuracy, independent sample t-tests were performed.

In verbal fluency, all the variables were normally distributed. All the variables were measured for each trial for the two fluency conditions for each participant. To arrive at the mean scores for each variable, the three trials were averaged in each condition; for semantic fluency animals, fruits and vegetables, and clothing were averaged; for letter fluency *F, A*, and *S* trials were averaged. A two-way ANOVA repeated measure was used on the following variables: number of CR, 1^{st}-RT, Sub-RT, cluster size and number of switches. In the design, Group (Monolingual; Bilingual) was treated as a between-subject factor, and Condition (Semantic; Letter) was treated as within-subject factor. An independent sample t-test was used on the FDS with Group as the between-subject factor. Two separate independent sample t-tests were conducted for initiation parameter and slope for semantic and letter fluency conditions with Group as the between-subject factor. Tukey's post hoc tests were applied for significant interaction effects at $p \leq 0.05$. To examine the relationship between the executive control measures and verbal fluency variables, Pearson's correlations were performed separately for each group for the Stroop ratio and verbal fluency variables. Spearman's correlations were performed separately for each group between the other two executive variables (switch cost (RT) and backward digit span) with the verbal fluency variables.

2.6 Results

The mean and standard deviation values and the results of the statistical tests for the bilingual's subjective language profile in Bengali and English are presented in Table 2.3. The mean and standard deviation values and the results of the statistical tests for the objective vocabulary tests and executive control measures are presented in Table 2.4. The mean and standard deviation values for the verbal fluency variables for Groups (Monolingual and Bilinguals) and Conditions (Semantic and Letter) averaged across participants are presented in Table 2.5 (standard deviation reflects between-subject variation). The results of the statistical tests are provided in Table 2.5 as well. Findings from the correlation analyses between the executive control measures and verbal fluency variables for each group are presented in Table 2.7. Findings for Group differences are presented first; followed by the findings on the relationship of executive control measures and verbal fluency variables.

2.6.1 Background and Executive Control Measures

Table 2.3 presents the results on various measures of bilingualism. There was no significant difference amongst bilinguals' Bengali and English on the language of instruction during education, subjective language proficiency ratings (speaking, comprehension, reading, and writing abilities) and language dominance; indicating a balanced bilingualism on these domains. However, during childhood, bilinguals had significantly greater Bengali exposure during acquisition (M = 14.3, SD = 2.6) than English (M = 2.5, SD = 2.3). Current usage of language was predominantly English; they were more prone to switch from Bengali to English than the reverse during day-to-day communication. As our bilinguals were staying in an English-speaking country, it was expected that they would use English more than Bengali.

The two groups did not differ on the receptive vocabulary measures (see Table 2.4). As could be seen in Table 2.4, the two groups differed significantly only on the Stroop ratio, Stroop incongruent trial and the switch cost accuracy. Compared to monolinguals, bilinguals demonstrated lesser Stroop ratio indicative of better inhibitory control and a smaller switch cost accuracy suggestive of superior shifting ability. However, bilinguals were overall slower in the incongruent trial of the Stroop test compared to monolinguals. Raw score for each individual on the subjective language background measures and executive control measures are provided in Appendix 2.6 and Appendix 2.7, respectively.

Table2.3

Mean (M), Minimum (Min) and Maximum (Max) values, Standard Deviations (SD), and Statistical Results of Bilinguals' Subjective Language Profile.

Measures	Bengali			English			Statistical results
	M	*Min-Max*	*SD*	*M*	*Min-Max*	*SD*	
Language acquisition history[7]	14.3[1]	9-17	2.6	2.5[1]	0-9	2.3	$t(24) = 14.9$, $p < .001$***
Language of instruction[7]	5.3[2]	1-8	1.9	5.9[2]	2-9	2.4	$t(24) = -.6$, $p = .53$
Self-rated language proficiency[7]							
Speaking	6.3[3]	5.5-7.5	.7	6.4[3]	6-7	.6	$t(24) = -.1$, $p = .91$
Comprehension	6.7[3]	6-7	.4	6.6[3]	6-7	.5	$t(24) = .7$, $p = .50$
Reading	6.7[3]	5-7	.6	6.7[3]	6-7	.5	$t(24) = -.3$, $p = .80$
Writing	6[3]	4-7	.9	6.4[3]	6-7	.6	$t(24) = -1.6$, $p = .13$
Language use[7]	12[4]	8-16	1.9	20.6[4]	15-22	2	$t(24) = -14.2, p < .001$***
Language dominance[8]	17[5]	11-20	3.2	18.2[5]	12-24	3.6	$t(24) = -.9$, $p = .37$
Language switching habit[9]	8.7[6]	7-10	1.1	7.7[6]	4-12	2.1	$t(24) = -2.3$, $p = .03$*

[1] – maximum possible score was 16, greater score in one language means greater immersion into that language during childhood; [2] – maximum possible score was 9, greater score in one language means greater number of years of education in that language; [3] – on a scale of zero to seven (0 = no proficiency, 7 = native like proficiency), greater score in language means greater proficiency in that language; [4] – maximum possible score was 25, greater score in one language means greater use of that language in daily life; [5] – maximum possible score was 31, dominant language is the language which obtains a greater score than the other language; [6] – maximum score possible was 12, greater score in one language means greater switch from that language to the other language; [7] – adapted from Muñoz, Marquardt & Copeland (1999); [8] – adapted from Dunn & Fox Tree, 2009; [9] – adapted from Rodriguez-Fornells et al., 2012. *** $p \leq .001$, * $p \leq .05$.

Table2.4

Mean (M), Minimum (Min) and Maximum (Max) values, Standard Deviations (SD), and Statistical Results of Receptive vocabulary and Executive Control Measures.

Measures	**Bilingual (N =25)**			**Monolingual (N = 25)**			**Statistical results**
	M	*Min-Max*	*SD*	*M*	*Min-Max*	*SD*	
OPT[1]	53.1	43-58	3.4	54.1	48-58	3.4	$U^6 = 251.5$, $p = .23$
BPVS III[2]	157.8	144-164	4.8	159.8	149-164	4.6	$U^6 = 269.5$, $p = .40$
Stroop task[3]							
Stroop ratio	23.5	5-39	8.5	30.7	18-47	10.2	$t(48) = -2.9$, $p = .005$**
Stroop incongruent	835.7	560-1141.2	163.7	694.1	553.3-1141	143.9	$U^6 = 136$, $p < .001$***
Stroop congruent	666.1	411.5-934.4	146.2	597	424-938.1	183.3	$U^6 = 225.5$, $p = .09$
Stroop difference	169.7	48.8-317.9	64.3	194.9	103.7-357.9	63	$t(48) = -1.4$, $p = .17$
Colour-shape switch task[4]							
Switch cost RT (ms)	266.4	48.1-511.7	154.1	235.8	48.7-530.5	97.3	$U^6 = 289.5$, $p = .65$
Switch cost accuracy	.02	6.9-16.9	3.3	2.8	-7.4-15.2	4.7	$t(48) = -2.4$, $p = .02$*
Digit span test[5]							
Backward digit span	6.1	4-7	1	5.6	4-7	0.9	$U^6 = 226$, $p = .08$

[1] – Oxford Quick Placement Test (Oxford University Press and Cambridge ESOL, 2001), maximum possible score was 60, higher score indicates higher receptive vocabulary; [2] – British Picture Vocabulary Scale, Third Edition (Dunn & Dunn, 2009), maximum possible score was 164, higher score indicates higher receptive vocabulary; [3] – Stroop task; [4] – adapted from Prior and MacWhinney, 2010; [5] – Digit span test (Wechsler, 1997); [6] - Mann-Whitney U test; *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$.

Table2.5

Means (M), Standard Deviations (SD) and the Statistical Results of the Dependent Variables by Group (Bilingual and Monolingual) and Conditions (averaged across trials)

	Bilingual (N = 25)		**Monolingual (N = 25)**		Total		**Statistical results (Group, Condition)**		
Measures	M	*SD*	*M*	*SD*	*M*	*SD*	Group	Condition	Group*Condition
CR[1]	18.8	3	18.7	3	18.7	3	F(1,48)=.01, p=.91, η_p^2= .001	F(1,48)=70.2, p<.001***, η_p^2= .59	F(1,48)=16.3, p<.001***, η_p^2= .25
Semantic	19.8	3.3	21.5	3.3	20.6	3.4			
Letter	17.8	3.5	15.8	3.5	16.8	3.5			
FDS[2]	.10	.12	.25	.16	.17	.16	t(48)=-3.9, p<.001***, d = 1.1		
First RT	1.2	.5	1.2	.5	1.2	.5	F(1,48)=.01, p=.92, η_p^2= .001	F(1,48)=.18, p=.67, η_p^2= .004	F(1,48)=.34, p=.56, η_p^2= .007
Semantic	1.3	.6	1.2	.7	1.2	.6			
Letter	1.2	.8	1.2	.7	1.2	.7			
Sub-RT	23.9	1.5	22.5	1.5	23.3	1.3	F(1,48)=11.4, p=.001***, η_p^2= .19	F(1,48)=83.8, p<.001***, η_p^2= .64	F(1,48)=2.4, p=.13, η_p^2= .05
Semantic	21.5	2.4	20.9	2.3	21.2	2.4			
Letter	26.2	1.5	24.1	1.9	25.2	1.9			
Initiation *Semantic*	3.9	.6	4.3	.9	4.1	.8	t(48)=-1.91, p=.06, d = .54		
Initiation *Letter*	2.4	.5	2.5	.6	2.5	.5	t(48)=-.46, p=.64, d = .13		
Slope Semantic	-1.2	.3	-1.3	.5	-1.3	.3	t(48)=-.81, p=.42, d = .22		
Slope Letter	-.5	.2	-.7	.2	-.6	.2	t(48)=-2.7, p=.008**, d = .76		
Cluster size	.60	.2	.57	.2	.59	.1	F(1,48)=.4, p=.54, η_p^2= .008	F(1,48)=62.1, p<.001***, η_p^2= .56	F(1,48)=8.1, p=.007**, η_p^2= .14
Semantic	.70	.3	.80	.3	.75	.2			
Letter	.49	.2	.34	.2	.42	.2			
Number of switches	11.7	2.4	12.2	2.1	11.9	2.1	F(1,48)=.7, p=.41, η_p^2= .01	F(1,48)=2.9, p=.09, η_p^2= .06	F(1,48)=1.2, p=.27, η_p^2= .02
Semantic	11.9	2.7	12.8	2.1	12.3	2.2			
Letter	11.6	3.1	11.6	2.7	11.6	2.7			
WCP[3]	1.9	.5	1.7	.5	1.8	.4	F(1,48)=1.5, p=.22, η_p^2= .03	F(1,48)=17.1, p<.001***, η_p^2= .26	F(1,48)=1.4, p=.23, η_p^2= .03
Semantic	1.5	.5	1.5	.5	1.5	.4			
Letter	2.4	.9	1.9	1.2	2.2	1			
BCP[4]	4	.9	4.1	.9	4	.8	F(1,48)=.2, p=.65, η_p^2=.01	F(1,48)=1.6, p=.21, η_p^2= .03	F(1,48)=6.8, p=.01**, η_p^2= .12
Semantic	4.1	1.3	3.7	1.1	3.9	1.2			
Letter	3.9	1.2	4.5	1.1	4.2				

[1] – number of correct responses, [2] – Fluency Difference Score, [3] – Within-Cluster Pauses, [4] – Between-Cluster Pauses, *** $p \leq .001$, ** $p \leq .01$, * $p \leq .05$, Condition (Semantic, Letter)

Table2.6

Best Fitting Multilevel Model Functions for the Time Course of Correct Responses in Verbal Fluency Task.

Measure	**Bilingual (*N* = 25)**	**Monolingual (*N* = 25)**
Semantic fluency	$y = 3.72 - 1.17\ln(t)$	$y = 4.28 - 1.33\ln(t)$
Letter fluency	$y = 2.44 - .58\ln(t)$	$y = 2.50 - .70\ln(t)$

Note: logarithmic function estimates are obtained from multilevel modelling with all observations.

Table 2.7

Correlation Coefficients amongst the Executive Control Measures and the Verbal Fluency Variables.

Executive control measures		**Fluency variables**									
		CR	FDS	1st RT	Sub-RT	Initiation	Slope	Cluster size	Number of switches	WCP	BCP
		Bilinguals (*N* = 25)									
Stroop ratio	*rs*[1]	-.10	.30	.21	.05	.33	.40*	.01	-.13	.22	.08
	p-value	.62	.14	.30	.81	.10	.04	.96	.52	.15	.36
Switch cost (RT)	*rs*[2]	-.36	.29	.26	.12	.02	.33	-.08	-.29	.18	.12
	p-value	.08	.15	.21	.56	.93	.11	.72	.16	.40	.57
Digit span backward	*rs*[2]	.23	.21	.22	.27	.18	.03	.02	.16	.17	.14
	p-value	.28	.32	.28	.20	.39	.87	.94	.44	.42	.50
		Monolinguals (*N* = 25)									
Stroop ratio	*rs*[1]	-.08	-.14	-.21	-.16	.16	.20	-.39	.16	-.13	.01
	p-value	.69	.51	.30	.44	.43	.33	.06	.45	.54	.97
Switch cost (RT)	*rs*[2]	.01	-.30	-.05	-.01	-.01	.16	.13	-.19	.17	.11
	p-value	.99	.14	.80	.98	.98	.44	.54	.38	.41	.59
Digit span backward	*rs*[2]	-.03	-.03	-.09	.21	-.09	-.22	-.01	.03	-.20	.11
	p-value	.87	.89	.67	.31	.68	.28	.97	.89	.35	.59

[1] - Pearson's correlation coefficient; [2] – Spearman's rho; * $p \leq .05$.

2.6.2 Group Differences in Verbal Fluency Performance

Differences between the monolinguals and bilinguals were observed either as a main effect of Group, or an interaction of Group X Condition for CR, FDS, Sub-RT, slope for letter fluency, cluster size, and BCP. There were no group differences in 1st-RT, initiation parameters for either semantic or letter fluency, slope for semantic fluency, number of switches, and WCP.

The CR showed a main effect of Condition (Semantic: M = 20.6, SD = 3.4; Letter: M = 16.8, SD = 3.5) and a significant interaction of Group X Condition (see *Figure 2.3*). Post-hoc analysis of the interaction revealed that there was no significant difference between the groups for semantic condition (p>.05). However, bilinguals produced significantly more number of CR in the letter fluency compared to monolinguals, $t(48)$ = 1.98, p = .05, d = .53. For FDS, bilinguals showed significantly smaller FDS (Bilingual: M =.12, SD = .15; Monolingual: M= .26, SD = .16; see *Figure 2.4*).

Sub-RT showed a significant main effect of Group, with bilingual demonstrating longer Sub-RT (Bilingual: M = 23.9, SD = 1.5; Monolingual: M = 22.7, SD = 1.5). Cluster size showed a main effect of Condition (Semantic: M = .7, SD = .2; Letter: M = .4, SD =.2) and an interaction of Group X Condition (see *Figure 2.5*). Post-hoc analyses were performed to compare the performance of the two groups within each fluency type. There was no significant difference for the cluster size between the bilinguals and monolinguals on the semantic fluency condition, $t(48)$ = -1.4, p = .17, d = .39 but bilinguals produced significantly larger cluster than the monolinguals on the letter fluency condition, $t(48)$ = 2.3, p = .02, d = .66.

Initiation parameter and slope were analysed as a function of the group after each time course was fitted to multilevel models. The estimated function for each fluency condition and groups are presented in Table 2.6. *Figure 2.7* represents the time course of the correct responses by the group for the semantic fluency condition and letter fluency condition. In the semantic fluency, there was no significant group difference in the initiation parameter, $t(48)$ = -1.9, p = .06, d = .54, or the slope, $t(48)$ = -.81, p = .42, d = .22. In the letter fluency, there was no significant group difference for the initiation parameter, $t(48)$ = -.46, p = .64, d = .13.

However, bilingual group had significantly flatter slope than the monolingual in the letter fluency condition, *t*(48) = -2.7, *p* = .008, d = .76. The results suggest bilinguals were better able to maintain their linguistic resources throughout the 1-minute of the verbal fluency task, especially in the difficult letter fluency condition.

BCP showed an interaction of Group X Condition (see *Figure 2.6*). Post-hoc analyses were performed to compare the performance of the two groups within each fluency type. There was no significant difference for the BCP between the bilinguals and monolinguals on the semantic fluency condition, *t*(48) = 1.2, *p* = .22, *d* = .35, but bilinguals took significantly lesser time than the monolinguals to switch between one cluster to another on the letter fluency condition, *t*(48) = -2.3, *p* = .02, *d* = .66. In addition, WCP showed only a main effect of Condition. All the participants took less time to access words within a cluster in the semantic fluency compared to the letter fluency condition (Semantic: *M* = 1.5, *SD* = .4; Letter: *M* = 2.2, *SD* = 1).

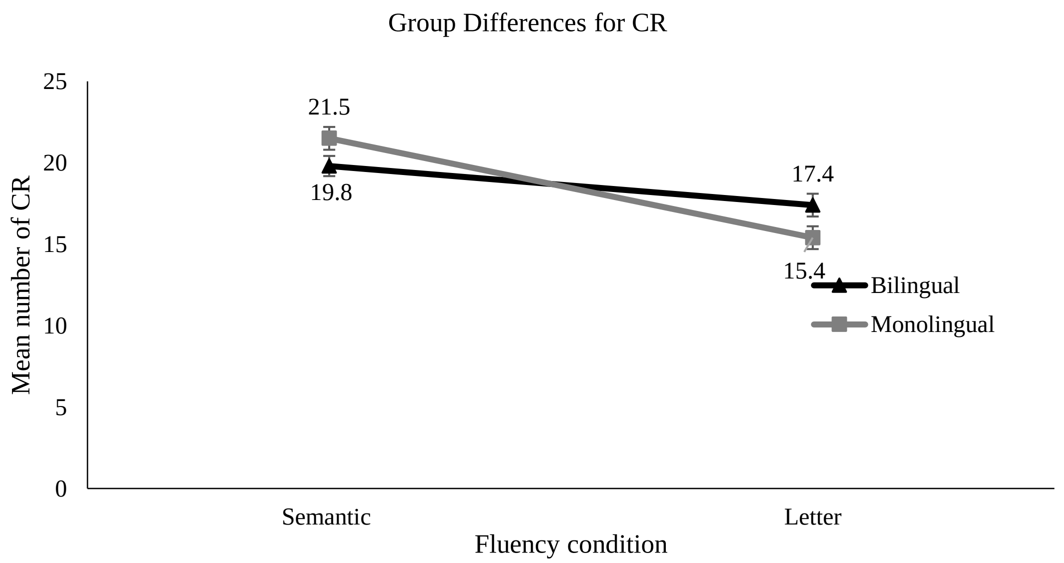


Figure 2.3 Comparison of mean number of correct responses (CR) between the groups by fluency condition (semantic and letter). Error bars represent standard error of the mean. * $p \leq .05$

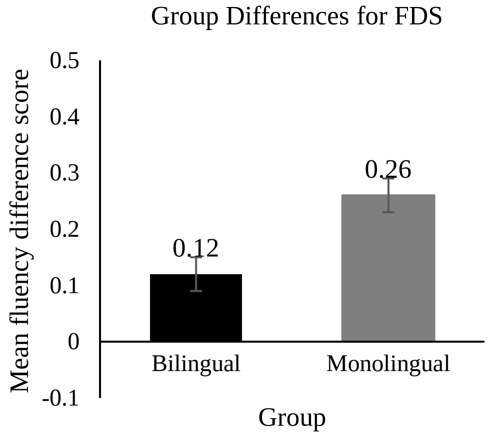


Figure 2.4 Comparison of mean proportion fluency difference scores (FDS) between the groups. Error bars represent standard error of the mean. * $p \leq .05$

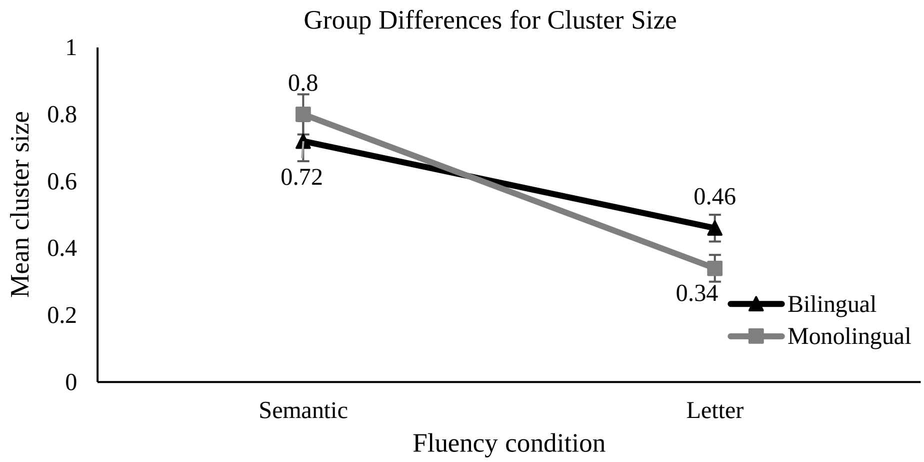


Figure 2.5 Comparison of mean cluster size between the groups by fluency condition (semantic and letter). Error bars represent standard error of the mean. * $p \leq .05$

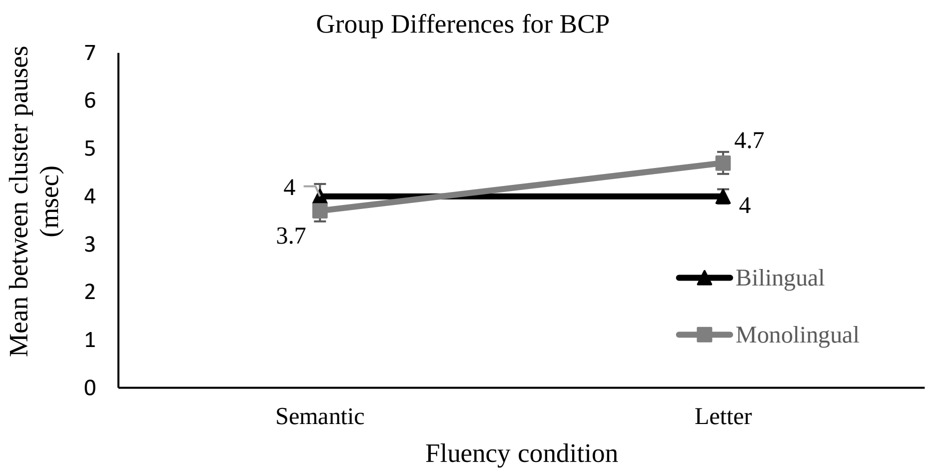
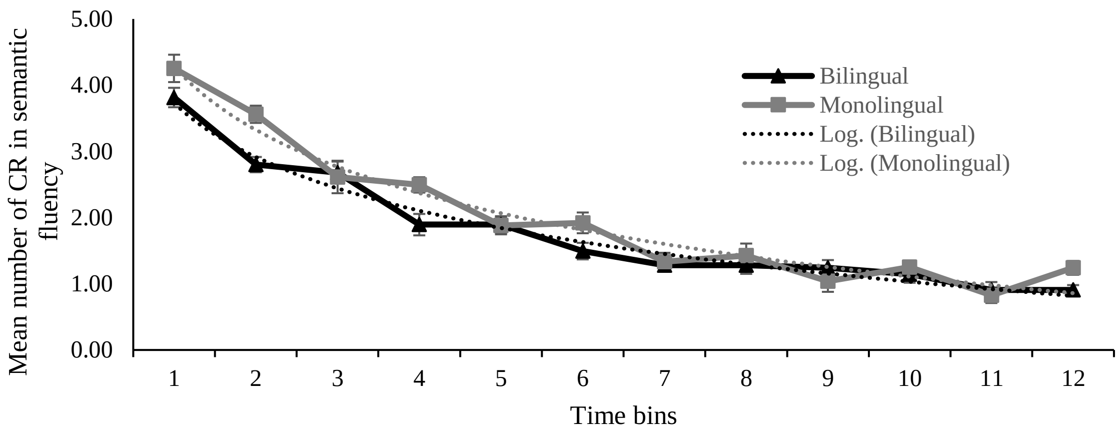


Figure 2.6 Comparison of mean between cluster pauses (BCP) between the groups by fluency condition (semantic and letter). Error bars represent standard error of the mean. * $p \leq .05$.



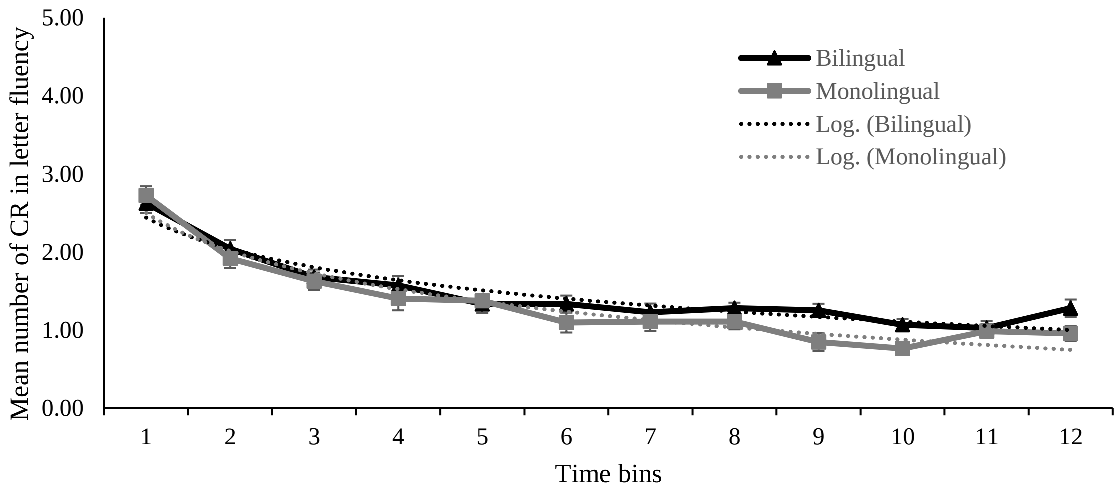


Figure 2.7 Comparison of number of correct responses (CR) produced as a function of 5-sec time intervals in the semantic (top panel) and letter fluency (bottom panel) conditions between the groups. Best-fit lines are logarithmic functions. Error bars represent standard error of the mean.

2.6.4 Verbal Fluency Performance and Executive Control Measures

Table 2.7 presents the correlation coefficients amongst the verbal fluency variables and executive control measures for monolinguals and bilinguals. *Figure 2.8* provides the scatterplots for the significant correlations. Highest Stroop ratio for bilinguals was 39 and 36% monolinguals had higher Stroop ratio than the highest value of the bilinguals. Therefore, as can be seen from *Figure 2.8*, data points of bilinguals were skewed on the left side whereas data points of monolinguals were skewed more on the right side. Correlation analyses revealed bilinguals showed significant positive correlations between Stroop and slope, *r* (23) = .40, *p* = .04 (see *Figure 2.8*). Bilinguals with lesser Stroop ratio illustrated a flatter slope indicating that the bilinguals with better inhibitory control could maintain their linguistic resources throughout the 1-minute of the verbal fluency task. Monolinguals did not show any significant correlation between any of the executive control measures and verbal fluency components.

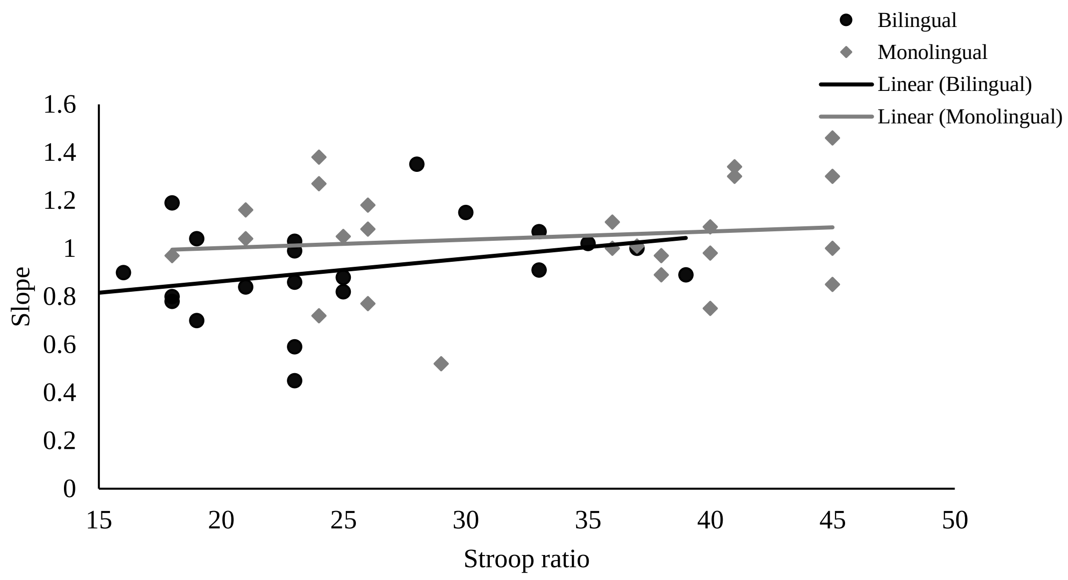


Figure 2.8 Correlation plots for the significant correlations between the Stroop ratio and slope of verbal fluency for the groups.

2.7 Discussion

The overarching aim of this study was to determine the contribution of linguistic and executive control processes to word retrieval in bilingual and monolingual participants. To meet the overall aim, the present study determined the group differences in verbal fluency performance between vocabulary-matched monolinguals and bilinguals and identified the executive control measures that mediate the performance difference between them. We used a large group of relatively homogeneous Bengali-English bilinguals who were matched for age, years of education, non-verbal IQ, and vocabulary with the monolinguals. We used a wide range of variables − CR, FDS, 1st-RT, Sub-RT, initiation, slope, clustering and switching, within-cluster pauses, and between-cluster pauses – that are thought to differentially contribute to the linguistic and executive components of verbal fluency task. In addition, we measured executive control in the domains of inhibition, switching and working memory, and linked the performance on the verbal fluency to the executive measures.

To summarize the main findings, compared to monolinguals, bilinguals showed differences in both linguistic and executive control domains as identified and indicated on Table 2.8. Specifically, differences were observed in CR for letter fluency, FDS, Sub-RT, slope for letter fluency, cluster size, and BCP for letter fluency. Despite lack of overall group difference on CR, bilinguals outperformed the monolinguals on letter fluency. Bilinguals and monolinguals were comparable on semantic fluency. Vocabulary matched bilinguals performing better than monolinguals on letter fluency corroborate research by other groups (Friesen et al., 2015; Luo et al., 2010). Both the studies found better performance for bilinguals on the letter fluency condition and had argued in favour of superior executive control for bilinguals as compared to monolinguals.

Table2.8

Results of Current Study in the Context of Verbal Fluency Variables and to their Linguistic and Executive Control Components.

Parameters	**Processes**		**Bilingual (B) vs Monolingual (M)**	
	Linguistic	Executive	Findings	Correlation with Executive Control
Quantitative				
1. Number of correct responses	√	√	Yes B > M (Letter)	No
2. Fluency difference score		√	Yes B < M	No
Time course				
1. 1st RT	√		No B = M	No
2. Sub-RT		√	Yes B > M	No
3. Initiation	√		No B = M	No
4. Slope		√	Yes B < M (Letter)	Yes (+) with Stroop Ratio for B
Qualitative				
1. Cluster size	√		Yes B > M (Letter)	No
2. Number of switches		√	No B = M	No
3. Within-cluster pauses	√		No B = M	No
4. Between-cluster pauses		√	Yes B < M (Letter)	No

Yes – significant findings, NO – not significant findings

Building on the evidence that bilinguals' might be having an advantage in executive control that is helping their performance in letter fluency task comes from two findings: One, bilinguals demonstrated significantly smaller FDS than monolinguals, which is claimed to reflect superior executive control. Second, longer Sub-RT with more number of CR in the letter fluency, a flatter slope and shorter BCP on letter fluency task may be attributed to superior executive control. As discussed in the introduction, longer Sub-RT can be either due to smaller vocabulary or superior executive control abilities of bilinguals compared to monolinguals (Luo et al., 2010). Since our groups were matched on vocabulary and we do not find any significant difference between the two groups on initiation parameter (which is a measure of initial linguistic resources), it is likely that bilinguals performance would be indicative of superior executive control (Luo et al., 2010). Luo et al (2010) have postulated that the superior executive control would result in a slower decline in retrieval speed or longer Sub-RT for bilinguals in combination with a higher number of CR and flatter slope than monolinguals. Overall, equivalent performance on the vocabulary test, longer Sub-RT, flatter slope and better performance on the letter fluency condition (higher CR and smaller FDS) for bilinguals compared to monolinguals suggest a bilingual advantage in verbal fluency task when there is a higher demand for controlled executive processing skills such as in the letter fluency.

On the qualitative measures, we expected bilinguals to produce smaller cluster size which utilizes the language processing mechanism and more number of switches which requires efficient executive control mechanism. However, we found that bilinguals produced bigger cluster size in letter fluency condition which can be due to a strategy to bolster their performance in letter fluency. Previous studies have found positive correlations between cluster size and number of correct responses (Bose et al., 2017). The lack of difference in switching is surprising as we expected bilingual participants to produce more number of switches compared to monolinguals as better executive control abilities have been linked with better switching abilities. Bilinguals took lesser time to switch between clusters in the letter fluency condition compared to the monolinguals. Previous studies have associated longer BCP with poorer executive control abilities (Raboutet et al., 2010; Rosen et al., 2005) and reduced productivity in the verbal fluency task (Bose et al., 2017). Therefore, shorter BCP for bilinguals compared to monolinguals reflect bilingual's superior executive control abilities and corroborates with previous studies. In addition, both groups also performed similarly on the non-verbal switching task (colour-shape switch task) which requires switching from one mental set to another. No difference between the groups on colour-shape switch task is consistent with the findings obtained by Paap and his colleagues (Paap & Greenberg, 2013; Paap & Sawi, 2014; Paap et al., 2017).

Results of correlation analyses further supports the idea that executive control advantage in bilinguals helping them to perform better in verbal fluency measures where task demand is higher. Variables that related to inhibitory control correlated with verbal fluency measure (slope) which taps into the executive component of the task (see Table 2.8). This correlation was found only for the bilinguals. Researchers have long contended the role of executive control ability in various verbal fluency parameters such as slope (Luo et al., 2010). However, this is the first study to relate specific measures of executive control with a broad range of measures of verbal fluency. Similar to Shao et al.'s (2014) study, we did not find any correlation between inhibitory control measures and the number of correct responses for both the monolingual and bilingual groups. These results support the claim made in the earlier section that executive control advantage of bilinguals helps them to outperform monolinguals in verbal fluency tasks, especially where task demands are higher. However, we must acknowledge that two of our executive control tests were verbal in nature and that might be a possible reason for getting significant correlations with the verbal fluency measures. To rule out the collinearity issue, we performed correlation between the executive control measures and the vocabulary measures. We did not find any significant correlations between the executive control measures and vocabulary measures (See Appendix 2.8). Future studies should consider taking a more challenging and different types of executive control measures (non-verbal) to investigate the role of executive control components in verbal fluency performance.

Though we have found clear differences between the two groups, on linguistic and executive control parameters, we must recognize the demographic and social differences that may have contributed to this performance difference. Both groups were different in terms of their occupational status, 56% of the monolingual participants of the present study were university student whereas majority of the bilingual participants consisted of homemakers (28%) and engineers (24%). Therefore, superior performance in the executive control measures could be attributed to the higher percentage of high skilled bilingual immigrants (engineers) in the present study. Poorer performance of the monolingual groups could also be ascribed to the low motivation of the participants, higher percentage of monolingual participants were university student (56%) who took part in the experiment for course credit whereas bilingual participants were self-motivated to take part in this study. Future studies should consider these social and demographic factors to better account for the performance differences between these two groups.

In summary, bilinguals when matched for vocabulary performed similarly to monolinguals in semantic fluency where demand of linguistic processes are higher and better compared to monolinguals in the difficult letter fluency where demands of executive control processes are higher. For bilinguals, executive control processes correlated with the verbal fluency measure where effortful controlled processing is required. These findings may not be visualised if only number of correct responses were taken as an indicator of verbal fluency performance. A range of verbal fluency variables are necessary to understand the differences in verbal fluency performances between bilingual and monolingual speakers. Present study also provides empirical support to the understanding in role of executive control in verbal fluency performance. Findings from the correlational analysis suggest that superior executive control abilities helped bilinguals to perform better than the monolinguals only where the task difficulty is high. Therefore, as recommended by Paap et al (2017), separate measures of verbal and executive control abilities are necessary to explain bilingual advantages and disadvantages in various measures.

Chapter 3. Semantic Context Effects and Executive Control in Healthy Monolingual and Bilingual Speakers

3.1 Abstract

Background. Given lexical selection happens through a competitive process during word production; the important question that arises is how monolingual and bilingual speakers resolve the lexical competitions in contexts where competition is increased. The blocked-cyclic picture naming is a well-established paradigm that has been used to explore lexical competition during word production. In this paradigm, objects are presented in a close succession either from same semantic categories (homogeneous, e.g. elephant, lion, deer, and hippopotamus) or different (heterogeneous, e.g. pear, shoes, lips, and deer). Naming gets slower and more error-prone in the homogeneous context as compared to heterogeneous context. This has been linked to the heightened activation of the competitors in the homogeneous set. In healthy monolingual speakers, executive control mechanisms especially inhibitory control helps to resolve this competition. However, it is yet not known whether bilingual speakers who often show better executive control but also faces greater lexical competition compared to monolinguals, will outperform monolinguals or not on a task where lexical competition is enhanced.

Aims. The overarching aim of this study was to determine the differences in linguistic and executive control contribution in word production between bilingual and monolingual participants by using a task where semantic activation and lexical competition can be manipulated. Specific aims were to investigate performance differences (context effect: RT difference between homogeneous and heterogeneous context; slope: changes in RT across cycles) in blocked-cyclic picture naming task between vocabulary-matched Bengali-English bilinguals and English monolinguals and if these differences can be explained by the differences in their executive control abilities.

Methods & Procedure. Blocked-cyclic picture naming task in English was administered on 25 Bengali-English bilinguals and 25 English monolinguals. Pictures were presented individually on a computer and accuracy, and naming latencies were analysed. The stimuli set included 25 monosyllabic nouns (5 semantic category × 5 words in each category). Five homogeneous and

five heterogeneous sets of five items each were created and presented in an alternating order. There were five cycles of presentation with each item presented once in each cycle. Dependent variables were: Context effect for all cycles, excluding the first cycle, and excluding cycle 2 to 5; Slope. Participants also completed the same executive control tests as described in Chapter 2.

Outcomes & Results. Both groups showed significant semantic context effect. However, compared to the monolinguals, bilinguals showed significantly lesser semantic context effect. Bilinguals also showed significant semantic facilitation on the first cycle. There were no significant correlations between any of the executive control measures and blocked-cyclic naming variables.

Conclusions & Implications. Similar to Chapter 2, bilinguals perform better than monolinguals even in a linguistic task where task difficulty is higher (homogeneous condition) and used better strategy to show semantic facilitation even in an alternating blocked-cyclic naming design. Overall, the present study supports the claim that executive control helps to reduce the semantic interference where lexical competition is heightened.

3.2 Introduction

Selection of the appropriate target word during conversation is an essential feature of successful communication in everyday life. To produce a word successfully, a speaker must select the target word from several other competing semantically related items (e.g. if the target is *dog*, items such as *cat* and *horse* will also compete for selection; see Caramazza, 1997, Dell, Schwartz, Martin, Saffran, & Gagnon, 1997, Levelt, Roelofs, & Meyer,1999). Studies have suggested that executive control mechanism especially inhibitory control helps to resolve this lexical competition (Crowther & Martin, 2014; Shao et al., 2015). However, there is currently no consensus in the literature as to whether this lexical competition is resolved in the same way by monolingual and bilingual speakers, as previous research has shown that these two populations differ in their use of executive control and resolution of lexical competition (see Chapter 2 for more detailed discussion on the differences between bilingual and monolingual executive control). For example, whereas bilingual speakers face both within- and between-language competition, monolingual speakers only have to resolve within language competition (Lee & Williams, 2001). On the other hand, executive control abilities especially inhibitory control has been shown to be stronger in bilinguals as compared to monolinguals (e.g. Bilaystok, 2009, Prior & MacWhinney, 2010; however, for exception see Paap & Greenberg, 2013; Paap & Sawi, 2014; Paap et al., 2017). The concept of increased lexical competition and stronger inhibitory control in bilinguals compared to monolinguals drives the research question of the present study. In this study, we investigated the relationship between increased lexical competition and executive control processes for bilingual and monolingual speakers using blocked-cyclic picture naming paradigm.

Blocked-cyclic picture naming paradigm is a simple, yet a powerful picture naming paradigm used to investigate the changes in semantic activation and lexical competition in healthy as well as neurologically impaired populations (e.g. Belke, Meyer, & Damian, 2005; Damian, Vigliocco, & Levelt, 2001; Schnur, Schwartz, Brecher, & Hodgson, 2006; Scott &

Wilshire, 2010). Blocked-cyclic naming also make use of same item sets in homogeneous and heterogeneous context, therefore, controls for lexical variables which often confounds studies involving word production. For the present study, we will focus on the findings related to the healthy population. In a typical semantically blocked-cyclic naming task, subjects are asked to name pictures from semantically homogeneous set (*Figure* 3.1) that is all the items are from same semantic category or name pictures from a heterogeneous set (*Figure* 3.1) that is items are from different semantic category.

Figure 3.1 Example of a semantically homogeneous set (left panel; elephant, lion, deer, and hippopotamus all are from the same semantic category) and heterogeneous set (right panel; pear, shoes, lips, and deer all are from different semantic category)

When homogeneous items are named in close succession, selection of the target becomes more difficult as the homogeneous items also compete for selection (Belke et al., 2005). Naming gets slower and more error prone in the homogeneous context as compared to heterogeneous context which is also called semantic context effect or semantic blocking effect. This has been linked to the heightened activation of the competitors in the homogeneous set (Belke et al., 2005; Schnur et al., 2006). Studies have shown that executive control mechanism especially inhibitory control and working memory helps to resolve this lexical competition (Belke, Humphreys, Watson, Meyer, & Telling, 2008; Crowther & Martin, 2014; Shao et al., 2015).

Therefore, blocked cycling naming is ideally suited to investigate the central question of this thesis that is the interaction of word production and executive control, and this paradigm has not been exploited in bilingual population. In the below section, we will briefly review the central findings related to the blocked cyclic naming in healthy adults and how it is related to the executive control mechanism.

3.2.1 Central Findings: Blocked-Cyclic Naming

In a standard blocked-cyclic naming design (*Figure* 3.2), items are presented in a cyclic fashion within a block (homogeneous or heterogeneous). The semantic context effect generally emerges from cycle two onwards and does not increase thereafter (Belke et al., 2005, See Belke & Steilow, 2013 for a review). Further, studies have shown either semantic facilitation (better performance in the homogeneous context compared to heterogeneous context) or no context effect in cycle 1 depending on the order of presentation (Belke et al., 2005; Damian and Als, 2005; Abdel Rahman & Melinger, 2007).

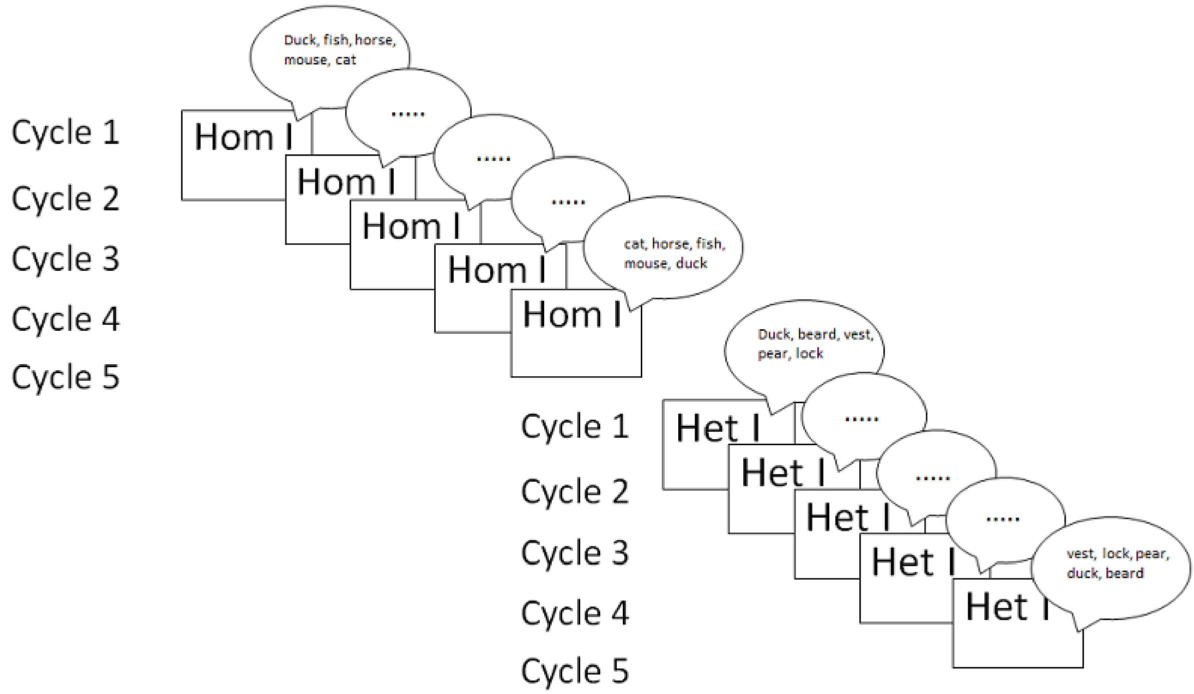


Figure 3.2. Schematic representation of a blocked-cyclic naming design with five items per category across five presentation cycles. Hom I represents first set of homogeneous contexts and Het I represents first set of heterogeneous contexts. Lists are presented in an alternated order. Adapted from Belke (2017).

Belke et al. (2005) investigated the semantic context effect and it's build up across cycles in a blocked cyclic-naming design with healthy undergraduate English monolingual students. Their blocked-cyclic naming design consisted of 32-line drawings, including four items from each of the four semantic categories (animals, tools, vehicle, and furniture) and 16 filler items and there were eight presentation cycles. List of homogeneous and heterogeneous set of items were presented in an alternate fashion (homogeneous-heterogeneous-homogeneous-heterogeneous). They found significant main effect of context that is items from the homogeneous sets were named slower compared to the items from the heterogeneous sets. There was a significant interaction of context and cycle when all presentation cycles were included; however, the interaction disappeared when cycle 1 was excluded from the analysis. They concluded that semantic interference increases in the homogeneous context and it is non-cumulative in nature.

Damian and Als (2005) have showed that the semantic context effect persists even when items were not named in close successive order. They tested groups of English monolingual participants (24 participants for Experiment 1, 8 participants for experiment 2, 10 participants for experiment 3, and 32 participants for experiment 4) on four blocked-cyclic naming experiments. On experiment 1, they found semantic context effect remains even when there is a gap of 12 second (filler trials) between consecutive trials. Results from experiment 2 revealed that filler trials consisting of items from different semantic categories also did not reduce the semantic context effect. On experiment 3, they found semantic context effect remains even when the distinction between homogeneous and heterogeneous experimental block is not present. Findings from experiment 4 showed that when filler trials were alternated between homogeneous and heterogeneous trials, semantic context effect persists. Overall the findings suggest that semantic context effect is long-lasting.

In another study done by Abdel Rahman and Malinger (2007) on 34 German monolingual speakers, they found semantic facilitation rather than interference on the first presentation cycle. Naming was slower on the heterogeneous condition compared to the homogeneous condition on the first presentation cycle but semantic context effect was present for the rest of the cycles. The context list was presented in a blocked manner (homogeneous-homogeneous-homogeneous-homogeneous-heterogeneous-heterogeneous-heterogeneous-heterogeneous).

Facilitation effect on the first presentation cycle have been said to be strategic nature (Damiand & Als, 2005; Oppenheim, Dell, & Schwartz, 2010; Belke, 2017). Belke (2017) in a review article investigated the strategic facilitation effect in the first cycle by reviewing 18 blocked-cyclic naming experiments. The author found that a minor change in the experimental design lead to the presence or absence of semantic facilitation effect on the first presentation cycle. Seven out of 10 blocked-cyclic naming experiments where context lists were presented in a blocked manner (homo-homo-homo-homo-hetero-hetero-hetero-hetero) have shown semantic facilitation. However, when context lists were presented in an alternating order (homo-het-homo-het-homo-het-homo-het), semantic facilitation effect disappears. The reason behind semantic facilitation when context lists were presented in a blocked manner is said to be strategically driven. Participants may prepare themselves in the blocked design due to the manner of the design and therefore use their executive control to facilitate the processing of semantic items in the homogeneous context.

Based on the review article from Belke (2017), we expect our monolingual speakers not to show any semantic facilitation on the first presentation cycle as present study uses an alternate blocked-cyclic naming design. However, if executive control helps to facilitate the processing of the semantic items on the first presentation cycle in the homogeneous context, bilingual speakers may show semantic facilitation even in alternating design. However, at present there is no study which has investigated the performance difference between monolingual and bilingual speakers on the first presentation cycle of a blocked-cyclic naming design. In this present study, we have addressed this gap in the literature.

3.2.2 Executive Control and Blocked-Cyclic Naming

In healthy speakers, the semantic interference observed in the blocked-cyclic naming task has been found to be related with the executive control mechanisms especially working memory and inhibitory control (Belke, 2008; Crowther & Martin, 2014; Shao et al., 2015). Belke (2008) tested 20 undergraduate native German monolingual speakers on a blocked-cyclic naming task by manipulating the working memory load. The blocked-cyclic naming task alternated between five semantic homogeneous and five semantic heterogeneous set with five presentation cycles. The working memory task was a digit retention task where participants had to remember a string of digit and had to compare it with a target string stating whether they are same or different. Context (homogeneous, heterogeneous), cycle (five), and working memory load (with and without) were varied within participants. Belke found significant effect of context that is items were named slower in the homogeneous compared to the heterogeneous context; the context effect was larger when the working memory load was present. Working memory load renders the efficiency of the executive control mechanism and allowed the bottom up effect (context manipulation) to emerge stronger.

Crowther and Martin (2014) tested 41 younger participants (mean age: 25.6 years, range: 18 years to 43 years) and 42 older participants (mean age: 62.9, range: 45years to 80 years) who were English monolingual on a blocked-cyclic naming task and three executive control tasks (word span, verbal Stroop, and recent negatives) to find out the relationship between the performance on blocked-cycling naming task and executive control measures. The blocked cyclic naming task had 16 homogeneous and 16 heterogeneous sets divided into two halves (each half contained 8 sets of each context) and had four presentation cycles. Dependent variables were context effect (reaction time difference between homogeneous and heterogeneous contexts), trial slope (slope across trials averaging across cycles), cycle slope (slope across cycles averaging across trials), and block slope (slope averaged across trials and task halves). Trial slope, cycle slope, and block slopes were calculated for each context separately. On the word span task (Baddeley & Hitch, 1974), participants were asked to repeat a list of words from a set of 10 words after the experimenter and the testing was interrupted where the participants failed to recall more than 50 % of the list in correct order. Word span task was used to measure the working memory capacity of the participants. On the Stroop task (Stroop, 1935), participants had to name the ink of the colour word by ignoring its name and the dependent variable (Stroop effect) was the reaction time difference for the incongruent trials and congruent trials (where the ink colour and the word's name was same).

On the recent negatives task (Monsell, 1978), participants listened to a list of three words followed by a probe word. Participants had to respond with a button press whether the probe word was there in the list of three words they heard. There were 48 positive trials (probe word present in the list) and 48 negative trials (probe word absent in the list). Negative trials were further divided into recent negatives and non-recent negatives. On the recent negatives, probe word was present in the immediately preceding list and on the non-recent negatives, probe word was not present in the present or immediately preceding list. Dependent measure was the difference in reaction time for recent negative and non-recent negative trials. Both the Stroop and recent negative tasks were used as a measure of inhibitory control, however, Stroop effect was an indicator of response-distractor inhibition whereas recent negatives task was used as an indicator of proactive interference.

Their findings from the blocked-cyclic naming task replicated the common findings from the literature that is significant effect of context, semantic facilitation in the first presentation cycle and no cumulative semantic interference after cycle 2. Crowther and Martin did correlation analysis between the executive control measures and the slopes (trial slope, cycle slope, block slope) for each context (homogeneous and heterogeneous). They found significant correlations amongst some the executive control measures and slopes. Better working memory performance was related to lesser semantic interference across trials for each context and better inhibitory control as measured by Stroop effect was related to lesser semantic interference across cycles in the homogeneous context. Better proactive interference as measured by recent negatives was related to greater semantic facilitation across cycles in the heterogeneous context. These results provide further evidence of the involvement of executive control in reducing the semantic interference during blocked cycling naming task.

Shao, Roelofs, Martin and Meyer (2015) tested 25 Dutch monolingual participants (mean age: 21.2 years, range: 18 years to 27 years) on several tasks such as blocked-cyclic naming task, Stroop task, and stop-signal task. Blocked cycling naming task had four homogeneous and four heterogeneous sets with each set having four items from one of the four semantic categories (animals, furniture, tools, and body parts). There were four presentation cycles and the dependent variables were context effect (reaction time difference between homogeneous and heterogeneous contexts) and slopes of the slowest delta segments. Delta plots were calculated by measuring the RT difference between homogeneous and heterogeneous context as a function of RT. At first RTs for each condition were rank-ordered and divided into quintiles or 20% bins. Then, the size of the interference or the magnitudes of RT differences (delta) were plotted for each quintile. Stroop task was the same as described in the previous paragraph. On the stop-signal task, participants were shown images of squares and circles in a random order and had to respond by pressing *I* key for circle and *Z* for square. There were two conditions: go-trials and stop-trials. Stop-trials were indicated by a tone and participants had to withhold their response on the stop-trials. The stop signal delay (SSD) was initially set for 250 msec following the fixation cross and for each successful inhibition the SSD was increased for 50 msec, SSD was decreased for 50 msec if the participants failed to inhibit their response. Dependent variable was the stop signal RT (SSRT) calculated as the time difference between the SSD averaged across all trials and the mean RT of the go-trials.

Shao et al found significant effect of context but no interaction of context by cycle on the blocked-cyclic naming task. Semantic context effects were correlated with the slopes of the slowest delta segment indicating participants with poorer inhibitory control abilities (steeper delta slope) had larger semantic interference. However, they did not find any significant correlation between the semantic context effects and any of the two executive control measures. They concluded that Stroop task did not represent the selective inhibition as widely believed.

In summary, based on the existing literature, it appears that at least in monolingual speakers executive control abilities especially inhibitory control and working memory play important role in reducing the semantic interference in the blocked-cyclic naming task. Executive control abilities particularly inhibitory control has been shown to be stronger in bilinguals as compared to monolinguals (e.g. Bilaystok, 2009, Prior & MacWhinney, 2010; however, for exception see Paap & Greenberg, 2013; Paap & Sawi, 2014, Paap et al., 2017). However, at present there is no study which has compared the performance difference in a blocked-cycling naming task between bilinguals and monolinguals and how it is related to differences in executive control abilities between the two groups.

3.3 The Current Investigation, Research Questions and Predictions

The overarching aim of this study was to determine the differences in linguistic and executive control contribution in word production between bilingual and monolingual participants by using a task where semantic activation and lexical competition can be manipulated. We compared the differences in blocked-cyclic naming performance of 25 young healthy English monolinguals and 25 healthy Bengali-English bilinguals. The two groups were matched on other background measures as explained in Chapter 2. We measured executive control processes using the same tasks as used in Chapter 2, such as Stroop (measured selective inhibition), the colour-shape switch task (measured shifting between mental sets) and the backward digital span (measured working memory) tasks. The specific research aims, and predictions were the following:

1. To determine differences in blocked cyclic naming performance between bilingual and monolingual participants.

   We expect bilinguals to show lesser semantic context effect compared to monolinguals as studies have shown better inhibitory control abilities leads to lesser semantic interference. As argued on the previous section based on Belke’s (2017) review study, on the first presentation cycle, we expect monolinguals to not show any semantic facilitation as the blocked cyclic task in the present study is alternating in design. However, based on the results from Chapter 2, we expect bilinguals to use better strategy and show semantic facilitation on the first presentation cycle.

2. To determine which measures of executive control (inhibitory control, mental set shifting, and working memory) mediate blocked-cyclic naming performance difference between the two groups.

   Based on previous findings (Belke, 2008; Crowther & Martin, 2014), we expect monolinguals with better inhibitory control and working memory abilities to face lesser semantic inference. This is the first study to relate the executive control abilities with the parameters from the blocked-cyclic naming design for the bilingual speakers. Therefore, we do not have any previous findings to formulate our hypothesis. However, based on Chapter 2 results, we expect inhibitory control to correlate with the semantic context effects for bilingual speakers.

3.4 Methods

3.4.1 Participants

Participants, background measures and executive control measures were same as described in Chapter 2.

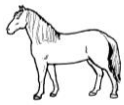
3.4.2 Blocked-Cyclic Picture Naming Task

3.4.2.1 Materials. The materials consisted of 25 black-and-white line-drawings, including five pictures each from five semantic categories (animals, body parts, clothing, fruits and vegetables, and tools). The images were selected from various sources, such as Philadelphia Naming Test database (PNT; Roach, Schwartz, Martin, Grewal, & Brecher., 1996), International Picture Naming Project database (IPNP; Szekely et al, 2004), Bank Of Standardized Stimuli database (BOSS; Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010), picture database given by Snodgrass and Vanderwart (1980), and internet resources. The average log word-form frequency in the CELEX database was 1.38/million (SD = 0.50), and the average age of acquisition was 4.60 years (SD = 1.18; Kuperman, Stadthagen-Gonzalez, & Brysbaert, 2012).

All picture names were monosyllabic except two picture names (*banana* had three syllables and *onion* had two syllables). The objects from the semantic categories were combined to create five homogeneous sets (see *Figure 3.3*) and five heterogeneous sets (see *Figure 3.3*).

Heterogeneous set contained one item each from each semantic category and were semantically unrelated. The picture names in a set were also unrelated in terms of phonological structure that is each word in a set had different initial phoneme and there were no Bengali-English cognates.

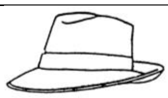




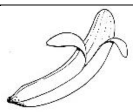






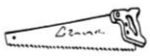










		Heterogeneous sets (Het)				
		Het 1	Het 2	Het 3	Het 4	Het 5
Homogeneous sets (Hom)	Hom 1 (Animals)	Duck /hãs/	Fish /matʃ^{h}/	Horse /g^{h}oɽa/	Mouse /ĩndur/	Cat /biɽal/
	Hom 2 (Body parts)	Beard /daɽi/	Palm /hat̪/	Lip /ʈ^{h}oʈ/	Heel /goɽali/	Ear /kan/
	Hom 3 (Clothing)	Vest /gendʒi/	Hat /ʈupi/	Sock /modʒa/	Shirt /dʒama/	Glove/dɔst̪ana/
	Hom 4 (Fruits and vegetables)	Pear/naʃpat̪i/	Banana /kɔla/	Corn /b^{h}utta/	Grapes /aŋur/	Onion /p̃ɛadʒ/
	Hom 5 (Tools)	Lock /t̪ala/	Nail /pɛrek/	Broom /d̪ʒ^{h}aru/	Key /tʃabi/	Saw /kɔrat̪/

Figure 3.3 Blocked cyclic naming design with five items per category. Horizontal row signifies the homogeneous set and the vertical column signifies the heterogeneous set. The IPA in the brackets represents the Bengali names of the stimulus.

3.4.2.2 Design. Context (homogeneous and heterogeneous) and presentation cycles (five levels) were varied within subjects. From the five sets of semantically homogeneous and five heterogeneous items, ten lists of trials were created, each including five presentation cycles (25 trials). Each presentation cycles had five successive trials where each item was shown once. The last item of a cycle was never the same as the first of the next cycle to avoid any repetition. The task was divided into two blocks with each test block consisted of 125 trials, including either two homogeneous and three heterogeneous sets or three homogeneous and two heterogeneous sets. Homogeneous and heterogeneous sets were presented in an alternating order within and between blocks (See *Figure 3.2*).

3.4.2.3 Procedures. Picture naming responses were elicited in English. Participants were familiarized with the pictures along with their names at the beginning of the test to avoid any errors due to unfamiliar items and/or use of different names for the same item. Following the familiarization, participants were shown the picture stimuli in one at a time in a computer screen using E-Prime software. Each trial started with a fixation cross for 250ms followed by a 100ms blank screen followed by the target stimuli with a beep sound for 2000ms. A blank screen appeared following the target stimuli for 500ms before beginning of a new trial. Participants were asked to respond verbally using a bare noun (e.g. banana) and no feedback was given. Responses were voice recorded using a digital voice recorder and transcribed.

3.4.2.4 Scoring. RTs for the correct naming responses were calculated. The onset of each response was labelled manually to obtain greater accuracy and the reaction time was measured from the onset of the beep to the onset of the naming response using PRAAT (Boersma & David, 2015).

3.5 Statistical Analysis

Data from 2.6% of the experimental trials (combined monolinguals and bilinguals) were excluded due to incorrect response or being an outlier (±2.5*SD). RTs for each participant for each cycle and in each context were calculated. For each group, the blocking effect and slopes were calculated twice separately, one including all the presentation cycles and another after exclusion of cycle 1. Context effect was the difference in mean RT of heterogeneous context from the homogeneous context. Slope was calculated by taking the blocking effect across cycles.

Reaction time for the correct responses were submitted to an analysis of variance (ANOVA) including the Context (homogeneous, heterogeneous) and Presentation Cycles (five) as within-participants factors whereas Group (bilingual, monolingual) was the between-participants factor. Another similar ANOVA was performed excluding the cycle 1 to look at the cumulative semantic interference. Further, to find out if there was any facilitation in cycle 1, another ANOVA was conducted where Context was within-participants factor and Group was between-participants factor. Tukey's post hoc tests were applied for significant interaction effects at $p \leq 0.05$. To examine the relationship between the executive control measures and blocked-cyclic naming variables (context effect for all cycles, context effect excluding cycle 1, slope for all cycles, and slope excluding cycle 1), Pearson's correlations (between Stroop ratio and blocked-cyclic naming variables) and Spearman's correlations (between the other two executive control variables and blocked-cyclic naming variables) were performed separately for each group.

3.6 Results

The mean and standard deviation values for the blocked cyclic naming variables for Groups (Monolingual and Bilinguals) and Context (Homogeneous and Heterogeneous) across all the five cycles averaged across participants are presented in Table 3.1 (standard deviation reflects between-subject variation). The results of the statistical tests are provided in Table 3.1 as well. Table 3.2 provides the results of the statistics test when cycle 1 was excluded from the analysis and Table 3.3 provides the results of the statistics test only for cycle 1. Findings from the correlation analyses between the executive control measures and semantic blocking variables for each group are presented in Table 3.4. Findings for Group differences are presented first; followed by the findings on the relationship of executive control measures and semantic blocking variables.

Table3.1

Means (M), Standard Deviations (SD) and the Statistical Results of the Dependent Variables (Hom for Homogeneous and Het for Heterogeneous) for RT (msec) for all cycles

Measures	Bilingual (N = 25)		Monolingual (N = 25)		Statistical results	
	M	*SD*	*M*	*SD*		
	629.8	86.5	595.9	86.5	Group	$F(1,48)=1.9$, $p=.17$, $\eta_p^2=.04$
Hom[1]	637.5	87.5	614.9	87.5	Context	$F(1,48)=71.6$, $p<.001$***, $\eta_p^2=.60$
Cycle1	673.2	77.5	656.4	129	Cycle	$F(4,192)=83$, $p<.001$***, $\eta_p^2=.63$
Cycle2	630.5	87.1	612.8	96.8	Group X Context	$F(1,48)=13.1$, $p=.001$***, $\eta_p^2=.21$
Cycle3	627.9	84.6	600.4	73.7	Group X Cycle	$F(4,192)=.23$, $p=.92$, $\eta_p^2=.005$
Cycle4	629.5	90.2	602.1	85.1	Context X Cycle	$F(4,192)=21.6$, $p<.001$***, $\eta_p^2=.31$
Cycle5	626.4	97.7	603	88.5	Group X Context X Cycle	$F(4,192)=.69$, $p=.60$, $\eta_p^2=.01$
Het[1]	622.2	87.5	576.8	87.5		
Cycle1	698.6	67.3	651	122		
Cycle2	604.2	70.4	563.2	88.9		
Cycle3	604.1	86	558.9	91		
Cycle4	598.1	90.3	557.3	90.7		
Cycle5	605.9	98.7	553.6	89.2		

[1] – Averaged across all cycles; * $p\leq.05$, ** $p\leq.01$, *** $p\leq.001$

Table3.2

Means (M), Standard Deviations (SD) and the Statistical Results of the Dependent Variables (Hom for Homogeneous and Het for Heterogeneous) for RT (msec) excluding cycle1.

Measures	Bilingual (*N* = 25)		Monolingual (*N* = 25)		Statistical results	
	M	*SD*	*M*	*SD*		
Total	615.8	85.1	581.4	85.1	Group	$F(1,48)=2, p=.16, \eta_p^2=.04$
Homo[1]	628.6	85.2	604.6	85.2	Context	$F(1,48)=120.1, p<.001^{***}, \eta_p^2=.71$
Cycle2	630.5	87.1	612.8	96.8	Cycle	$F(3,144)=.5, p=.65, \eta_p^2=.01$
Cycle3	627.9	84.6	600.4	73.7	Group X Context	$F(1,48)=10.1, p=.003^{**}, \eta_p^2=.17$
Cycle4	629.5	90.2	602.1	85.1	Group X Cycle	$F(3,144)=.54, p=.65, \eta_p^2=.01$
Cycle5	626.4	97.7	603	88.5	Context X Cycle	$F(3,144)=.33, p=.80, \eta_p^2=.007$
Het[1]	603.1	86.5	558.2	86.5	Group X Context X Cycle	$F(3,144)=.57, p=.64, \eta_p^2=.01$
Cycle2	604.2	70.4	563.2	88.9		
Cycle3	604.1	86	558.9	91		
Cycle4	598.1	90.3	557.3	90.7		
Cycle5	605.9	98.7	553.6	89.2		

[1] – Averaged across cycles 2-5; * $p\leq.05$, ** $p\leq.01$

Table3.3

Means (M), Standard Deviations (SD) and the Statistical Results of the Dependent Variables for Cycle 1 only.

Measures	Bilingual (*N* = 25)		Monolingual (*N* = 25)		Total (*N* = 50)		Statistical results		
	M	SD	M	SD	M	SD	Group	Context	Group X Context
Homogeneous	673.2	77.5	656.4	129	664.8	106	$F(1,48) = 1.3, p=.27, \eta_p^2=.03$	$F(1,48) = 4, p=.05^{*}, \eta_p^2=.08$	$F(1,48) = 9.5, p=.003^{**}, \eta_p^2=.17$
Heterogeneous	698.6	67.3	651	122	674.8	100			

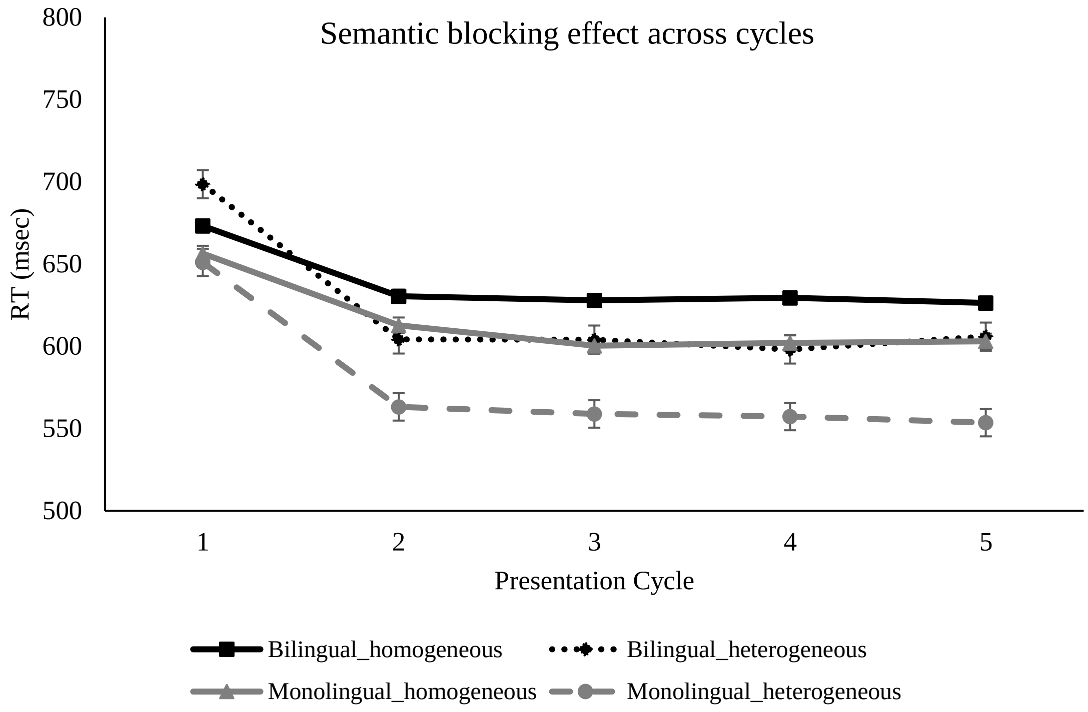


Figure 3.4 Mean RT by context (homogeneous and heterogeneous) for each group (bilingual and monolingual) for each presentation cycle. The error bar represents standard error of the means.

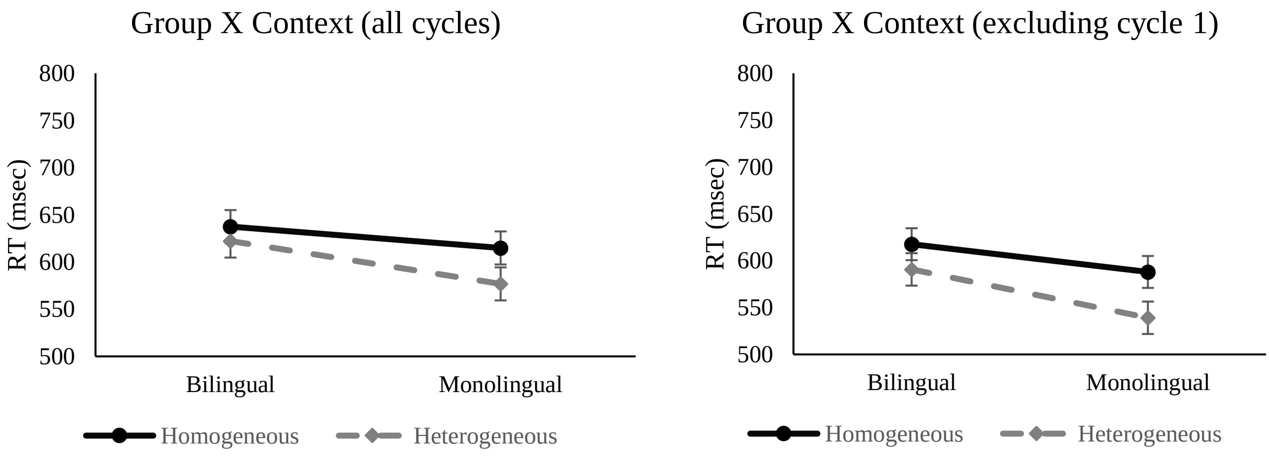


Figure 3.5 Mean RT by context (homogeneous and heterogeneous) for each group (bilingual and monolingual) averaged across all the presentation cycles (left panel) and excluding cycle 1 (right panel). The error bar represents standard error of the means. ** $p \leq .01$, *** $p \leq .001$

3.6.1 Group Differences in Blocked-Cyclic Naming Performance

Figure 3.4 shows the RT in each context across the five presentation cycles. The ANOVA revealed no Group differences that is overall bilinguals (M = 629.8, SD = 86.5) took similar time to name pictures compared to monolinguals (M = 595.9, SD = 86.5, p = .17). There was main effect of Context and Cycle, items were named slower in the homogeneous context (*M* = 626.2, *SD* = 87.7) compared to the heterogeneous context (*M* = 599.5, *SD* = 87.4). Two-way interactions were observed for the Group-by-Context and Context-by-Cycle. Paired-wise comparison on Group X Context revealed significant effect of Context for both groups ($p = .001$ for bilinguals and $p < .001$ for monolinguals) but monolinguals (Mean difference = 38.1 msec, effect size = .6) showed significantly greater blocking effect compared to bilinguals (Mean difference = 15.3 msec, effect size = .2; see *Figure 3.5*).

As *Figure 3.4* shows there was no blocking effect on Cycle 1, the blocking effect emerges from Cycle 2 and remained stable thereafter. Therefore, when Cycle 1 was excluded from the analysis, main effect of Cycle and Context X Cycle interaction were no longer observed, only main effect of Context (Homogeneous, *M* = 616.6, *SD* = 60.2; Heterogeneous, *M* = 580.7, *SD* = 61.1) and Group X Context interactions were present. Paired-wise comparison on Group X Context revealed significant effect of Context for both groups but monolinguals (Mean difference = 46.3 msec, effect size = .7) showed significantly greater blocking effect compared to bilinguals (Mean difference = 25.5 msec, effect size = .4; see *Figure 3.5*).

In terms of facilitation on presentation cycle 1 (see Table 3.3), there was no main effect of Group that is overall both groups took similar time on cycle 1. However, there was a significant effect of Context and Group X Context interaction was present. Facilitation was observed for the homogeneous context (*M* = 664.8, *SD* = 106) as compared to the heterogeneous context (*M* = 674.8, *SD* = 100). Paired-wise comparison revealed bilinguals showed significant facilitation of homogeneous context over heterogeneous context (Mean difference = - 25.4 msec, $p = .001$) whereas monolinguals did not show any facilitation (Mean difference = 5.4 msec, $p = .45$).

3.6.2 Blocked-Cyclic Naming Performance and Executive Control Measures

Table 3.4 presents the correlation coefficients amongst the blocked-cyclic naming variables and executive control measures for monolinguals and bilinguals. Correlation analyses did not reveal any significant relationship between the executive control variables and blocked-cyclic naming variables for both groups.

Table3.4

Correlation Coefficients amongst the Executive Control Measures and the Blocked Cyclic Naming Variables

Executive control measures		Semantic blocking variables			
		Context effect (all cycles)	Context effect (excluding cycle1)	Slope (all cycles)	Slope (excluding cycle1)
Bilingual (*N* =25)					
Stroop ratio	*rs*[1]	-.08	-.08	-.05	.05
	p	.69	.69	.79	.80
Switch cost (RT)	*rs*[2]	-.02	-.08	-.30	-.01
	p	.93	.68	.15	.95
Digit span backward	*rs*[2]	.19	.08	.15	.05
	p	.35	.69	.49	.82
Monolingual (*N* =25)					
Stroop ratio	*rs*[1]	.25	.23	-.14	-.06
	p	.21	.26	.51	.75
Switch cost (RT)	*rs*[2]	-.03	.04	-.12	-.28
	p	.88	.83	.58	.18
Digit span backward	*rs*[2]	-.17	-.09	.27	.17
	p	.43	.64	.19	.42

[1] - Pearson's correlation coefficient; [2] - Spearman's correlation coefficient * $p \leq .05$

3.7 Discussion

The overarching aim of this study was to determine the contribution of linguistic and executive control processes to word retrieval in bilingual and monolingual participants in a linguistic paradigm where executive control demands were varied from low to high. We had a large group of homogeneous Bengali-English bilinguals who were matched for age, education, non-verbal IQ, and gender with the monolinguals. We measured the semantic context effect, semantic facilitation effect on the first presentation cycle, and slope across cycles in the blocked cycling naming task. In addition, present study investigated the executive control abilities in the domains of inhibition, switching and working memory, and linked the performance on the blocked cyclic naming task to the executive measures.

Overall items were named slower in the homogeneous context compared to the heterogeneous context and the semantic context effect emerged from cycle two onwards and did not increase thereafter. Differences between the monolinguals and bilinguals were observed in terms of semantic context effect and semantic facilitation effect. Bilinguals showed significantly lesser semantic context effect that is lesser semantic interference compared to monolinguals; bilinguals showed semantic facilitation effect on the first presentation cycle whereas monolinguals did not show any semantic facilitation.

Greater semantic interference in the homogeneous context compared to the heterogeneous context and relatively stable semantic interference after cycle 2 corroborates with the research by other groups (Belke et al., 2005; See Belke & Steilow, 2013 for a review). These findings support the claim that semantic interference in the blocked cyclic naming is non-cumulative (Belke et al., 2005; Damian & Als, 2005; Abdel Rahman & Melinger, 2007).

This is the first study to report vocabulary-matched bilinguals performing better than monolinguals that is lesser semantic interference for bilinguals. This is a novel finding and can be linked to the studies which have suggested the role of executive control in reducing the semantic interference in blocked-cyclic naming task (Belke, 2008; Crowther & Martin, 2014; Shao et al., 2015). Further, building on the evidence that bilinguals' might have an advantage in executive control that is helping their performance in blocked-cyclic naming task comes from two findings: One, bilinguals demonstrated significantly lesser semantic context effect than monolinguals, which can be linked to superior executive control (as can be seen from Chapter 1 executive control findings). Previous studies have shown participants with better working memory and inhibitory control abilities have lesser semantic context effects (Belke, 2008; Crowther & Martin, 2014; Shao et al., 2015); Second, semantic facilitation on the first presentation cycle shown by bilinguals may be attributed to strategic facilitation or better executive control abilities (Belke, 2017). Belke (2017) reviewed studies with monolingual participants on two types of blocked cyclic naming tasks, namely alternating and blocked design. Studies with blocked design that is when homogeneous and heterogeneous sets are presented in blocks, participants develop awareness of the semantic category and use strategy to perform better in the homogeneous context compared to the heterogeneous context on the first presentation cycle.

Another possible reason of semantic facilitation on first presentation cycle as specified by Belke (2017) is the use of executive control abilities to bias the selection of items in the homogeneous context. However, in the alternating design participants did not show any semantic facilitation. All the studies reviewed by Belke were of monolingual participants. In this study which has an alternating design, monolinguals did not show any semantic facilitation. This finding is in line with the previous studies reviewed by Belke. However, bilingual participants of the present study behaved similar to the monolinguals on the blocked design that is even on the alternating design bilingual participants could bias the selection of items in the homogeneous context on the first presentation cycle. This is a novel finding in the literature and supports our results found in Chapter 2 where bilinguals used better strategy (bigger cluster size, more number of switches, and smaller BCP) to outperform the monolinguals in the difficult letter fluency condition.

Results of correlation analyses did not reveal any significant relationship between the executive control variables and blocked-cyclic naming variables for any of the two groups. This finding is not entirely consistent with previous studies (Crowther & Martin, 2014; Shao et al., 2015). Crowther and Martin (2014) found better inhibitory control as measured by Stroop effect was related to lesser semantic interference across cycles in the homogeneous context. However, we did not correlate our executive control measures with each context of the blocked-cyclic naming task. Future studies involving bilingual speakers might consider correlating Stroop effect with each context of the blocked-cyclic naming task to further understand the relationship between inhibitory control and semantic interference in blocked-cyclic picture naming. Shao et al (2015) found better inhibitory control abilities were related to smaller semantic interference. Shao et al found that semantic context effects were correlated with the slopes of the slowest delta segment indicating participants with poorer inhibitory control abilities had larger semantic interference. We did not perform the delta analysis for this present study. Future studies should consider investigating the differences in delta segment between bilinguals and monolinguals to ascertain whether the performance differences between the two groups is mediated by their inhibitory control differences in terms of delta segment.

Previous studies have shown better working memory leads to smaller semantic interference (Belke, 2008; Crowther & Martin, 2014). However, we did not find any correlation with the working memory and task switching measure. To measure the working memory, digit retention task was used in Belke’s study whereas word span task was used in Crowther and Martin’s study. We measured backward digit span test as a measure of working memory where both of our groups performed almost at a ceiling level giving less spread to the data. Therefore, one of the reasons for not getting any relationship with working memory can be linked to the difficulty level of the task. Future studies should look into different types of working memory measures to explore the relationship between working memory and semantic context effect.

This is the first study to look into the relationship between mental set-shifting and semantic context effect and it is not surprising to see any relationship between these two. Our mental set-shifting task was non-verbal whereas other two executive control measures were verbal in nature. It can be assumed that blocked cyclic naming task does not require one to switch from one mental set to another; therefore, participants may not utilize their mental set-shifting ability to perform in this task. However, future studies should investigate mental-set shifting tasks where verbal domain is involved.

No significant correlation between the executive control measures and blocked-cyclic naming measures for bilinguals could be attributed to the nature of bilingualism in the present study. All the bilinguals were homogeneous and highly proficient and there was not much spread in neither the blocked cyclic naming task nor the inhibitory control task. Another reason of no significant correlations can be ascribed to the factor that bilinguals in this study had better inhibitory control to begin with compared to monolinguals; hence, the simple nature of the task may not have stretched bilinguals enough to utilize their inhibitory control abilities. Future studies should examine how the individual differences in the executive control abilities amongst bilinguals are linked with performance in the blocked-cyclic naming task.

This is the first study to compare bilinguals and monolinguals on a blocked-cyclic naming task where semantic interference is heightened. Similar to Chapter 2, we found clear evidence of bilingual advantage even in a linguistic task where task difficulty is higher (homogeneous condition). We also found bilinguals to use better strategy on the first presentation cycle even in an alternating blocked-cyclic naming design. Overall, present study provided evidence for bilingual advantage in a linguistic task where executive control demands were higher. Future studies should explore the relationship between semantic interference and executive control across different types of population (e.g. bilinguals with different levels of proficiency, bilinguals with neurogenic disorder), broad range of executive control measures, different blocked-cyclic naming paradigm (alternate vs. blocked) etc.

Chapter 4. Verbal Fluency in Bilingual Aphasia: Linguistic and Executive Control Contribution

4.1 Abstract

Background. Executive control differences and its relationship with word production abilities between healthy monolingual and bilingual speakers' remains a hotly debated area in the literature. However, it is still not clear whether bilinguals with aphasia (BWA) would show a similar relationship between executive control and word production abilities as demonstrated by healthy bilinguals. From healthy bilingual literature (Chapter 2), we found clear differences between monolingual and bilinguals in verbal fluency task and some of these differences were mediated by the executive control abilities. In this present study, we aim to establish further the relationship between word production and executive control abilities in BWA using verbal fluency task and separate executive control measures.

Aims. To determine the contribution of linguistic and executive control processes to word retrieval in bilinguals with aphasia (BWA) and bilingual healthy adults (BHA) by using verbal fluency task.

Methods & Procedure. Verbal fluency data for semantic (*animals, fruits and vegetables*) and letter fluency (*F, A, S*; *P, K, M*) were collected from eight non-fluent Bengali-English BWA and eight Bengali-English BHA in Bengali and English. The groups were matched for age, sex, years of education, and other bilingualism measures, such as language acquisition history, the language of instruction during education, self-rated language proficiency, language usage, and language dominance. Traditional analysis (e.g., number of correct responses) along with involved analysis techniques – such as fluency difference scores (FDS) between semantic and letter fluency conditions, time course analysis, and qualitative analysis (e.g. clustering, switching, within-cluster pause and between-cluster pause) were performed. Participants also performed three executive control tests tapping into inhibitory control processes (Stroop ratio), mental-set shifting (TMT difference) and working memory (backward digit span).

Outcomes & Results. Both groups performed better in the semantic fluency compared to the letter fluency. BWA performed poorer compared to BHA on both linguistic (number of correct responses, initiation parameter) and executive control (FDS, slope, number of switches, between-cluster pauses) components of the verbal fluency task. However, both groups performed similarly on measures (response latency, cluster size, within-cluster pauses) where executive control demands were relatively smaller. There were no cross-linguistic differences for BWA. However, BHA group performed better in their dominant language (Bengali) on the semantic fluency and in their non-dominant language (English) on the letter fluency. Compared to the BHA, BWA showed significantly poorer inhibition and mental shifting skills but a comparable working memory. Correlation analysis between the executive control and verbal fluency measures revealed significant correlations only for the BWA group, specifically for inhibitory control and mental set-shifting abilities. BWA with better inhibitory control and mental set-shifting abilities produced more number of correct responses, took less time to come up with the first response, had more linguistic resources to begin with and switched more number of occasions.

Conclusions & Implications. In conclusion, we found BWA had difficulty in the executive control component of the verbal fluency task in addition to their linguistic deficits which is further supported by the findings from separate executive control and correlation analysis. Further, present study confirms that inhibitory control and mental shifting abilities played a key role in the verbal fluency performance differences between BWA and BHA. From the clinical perspective, this research highlights the importance of using a full range of verbal fluency and executive control measure to tap into the linguistic as well as executive control abilities of BWA. This type of evidence is currently lacking in the literature.

4.2 Introduction

Research has shown that the impairment in executive control may influence the word production abilities in people with aphasia (PWA) (Kuzmina & Weekes, 2017; Murray, 2012; Villard & Kiran, 2016). However, studies investigating the relationship between the word production and executive control processes are mostly limited to monolingual PWA and very little is known about bilinguals with aphasia (BWA). It is important to investigate whether BWA would show similar relationship between executive control and word production abilities as shown by healthy bilinguals. In Chapter 2, we found clear differences between monolingual and bilinguals in verbal fluency task and some of these differences were mediated by the executive control abilities. In this present study, we aim to further establish the relationship between word production and executive control abilities in BWA using verbal fluency task and executive control measures. Studies involving BWA provide valuable information not only to the researchers but also will help clinicians to develop appropriate assessment and treatment protocol for BWA which is lacking at present moment.

It is well established that PWA produce fewer exemplars in a verbal fluency task than HA and the productivity reduces as a function of time (e.g., Adams et al., 1989; Arroyo-Anlló et al., 2011; Baldo et al., 2010; Bose et al., 2017; Helm-Estabrooks, 2002; Kiran et al., 2014; Roberts & Le Dorze, 1994; Sarno et al., 2005). Depending on the type of aphasia, PWA could show dissociation in semantic and letter fluency. For example, Baldo et al (2010) tested two participants, one with Wernicke's aphasia (based on WAB) and another with mild Broca's aphasia (based on clinical symptom, WAB: Conduction aphasia), on a semantic (fruits, animals, and supermarket items) and letter fluency (F, A, S) task. Results revealed double dissociation. Participant with Wernicke's aphasia showed reduced cluster size on the semantic fluency but normal cluster size on the letter fluency, whilst the participant with

Broca's aphasia demonstrated unimpaired cluster size on the semantic fluency but reduced cluster size on the letter fluency.

Most studies involving PWA used a limited number of variables in describing verbal fluency performance (Bose et al., 2017; Faroqi-Shah et al., 2016; Kiran et al., 2014). Bose et al. (2017) demonstrated that on a semantic fluency task, compared to monolingual healthy adults, monolingual PWA produced significantly fewer words, smaller cluster size, longer within- and between-cluster pauses, and number of switches were significantly correlated with a decrease in between-cluster pauses. Bose et al. concluded that poorer performance of PWA arose primarily from the lexical retrieval deficit but speculated that executive control deficits may also contribute to the performance deficits. However, Bose et al.'s study did not include full range of assessment (fluency difference score and time-course analysis were not included), letter fluency condition and separate executive control measures to confirm the role of executive control in lexical retrieval deficit.

Similarly, Kiran et al (2014) tested 10 Spanish-English BWA and 12 bilingual healthy adults (BHA) on a semantic fluency (animals, food, and clothing) task. BWA produced fewer correct responses, smaller cluster sizes, and fewer numbers of switches compared to BHA. In terms of correct responses and cluster size, BHA group performed significantly better in their most currently used language (English). However, there were no cross-linguistic differences in any of the above-mentioned measures for BWA. Case series analysis found that most of the patients performed better in their most proficient and currently used language (Spanish). The author concluded that the differences in both the groups arise from the lexical retrieval deficits in BWA and can be linked to their language proficiency in the two languages.

Except for Faroqi-Shah et al. (2016), no research has linked verbal fluency performance with executive control measures in PWA. Faroqi-Shah et al tested three groups of PWA: 18 English monolingual PWA, 10 English dominant BWA (non-dominant language included Russian, French, Hungarian, and Spanish), and 10 Tamil dominant BWA (non-dominant language was English) on a semantic fluency task (animals), and a verbal Stroop task. Dependent variable for the semantic fluency task was number of correct responses and for the Stroop test, Stroop difference and Conflict ratio were measured. Stroop difference was the difference in accuracy/RT between incongruent and congruent trials. Conflict ratio was calculated as the accuracy/RT difference between incongruent and congruent divided by the congruent trials. On semantic fluency task, PWA produced significantly fewer correct responses compared to healthy adults. On Stroop test, PWA performed significantly poorer as compared to healthy adults. There were no significant correlations between any of the Stroop measures and number of correct responses on the semantic fluency task for any group.

These studies have emphasized the greater role of linguistic processes in verbal fluency performance difference between PWA and healthy adults; however, these studies suffer from not including letter fluency condition which is thought to be more dependent on the executive control abilities (Delis et al., 2001). Importantly, they do not include a more involved method of verbal fluency (see Chapter 2, Table 2.1) which is crucial for a comprehensive understanding of the interaction of executive control and linguistic processes in the verbal fluency task. As seen in Chapter 2 and other healthy literature, executive control especially better inhibitory control leads to superior performance in verbal fluency task. In addition, better performance in letter fluency compared to semantic fluency cannot be taken as a sole indicator of superior executive control abilities; however, such claims need to be backed up by separate and independent executive control measures (Paap et al., 2017). As far our knowledge, Faroqi-Shah et al.'s study is the only study which has correlated the performance in the verbal fluency with separate executive control measures in PWA; however, they measured only number of correct responses for the semantic fluency task and inhibitory control for the executive control measure.

In the present study, we aim to fulfill these gaps in the literature by including both semantic and letter fluency tasks and a full range of verbal fluency measures (see Chapter 2, Table 2.1) where both the linguistic and executive control processes can be tested. In addition, separate measures of executive control (inhibitory control, mental-set shifting, and working memory) were administered to find out the relationship between the word production and executive control in BWA.

Present study also aims to add to the literature of executive control abilities in aphasia by comparing BWA with BHA on three extensively tested measures of executive control (Miyake et al., 2000) – inhibitory control (Stroop test), task switching (Trail Making Test), and working memory (backward digit span test).

4.3 The Current Investigation, Research Questions and Predictions

In this research, we compared the differences in verbal fluency performance between 8 Bengali-English non-fluent BWA and 8 BHA to understand the relative contribution of linguistic and executive control processes during word production in BWA. The two groups were matched on age, sex, years of education, and pre-stroke language abilities (acquisition history, language of instruction during education, self-rated language proficiency, language usage, and dominance). We collected semantic (Bengali and English: animals, fruits and vegetables) and letter (English: F, A, S; Bengali: P, K, M) fluency data for 60 s in English and Bengali. We provided detailed characterization of our participants on relevant variables for bilingualism: language history and acquisition patterns, usage patterns, proficiency and dominance. In addition, we characterized our BWA on type, severity of aphasia as well as their post-stroke linguistic profile (naming, repetition, word-to-picture matching, and reading aloud) in both languages.

We quantified the verbal fluency performance in terms of quantitative (number of correct responses, fluency proportion difference score), time course (1st-RT, Sub-RT, initiation, slope), and qualitative (cluster size, number of switches, within-cluster pauses, between-cluster pauses) measures (See Table 1 for a complete description of these variables). We analyzed the verbal fluency data both at the group level as well as at the individual level. Individual level analyses were carried out only for the selected variables: number of correct responses (CR), fluency proportion difference score (FDS), cluster size, and number of switches. We tested executive control processes using the same executive control measures as described in Chapter 2, except for the mental-set shifting. The colour-shape switch task used for the mental-set shifting in healthy adults was too difficult for the BWA. Hence, we decide to replace this task with Trail Making Test (Reitan, 1986) which is widely used test in PWA (I. Sánchez-Cubillo et al., 2009). The overarching research aim of this study was to determine the relative contribution of linguistic and executive control processes during word production in BWA and BHA population by using verbal fluency task. Following were the specific research aims and predictions:

1. To determine the differences (between group: BWA and BHA, between languages: English and Bengali) in verbal fluency performance (quantitative, time-course, and qualitative analysis).

   We expect BWA group to produce fewer number of correct responses in both semantic and letter fluency as compared to BHA. A larger FDS would be obtained for BWA compared to BHA if they demonstrate poorer executive control abilities in addition to their linguistic deficits. Similarly, if BWA group have executive control difficulties, then in the time course analysis, we expect BWA have shorter Sub-RT and steeper slope compared to BHA. Similar to Bose et al.'s (2017) study, we expect BWA to have smaller cluster size, produced fewer number of switches and having longer within- and between-cluster pause compared to BHA, indicative of poorer lexical and executive control abilities. At individual level, we expect BWA to perform better in semantic fluency condition as compared to letter fluency condition, especially for the cluster size (Baldo et al., 2010). On cross-linguistic comparison, similar to Kiran et al.'s (2014) study, at group level, we expect BHA to perform significantly better in their most currently used language and no cross-linguistic differences for the BWA. At the individual level, we expect BWA to perform better in their most currently used and proficient language especially on number of correct responses and cluster size.

2. To determine whether the differential verbal fluency performance was influenced by the differences in the executive control abilities for BWA and BHA.
   We expect executive control measures to correlate significantly with the verbal fluency measures for both BWA and BHA. However, we expect BWA to have stronger correlation between executive control and verbal fluency measures compared to BHA. This prediction is an extrapolation from the observation that low proficient bilinguals engage with their executive control mechanism while performing task in their less proficient language (Hernandez & Meschyan, 2006). Following on the similar argument, BWA would need to recruit their executive control processes to compensate for their linguistic difficulties while performing in the verbal fluency task. However, high proficient BHA may or may not need their executive control processes to perform in this task.

4.4 Method

4.4.1 Participants

Eight Bengali-English BWA (*M* = 47.75 years, *SD* = 11.9) and eight Bengali-English BHA (*M* = 43.13 years, *SD* =15.30) participated in this study. BWA were recruited via contacts with certified speech-language therapists from Kolkata, India and control speakers were recruited via researcher's personal contacts.

All BWA speakers sustained a single left hemisphere CVA resulting in aphasia at least six months prior to participation. Medical and neurological reports were reviewed to establish medical history. All the participants were right handed (pre-stroke for BWA) and had at least twelve years of education (BWA: M = 16.63 years, SD = 2.33; BHA: M = 16.88 years, SD = 1.88). There was no history of other neurological conditions, alcohol or drug abuse, neuropsychiatric conditions or dementia. All BWA were matched with BHA on age, sex, and years of education (all *p*s >.05, see Table 4.1). The demographic and neurological details of BWA are summarized in Table 4.1. The demographic details of BHA are summarized in Table 4.2. Participation in this study was voluntary and participants provided written consent prior to participation (See Appendix 4.1 for an example of information sheet and consent form). All the procedures in this study were approved by the University of Reading Research Ethics Committee (Ethical approval code: 2014/060/AB).

4.4.2 Language Background and Executive Control Measures

In this section, we will discuss the background measures and the findings of those measures. First, we will describe the subjective measures used for characterising our bilingual participants followed by the test batteries to characterise the severity and type of aphasia in both languages, and the extent of language impairment at the single word level in both languages. At the end, we will discuss the executive control measures and the findings.

4.4.2.1 Bilingualism measures. All the speakers completed the same subjective language background questionnaires (language acquisition history, language of instruction, self-rated language proficiency, language usage, and language dominance) as described in Chapter 2. BWA speakers completed twice to separately report pre-stroke and post-stroke language abilities, with the support from caregiver or family members, as needed. BWA were matched (pre-stroke) with BHA on language acquisition history, language of instruction during education, self-rated language proficiency, language usage and language dominance (all *p*s >.05, see Table 4.3). All participants were sequential bilinguals, that is, they had acquired Bengali before English (age of onset for English is 5 years or more). English was the language of instruction during higher education for all the participants.

On a scale of zero to seven (0 = no proficiency, 7 = native like proficiency), all the participants completed self-rated proficiency questionnaires (BWA reported post-stroke proficiency scores as well). Proficiency scores were averaged across speaking, comprehension, reading and writing domains. All speakers reported proficiency level of 5 or more in Bengali (except BWA3, pre= 2.8, post= 2.5) and in English (except BWA2 pre= 3.8, post= 2.2; BWA8 pre= 4.2, post= 2.7). All the participants reported Bengali as their most used language except BWA3 and BWA6 who used English comparatively more than Bengali both pre-and -post stroke. This could be attributed to their pre-morbid professional occupations. BWA3 was marketing and management personnel in a multinational company, whereas BWA6 was a software engineer. Reflecting the proficiency score, as a group BWA participants were Bengali dominant ($M_{\text{Bengali dominance}}$ M_{pre}= 25.4, SD = 5.4; M_{post}= 24.8, SD = 7.2; $M_{\text{English dominance}}$ M_{pre}= 16.6, SD = 4.9; M_{post}= 14.8, SD = 5.9). The exceptions were BWA3 and BWA7 who were English dominants, while BWA6 showed equal dominance in both languages. Language background scores obtained from the language background questionnaire of BWA and BHA groups are summarized in Table 4.3 and Table 4.4 respectively.

Table4.1

Demographic Profiles of each BWA, Mean and Standard Deviations of BWA and BHA Groups and the Statistical Results Comparing the Groups.

Variables	BWA1	BWA2	BWA3	BWA4	BWA5	BWA6	BWA7	BWA8	**BWA (N = 8)**		**BHA (N = 8)**		Statistical results
									M	*SD*	*M*	*SD*	
Age	50	58	50	54	35	35	34	66	47.4	12.9	44.9	16.5	$t(14)=.67$, $p=.51$
Sex	Male	Female	Male	Male	Female	Male	Male	Male	Female (2)	Male (6)	Female (2)	Male (6)	$\chi2\ (1) = 0, p = 1$
Years of education	18	12	17	18	20	16	16	16	16.6	2.5	16.8	1.8	$t(14)=-.23$, $p=.82$
Highest degree	Postgraduate	High school	Graduate	Graduate	Postgraduate	Graduate	Graduate	Graduate					
Time post onset (months)	17	58	19	12	27	40	22	27	27.8	14.8	-	-	
Pre-stroke occupation	Accountant	Homemaker	Marketing	General manager	PhD student	Software Engineer	Marketing	Clerk					
Aphasia type[2]													
Bengali	Broca's	Broca's	CNT[3]	Transcortical motor	Broca's	CNT[3]	Broca's	Broca's					
English	Broca's	CNT[3]	Broca's	Transcortical motor	Broca's	Broca's	Broca's	CNT[3]					
Severity[3]													
Bengali	Moderate	Moderate	CNT[3]	Mild	Mild	CNT[3]	Mild	Moderate					
English	Moderate	CNT[3]	Moderate	Mild	Moderate	Severe	Mild	CNT[3]					

Note: [1]- Middle Cerebral Artery, [2]- Type and severity of aphasia were classified based on WAB-R (Kertesz, 2006) in English and the adapted version in Bengali (Keshree, Kumar, Basu, Chakrabarty, & Kishore, 2013); [3]- Could Not be Tested due to unavailability.

Table 4.2

Demographic Profiles of each BHA.

Variables	BHA1	BHA2	BHA3	BHA4	BHA5	BHA6	BHA7	BHA8
Age	29	66	52	27	31	58	51	31
Sex	Female	Male	Female	Male	Male	Male	Male	Male
Years of education	19	16	15	15	19	15	17	19
Highest degree	Postgraduate	Graduate	Graduate	Graduate	Postgraduate	Graduate	Postgraduate	Postgraduate
Occupation	PhD student	Businessman	Homemaker	Marketing	Software Engineer	School Teacher	School Teacher	Software Engineer

Table4.3

Self-reported Language Background Questionnaire Scores of each BWA, Means and Standard Deviations of BWA and BHA Groups and the Statistical Results Comparing the Groups.

Measures	BWA1		BWA2		BWA3		BWA4		BWA5		BWA6		BWA7		BWA8								
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	**BWA (*N* = 8)**						
																	Pre		Post		**BHA (*N* =8)**		
																	M	*SD*	*M*	*SD*	*M*	*SD*	Statistical results[8]
Bengali																							
Language acquisition history[1,6]	16		16		12		15		14		12		14		14		14.1	1.5	-	-	14.9	1.1	$t(14)=-1.1$, $p=.29$
Language of instruction[2,6]	9		6		6		9		9		3		6		8		7	2.1	-	-	6.8	2.5	$t(14)=.10$, $p=.91$
Self-rated language proficiency[3,6]	7	5	7	4.5	2.8	2.5	7	5.2	7	4.5	5.5	3.5	6	4.8	7	4.2	6.2	1.5	4.3	.8	6.6	.57	$t(14)=-.77$, $p=.45$
Speaking	7	4	7	4	4.5	3	7	5	7	4	7	2	7	6	7	3	6.7	.9	3.9	1.2	7	-	
Comprehension	7	7	7	6	5	5	7	6	7	6	7	6	7	7	7	6	6.7	.7	6.1	.6	7	-	
Reading	7	6	7	4	1	1	7	5	7	4	4	3	5	3	7	4	5.6	2.2	3.7	1.5	6.2	1	
Writing	7	3	7	4	1	1	7	5	7	4	4	3	5	3	7	4	5.6	2.2	3.4	1.2	6.1	1.3	
Language use[4,6]	30	30	30	30	17	14	30	30	24	26	19	13	23	26	30	30	25.4	5.4	24.8	7.2	25.8	7.7	$t(14)=-.11$, $p=.91$
Language dominance[5,7]	23		26		12		23		25		19		11		26		20.6	6	-	-	20.9	5.8	$t(14)=-.08$, $p=.93$
English																							
Language acquisition history[1,6]	2		0		3		1		5		4		1		0		2	1.8	-	-	2.9	1.4	$t(14)=-.10$, $p=.31$
Language of instruction[2,6]	3		0		9		6		2		9		9		3		5.1	3.6	-	-	5.6	1.3	$t(14)=-.37$, $p=.72$
Self-rated language proficiency[3,6]	6.5	4.4	3.8	2.2	6	4.8	6	4.1	5.6	4	7	4.8	7	4.5	4.2	2.7	5.8	1.2	3.9	.9	4.8	1.5	$t(14)=1.3$, $p=.21$
Speaking	6	2	2	2	6	4	6	3.5	4.5	3	7	3	7	3	3	2	5.2	1.9	2.8	.7	4.6	1.8	
Comprehension	6	6	3	3	6	6	6	5	6	5	7	6	7	6	4	3	5.6	1.4	5	1.3	4.8	1.8	
Reading	7	6	5	2	6	5	6	4	6	4	7	5	7	4	5	3	6.1	.8	4.1	1.2	5.2	1	
Writing	7	3.5	5	2	6	4	6	4	6	4	7	5	7	5	5	3	6.1	.8	3.8	.9	4.7	1.7	
Language use[4,6]	18	13	8	6	24	21	16	12	16	15	21	24	18	15	12	12	16.6	4.9	14.8	5.9	15.1	7.7	$t(14)=.71$, $p=.49$
Language dominance[5,7]	7		2		17		9		8		20		23		5		11.4	7.6	-	-	12	4.5	$t(14)=-.20$, $p=.84$

Note: [1] – maximum score possible 16, greater score in one language means greater immersion into that language during childhood; [2] – maximum score possible 9, greater score in one language means greater number of years of education in that language; [3] – On a scale of zero to seven (0 = no proficiency, 7 = native like proficiency),greater score in language means greater proficiency in that language; [4] – maximum score possible 25, greater score in one language means greater use of that language in daily life; [5] – maximum score possible 31, dominant language is the language which obtains a greater score than the other language; [6] – adapted from Muñoz et al., 1999; [7] – language dominance questionnaire (Dunn & Fox Tree, 2009); [8] – independent sample t-test was conducted between the pre-stroke language abilities of BWA and language abilities of BHA.

Table4.4

Self-reported Language Background Questionnaire Scores of each BHA, Means and Standard Deviations.

Measures	BHA1	BHA2	BHA3	BHA4	BHA5	BHA6	BHA7	BHA8	*M*	*SD*
Bengali										
Language acquisition history[1,6]	14	17	15	14	14	15	14	16	14.9	1.1
Language of instruction[2,6]	3	8	7	3	9	8	9	8	6.8	2.5
Self-rated language proficiency[3,6]	5.7	7	7	5.7	6.7	7	6.5	7	6.6	.57
Speaking	7	7	7	7	7	7	7	7	7	-
Comprehension	7	7	7	7	7	7	7	7	7	-
Reading	5	7	7	5	7	7	5	7	6.2	1
Writing	4	7	7	4	6	7	7	7	6.1	1.3
Language use[4,6]	8	30	30	22	28	30	30	28	25.8	7.7
Language dominance[5,7]	11	24	24	12	24	24	24	24	20.9	5.8
English										
Language acquisition history[1,6]	6	2	2	4	3	2	2	2	2.9	1.4
Language of instruction[2,6]	7	5	6	7	6	3	6	5	5.6	1.3
Self-rated language proficiency[3,6]	7	3.5	3.2	6.2	5.7	3.5	3.7	6	4.8	1.5
Speaking	7	3	3	6	6	3	3	6	4.6	1.8
Comprehension	7	4	3	7	6	3	3	6	4.8	1.8
Reading	7	4	4	6	5	5	5	6	5.2	1
Writing	7	3	3	6	6	3	4	6	4.7	1.7
Language use[4,6]	16	18	16	18	8	16	13	16	15.1	7.7
Language dominance[5,7]	18	8	8	20	11	10	10	11	12	4.5

Note: [1] – maximum score possible 16, greater score in one language means greater immersion into that language during childhood; [2] – maximum score possible 9, greater score in one language means greater number of years of education in that language; [3] – On a scale of zero to seven (0 = no proficiency, 7 = native like proficiency),greater score in language means greater proficiency in that language; [4] – maximum score possible 25, greater score in one language means greater use of that language in daily life; [5] – maximum score possible 31, dominant language is the language which obtains a greater score than the other language; [6] – adapted from Muñoz et al., 1999; [7] – language dominance questionnaire (Dunn & Fox Tree, 2009);

4.4.2.2 Western Aphasia Battery-Revised (WAB-R). We administered WAB-R in English (Kertesz, 2006) and its adapted version in Bengali (Keshree, Kumar, Basu, Chakrabarty, & Kishore, 2013) to assess the type and severity of aphasia in both languages. WAB-R assesses four language areas: spoken language, auditory comprehension, repetition and naming. Participant BWA3 and BWA6 was not available for the Bengali version of the test and BWA2 and BWA8 was not available for the English version of the test. Severity of language deficits (Aphasia Quotient; AQ) and aphasia type were determined based on the performance on these subtests. Details of participants' performance on the individual subtests are provided in Table 4.5 and Table 4.6 provides the picnic picture description. All BWA showed good auditory comprehension but demonstrated variable level of difficulty in spoken language production, naming, and repetition (see Table 4.5). Based on the test results, BWA presented with non-fluent aphasia with mild to moderate severity in both languages, except BWA6 who had severe aphasia in English and was not available for testing in Bengali. Therefore, BWA group were relatively homogenous in terms type of aphasia (all non-fluent) in both languages.

Table4.5

Western Aphasia Battery Test Scores in Bengali (Keshri et al., 2013) and English (Kertesz, 2006) of each BWA.

Participants	Spontaneous Speech (SS)[3]			Auditory Verbal Comprehension (AVC)					Repetition		Naming							Aphasia severity[18]	Aphasia Type
	Information Content[1]	Fluency[2]	Score[3]	Yes/No questions[4]	Auditory word Recognition[5]	Sequential commands[6]	Total[7]	Score[8]	Repetition[9]	Score[10]	Object naming[11]	Fluency[12]	Sentence completion[13]	Responsive speech[14]	Total[15]		Aphasia Quotient (AQ)[17]		
Bengali																			
BWA1	7	4	11	60	60	80	200	10	64	6.4	42	10	9	8	69	6.9	68.6	Moderate	Broca's
BWA2	8	4	12	60	60	80	200	10	65	6.5	54	7	6	8	75	7.5	75	Moderate	Broca's
BWA3	CNT[19]																		
BWA4	8	5	13	60	60	80	200	10	100	10	57	12	9	10	88	8.8	83.6	Mild	Transcortical Motor
BWA5	8	4	12	60	60	80	200	10	78	7.8	57	10	9	10	86	8.6	76.8	Mild	Broca's
BWA6	CNT[19]																		
BWA7	8	4	12	60	60	80	200	10	78	7.8	57	12	9	10	88	8.8	77.2	Mild	Broca's
BWA8	7	4	11	60	60	80	200	10	65	6.5	45	8	8	8	69	6.9	68.6	Moderate	Broca's
English																			
BWA1	7	4	11	54	60	80	194	9.7	49	4.9	38	16	8	4	66	6.6	64.4	Moderate	Broca's
BWA2	CNT[19]																		
BWA3	9	4	13	60	60	80	200	10	77	7.7	42	11	8	4	65	6.5	74.4	Moderate	Broca's
BWA4	8	4	12	60	60	80	200	10	90	9	54	16	9	10	89	8.9	79.8	Mild	Transcortical Motor
BWA5	8	4	12	60	60	80	200	10	76	7.6	48	11	8	8	75	7.5	74.2	Moderate	Broca's
BWA6	4	2	6	54	56	66	176	8.8	30	3	45	5	6	6	62	6.2	48	Severe	Broca's
BWA7	8	4	12	60	60	80	200	10	76	7.6	57	13	8	8	86	8.6	76.4	Mild	Broca's
BWA8	CNT[19]																		

Note: [1]- maximum possible score 10; [2]- maximum possible score 10; [3]-sum of information content and fluency score; [4]- maximum possible score 60; [5]- maximum possible score 60, [6] – maximum possible score 80; [7]- sum of yes/no question, auditory word recognition and sequential commands; [8]- total score divided by 20; [9]- maximum possible score 100; [10]- repetition score divided by 10; [11]- maximum possible score 60; [12] – maximum possible score 20; [13]- maximum possible score 10; [14]- maximum possible score 10; [15]- sum of all the naming subtests scores; [16]- total divided by 10; [17]- AQ was calculated by using the following formula {AQ= (SS score+ AVC score+ Repetition score+ Naming score)*2}; [18]- Severity rating scale= Mild (76 and above), Moderate (51-75), Severe (26-50), Very severe (0-25); [19]- Could Not be Tested due to unavailability.

Table4.6

Connected speech elicited through the Picnic Picture description for Each BWA in the Bengali (Keshri et al., 2013) and English (Kertesz, 2006) version of Western Aphasia Battery. Dots indicate pauses.

	Bengali	**English**
BWA1	cheleta porche..aa.mach umm..nic..gach bari student dudh dhalche. flag kukur nouko ghuri..cheleta cheleta orache ghuri...nouko cholche	student oh.. student student earling learning classbook. uuh.. girls milk milk..hmm..milk..home home tree log dog river boat flag. kite kite..the boy kite flying..boy learning classbook..girls milk milk transistor.
BWA2	feast korte ge..gechilo. ghuri orano..ghuri oray..ora..orache ar poralekha korche. ghol na ki ghol na ki cha.gan sun..sun..sunchilo radio. kukur pase. nouka chorbe dariye chele. gach.	CNP[1]
BWA3	CNP[1]	aa..man is aa..man is..aa..umm..reading book..the man and his wife ii..aaare having the picnic..aa..his wife is..umm..aa..pouring coffee in the aa..umm..in the glass..and..in the fask..fask..um..it is..dog is looking in the umm..in the the ..the dog is looking in the family and..hope family give me food..aa..boy is flying a kite..aaa..umm..ba..on the river sailboat..two man in the sailboat..aa..umm..is there..the tall flagpole is there..and the tree is there and aaa..aaa..house aa..its..house in the garage is there and the leave me..the neighbourhood was grassy..grassy..the neighbourhood is in the countryside.
BWA4	Eta ekta gramer chobi..ekhane kichu lok bose nana kaj korche..ekjon boi porche..arekjon flask theke cha dhalche..baire ekta radio bajche..Radio na transistor bajche..koyekta kukur edik oduk ghure berache..ekta chele ghuri orache…arekta nouko moto..aa..ekta jhil moto ache..ba nodio bola jay..setay ekta nouko ghurche,.,.pal tola nouko..tate duto lok aaa mane bose ache..ekta pataka urche..ekta bari ache..barir samne ekta gario dariye ache..mone hoy ei garite kore era ekhane picnic korte eseche…vodrolok boi porche ar vodromahila cha dhalche..ar ekta choto chele se ghuri orache.	Its seems a picnic was going on..some kids were playing football..someone is cooking on the aa..and someone is playing ..some kids with ball..and top..and aa..and what..there are so many vegetables there..someone is reading newspaper..someone is playing song on a tape..some birds are playing,..some dogs are also playing and..what else....the scenery is quite good by the side of the river. All are in very jubilant mood. That's all.
BWA5	Picnic spot. Garita park koreche..couple bose ache..mon diye boi porche..vodromohila radio te gan sunche..weather ta valo mone hoche akron ghuri urche..ar nodite nouko cholche..doggy o ache..anek cute..amio future e erkm picnic e jabo.	the cark is park there..behind the picnic spot..
BWA6	CNP[1]	Boy..boy cook..mother..father paper reading..football..football..playing..boy and baby and ball car.
BWA7	Ei chobite ami dekhte pachi ekta park ache..sekhane kichu lok kichu activity korchen..ekta family bose picnic korchen..aa..ekta chele ghuri orache..ekta aaa..chagol pase bose ache..ekta nouko pase nodite vese jache.	Aa..lot of people are there in the picnic spot..a lady is cooking something..two kids are watching along..two kids are playing football..a gentleman a is reading newspaper..on a mat..and two..aa..kids are listen to something…a father mother along with their kid are sightseeing.
BWA8	Ekhane choruivati hoche..thik ache..ekhane ekhane baji sunche…ekhane eita hoche oitake bole..ummmm…acha..ekhane hoche choruivati..ball khelche..thik ache..ekhane ekhane mane..ei duto lok..ei duto chele..ei duto sami stri ei bachatake niye eseche ekhane dekhte..eta samudrer jol..samudro na nodi..thik ache..ekhane ranna hoche..jai hok..ki ache..umm..	CNP[1]

Note:[1]Could Not Perform.

4.4.2.3 Croft's test battery. As there is no comprehensive psycholinguistic test like Psycholinguistic Assessments of Language Processing in Aphasia (PALPA; Kay, Lesser & Coltheart, 1992) which is culturally and linguistically appropriate in Bengali, we chose to administer the test battery developed by Croft, Marshall, Pring, and Hardwick (2015). Croft developed a test battery to measure language production and comprehension of spoken nouns at a single word level in each language. The test battery included picture naming, spoken word-to-picture matching, word repetition, and reading aloud tasks. Each task included 30 items; same items were used for the naming and repetition task which allows comparing performance across items. Spoken word-to-picture matching and reading aloud had same items for similar reason. Croft had tested 6 Bengali-English BWA and 15 BHA (Croft et al., 2015). We chose to use the Croft's test for the following reason:

1. Although, the test was developed involving Sylheti (dialect of Bengali) speakers from Bangladesh living in UK, words that were not cognates in Sylheti and Bengali were excluded during the development. Further, to validate the cultural and linguistic relevance for the present study, we administered the Croft's test on our 8 BHA. Our BHA performed at the ceiling in both languages. Therefore, the test can be considered culturally and linguistically appropriate for the Bengali speakers living in India.
2. Croft's test uses same line drawings to elicit the target items across the languages which allows for testing cross-linguistic differences.
3. Word pairs across the two languages were matched for mean naming response latencies and there were no cognates across languages, which were important consideration (see Chapter 5). Stimuli were also matched for frequency within each task (14 high frequency words and 16 low frequency words).

Table 4.8 represents the results for all the participants in Bengali and English. Participants were tested on both English and Bengali on different day and the order of stimuli set was randomized between languages. Instructions were given in written format as well as verbally in the corresponding language.

4.4.2.3.1 Spoken word-to-picture matching. In this task, participants were given an A4 page where along with the target picture, four distractors were present. Stimuli were black and white line drawings. This task mirrored the spoken word-to-picture matching subtest of PALPA (Kay et al., 1992) where the distractors were of following four types: close semantic distractor (e.g. target 'leaf', distractor 'flower'), distant semantic distractor (e.g. target 'leaf', distractor 'nut'), visually related distractor (e.g. target 'leaf', distractor 'feather') and unrelated distractor (e.g. target 'leaf', distractor 'bird'). Participants were asked to listen to the spoken noun said by the experimenter and point to the target picture. Participant's responses were recorded. All the BWA speakers performed at the ceiling level, showing no difficulty in single word comprehension suggestive of intact semantic system at least at a single word level. Results of this task are also consistent with the auditory verbal comprehension subtest scores of WAB.

4.4.2.3.2 Picture naming. Items were English nouns and their translation equivalents in Bengali (*neck, /gɔla/; rabbit, /kʰɔrgos/; road, /rasta/; teeth, /dant̪/; tiger, /bagh/; swan, /hãs/; umbrella, /tʃʰat̪a/; onion, /peỹaj/; foot, /pa/; monkey, /bãdɔr/; watch, /gʰori/; pineapple, /anarɔs/; owl, /pætʃa/; hair, /tʃul/; butterfly, /prɔd͡ʒapɔti/; grapes, /an̊gur/; house, /bari/; goat, /tsʰagol/; spoon, /tʃamɔtʃ/; camel, /uːt/; prawn, /tʃingri/; lock, /t̪ala/; ship, /d͡ʒahad͡ʒ/; dog, /kukur/; letter, /tʃitʰi/; frog, /bæng/; key, /tʃabi/; sun, /surd͡ʒo/; nose, /nak/; boy, /tsʰele/*). They were depicted by black and white line drawings and were presented one at a time on a 17" laptop screen until the participants responded or for a maximum time of 4 seconds. Their responses were recorded using a digital voice recorder. Phonetic and orthographic transcriptions of all the responses were performed. Other than occasional encouragements, no corrective feedbacks were provided during the testing.

Responses were coded as the first complete non-fragmented response within 4-sec after the stimuli presentation (Roach et al., 1996). The classification and coding used for correct responses and errors are presented in Table 4.9. Naming responses and error types for all BWA are presented in Table 4.10. To compare the BWA performance in relation to the BHA, separate independent sample t-test was conducted for Bengali and English. As expected, BWA (Bengali, $M = 23.1$, $SD = 7.2$; English, $M = 21.1$, $SD = 8.9$) showed significantly poorer naming abilities compared to BHA (Bengali, $M = 30$, $SD = 0$; English, $M = 30$, $SD = 0$) on both languages.

Cross linguistic differences in the naming scores between Bengali and English were contrasted for each BWA using chi-square test. Only BWA2 and BWA6 performed significantly better in their most used language. That is, BWA2 better naming in Bengali, whilst BWA6 better naming in English. In terms of errors, both target language errors as well as cross-linguistic errors were observed for BWA. Semantic errors and no responses were the most common type of target language error, which are a characteristic feature of Broca's and non-fluent aphasia. Semantic errors in naming can either be due to semantic deficits (Howard & Orchard-Lisle, 1984) or post-semantic deficits (Caramazza & Hills, 1990). However, all BWA participants have showed good auditory verbal comprehension in the WAB test and intact word-to-picture matching on the Croft's word-to-picture matching task. Therefore, we can rule out the semantic deficit hypothesis. Semantic error produced by BWA may be attributed to the deficit in activating the representation within the phonological output lexicon or due to difficulty in transmission from semantic to phonological output lexicon.

In terms of cross-linguistic errors, out of a total of 68 cross linguistic errors, 61 (90%) of them were translational equivalents. Except BWA4, BWA5 and BWA7, all the other participants made cross-linguistic errors by switching into their most used language. BWA1, BWA2, and BWA6 named items in Bengali (most used) while performing the task in English, whereas BWA3 and BWA8 did the opposite. Overall, the naming test results corroborated with the self-rated language history questionnaire that is BWA made fewer cross-linguistic errors in their most used language.

4.4.2.3.3 Repetition. Participants were asked to repeat the word as said by the experimenter. Responses were recorded using a voice recorder. Responses were marked as correct and incorrect. Incorrect responses were classified according to the error type as with naming responses. To compare the BWA performance in relation to the BHA, similar to naming task, separate independent sample t-test was conducted for Bengali and English. As expected, BWA showed significantly poorer repetition abilities compared to BHA on Bengali (BWA: M = 25.9, SD = 4.3; BHA: M = 30, SD = 0, p = .03) and a marginal significant effect on English (BWA: M = 27.1, SD = 4.3; BHA: M = 30, SD = 0, p = .06). Repetition scores in Bengali and English were contrasted for each BWA using chi-square test to assess cross-linguistic difference. All participants performed similarly in both languages except BWA2 who could not repeat the words in English. Overall, BWA showed relatively preserved and comparable repetition skills (Mean accuracy $_{\text{Bengali}}$: 86.3 %, SD accuracy $_{\text{Bengali}}$: 14.1%; Mean accuracy $_{\text{English}}$: 90.5%, SD accuracy $_{\text{English}}$: 10.8%) in both languages.

As the stimuli were same for the naming and repetition tasks, we also compared the test scores between these two tasks within language as well as averaged across language for BWA to find out between task effects. BWA performed significantly better in single word repetition as compared to naming when the test scores were averaged across languages (See Table 4.7) suggestive of difficulty in the phonological output lexicon pathway. In terms of errors (Table 4.11), only target language errors were observed. Formal errors were the most common type of error in this task for BWA. There were no cross-linguistic errors in repetition which may indicate that lexical interference from the non-target language does not affect at the post-semantic level once the meaning of the word is successfully processed at the post-lexical level.

Table4.7

Test Scores (%) in Naming and Repetition subtests of Croft's Test Battery in Each Language and Averaged across Languages for Each BWA and the Statistical Results of Between Task Effects.

Participants	Naming in Bengali	Repetition in Bengali	Naming in English	Repetition in English	Naming average	Repetition average
BWA1	93.3	70	73.3	73.3	83.3	71.65
BWA2	76.7	90	6.7	CNP[1]	41.7	90
BWA3	50	73.3	86.7	86.7	68.35	80
BWA4	96.7	100	96.7	93.3	96.7	96.65
BWA5	96.7	90	80	100	88.35	95
BWA6	33.3	66.7	76.7	80	55	73.35
BWA7	96.7	100	96.7	100	96.7	100
BWA8	73.3	100	50	100	61.65	100
Mean	77.1	86.3	70.9	90.5	74.0	88.3
SD	24.1	14.2	29.9	10.8	20.4	11.7
Statistical results[2]	$t(7) = -1.4$, $p = .06$		$t(6) = -1.4$, $p = .11$		$t(7) = -2.1$, $p = .04$*	

[1] – Could Not Perform, [2] – Paired sample t-test (one tailed), * $p \leq .05$

Table4.8

Accuracy (Raw score and %) in Language Background Test Scores of BWA using Croft's Test Battery.

Croft's test battery[1]	BWA1	BWA2	BWA3	BWA4	BWA5	BWA6	BWA7	BWA8	**BWA (N = 8)**		**BHA (N=8)**		
									M	*SD*	*M*	*SD*	Statistical Analysis[4]
Naming[2]													
Bengali	28(93.3%)	23(76.7%)	15(50%)	29(96.7%)	29(96.7%)	10(33.3%)	29(96.7%)	22(73.3%)	23.1(77%)	7.2(24.1%)	30(100%)	-	$t(7)=2.7$, $p=.03$*
English	22(73.3%)	2(6.7%)	26(86.7%)	29(96.7%)	24(80%)	23(76.7%)	29(96.7%)	15(50%)	21.1(70%)	8.9(29.8%)	30(100%)	-	$t(7)=2.7$, $p=.03$*
Difference[3]	$p=.39$	$p<.001$***	$p=.08$	$p=1$	$p=.49$	$p=02$*	$p=1$	$p=.24$	$p=.63$		$p=1$		
Repetition[2]													
Bengali	21(70%)	27(90%)	22(73.3%)	30(100%)	27(90%)	20(66.7%)	30(100%)	30(100%)	25.9(86.3%)	4.3(14.1%)	30(100%)	-	$t(7)=2.7$, $p=.03$*
English	22(73.3%)	CNP	26(86.7%)	28(93.3%)	30(100%)	24(80%)	30(100%)	30(100%)	27.1(90.5%)	3.2(10.8%)	30(100%)	-	$t(6)=2.3$, $p=.06$
Difference[3]	$p=.88$	-	$p=.56$	$p=.79$	$p=.69$	$p=.54$	$p=1$	$p=1$	$p=.15$		$p=1$		
Word to picture matching[2]													
Bengali	30(100%)	30 (100%)	30(100%)	30(100%)	30(100%)	30(100%)	30(100%)	30(100%)	30(100%)	-	30(100%)	-	$p=1$
English	30(100%)	30(100%)	30(100%)	30(100%)	30(100%)	30(100%)	30(100%)	30(100%)	30(100%)	-	30(100%)	-	$p=1$
Difference[3]	$p=1$	$p=1$	$p=1$	$p=1$	$p=1$	$p=1$	$p=1$	$p=1$	$p=1$		$p=1$		
Reading Aloud[2]													
Bengali	23(76.7%)	16(53.3%)	CNP	29(96.7%)	28(93.3%)	12(40%)	24(80%)	30(100%)	23.1(87.1%)	6.8(21.9%)	30(100%)	-	$t(6)=2.6$, $p=.04$*
English	19(63.3%)	CNP	27(90%)	29(96.7%)	29(96.7%)	24(80%)	30(100%)	CNP	26.3(87.8%)	4.2(13.9%)	30(100%)	-	$t(5)=2.1$, $p=.08$
Difference[3]	$p=.53$	-	-	$p=1$	$p=.89$	$p=.04$*	$p=.41$	-	$p=.18$		$p=1$		

[1] – Croft's test battery (Croft et al., 2015). [2] – Maximum score possible is 30. [3] – Chi-square test was conducted to compare the cross-linguistic differences for each BWA. [4] – Independent sample t-test was conducted to compare the differences at the group level. * $p \leq .05$

Table4.9

Classification of Naming Responses of BWA with Examples from English.

Response type	Code	Definition	Examples of target	Examples of response
Correct	1	Phonologically accurate description of the target (plural forms are acceptable)	Dog	Dog
Correct with variations	10	Correct following hesitations or fragments	Prawn	aa..prawn
Target language errors				
Semantic	22	Semantically related to the target	Rabbit	Tortoise
Formal	23	Response that begin or end with the same phoneme as the target, or have at least 50% overlap.	Dog	Dot
Mixed	26	Response both semantically and phonologically related to the target word	Lock	Latch
Non-word	24	Non-lexical error, i.e., form that does not exist in the dictionary of the language.	Frog	/bufo/
No response	20	No response, omissions, or participants saying they cannot name	Neck	Do not know
Unrelated	25	Real word but semantically or phonologically not related to the target word	Tortoise	Book
Descriptive	21	Describing the function or other attributes of the target	Letter	Writing
Cross-linguistic errors				
Semantic	61	Response word in the non-target language that is semantically related to the target	Dog	/gɔru/[1] (cow)
Formal	62	Response word in the non-target language that begin or end with the same phoneme as the target, or have at least 50% overlap	Goat	/gol/[1] (Round)
Translation equivalent	60	Translation equivalent of the target word	Hair	/tʃul/[1] (Hair)
Unrelated	63	Real word in the non-target language but semantically or phonologically not related to the target word	Neck	/katʃ/[1] (glass)

[1] – Cross-linguistic errors are coded in IPA format and the translation equivalents are given in bracket.

Table4.10

Accuracy (Raw score, N=30 and %) and Error Classifications of BWA in Bengali (B) and English (E) in Croft's Naming Task.

Response type	BWA1		BWA2		BWA3		BWA4		BWA5		BWA6		BWA7		BWA8	
	B	E	B	E	B	E	B	E	B	E	B	E	B	E	B	E
Correct	27	21	22	2	12	23	29	26	29	23	10	23	26	26	22	15
Correct with variations	1	1	1	-	3	3	-	3	-	1	-	-	3	3	-	-
Total correct (%)	28 (93.3)	22 (73.3)	23 (76.7)	2 (6.7)	15 (50)	26 (86.7)	29 (96.7)	29 (96.7)	29 (96.7)	24 (80)	10 (33.3)	23 (76.7)	29 (96.7)	29 (96.7)	22 (73.3)	15 (50)
Error types in target language																
Semantic	2	2	2	-	-	1	1	1	1	-	-	3	-	1	4	2
Formal	-	-	1	-	3	3	-	-	-	-	1	-	-	-	-	-
Mixed	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-
Non-word	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
No response	-	2	-	2	3	-	-	-	-	2	3	4	-	-	4	2
Unrelated	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2
Descriptive	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Total errors in target language (%)	2 (6)	4 (13)	5 (17)	2 (6)	6 (20)	4 (13)	1 (3)	1 (3)	1 (3)	5 (17)	4 (13)	7 (23)	0 -	1 (3)	8 (27)	6 (20)
Cross-linguistic error types																
Semantic	-	-	-	3	-	-	-	-	-	-	1	-	-	-	-	1
Formal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Translational equivalents	-	4	1	22	9	-	-	-	-	1	15	-	1	-	-	8
Unrelated	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Total cross-linguistic errors (%)	0 -	4 (13)	2 (6)	26 (86.7)	9 (30)	0 -	0 -	0 -	0 -	1 (1)	16 (53)	0 -	1 (3)	0 -	0 -	9 (30)

Table4.11

Accuracy (Raw score, N=30 and %) and Error Classifications of BWA in Bengali (B) and English (E) in Croft's Repetition Task.

Response type	BWA1		BWA2		BWA3		BWA4		BWA5		BWA6		BWA7		BWA8	
	B	E	B	E	B	E	B	E	B	E	B	E	B	E	B	E
Correct	20	20	27	CNP	21	22	30	28	27	30	19	24	30	30	30	30
Correct with variations	1	2	-		1	4	-	-	-	-	1	-	3	3	-	-
Total correct (%)	21 (93.3)	22 (73.3)	27 (90)		22 (73.3)	26 (86.7)	30 (100)	28 (93.3)	27 (90)	30 (100)	20 (66.7)	24 (80)	30 (100)	30 (100)	30 (100)	30 (100)
Error types in target language																
Semantic	-	-	-		-	-	-	-	-	-	1	-	-	-	-	-
Formal	9	8	2		8	2	-	1	3	-	6	4	-	-	-	-
Mixed	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
Non-word	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
No response	-	-	-		-	-	-	1	-	-	3	2	-	-	-	-
Unrelated	-	-	1		-	2	-	-	-	-	-	-	-	-	-	-
Descriptive	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
Total errors in target language (%)	9 (30)	8 (26.6)	3 (10)		8 (26.7)	4 (13.3)	0	2 (6.7)	3 (10)	0	10 (33.3)	6 (20)	0	0	0	0
Cross-linguistic error types																
Semantic	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
Formal	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
Substitution	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
Unrelated	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
Total cross-linguistic errors (%)	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0

4.4.2.3.4 Reading aloud. Participants were shown one written word at a time on a computer screen and were asked to name them. Responses were recorded using a voice recorder. Responses were marked as correct and incorrect. Incorrect responses were classified according to the error type as with naming responses. BWA showed significantly poorer reading aloud abilities compared to BHA on Bengali (BWA: M = 23.1, SD = 6.8; BHA: M = 30, SD = 0; p = .04) and a marginal significant effect on English (BWA: M = 26.3, SD = 4.2; BHA: M = 30, SD = 0; p = .08). Cross linguistic differences in the reading aloud scores between Bengali and English were contrasted for each BWA using chi-square test. BWA2 and BWA8 could not perform the task in Bengali and BWA3 could not perform the task in English due to poor pre-stroke reading abilities in Bengali and English, respectively. BWA6 performed significantly better in English (24 correct out of 38) as compared to Bengali (12 correct out of 38) which can again be attributed to the differences in pre-stroke reading abilities between Bengali (self-rated 4 out of 7) and English (self-rated 7 out of 7). Overall, BWA showed a relatively better (compared to naming) and comparable reading abilities in Bengali (accuracy = 87.1%) and English (accuracy = 87.8%).

In summary, from the Croft's test battery, following picture emerges: as a group BWA had difficulties in picture naming with semantic errors in the target language and translation equivalent cross-linguistic errors, relatively preserved repetition with formal errors but no cross-linguistic errors, intact spoken word comprehension and relatively preserved reading aloud abilities. Therefore, we can assume that our BWA showed intact semantic system with deficit either in phonological output lexicon or in lexical access (accessing the phonological word form from the semantic system).

4.4.2.4 Inhibitory control (Stroop tests). Inhibitory control was assessed using the verbal colour-word Stroop test with the same procedure and stimuli sets as used in Chapter 2 (Please see Chapter 2 method section for detailed description).

4.4.2.5 Shifting between task-sets (Trail Making Test). The Trail Making Test (TMT) from the Halstead-Reitan Test Battery (Reitan, 1986) is one of the most widely used neuropsychological tests to assess mental set shifting (I. Sánchez-Cubillo et al., 2009). The test consists of two parts, A and B. On part A, participants are asked to connect 25 circled numbers (e.g. 1, 2, 3, 4, etc.) distributed on a paper using a pen/pencil. On part B, participants need to connect the circles but alternating between circled numbers and letters (e.g. 1, A, 2, B, 3, C, etc.). All the participants completed both parts of the test. We measured the total time in second for both parts of the test, therefore, achieving two scores, TMT-A and TMT-B. The dependent variable was the difference score (B -A) which has been said to be the best indicator of task switching ability of the TMT test and correlates significantly with the switch cost generated from the Wisconsin cars sorting test (I. Sánchez-Cubillo et al., 2009).

4.4.2.6 Working memory (Digit span test). Working memory was assessed by administering the backward digit span test (Wechsler, 1999). The description of the test and procedure was same as described in Chapter 2.

Independent samples t-test was used separately on the Stroop ratio and Stroop difference measures and non-parametric version of independent samples t-test (Mann-Whitney U test) was used separately (as the data was not normally distributed) on TMT difference and backward digit span measures between the groups. As could be seen in Table 4.12, the two groups differed significantly only on the Stroop ratio, Stroop difference and the TMT difference score. Compared to BWA, BHA demonstrated lesser Stroop ratio indicative of better inhibitory control and a smaller TMT difference suggesting superior shifting ability. We did not find any difference on the working memory measure between the two groups which may be due to the difficulty level of the task and/ or the severity level of the aphasia of our BWA group.

At the individual level, as can be seen in Table 4.13, BWA2 and BWA8 were most affected on all the three executive control measures. BWA5 and BWA7 showed smaller Stroop ratio compared to others which indicates relatively preserved inhibitory control abilities. BWA4 and BWA7 had smaller TMT difference compared to others suggestive of better mental-set shifting abilities. On working memory measure, BWA6 and BWA7 performed better compared to others whereas BWA2, BWA3, and BWA8 performed poorer compared to others. Raw data for each BWA and BHA for all the executive control variables (Stroop incongruent, Stroop congruent, Stroop difference, Stroop ratio, TMT-A, TMT-B, backward digit span) are provided on Appendix 4.2.

Table4.12

Mean Values (M), Standard Deviations (SD) and the Statistical Results of the Executive Control Measures by Group.

Measures	BWA (N =8)			BHA (N = 8)			
	M	*Min-Max*	*SD*	*M*	*Min-Max*	*SD*	
Stroop ratio	48.7	4-85	30.2	23.5	2-35	11.2	t (8.9) = 2.2, p = .05*
TMT difference	193.1	32.6-759	245.8	31.8	10.9-61.2	20.7	U^1 = 13, p = .005**
Backward digit span	3.9	3-5	.8	4.5	3-7	1.6	U^1 = 27, p = .64

*p<.05, **p<.01; [1]Mann-Whitney U test

Table4.13

Mean Values (M), Standard Deviations (SD) and the Statistical Results of the Executive Control Measures for each BWA.

BWA	Stroop ratio	TMT difference	Backward digit span
BWA1	36	66	4
BWA2	76	316	3
BWA3	57	82	3
BWA4	33	32.6	4
BWA5	4	123	4
BWA6	80	129	5
BWA7	19	37.1	5
BWA8	85	759	3
Mean	48.7	193.1	3.9
SD	30.2	245.8	.8
BHA			
M	23.5	31.8	4.5
SD	11.2	20.7	1.6

4.4.3 Verbal Fluency Measures

4.4.3.1 Trials and procedure. All the participants completed two verbal fluency conditions − semantic and letter – in both languages. They were asked to produce as many words as possible in 60 s. In semantic fluency condition, participants produced words in two categories− animals, and fruits and vegetables. In letter fluency condition, participants were asked to produce words that start with letters *F, A,* and *S* for the English language and letter *P*, *K,* and *M* for the Bengali. The instruction for the Bengali letter fluency task was different from the English letter fluency task (as described in Chapter 2) due to the phonology of Bengali language. In the Bengali letter fluency task, participants were asked to name words that starts with the sound (e.g. /p/) rather than the letter (e.g. P). Please refer to Chapter 2 for a detailed description and procedure of the verbal fluency task.

4.4.3.2 Data coding and analysis. We followed the same procedure for data coding and analysis as described in Chapter 2 and generated the following variables: number of CR, FDS, 1st-RT, sub-RT, cluster size, number of switches, within-cluster pause and between-cluster pause.

4.5 Statistical Analysis

All the variables were measured for each trial for the two fluency conditions for each participant in each language. To arrive at the mean scores for each variable in each language, two trials were averaged for semantic fluency and three trials were averaged for letter fluency condition. A two-way ANOVA repeated measure was used on the following variables: number of CR, FDS, 1st-RT, sub-RT, cluster size, number of switches, within-cluster pause, and between-cluster pause. In the design, Group (BWA, BHA) was treated as a between-subject factor, Language (Bengali, English) and Condition (Semantic, Letter; except for FDS) was treated as within-subject factor. Two separate two-way ANOVAs were conducted for initiation parameter and slope of semantic and letter fluency conditions with Group being the between-subject factor and Language as within subject factor. Since, we performed multiple comparisons; we set our significance value at $p \leq 0.01$, instead of $p \leq 0.05$. Tukey's post hoc tests were applied for significant interaction effects at $p \leq 0.01$. To facilitate individual level data analysis, raw scores of each BWA individuals were reported for the number of CR, FDS, cluster size and number of switches in each language and in each fluency condition (except for FDS).

To examine the relationship between the executive control measures and verbal fluency variables, Spearman's correlations were performed separately for each group.

4.6 Results

The mean and standard deviation values for the verbal fluency variables for Groups (BWA and BHA), Language (Bengali and English) and Condition (Semantic and Letter) averaged across participants are presented in Table 4.14 (standard deviation reflects between-subject variation). The results of the statistical tests are also provided in Table 4.14. Raw scores for each BWA in each condition are presented in Table 4.15. Findings from the correlation analyses between the executive control measures and verbal fluency variables for each group are presented in Table 4.16. Findings for Group differences are presented first; followed by the individual level performance. Findings on the relationship of executive control measures and verbal fluency variables are presented at the end.

4.6.1 Group Differences in Verbal Fluency Performance

Differences between the BWA and BHA in terms of main effect of Group or an interaction of Group X Condition were observed for CR, FDS, initiation, slope, switches and between-cluster pauses. There were no group differences in 1^{st}-RT, sub-RT, cluster size, and within-cluster pauses. Figure 4.1 depicts the significant group differences. There was no main effect of Language or interactions with any other factors, except for the FDS where a Group X Language interaction was observed.

The CR showed a main effect of Group (BWA: *M* =6.3, *SD* = 3.2; BHA: *M* = 15.4, *SD* = 3.2) and Condition (Semantic: *M* = 13.4, *SD* = 2.9; Letter: *M* = 8.3, *SD* = 2.2) and a significant three-way interaction of Group X Language X Condition with a large effect size of 0.72 (see *Figure 4.1a*). Post-hoc analysis of the interaction revealed that there were no significant cross-linguistic differences either for semantic (Bengali: *M* = 8.9, *SD* = 4; English: *M* = 8.1, *SD* = 5.2; *p* = .60) or letter (Bengali: *M* = 3.9, *SD* = 2.8; English: *M* = 4.2, *SD* = 3.9; *p* = .79) for the BWA group. However, BHA performed significantly better in Bengali compared to English in semantic fluency (Bengali: *M* = 20.8, *SD* = 4; English: *M* = 15.7, *SD* = 5.2; *p* = .005). As expected, BWA showed significant word retrieval difficulties compared to BHA in both languages and in both fluency conditions. BHA performed better in Bengali compared to English in the semantic fluency which is reflective of their language acquisition history, self-rated language proficiency, current language usage pattern, and language dominance.

For FDS, there was a main effect of Group (BWA: *M* = .59, *SD* = .19; BHA: *M* = .26, *SD* = .24) and a significant two-way interaction of Group X Language with a large effect size of .60 (see *Figure 4.1b*). Post-hoc analysis of the interaction revealed no significant cross-linguistic difference for the BWA group (Bengali: *M* = .56, *SD* = .19; English: *M* = .62, *SD* = .34; *p* = .59) but BHA had significantly smaller FDS score in English compared to Bengali (Bengali: *M* = .46, *SD* = .19; English: *M* = .06, *SD* = .34; *p* = .004). Smaller FDS score for BHA compared to BWA suggestive of superior linguistic and executive control abilities for BHA. Again, smaller FDS score for BHA in English suggestive of recruitment of stronger executive control processing in English to overcome the cross-linguistic competition faced from their dominant language (Bengali). Another possible reason for smaller FDS score in English compared to Bengali can be attributed to the nature of the letter fluency task where BHA performed better in English compared to Bengali. All of our BHA participants were highly educated (except BHA2) and had English as their writing medium. As letter fluency is a very artificial task and depends on the phonology of the language, better education in English maybe another reason for smaller FDS in English.

Figure 4.2 presents the time course analysis for groups across two fluency conditions. There were significant main effects of Group on both initiation and slope for both conditions. BHA had significantly larger initiation parameter and steeper slope compared to BWA in both conditions, suggestive of reduced linguistic resources and slower lexical access for BWA compared to BHA. Flatter slope in conjunction with longer sub-RT and more number of CR usually indicates better executive control abilities in healthy adults, however, in this case BWA produced fewer number of CR and there was no difference between the groups on sub-RT. Therefore, we cannot assume flatter slope for BWA indicative of better executive control.

As expected, there was a main effect of Condition for the cluster size that is both groups had bigger cluster size in semantic fluency compared to the letter fluency condition. However, there were no main effects of Group or any interaction of Group X Condition. Both groups performed similarly on cluster size which suggests both groups used similar search strategy to access the mental lexicon.

Number of switches evidenced a significant main effect of Group (BWA: M = 4, SD = 2.2; BHA: M = 9, SD = 1.8), Conditions (Semantic: M = 7.4, SD = 2.3; Letter: M = 5.6, SD = 2.2), and a significant two-way interaction of Language X Condition with a large effect size of 0.65, and three-way interaction of Group X Language X Condition with a large effect size of .70 (see *Figure 4.1c*). Post-hoc analysis of the three-way interaction revealed that there was no significant cross-linguistic difference either for semantic (Bengali: M = 4.9, SD = 2.3; English: M = 4.8, SD = 2.9; p = 1) or letter condition (Bengali: M = 3.3, SD = 2.3; English: M = 3, SD = 3.2; p = .76) for BWA group. However, BHA switched significantly more number of times in English compared to Bengali (Bengali: *M* = 6.7, *SD* = 1.8; English: *M* = 9.5, *SD* = 2.4; *p* = .01) in letter fluency. This could mean that the BHA group has used switching as a successful strategy to produce newer exemplars especially in their non-dominant language where there is greater cross-linguistic interference.

For within-cluster pauses, there were no main effects of Group or Language or Condition and neither any significant interaction between these variables. For between-cluster pauses, there was only a main effect of Group (BWA: *M* = 9.2, *SD* = 4; BHA: *M* = 4.5, *SD* = .64), BWA showed significantly longer between-cluster pauses compared to BHA. Longer between-cluster pause with reduced switching abilities for BWA indicates a difficulty in executive control component (in addition to the difficulty in lexical access) of the verbal fluency task (Rosen et al., 2005; Raboutet et al., 2010).

Table4.14

Means (M), Standard Deviations (SD) and the Statistical Results of the Dependent Variables by Group (BWA: Bilingual with aphasia; BHA: Bilingual Healthy Adults), Conditions (averaged across trials), and Language (Bengali and English)

Measures	BWA (N = 8)						BHA (N = 8)						Statistical analysis (Group, Language, Condition)						
	B		E		Total		B		E		Total								
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	Group (G)	Lang (L)	Cond (C)	G*L	G*C	C*L	G*L*C
CR[1]	6.4	3.1	6.1	3.7	6.3	3.1	16.0	3	14.9	4.4	15.4	1.2	$F(1,14)=32.2, p<.001^{***}, \eta_p^2=.70$	$F(1,14)=.73, p=.41, \eta_p^2=.05$	$F(1,14)=35.5, p=.009^{**}, \eta_p^2=.72$	$F(1,14)=.27, p=.61, \eta_p^2=.02$	$F(1,14)=.65, p=.43, \eta_p^2=.04$	$F(1,14)=27.1, p<.001^{***}, \eta_p^2=.66$	$F(1,14)=15.5, p<.001^{***}, \eta_p^2=.53$
Semantic	8.9	4	8.1	4.8	8.5	3.9	20.8	4	15.8	5.6	18.3	4.3							
Letter	3.9	2.7	4.2	3.4	4.1	2.9	11.1	3	14	4.4	12.5	3.2							
FDS[2]	.56	.24	.62	.26	.59	.19	.46	.14	.06	.40	.26	.24	$F(1,14)=8.9, p=.01^{**}, \eta_p^2=.39$	$F(1,14)=4.2, p=.06, \eta_p^2=.23$		$F(1,14)=8, p=.01^{**}, \eta_p^2=.36$			
1st RT	5.2	5.5	4.6	4.7	4.9	3.9	1.2	.7	1.5	.6	1.3	.4	$F(1,14)=6.54, p=.02, \eta_p^2=.32$	$F(1,14)=.01, p=.92, \eta_p^2=.001$	$F(1,14)=.07, p=.79, \eta_p^2=.005$	$F(1,14)=.14, p=.72, \eta_p^2=.01$	$F(1,14)=.01, p=.94, \eta_p^2=.001$	$F(1,14)=1.3, p=.28, \eta_p^2=.08$	$F(1,14)=2.1, p=.17, \eta_p^2=.13$
Semantic	3.4	2.4	5.9	8	4.7	4.4	1.2	.7	1.2	.5	1.2	.3							
Letter	6.9	11	3.3	2	5.1	5.8	1.1	.9	1.8	.8	1.4	.5							
Sub-RT	20.4	6.5	18.5	7.3	19.5	4.6	22	2.3	23	1.5	22.5	1.7	$F(1,14)=3.2, p=.10, \eta_p^2=.18$	$F(1,14)=.21, p=.65, \eta_p^2=.01$	$F(1,14)=4.1, p=.06, \eta_p^2=.22$	$F(1,14)=.28, p=.60, \eta_p^2=.02$	$F(1,14)=.88, p=.36, \eta_p^2=.06$	$F(1,14)=.62, p=.44, \eta_p^2=.04$	$F(1,14)=2, p=.17, \eta_p^2=.13$
Semantic	21.2	7.6	16.4	7.6	18.8	5.8	20	3.2	21	3.5	20.6	2.8							
Letter	19.6	8.2	20.7	9.7	20.2	5.2	25	2.6	24	3.5	24.5	2.4							
Semantic Initiation	1.5	.62	1.5	1.1	1.5	.79	3.9	.89	3	1	3.5	.55	$F(1,14)=33.8, p<.001^{***}, \eta_p^2=.71$	$F(1,14)=1.7, p=.21, \eta_p^2=.11$		$F(1,14)=1.7, p=.21, \eta_p^2=.14$			
Letter Initiation	1.1	.58	.77	.66	.93	.56	1.9	.27	2.1	.46	2	.33	$F(1,14)=21.1, p<.001^{***}, \eta_p^2=.60$	$F(1,14)=.06, p=.81, \eta_p^2=.004$		$F(1,14)=7.2, p=.02, \eta_p^2=.34$			
Semantic slope	-.44	.25	-.52	.46	-.48	.32	-1.3	.46	-1	.42	-1.2	.25	$F(1,14)=23.6, p<.001^{***}, \eta_p^2=.63$	$F(1,14)=.50, p=.49, \eta_p^2=.03$		$F(1,14)=1.6, p=.22, \eta_p^2=.10$			
Letter slope	-.37	.20	-.25	.23	-.31	.18	-.56	.19	-.58	.18	-.57	.15	$F(1,14)=9.51, p=.008^{**}, \eta_p^2=.40$	$F(1,14)=.66, p=.43, \eta_p^2=.04$		$F(1,14)=1.5, p=.24, \eta_p^2=.10$			
Cluster size	.49	.30	.50	.23	.50	.20	.74	.20	.56	.12	.65	.14	$F(1,14)=3.1, p=.10, \eta_p^2=.18$	$F(1,14)=1.5, p=.23, \eta_p^2=.10$	$F(1,14)=18.7, p<.001^{***}, \eta_p^2=.57$	$F(1,14)=1.7, p=.21, \eta_p^2=.11$	$F(1,14)=2.3, p=.15, \eta_p^2=.14$	$F(1,14)=2, p=.18, \eta_p^2=.12$	$F(1,14)=.08, p=.79, \eta_p^2=.005$
Semantic	.83	.53	.76	.48	.79	.45	.93	.24	.65	.23	.79	.21							
Letter	.16	.22	.24	.21	.20	.12	.55	.28	.47	.21	.51	.17							
Switches	4.1	2.1	3.9	2.6	4	2.2	8.7	1.4	9.3	2.5	9	1.8	$F(1,14)=24.9, p<.001^{***}, \eta_p^2=.64$	$F(1,14)=.27, p=.61, \eta_p^2=.02$	$F(1,14)=9.7, p=.008^{**}, \eta_p^2=.41$	$F(1,14)=.61, p=.45, \eta_p^2=.04$	$F(1,14)=.01, p=.97, \eta_p^2=.000$	$F(1,14)=10.6, p=.006^{**}, \eta_p^2=.43$	$F(1,14)=13.4, p=.003^{**}, \eta_p^2=.49$
Semantic	4.9	2.3	4.8	2.9	4.9	2.4	10.6	1.7	9.1	3.3	9.9	2.3							
Letter	3.3	2.3	3	3.2	3.2	2.5	6.7	1.8	9.5	2.4	8.1	1.7							
WCP[3]	3	1.8	3	1.8	3	1.3	3.1	1.1	3.6	2.1	3.4	1.6	$F(1,14)=.23, p=.64, \eta_p^2=.02$	$F(1,14)=.34, p=.57, \eta_p^2=.02$	$F(1,14)=2, p=.17, \eta_p^2=.13$	$F(1,14)=.27, p=.61, \eta_p^2=.02$	$F(1,14)=6.5, p=.02, \eta_p^2=.32$	$F(1,14)=3.9, p=.07, \eta_p^2=.22$	$F(1,14)=3.6, p=.08, \eta_p^2=.21$
Semantic	3.8	1.4	3	.8	3.4	.65	1.7	.54	2.3	.90	2	.51							
Letter	2.2	3.1	3.1	3.2	2.6	2.6	4.4	2.2	5	3.6	4.7	2.8							
BCP[4]	8.1	2.5	10.3	5.8	9.2	4	4.3	.78	4.7	.97	4.5	.64	$F(1,14)=10.9, p=.005^{**}, \eta_p^2=.44$	$F(1,14)=2.8, p=.79, \eta_p^2=.17$	$F(1,14)=.08, p=.79, \eta_p^2=.005$	$F(1,14)=1.6, p=.22, \eta_p^2=.10$	$F(1,14)=.14, p=.71, \eta_p^2=.01$	$F(1,14)=.16, p=.69, \eta_p^2=.01$	$F(1,14)=.33, p=.58, \eta_p^2=.02$
Semantic	8.2	5.6	10.3	7.8	9.3	6.4	3.4	.49	4.6	1.4	4.1	.75							
Letter	7.9	4	10.4	9	9.1	5.2	5.3	1.5	4.7	1.1	5	.99							

[1] – number of correct responses, [2] – Fluency Difference Score, [3] – Within-Cluster Pauses, [4] – Between-Cluster Pauses, ** $p \leq .01$, * $p \leq .05$, Condition (Semantic, Letter), $^{**}p<.01$, $^{***}p<.001$

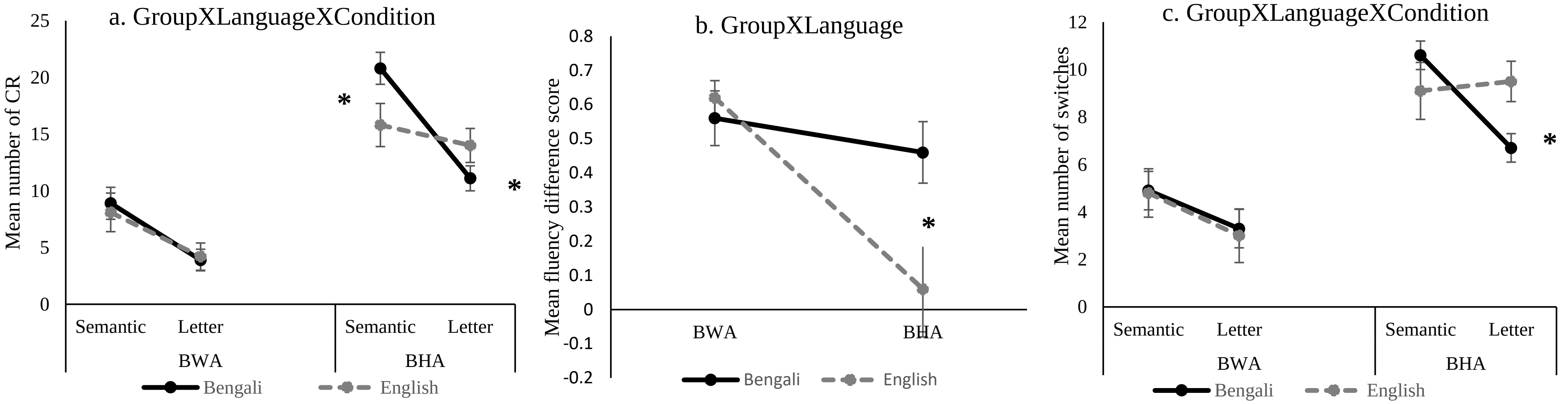


Figure 4.1 All the three-way and two-way significant interactions are presented. Error bars represent standard error of the means. BWA: Bilingual with aphasia: BHA: Bilingual Healthy Adults. * $p \leq .01$

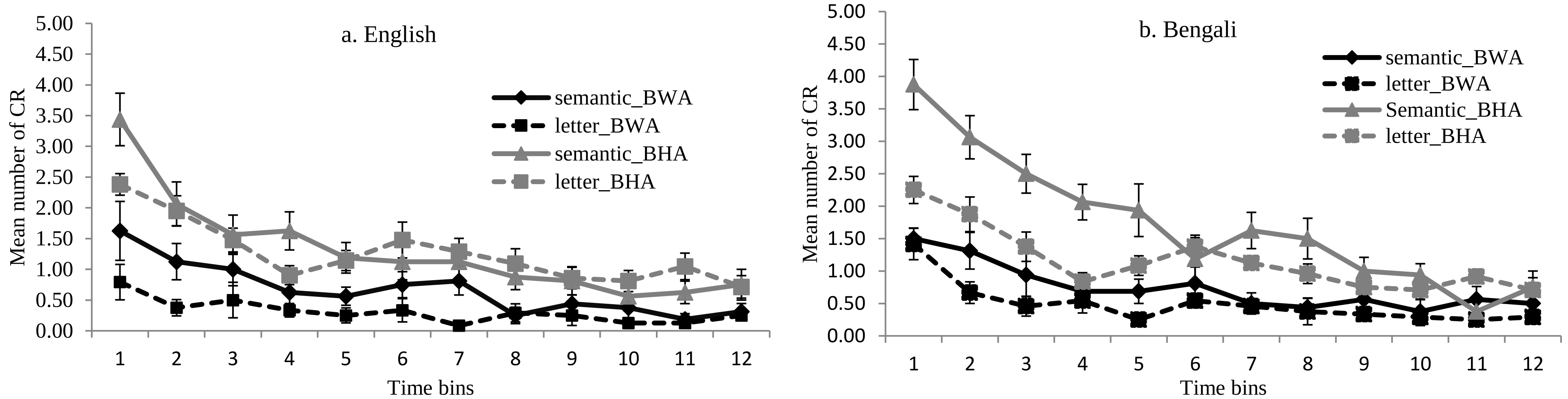


Figure 4.2 Comparison of number of correct responses (CR) produced as a function of 5-sec time intervals in the semantic and letter fluency conditions between the groups for English (left panel) and Bengali (right panel). Error bars represent standard error of the means. BWA: Bilingual with aphasia: BHA: Bilingual Healthy Adults.

4.6.2 Verbal Fluency Performance at Individual Level

Table 4.15 presents the raw score of each BWA in each condition for the number of CR, FDS, cluster size, and number of switches. As expected, All BWA individuals performed better in semantic fluency compared to letter fluency. BWA4 and BWA7 made more number of CR and switches in both the conditions compared to others. BWA4 and BWA7 also showed smaller FDS score compared to others. BWA8, who performed poorly across all the executive control measures, showed the largest FDS and made lesser number of switches compared to others.

Table4.15

Raw score of each BWA in semantic and letter fluency condition for the verbal fluency variables

BWA	CR		FDS	Cluster size		Number of switches	
	Semantic	Letter		Semantic	Letter	Semantic	Letter
BWA1	10.75	3.50	0.69	0.40	0.19	7.75	2.83
BWA2	4.25	4.79	0.59	0.72	0.29	3.00	2.17
BWA3	7.50	2.34	0.68	0.27	0.28	6.25	1.50
BWA4	12.00	9.83	0.19	1.03	0.32	5.50	7.67
BWA5	11.00	4.17	0.62	0.90	0.31	6.00	2.83
BWA6	3.25	1.50	0.55	0.61	0.09	1.75	1.17
BWA7	13.75	6.17	0.55	0.72	0.14	7.25	6.50
BWA8	5.25	0.50	0.87	1.71	0.35	1.50	0.67
Mean	8.47	4.10	.59	.79	.24	4.88	3.17
SD	3.93	2.95	.19	.45	.10	2.45	2.55
BHA							
Mean	18.28	12.54	.26	.79	.51	9.88	8.12
SD	4.31	3.18	.15	.21	.17	2.30	1.74

4.6.2 Verbal Fluency Performance and Executive Control Measures

Table 4.16 presents the correlation coefficients amongst the verbal fluency variables and executive control measures for BWA and BHA. *Figure 4.3* provides the scatterplots for the significant correlations. BWA showed a significant correlation for the Stroop ratio with CR (negative), 1st RT (positive), initiation (negative), and number of switches (negative). BWA also showed a significant correlation for the TMT difference with CR (negative), initiation (negative), and number of switches (negative). BWA with lesser Stroop ratio or better inhibitory control produced more number of correct responses, took less time to produce the first response, had greater linguistic resources to begin with, and switched more between clusters. BWA with lesser TMT difference or better mental shifting ability produced more number of correct responses, had greater linguistic resources to begin with, and switched more between clusters. For the BHA group, we did not find any significant correlation between any executive control measures and verbal fluency measures. Significant correlations between executive control measures and verbal fluency measures only for BWA can be attributed to greater executive control demands faced by BWA compared to BHA while performing the verbal fluency tasks.

Table4.16

Correlation Coefficients between the Executive Control Measures and the Verbal Fluency Variables for Each Group.

Executive control measures		**Fluency variables**									
		CR	FDS	1st RT	Sub-RT	Initiation	Slope	Cluster size	Number of switches	Within-cluster pauses	Between-cluster pauses
		BWA (*N* = 8)									
Stroop ratio	*rs*[1]	-.88*	.35	.95**	-.52	-.90*	.76	.02	-.86*	-.71	.55
	p-value	.004	.40	<.001	.18	.002	.03	.95	.007	.05	.16
TMT diff	*rs*[1]	-.86*	.50	.74	-.69	-.81*	.71	.24	-.93**	-.69	.59
	p-value	.007	.24	.04	.06	.01	.05	.57	.001	.06	.12
		BHA (*N* = 8)									
Stroop ratio	*rs*[1]	-.37	.58	.46	-.25	-.34	-.02	.48	-.71	.67	.71
	p-value	.41	.13	.25	.55	.41	.96	.23	.05	.07	.05
TMT diff	*rs*[1]	-.45	.55	.14	-.45	-.21	-.26	.31	-.74	.52	.62
	p-value	.26	.16	.74	.26	.61	.53	.46	.04	.18	.10

[1] – Spearman's correlation. * Significance assumes at $p \leq .01$, **Significance assumes at $p \leq .001$. BWA: Bilingual with aphasia: BHA: Bilingual Healthy Adults.

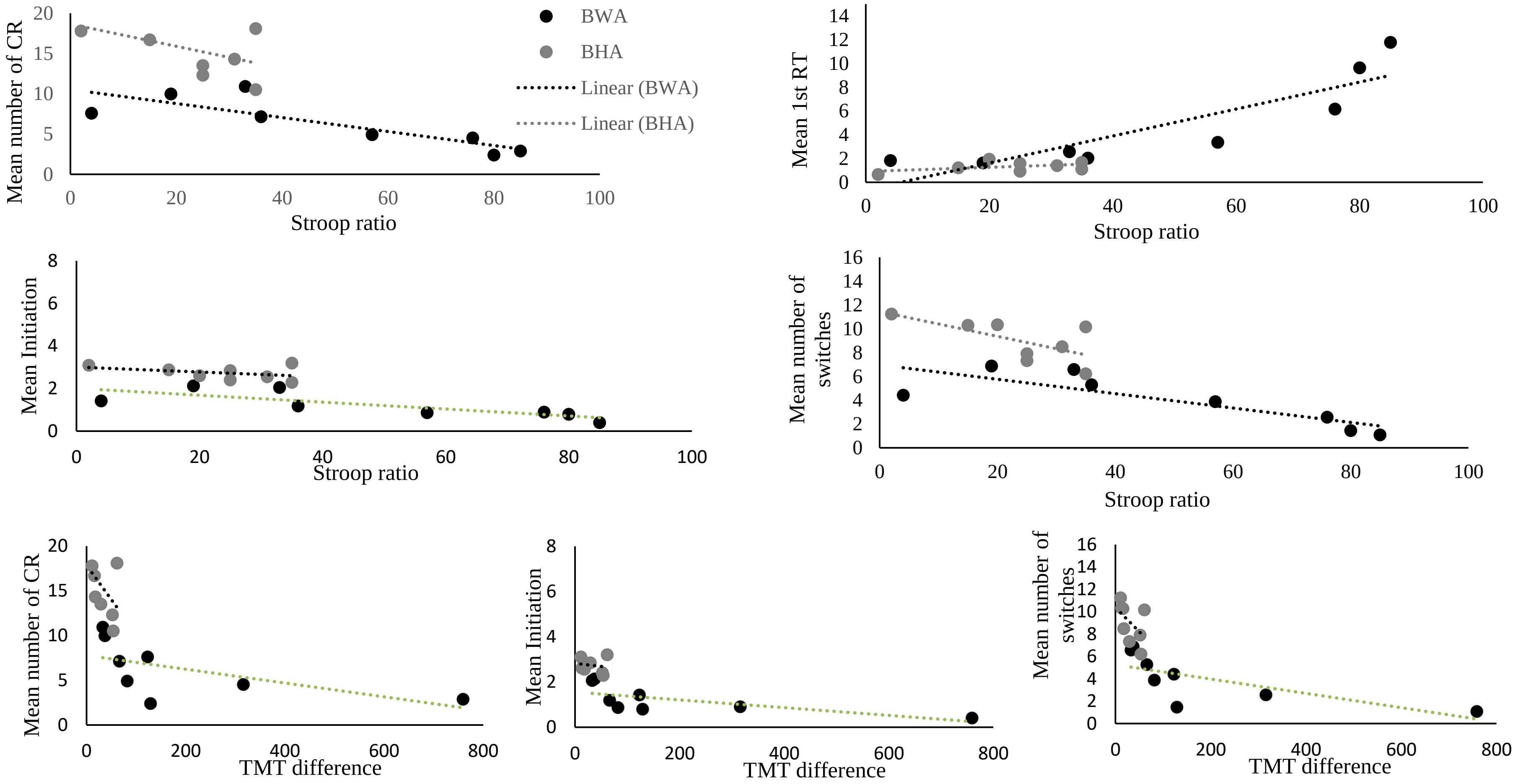


Figure 4.3 Correlation plots for the significant correlations between the a) Stroop ratio and verbal fluency parameters: number of CR (top left panel), mean 1st RT (top right panel), mean initiation (middle left panel), number of switches (middle right panel), and b) TMT difference and verbal fluency parameters: number of CR (bottom left), mean initiation (bottom middle), number of switches (bottom right panel) for the two groups. However, the significant correlation for BWA between TMT difference and other three verbal fluency variables (Mean number of CR, Initiation, and mean number of switches) diminished (Mean number of CR: *rs* = -.85, *p* =.01; Mean initiation: *rs* = -.71, *p* = .07; Mean number of switches: *rs* = -.89, *p* = .007) when we excluded the data of BWA8 (TMT difference: 759). BWA: Bilingual with aphasia: BHA: Bilingual Healthy Adults.

4.7 Discussion

Present study aimed to investigate the contribution of word production and executive control processes during word production in BWA and BHA adults. We used a group of non-fluent Bengali-English BWA who were matched for the demographic and bilingualism related variables with the BHA. For the verbal fluency task, we used a wide range of variables − CR, FDS, 1st-RT, Sub-RT, initiation, slope, clustering and switching, within-cluster pause and between-cluster pauses – that are thought to differentially contribute to the linguistic and executive components of verbal fluency task. In addition, we measured executive control in the domains of inhibition, switching and working memory, and linked the performance on the verbal fluency to the executive measures. To summarise the main findings, compared to BHA, BWA showed differences in both linguistic and executive control domains as identified on Table 4.17.

Table4.17

Results of the Current Study in the Context of the Verbal Fluency Variables and their Linguistic and Executive Control Components.

Parameters	Processes		Bilingual Aphasia (BWA) vs. Bilingual Healthy (BHA)	
	Linguistic	Executive	Findings	Correlation with Executive Control
Quantitative				
1. Number of correct responses	√	√	Yes BWA < BHA	Yes (negative) with Stroop ratio and TMT difference for BWA
2. Fluency difference score		√	Yes BWA > BHA	No
Time course				
1. 1st RT	√		No BWA = BHA	Yes (positive) with Stroop ratio for BWA
2. Sub-RT		√	No BWA = BHA	No
3. Initiation	√		Yes BWA < BHA	Yes (negative) with Stroop ratio and TMT difference for BWA
4. Slope		√	Yes BWA > BHA	No
Qualitative				
5. Cluster size	√		No BWA = BHA	No
6. Number of switches		√	Yes BWA < BHA	Yes (negative) with Stroop ratio and TMT difference for BWA
7. Within-cluster pauses	√		No BWA = BHA	No
8. Between-cluster pauses		√	Yes BWA > BHA	No

Yes – significant findings, NO – not significant findings

On the verbal fluency tasks, BWA produced fewer number of CR (linguistic and executive control), had larger FDS score (executive control), longer initiation parameter (linguistic), flatter slope (executive control), switched fewer times (executive control) and took longer time to switch between clusters (executive control). Both groups showed similar clustering score (linguistic) and took similar time to access new words once a subcategory has been accessed as indicated by within-pause cluster (linguistic). On the separate executive control measures, BWA showed difficulty in inhibitory control and task switching measure but comparable working memory. On the correlation analysis, only BWA showed significant correlation between the executive control measures (inhibitory control and mental shifting abilities) and verbal fluency measures (number of CR, 1st-RT, initiation, and number of switches). Overall, the BWA group showed specific differences with respect to word retrieval and executive control components of the verbal fluency tasks which is again supported by the findings from the separate executive control measures and correlations.

Compared to BHA, BWA retrieved and generated fewer correct words irrespective of the fluency condition which corroborates with the aphasia literature which has shown PWA have difficulty in lexical retrieval and production (Bose et al., 2017; Baldo et al., 2010, Kiran et al., 2014, Roberts & Le Dorze, 1994). Both BWA and BHA performed better in the semantic fluency compared to letter fluency in terms of number of CR, cluster size, and number of switches. BWA showed no cross-linguistic difference which is consistent with the findings in the aphasia literature involving verbal fluency tasks (Kiran et al., 2014). Though BWA were Bengali dominant as a group but the comparable performance in the verbal fluency task across languages is consistent with the performance in Croft's materials, where we did not find any language difference. One possible reason for no cross-linguistic differences in BWA can be attributed to the comparable aphasia severity in both the languages. However, BHA group performed better in Bengali compared to English on the semantic fluency task and reverse was found on the letter fluency task. BHA group were overall Bengali dominant and used Bengali more in their day-to-day life, therefore better performance in Bengali for the semantic fluency task is consistent with the literature which assumes current language usage as one of the important factor in verbal fluency performance (Kiran et al., 2014). A possible reason for generating more number of correct responses in letter fluency and smaller FDS score in English can be attributed to the nature of the letter fluency task where BHA performed better in English compared to Bengali. All of our BHA participants were highly educated (except BHA2) and had English as their writing medium.

As letter fluency depends on the phonology of the language, better writing proficiency in English may have aided the productivity in the English version of the task which can be another reason for smaller FDS in English. However, present study did not have any sensitive measure of writing proficiency which could confirm the relationship between writing proficiency in a particular language and performance in the letter fluency. Future studies may consider investigating the role of writing efficiency and how that can influence the productivity in letter fluency in a particular language.

On the qualitative measures, compared to BHA, BWA had similar cluster size and within-cluster pause but fewer number of switches and longer between-cluster pauses. Previous studies have shown reduced cluster size and longer within-cluster pauses in PWA compared to heathy participants indicating limited lexical resources and/or difficulty in accessing the lexical store and generalized slowing in terms of processing speed (Bose et al., 2017; Baldo et al., 2010; Kiran et al., 2014). In Bose et al.'s study, PWA group consisted of monolingual speakers with a mixture of 11 fluent, 17 non-fluent, and six mixed aphasia. Participants in the Baldo et al.'s study were two native English speakers with moderate severity of aphasia (one fluent and another non-fluent) and the non-fluent PWA showed normal cluster score on the semantic fluency task but impaired reduced cluster score on the letter fluency task. Participants in the Kiran et al.'s study, were 10 Spanish-English BWA who were not defined in terms of type and severity of aphasia. However, all the participants showed difficulty in single word comprehension on both languages (English: 47.96%; Spanish: 69.26%).

No difference in cluster size and within-cluster pause and difficulty in switching between one cluster to another can be attributed to the type of aphasia in our BWA group. In the present study, all BWA were of non-fluent type in both languages. Difficulty in switching with relatively preserved ability to access the mental lexicon is a marker of focal frontal lobe lesions (Troyer et al., 1998). Therefore, non-fluent BWA may not show difficulty in accessing words within a cluster, and once a cluster was accessed, the retrieval of words within the cluster was not affected. However, BWA showed difficulty in switching between one cluster to another in both semantic and letter fluency tasks which corroborates with the previous literature involving PWA (Bose et al., 2017; Kiran et al, 2014). Both Bose et al.'s and Kiran et al.'s study found reduced number of switches in the semantic fluency task for PWA compared to healthy adults. Present study supports the previous findings but at the same time extends the literature to show that the difficulty in switching from one cluster to another evidenced not only for the semantic fluency condition but also on the letter fluency condition. Further BWA in the present study took longer time to switch from one cluster to another which is again supportive of Bose et al.'s finding who found reduced number of switches to correlate with longer between-cluster pauses. Reduced number of switches in conjunction with longer between-cluster pauses for BWA in the present study indicative of difficulty with the executive control component of the task (Rosen et al., 2005).

On the time-course analysis, BWA had significantly smaller initiation parameter and flatter slope compared to BHA (see *Figure* 4.2). Our findings corroborate with the observation by Rohrer et al. (1995). According to Rohrer et al. (1995), impaired performance in the verbal fluency tasks but intact semantic comprehension (as established by spoken-to-picture word matching in Croft's material) can be attributed to mainly two reasons, one is the breakdown in the semantic structure that is loss in the association between the lexical items within the semantic store, and second is the difficulty in accessing the semantic store.

On the individual analysis, BWA4 and BWA7 performed relatively well on both the semantic and letter fluency conditions compared to others. Both these patients had mild aphasia on both languages and performed almost at the ceiling level on the Croft's picture naming task (BWA4: 96.7% both languages; BWA7: 96.7% both languages), repetition

(BWA4: Bengali - 100%, English - 93.3%; BWA7: 100% both languages task) and reading aloud task (BWA4: 96.7% both languages; BWA7: Bengali - 80%, English - 100%). BWA4 and BWA7 also had relatively preserved executive control abilities as evidenced by their performance on the Stroop task, TMT test, and backward digit span test. Therefore, individuals' findings from the verbal fluency performance is consistent with the performance on all the other background and executive control measures which again signifies the importance of including extensive background and executive control measures.

Therefore, in the present study, intact semantic comprehension on the background language task, limited lexical resources available at the beginning of the verbal fluency task, similar clustering strategy and intact retrieval of words within a cluster with impaired switching and longer between-cluster pauses for the BWA possibly indicates impaired lexical access and/or loss of association between the lexical items in the semantic store and greater impairment in the executive control components of the verbal fluency task.

Finally, the correlation analyses revealed the association between executive control measures and verbal fluency measures. BWA with lesser Stroop ratio or better inhibitory control and lesser TMT difference or better mental shifting abilities produced more number of correct responses, took less time to produce the first response, had greater linguistic resources available at the beginning of the task, and switched more between clusters. Significant correlations between executive control measures and verbal fluency measures only for BWA can be attributed to greater demands (linguistic as well as executive control) faced by BWA compared to BHA while performing the verbal fluency tasks. Switching between clusters has been linked with executive control aspect of the verbal fluency tasks (Bose et al., 2017) and to be a strong predictor for total CR (e.g., Troyer et al. 1997). Present study confirms the relationship of executive control, especially for the inhibitory control and mental shifting abilities with the switching component of the verbal fluency task. However, Faroqi-Shah et al. (2016) did not find any relationship between Stroop conflict ratio and number of correct responses for their PWA which may be due to the nature of fluency task they administered. Faroqi-Shah et al. measured number of CR only for the semantic fluency but not for the letter fluency. As previously discussed, executive control demands are higher in the letter fluency condition, and PWA may not require their executive control abilities to perform in the semantic fluency condition. Therefore, significant correlations between Stroop ratio and verbal fluency measures for the present study signify the role of executive control abilities during word production in BWA population.

Difficulty in the executive control components of the verbal fluency task for the BWA was further supported by the results obtained from the separate executive control measures. As expected, compared to BHA, BWA showed significantly larger Stroop ratio or difficulty in the inhibitory control component of the Stroop test. The findings are consistent with previous studies on aphasia and inhibitory control (Faroqi-Shah et al., 2016). On the task switching measure, BWA showed larger TMT difference compared to BHA indicative of difficulty in switching between mental sets. Previous studies have shown PWA to have difficulty in task switching compared to healthy adults (Helm-Estabrooks, 2002; Chiou & Kennedy, 2006). In terms of working memory, previous studies have shown working memory deficits in monolingual PWA involving backward digit span task (Laures-Gore, Marshall, & Verner, 2010; Ween, Alexander, D'esposito, & Roberts, 1996). However, we did not find any group difference on the working memory measure which is not surprising as previous studies have shown BWA to perform within normal limits in working memory measures (Penn, Frankel, Watermeyer, & Russel, 2010). Penn, Frankel, Watermeyer, and Russel (2010) tested two BWA on three working memory measures: Self ordered pointing test, complex figures, and Wisconsin card sorting test. Penn et al (2010) found intact working memory function for those two BWA individuals compared to healthy adults. In this study, we have included only one measure for each executive control domain which renders the convergent validity of the present findings. Therefore, future studies should look into the performance of BWA on a broad range of executive control measures.

In terms of individual level analysis, not all the BWA showed executive control impairments on all the domains. BWA4 and BWA7 had relatively preserved executive control abilities across the three domains (inhibitory control, mental-set shifting, and working memory). BWA5 showed preserved inhibitory control abilities but was affected on the mental-set shifting abilities. These results signify the importance of including a broad range of executive control measures and also the importance of looking at individual level data while analyzing data involving BWA.

This study is the first study to our knowledge involving BWA where verbal fluency performance was assessed using a broad range of measures (quantitative, qualitative, and time-course) on both semantic and letter fluency conditions. We found BWA to be affected across the three measures (quantitative, qualitative, and time-course) especially where executive control demands were higher (FDS, number of switches) compared to BHA and more on the letter fluency (higher executive control demands) compared to semantic fluency. Previous studies have looked into the performance of PWA in verbal fluency, but all those studies had limitations such as some of the studies (Bose et al., 2017; Kiran et al., 2014) have only used semantic fluency and not letter fluency, others (Faroqi-Shah et al., 2016) have taken only number of CR as a dependent variable. However, as seen from the present study, inclusion of letter fluency and a full range of verbal fluency measures are necessary to understand the effect of executive control deficit in verbal fluency performance. Therefore, future studies should include both the fluency conditions as well as a full range of verbal fluency measures to better inform the debate on relative contribution of linguistic and executive control abilities in verbal fluency tasks.

In conclusion, the observation of larger FDS, lower switching scores, and longer between-cluster pauses give us the evidence that BWA had difficulty in the executive control component of the verbal fluency task in addition to their linguistic deficits which is further supported by the findings from separate executive control and correlation analysis. Further, previous studies have speculated the role of executive control in verbal fluency measures, but present study uses separate experimental measures of executive control to confirm that inhibitory control and mental shifting abilities plays a key role in the verbal fluency performance difference between BWA and BHA. From the clinical perspective, this research highlights the importance of using a full range of verbal fluency and executive control measure to tap into the linguistic as well as executive control abilities of BWA. This type of evidence is currently lacking in the literature.

Chapter 5. Cognate Production and Executive Control in Bilingual Aphasia

5.1 Abstract

Background. Studies have compared performance differences between cognate (same meaning and similar phonology across the two languages) and non-cognate (share only the meaning but not the phonology) words using picture naming task to investigate the influence of linguistic variation in bilinguals, especially in bilinguals with aphasia (BWA). Studies have shown mixed results ranging from cognate facilitation to cognate interference to no difference between cognates and non-cognates. Language proficiency and executive control components modulate the cross-language activation in BHA during cognate production, but it is still not clear which executive control components modulates the cross-language activation in BWA.

Aims. To investigate the cross-linguistic interference/activation using a picture naming task with cognates and non-cognates in BWA and BHA. To investigate whether the differential cognate/non-cognate naming abilities were influenced by their executive control abilities.

Methods & Procedure. Picture naming task in Bengali and English was administered on seven non-fluent Bengali-English BWA and 8 Bengali-English BHA. Characteristics of the participants are described in Chapter 4. Images were nouns and consisted of black-and-white line drawings of 38 cognates (e.g., /bʌtən/ in English and /bɔtʌm/ in Bengali) and 38 non-cognates (e.g., /haʊs/ in English and /bʌri/ in Bengali) matched for syllable length and subjective familiarity. Dependent variables were differences in naming accuracy and RT between cognate words and non-cognate words. Participants also completed the same executive control tests described in Chapter 4.

Outcomes & Results. Both groups showed significant cognate facilitation in both languages at group level for both accuracy and RT. Error and individual analysis of BWA showed difficulty in cognate words production for balanced BWA. Correlation analysis revealed both

BWA and BHA with better inhibitory control and mental-set shifting abilities showed lesser cognate facilitation.

Conclusions & Implications. We found evidence of cognate facilitation as well as cognate interference for BWA. Results support the claim of greater cross-linguistic competition faced by cognates during picture naming task, especially for unbalanced BWA. Findings from the present study are discussed regarding its clinical implications and future directions.

5.2 Introduction

One of the most debated topics in the bilingual literature is whether bilinguals have an integrated lexicon or two separated lexicons, one for each language and if there is activation from both languages even when only a single language is pertinent that time. There is behavioural evidence from bilingual healthy adult (BHA) as well as bilinguals with aphasia (BWA) to show that even when bilinguals are speaking in one language, both languages are activated which is also called language-nonselective lexical access (Abutalebi & Green, 2007; Green, 1998). To support the language-nonselective hypothesis, researchers have considered the production of cognates in both BHA and BWA population. Studies have shown that bilinguals are faster and more accurate while naming cognate words that share the same meaning and similar phonology across the two languages (e.g., /bʌtən/ in English and /bɔtʌm/ in Bengali) compared to non-cognate words that share only the meaning but not the phonology (e.g., /haʊs/ in English and /bʌri/ in Bengali; see, e.g. Costa et al., 2000; Roberts & Deslauriers, 1999; Lalor & Kirsner, 2001). The cognate facilitation effect which is assumed to arise from the shared phonological segments in both languages resulting in higher activation for the cognates, whereas the non-cognate words receive activation only from the target language (see *Figure 5.1*).

While the cognate facilitation provides evidence for the language-nonselective lexical access, the findings remain equivocal. Studies have shown cognate inhibition as well as no difference between cognate and non-cognates (Broersma et al., 2016; Kurland & Falcon, 2011; Tiwari & Krishnan 2015) supporting the inhibitory control model of lexical access. According to the inhibitory control model (Green, 1998), the cross-language competition leads to the inhibition of the non-target word and the inhibition is more for the cognates as compared to non-cognates resulting in cognate inhibition (Declerck & Philipp, 2015). Further, studies have shown executive control components, especially inhibitory control and working memory modulates the cross-language activation in BHA during cognate production (Linck et al., 2008) but it is still not clear which executive control components modulates the cross-language activation in BWA.

Therefore, the present study examines the effect of cognateness in BWA and BHA and aims to explore the relationship between executive control and the cross-language activation/competition in BWA and BHA using a picture naming task. In the following section, we will review the findings from the BWA literature on cognate production followed by the relationship between cognate production and executive control in BWA.

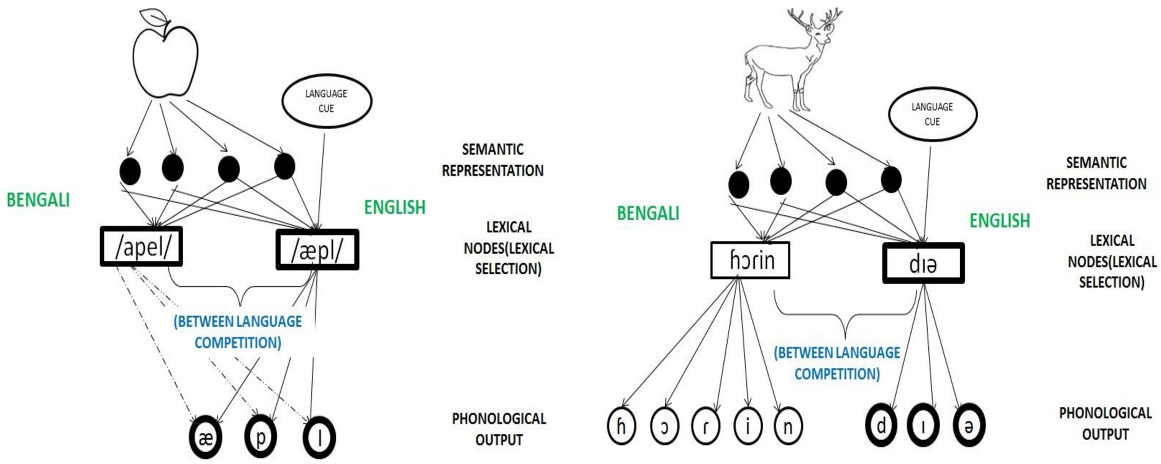


Figure 5.1 Schematic representation of the cognate word production (left panel) and non-cognate word production (right panel). Words are written in IPA format for both English and Bengali. Thickness of the circles and rectangle indicates level of activation of the lexical nodes (Adapted from Costa, 2005).

5.2.1 Cognate Effects

Studies have shown cognate facilitation (Detry et al., 2005; Kohnert, 2004; Lalor & Kirsner, 2001; Roberts & Deslauriers, 1999), cognate inhibition (Broersma et al., 2016; Kurland & Falcon, 2011; Tiwari & Krishnan 2015) and no difference between cognates and non-cognates (Verreyt et al., 2013) in terms of accuracy and RT for both BWA and BHA in a range of tasks – picture naming, picture to word verification, word reading, lexical decision, and translation tasks.

Detry, Pillon, and de Partz (2005) tested a 40-year old non-fluent French-English BWA on a picture naming task (production) and a picture-to-word verification task (comprehension). Stimuli were the same set of items (30 cognates and 30 non-cognates matched for number of phonemes and word frequency) for both languages and both tasks. Detry et al. (2005) found poorer picture naming abilities in English (L2) compared to French (L1), but cognate facilitations were observed in both languages and for both tasks. Detry et al. concluded that cognate words are better preserved following a brain damage compared to non-cognates but they did not make any comment on the relationship between the language proficiency and cognate facilitation.

Kohnert (2004) tested a 62-year old non-fluent Spanish-English BWA on two consecutive treatment designs – cognitive intervention and cognate intervention – to investigate the generalization within and across cognitive-linguistic domains. For the cognitive intervention, treatment focus was to improve non-verbal skills such as categorization, attention, visual perception. The treatment was carried on for two months. Following the cognitive treatment, Kohnert found improvements in cognition as well as in linguistic domains. Improvement in the language abilities following cognitive treatment reflected the generalization from non-linguistic to linguistic domain. Cognate based treatment was focused at the linguistic-semantic level involving cognate and non-cognate nouns. Before therapy, Kohnert found cognate facilitation only in Spanish, and after treatment, cross-linguistic generalisation happened only for cognates. Kohnert suggested that the interconnections between two languages and linguistic and cognitive domains can be used to develop successful intervention techniques.

Lalor and Kirsner (2001) tested a 63-year old multilingual aphasia individual who before the stroke was fluent in English, Italian, and Arabic. Bilingual Aphasia Test (BAT, Paradis, Hummel, & Libben, 1989) results revealed both English and Italian were impaired on the receptive language tasks whereas on the expressive language tasks Italian was more impaired. The experimental tasks were word naming, and lexical decision task involving cognate and non-cognate words. The participant performed the task in English and Italian. On the word naming task, there was a main effect of language that is the participant performed better in English as compared to Italian which was consistent with the findings from the BAT. Low-frequency Italian cognates with high-frequency translations were recognised faster as compared to low-frequency Italian cognates with low-frequency translation. However, this pattern was not observed in English and for non-cognate words. On the lexical decision task, English words were processed faster as compared to Italian words. The participant made a higher number of errors on the non-cognate words as compared to cognates in both languages. Lalor and Kirsner's study provided support for the language-nonselective lexical access by showing facilitation for cognate words.

In another study, Roberts and Deslauriers (1999) administered a confrontation naming task on an English-French group of 15 BWA (10 non-fluent and five fluent) and 15 BHA. All the participants were self-reported balanced bilinguals. Stimuli for the task were colour photographs of 25 cognates and 25 non-cognate nouns in each language, matched for syllable length and subjective familiarity. Roberts and Deslauriers tested naming accuracy and error patterns for both the cognate and non-cognate conditions. For accuracy, cognate facilitation was observed only in French (L2), but not in English (L1). Error analysis revealed semantic and cross-linguistic errors were more prevalent while naming non-cognates, whereas no response and descriptive errors were more common while naming cognates.

In a study involving bilingual healthy adults, Broersma, Carter, and Acheson (2016) tested English-dominant, Welsh-dominant and balanced BHA on a picture naming task with 36 cognates and 36 non-cognate nouns. Broersma et al. (2016) found the language dominance modulated evidence of both facilitation and inhibition for cognates. English-dominant group showed cognate inhibition in their nondominant language (Welsh), and no difference between cognates and non-cognates in their dominant language (English), whereas Welsh-dominant and balanced group showed cognate facilitation in both languages. The findings of cognate inhibition were attributed to the greater cross-linguistic competition in the nondominant language faced by English-dominant group while naming cognates compared to non-cognates. The author supported the models of lexical selection that advocates the role of inhibitory control during lexical selection and suggested that cross-linguistic competition can be observed even in highly proficient bilinguals.

Kurland and Falcon (2011) found cognate interference when they tested a 60-year old severely non-fluent Spanish-English BWA on a picture naming task (16 cognates and 16 non-cognates) following an intensive semantic naming treatment. They found improved naming accuracy for non-cognates compared to cognates following the treatment suggestive of increased interference for cognate stimuli compared to non-cognates.

Tiwari and Krishnan (2015) tested a self-reported balanced (pre-morbid) Kannada-Malayalam BWA on a picture naming task (28 cognates and 30 non-cognates) and found selective naming difficulty for cognates in their less dominant language (Malayalam). The authors suggested that the cognate inhibition in L2 arises due to the greater inhibition faced by the cognate words in their non-dominant language.

Verreyt, De Letter, Hemelsoet, Santens, and Duyck (2013) have reported no differences between the cognate and non-cognate naming conditions. Verreyt et al. (2013) tested a 78-year old non-fluent French-Dutch BWA (greater impairment in Dutch compared to French) individual on three lexical decision (LD) tasks: generalised LD, L1 (French) selective LD and L2 (French) selective LD task. In the generalised LD task, the participant had to respond whether the stimuli are words or not irrespective of language (L1 or L2). In the selective task, participants had to respond whether the stimuli are words or not in that particular language (in French for the L1 selective task and Dutch for the L2 selective task). Stimuli were 30 French-Dutch cognates, 30 Dutch non-cognates, 30 French non-cognates and 90 non-words. The authors found cognate facilitation on the generalised task but no cognate advantage on the L1 selective task and cognate interference on the L2 selective task. Verreyt et al. attributed this no cognate facilitation effect to greater cross-linguistic competition when the task demand is higher.

In summary, studies on cognate effects have reported mixed results ranging from facilitation to interference to no difference. Most of the studies on BWA are single case studies and often they have not included an extensive measure of language background neither separate executive control measures. In this present study, we address these methodological challenges by including a range of language background measures and a group of seven Bengali-English BWA and eight BHA to investigate the cognate effects using a picture naming task.

5.2.2 Cognate Effects and Executive Control

Previous studies have argued about the role of executive control, especially inhibitory control in cognate production in BWA (Verreyt et al., 2013) and BHA (Acheson, Ganushchak, Christoffels, & Hagoort, 2012; Linck et al., 2008). In an ERP study, Acheson et al. (2012) tested 24 German-Dutch BHA on a mixed picture naming task involving 24 cognates and 24 non-cognate items. The mixed picture naming consisted of two conditions: blocked and mixed. In the blocked naming condition, participants were asked to respond once in German (L1) and once in Dutch (L2). Mixed condition had switch and non-switch trials. In the switch trial, participants had to alternate between L1 and L2 (L1-L2 or L2-L1) whereas in the non-switch trials two consecutive trials were of the same language (L1-L1 or L2-L2). They found cognate facilitation in RT but increased response conflict or increased error related negativity (ERN) for the cognates compared to non-cognates. Acheson et al. concluded that even though production of cognates took less time compared to non-cognates, cognates faced greater response conflict due to increased feature overlap.

As previously mentioned Verreyt et al. (2013) tested a French-Dutch BWA on a cognate picture naming task and found cognate facilitation only on the easier lexical decision task. In addition, Verreyt et al. also administered a flanker task to investigate the executive control ability of the BWA participant. The participant made significantly greater error on the incongruent trials compared to the congruent trials (congruency effect) and this congruency effect was significantly greater compared to 19 balanced healthy Dutch-French bilinguals. The researchers linked the executive control deficit to the cognate pattern shown by the patient. However, they did not correlate executive control measure with the cognate effect because of single case design.

Linck et al. (2008) tested two groups of BHA, 34 Spanish-English and 26 Japanese-English on a cognate picture naming task in their L2 (English) and two executive control tasks, working memory (operation span) and inhibitory control (Simon task). They found better inhibitory control abilities (smaller Simon effect) resulted in lesser cross-language activation or lesser cognate facilitation but did not find any relationship with the working memory measure. However, at present, there is no study which has linked the role of executive control in cognate production in BWA population. The present study aims to examine the relationship between executive control and cross-language activation using a full range of executive control measures and a picture naming task involving cognates and non-cognates.

5.3 The Current Investigation, Research Questions and Predictions

The overarching aim of this study was to investigate the cross-linguistic interference/activation using a picture naming task with cognates and non-cognates in BWA and BHA. Further, to investigate whether the differential cognate/non-cognate naming abilities were influenced by their executive control abilities. In this research, we compared the differences (accuracy, RT) in picture naming performance between cognates and non-cognates in seven Bengali-English non-fluent BWA and eight BHA. We also performed error analysis, individual level analysis and item-wise analysis to better inform the cognate effect in BWA. We provided a detailed characterisation of our participants in Chapter 4. We tested executive control processes using the same executive control measures that we used in Chapter 4. Therefore, the present study had the following executive control measures: Stroop test (measured selective inhibition), Trail Making Test (TMT, measured shifting between mental sets) and the backward digit span test (measured working memory). Following were the research aims and predictions:

1. To determine the differences (between group: BWA and BHA, between languages: English and Bengali) in naming performance (accuracy and RT) between cognate and non-cognate picture nouns.
   Based on the previous studies, we expect both groups to show either cognate facilitation (Detry et al., 2005; Kohnert, 2004; Roberts & Deslauriers, 1999) or cognate interference/no difference (Broersma et al., 2016; Tiwari & Krishnan, 2015; verreyt et al., 2013) in accuracy and RT in both languages at the group level. Cognate facilitation would provide support for the language selective hypothesis whereas cognate interference/no difference would provide evidence for the inhibitory control model of lexical access as described earlier. Again, we expect greater cognate

facilitation (Roberts & Deslauriers, 1999) or cognate interference in the nondominant language (Broersma et al., 2016; Tiwari & Krishnan, 2015).

2. To determine whether differential cognate abilities are influenced by differences in their executive control abilities.

   We expect executive control measures, especially inhibitory control (Stroop ratio) to correlate significantly with the cognate naming abilities for both BWA and BHA (Linck et al., 2008). Similar to chapter 4, we expect BWA to have a stronger correlation between inhibitory control and cognate naming abilities compared to BHA. BWA would need to recruit their executive control processes to compensate for their linguistic difficulties while performing in the picture naming task especially in the nondominant language (Hernandez & Meschyan, 2006).

5.4 Method

5.4.1 Participants

All participants in Chapter 4, except BWA3, participated in this study. Participation was voluntary, and participants provided written consent before participation. The University of Reading Research Ethics Committee approved all the procedures in this study.

5.4.2 Cognate Picture Naming

All the participants performed a picture naming task. Details of the stimuli, procedure and scoring are provided in the following sections:

5.4.2.1 Stimuli. Stimuli were nouns consisted of black-and-white line drawings of 38 cognates (e.g., /bʌtən/ in English and /bɔtʌm/ in Bengali) and 38 non-cognates (e.g., /haʊs/ in English and /bʌri/ in Bengali). Images were taken from various picture databases, such as Philadelphia Naming Test database (PNT; Roach et al., 1996), International Picture Naming Project database (IPNP; Szekely et al, 2004), Bank Of Standardized Stimuli database (BOSS;

Brodeur et al, 2010), picture database given by Snodgrass and Vanderwart (1980), and internet resources.

Both subjective and objective methods were used to determine the cognate status of the stimuli. Initially, 46 cognate nouns and 46 non-cognate nouns were chosen. In the subjective method, the experimenter classified the picture names as cognates or non-cognates based on minimum phonemic feature overlap of at least 70% across languages (Mackay, 1971). Another independent judge (psycholinguistic and aphasia researcher) was asked to classify the words into cognates and non-cognates. Both the experimenter and the independent judge were native speakers of Bengali and were highly proficient in English. A final stimuli list (See Table 5.1 for the complete list of stimuli and their characteristics) consisted of 38 cognates and 38 non-cognates where both the experimenter and the independent judge agreed whether words were cognates or not.

The objective method was based on the phonemic similarity approach given by Mackay (1971). Cognate words were selected based on minimum phonemic feature overlap of at least 70% across language. The words were matched for syllable length across word types and languages (See Table 5.1). Familiarity ratings for each word in each language were obtained by giving a 7-point scale (1 – not familiar, 7 – most familiar) from 7 Bengali-English BHA recruited from India. Familiarity ratings were used as frequency measures were not available for Bengali words. Participants were asked to give a rating to each word from 1 to 7. Following this method, we derived mean familiar ratings for cognate and non-cognate words in each language. The statistical results revealed no significant differences regarding familiarity ratings between cognates and non-cognates (See Table 5.2).

Table5.1

Stimuli List (Cognates and Non-Cognates) and their Syllable Lengths (SL), Familiarity Ratings (FR) in English and Bengali (in IPA Format).

S/N	**Cognate**						**Non-cognate**					
	English			**Bengali**			**English**			**Bengali**		
	Stimuli	SL	FR	Stimuli	SL	FR	Stimuli	SL	FR	Stimuli	SL	FR
1	apple	2	7.0	apel	2	7.0	potato	3	7.0	alu	1	7.0
2	pencil	2	6.1	penʃil	2	6.4	magnet	2	5.4	tʃumbɔk	2	6.3
3	cup	1	6.4	kap	1	6.6	tea	1	6.7	tʃa	1	7.0
4	bottle	2	5.9	bot̪ol	2	5.4	house	1	7.0	gʱɔr	1	7.0
5	tomato	3	6.4	ʈɔmɛʈo	3	6.7	onion	3	7.0	p̃ɛdʒ	2	7.0
6	cycle	2	7.0	saikel	2	7.0	ship	1	5.9	dʒɑhadʒ	2	6.4
7	plug	1	5.1	plag	1	5.4	tap	1	4.7	kɔl	1	5.9
8	zebra	2	6.3	dʒebra	2	5.9	lion	1	5.9	singʱɔ	2	6.3
9	giraffe	2	6.4	dʒiraf	2	5.9	peacock	2	5.6	mɔyur	2	6.3
10	police	2	7.0	puliʃ	2	7.0	bone	1	5.9	haɽ	1	6.4
11	kettle	2	5.3	keʈli	2	6.1	teacher	2	7.0	ʃikʰɔk	2	6.7
12	box	1	5.0	bakʃɔ	2	5.4	paper	2	6.6	kagɔdʒ	2	6.6
13	torch	1	7.0	ʈɔrtʃ	1	7.0	moon	1	7.0	tʃ̃and̪	1	6.9
14	doctor	2	6.4	dakt̪ar	2	7.0	medicine	3	7.0	oʃuɖʱ	2	7.0
15	button	2	5.7	bot̪am	2	6.0	needle	2	5.4	ʃutʃ	1	5.7
16	rickshaw	2	6.4	rikʃa	2	6.6	tail	1	5.9	ledʒ	1	5.9
17	bus	1	7.0	baʃ	1	7.0	foot	1	6.7	pa	1	7.0
18	battery	3	7.0	bɛʈari	3	7.0	lip	1	7.0	ʈʰoʈ	1	7.0
19	drum	1	6.6	ɖram	1	6.7	ladder	2	5.6	s̃iɽi	2	6.0
20	guitar	2	6.9	giʈar	2	6.7	bell	1	5.9	gʱɔnʈa	2	6.4
21	sofa	2	6.4	sofa	2	6.3	pillow	2	6.7	baliʃ	2	6.7
22	bat	1	6.0	bɛʈ	2	6.3	cap	1	6.3	ʈupi	2	7.0
23	ball	1	6.3	bɔl	1	6.3	medal	2	5.6	pɔd̪ɔk	2	5.0
24	glass	1	6.7	glas	1	7.0	duck	1	6.6	ɦ̃as	1	6.4
25	calendar	3	7.0	kɛlenɖar	3	7.0	letter	2	6.7	tʃiʈʰi	2	7.0
26	bag	1	6.4	bɛg	1	6.6	basket	2	5.4	dʒʱuɽi	2	6.3
27	train	1	5.7	rel	1	5.4	bricks	1	5.3	ĩʈ	1	6.7
28	pin	1	5.3	pin	1	4.9	umbrella	3	6.4	tʃʰat̪a	2	7.0
29	cake	1	6.3	kek	1	6.6	window	2	5.9	dʒanala	3	6.7
30	chair	1	6.6	tʃɛar	1	6.7	curtain	2	5.3	pɔrd̪a	2	6.6
31	bench	1	6.7	bentʃ	1	7.0	tree	1	7.0	gatʃʰ	1	7.0
32	table	2	7.0	ʈebil	2	7.0	camel	2	6.4	ũːnʈ	1	5.7
33	pant	1	7.0	pɛnʈ	1	7.0	shirt	1	6.7	dʒama	2	6.4
34	biscuit	2	6.7	biskiʈ	1	6.6	sweet	1	6.9	miʃʈi	2	6.0
35	icecream	2	6.7	aiskrim	2	6.9	banana	3	7.0	kɔla	2	7.0
36	belt	1	7.0	belʈ	1	7.0	shoe	1	7.0	dʒut̪o	2	6.6
37	cheetah	2	6.6	tʃit̪a	2	6.4	fish	1	7.0	matʃʰ	1	7.0
38	balloon	2	6.7	belun	2	7.0	roof	1	5.3	tʃʰad̪	1	6.6
M		1.6	6.4		1.6	6.5		1.6	6.5		1.6	6.3
SD		.6	.6		.6	.6		.5	.5		.7	.7

Table5.2

Stimuli Characteristics for Cognates (Cog) and Non-cognates (Non-cog) in Bengali (B) and English (E) and the Statistical Results of the Dependent Variables.

Variables	Syllable length						Subjective familiarity ratings					
				Statistical results[1]						Statistical results[1]		
	M	*SD*	*Range*	cog vs. non-cog	B.Cog vs. E.Cog	B.non-cog vs. E.non-cog	*M*	*SD*	*Range*	cog vs. non-cog	B.Cog vs. E.Cog	B.non-cog vs. E.non-cog
Cog	1.6	.6	1-3	$t(74)=.30$, $p=.76$	$t(74)=.18$, $p=.86$	$t(74)=0$, $p=1$	6.4	.5	5-7	$t(74)=.42$, $p=.67$	$t(74)=.51$, $p=.61$	$t(66.3)=1.9$, $p=.06$
B	1.6	.6	1-3				6.5	.6	5-7			
E	1.6	.6	1-3				6.4	.6	5-7			
Non-cog	1.6	.5	1-3				6.4	.5	5-7			
B	1.6	.7	1-2				6.3	.7	4-7			
E	1.6	.5	1-3				6.5	.5	5-7			

[1] – Paired sample t-tests were performed for between language comparisons.

5.4.2.2 Procedure. Participants completed the task both in English and Bengali on different days. Participants were familiarised with the pictures at the beginning of the test to avoid errors due to unfamiliarity. Following the familiarisation, participants were shown the picture stimuli in random order one at a time on a computer screen using E-Prime software. Each trial started with a fixation cross for 250ms followed by a 100ms blank screen followed by the target stimuli with a beep sound for 4000ms. A blank screen appeared following the target stimuli for 2000ms before the beginning of a new trial. Participants were asked to respond verbally, and there were no feedbacks except occasional encouragement. Responses were voice recorded and transcribed.

5.4.2.3 Scoring. We calculated the accuracy and RT of naming responses across word types and languages. The onset of each response was labelled manually using PRAAT to obtain greater accuracy and the RT was measured from the beginning of the beep to the onset of the naming response (Boersma & David, 2015). We also measured proportion difference score for naming for both accuracy (cognate - non-cognate/cognate) and RT (non-cognate -

cognate/cognate). Scoring criteria for the errors were same as utilised for the Croft's picture stimuli described in Chapter 4.

5.5 Statistical Analysis

For the RT analysis, data from 3.2% of the experimental trials (combined BWA and BHA) were excluded due to incorrect response or being an outlier (±2.5*SD). Familiarisation of all the test items before the testing resulted in very low error rate. All the variables were measured for each condition (cognate and non-cognate) for each participant in each language. We performed the following analysis which can be classified broadly into six subcategories:

5.5.1 Group Analysis

Two separate two-way ANOVA repeated measure was used, one for accuracy and another for RT, where Group (BWA, BHA) was treated as a between-subject factor, Language (Bengali, English) and Condition (cognate, non-cognate) were considered as within-subject factors. Tukey's post hoc tests were applied for significant interaction effects at $p\leq 0.05$.

5.5.2 Within-Group Analysis

Within-group analysis was performed to provide further insight into the group analysis of BWA. For each group, two separate two-way ANOVA repeated measure was used, one for accuracy and another for RT, where Language (Bengali, English) and Condition (cognate, non-cognate) were treated as within-subject factors. Tukey's post hoc tests were applied for significant interaction effects at $p\leq 0.05$.

5.5.3 Error Analysis

Total numbers of errors were calculated separately for BWA and BHA group in each language and each condition following the same error classification as described in Chapter 4.

5.5.4 Individual Level Analysis

To better understand the performance in cognate production, separate analysis at the individual level was performed for all BWA. Cognate advantage regarding accuracy and RT in each language was analysed for each BWA using chi-square goodness of fit test for the accuracy and Student's independent sample t-test for RT. Further to support the findings from BWA, individual level differences were compared with the BHA group using revised standardised difference test (RSDT; Crawford, Garthwaite, & Porter, 2010). RSDT assessed whether the difference between a BWA individual's standardised scores on two tasks (cognate and non-cognate) is significantly different from the differences observed in the BHA sample.

5.5.5 Item-Wise Analysis

We also did an item-wise analysis (Roberts & Deslauriers, 1999) to further validate the cognate facilitation effect across items for both BWA and BHA groups. However, for this analysis, we had six participants in each group as BWA2 could not complete the task in English whereas BHA2 and BHA4 were not available to complete the task in Bengali. We calculated accuracy for each word (cognates and non-cognates) across participants for the following conditions: correct in both languages, Bengali correct, and English correct. The maximum score possible for each condition was the number of participants in each group (6). Therefore, three one-way ANOVA was conducted separately (alpha level set at .05/3 = .02) for the three conditions to find out the cognate advantage in both BWA and BHA groups.

5.5.6 Correlational Analysis

Finally, to examine the relationship between the executive control measures and cognate variables, Spearman's correlations were performed separately for each group between the cognate difference (accuracy and RT), proportion difference score (accuracy and RT), and two executive control measures (Stroop ratio, and TMT difference) where both groups performed significantly different. Based on the study by Linck et al. (2008), we correlated the executive control measures with cognate difference score rather than the naming score in each condition as our aim of the study was to see whether differential cognate naming abilities were influenced by differences in the executive control abilities.

5.6 Results

The raw scores (accuracy, RT, and proportion difference score) for each individual in each condition and each language, are presented in Table 5.3. The mean and standard deviation values for the cognate variables for Groups (BWA and BHA), Language (Bengali and English) and Condition (cognate and non-cognate) averaged across participants are presented in Table 5.4 (SD reflects between-subject variation). The results of the statistical tests are provided in Table 5.4 as well. The results of the statistical tests along with the means for the within group analysis are presented in table 5.5. Findings from the error analysis are presented in Table 5.6. The results of the statistical findings for each BWA are shown in table 5.7.

Table 5.8 summarises the cognate effects at Group level and individual level along with the RSDT analysis, aphasia severity, Croft's naming test accuracy, and self-rated language proficiency (pre-and-post stroke). Item-wise analysis and the correlation analyses between the executive control measures and cognate measures are presented in Table 5.9 and Table 5.10, respectively.

Findings for Group differences are presented first; followed by the findings from the within group analysis, error analysis, individual level analysis and item-wise analysis. The relationship between the executive control measures and cognate measures are presented at the end.

Table5.3

Each Participant's Performance (Accuracy[1] and RT) in Cognate (Cog) and Non-cognate (Non-cog) Picture Naming Tasks across Languages.

Participants	**Bengali**						**English**					
	Accuracy[1]			RT (msec)			Accuracy[1]			RT (msec)		
	Cog	Non-cog	Proportion difference score	Cog	Non-cog	Proportion difference score	Cog	Non-cog	Proportion difference score	Cog	Non-cog	Proportion difference score
BWA												
BWA1	28 (73.6)	27 (71)	.03	816.4	1019.7	.25	28(73.7)	24(63.1)	.14	1416.3	1403.3	-.01
BWA2	25 (65.8)	27 (71)	-.08	1662.9	2270.2	.36	CNP[2]	CNP[2]	CNP[2]	CNP[2]	CNP[2]	CNP[2]
BWA4	33 (86.8)	32 (84.2)	.03	846.1	932.3	.10	35 (92.1)	37 (97.4)	-.05	801.2	898	.12
BWA5	34 (89.5)	30 (78.9)	.12	1885.9	2106.4	.12	29 (76.3)	29 (76.3)	0	1948.4	2552.7	.31
BWA6	29 (76.3)	15 (39.5)	.48	1679.5	2127.7	.27	29 (76.3)	25 (65.8)	.14	1609.3	1711.9	.06
BWA7	34 (89.5)	26 (68.4)	.23	1286.9	1206.2	-.06	34 (89.5)	34 (89.5)	0	1098.5	1228.4	.12
BWA8	19 (50)	21 (55.3)	-.10	1277.9	1259.9	-.01	22 (57.9)	8 (21)	.64	1256.4	1743.9[3]	.39
M	28.9(76)	25.4(67)	.10	1350.8	1560.3	.15	29.5(78)	26.2(69)	.14	1355.1	1589.7	.17
SD	5.5(14)	5.7(15)	.20	416.6	581.1	.16	4.7(12)	10.2(27)	.20	400.7	567.4	.14
BHA												
BHA1	37 (97.4)	30 (78.9)	.19	945.9	892	-.06	37 (97.4)	37 (97.4)	0	781.9	858.2	.09
BHA2	NAT[4]	NAT[4]		NAT[4]	NAT[4]		33 (86.8)	35 (92.1)	-.06	754.7	984.2	.30
BHA3	36 (94.7)	31(81.6)	.14	1076.8	1002.9	-.07	33 (86.8)	27 (71)	.18	883.8	1102.7	.25
BHA4	NAT[4]	NAT[4]	.07	NAT[4]	NAT[4]	.07	38 (100)	36 (94.7)	.05	788.8	784	-.01
BHA5	37 (97.4)	34 (89.5)	.08	805.7	981.1	.22	36 (94.7)	34 (89.5)	.05	571	675	.18
BHA6	28 (73.7)	28 (73.6)	0	951.9	1221.4	.28	29 (76.3)	28 (73.6)	.03	1122.6	1271	.13
BHA7	31 (81.6)	32 (84.2)	-.03	865.4	828.2	-.04	30 (78.9)	32 (84.2)	-.07	1150.8	1239.2	.08
BHA8	37 (97.4)	36 (94.7)	.03	1019.6	1138.8	.12	36 (94.7)	36 (94.7)	0	1070.3	1139.1	.06
M	34.3(90)	31.8(84)	.07	944.2	1010.7	.07	34(90)	33.1(87)	.02	890.5	1006.7	.14
SD	3.9(10)	2.9(7)	.07	98.7	147.7	.13	3.3(9)	3.8(10)	.10	205.9	218	.10

[1] – Accuracy indicating raw score and percentage in the bracket, calculated out of 38 items in each condition. [2] – Could not perform due to poor language ability. [3] – RT data may not be reliable due to fewer accurate trials. [4] – Not available for testing.

Table5.4

Mean values (M), Standard Deviations (SD) of Conditions (Cognate, Non-cognate) across Languages (Bengali, English) and Groups (BWA, BHA) and the Statistical Results of the Dependent Variables.

Measures	**BWA (N = 7)**						**BHA (N = 8)**						**Statistical analysis (Group, Language, Condition)**						
	Bengali		English		Total		Bengali		English		Total								
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	Group (G)	Lang (L)	Cond (C)	G*L	G*C	L*C	G*L*C
Accuracy[1]																			
Condition	27	4	27	5	27	4	33	4	33	5	33	4	$F(1,13)=6.9$, $p=.02$*, $\eta_p^2=.35$	$F(1,13)=.52$, $p=.48$, $\eta_p^2=.04$	$F(1,13)=12.7$, $p=.003$**, $\eta_p^2=.50$	$F(1,13)=.02$, $p=.90$, $\eta_p^2=.001$	$F(1,13)=1.4$, $p=.26$, $\eta_p^2=.09$	$F(1,13)=.27$, $p=.61$, $\eta_p^2=.02$	$F(1,13)=.21$, $p=.65$, $\eta_p^2=.02$
Cognate	29	5	29	4	29	4	34	3	34	3	34	4							
Non-cognate	25	6	26	9	26	5	32	2	33	4	32	5							
RT (msec)																			
Condition	1455	339	1472	332	1463	308	977	339	948	332	963	302	$F(1,13)=9.9$, $p=.008$**, $\eta_p^2=.43$	$F(1,13)=.01$, $p=.93$, $\eta_p^2=.001$	$F(1,13)=25.7$, $p<.001$** $\eta_p^2=.67$	$F(1,13)=.11$, $p=.74$, $\eta_p^2=.008$	$F(1,13)=4.5$, $p=.06$, $\eta_p^2=.26$	$F(1,13)=.30$, $p=.59$, $\eta_p^2=.02$	$F(1,13)=.03$, $p=.86$, $\eta_p^2=.002$
Cognate	1351	417	1355	366	1533	263	944	83	890	206	917	263							
Non-cognate	1560	581	1590	518	1575	357	1011	125	1007	218	1009	357							

[1] – Accuracy is indicating the raw score, calculated out of 38 items in each condition. ** $p\leq.01$, * $p\leq.05$

Table5.5

Mean values (M), Standard Deviations (SD) of Conditions (Cognate, Non-cognate) across Languages (Bengali, English) for Each Group and the Statistical Results of the Dependent Variables.

Measures	Bengali		English		Total		Language	Condition	Language X Condition
	M	*SD*	*M*	*SD*	*M*	*SD*			
			BWA (*N* = 7)						
Acc[1]									
Condition	27	5	28	7	27	4	*F*(1,6)=.22, *p*=.65, η_p^2= .04	*F*(1,6)=7.5, *p*=.03*,η_p^2= .56	*F*(1,6)=.01, *p*=.97, η_p^2= .001
Cog	29	5	29	4	29	4			
Non-cog	25	6	26	9	26	5			
RT									
Condition	1456	524	1472	464	1464	127	*F*(1,6)=.02, *p*=.90, η_p^2= .003	*F*(1,6)=13.7, *p*=.01**,η_p^2= .70	*F*(1,6)=.03, *p*=.86, η_p^2= .006
Cog	1351	417	1355	366	1353	269			
Non-cog	1560	581	1590	517	1575	464			
			BHA (*N* = 8)						
Acc[1]									
Condition	33	3	33	3	33	3	*F*(1,7)=.33, *p*=.58,η_p^2= .04	*F*(1,7)=4.7, *p*=.07,η_p^2= .40	*F*(1,7)=2.7, *p*=.14,η_p^2= .28
Cog	34	3	34	3	34	3			
Non-cog	32	2	33	4	32	3			
RT									
Condition	977	203	949	88	963	125	*F*(1,7)=.18, *p*=.69, η_p^2= .03	*F*(1,7)=13.7, *p*=.008**,η_p^2 = .66	*F*(1,7)=.90, *p*=.37, η_p^2= .11
Cog	944	83	890	206	917	124			
Non-cog	1011	125	1007	218	1009	135			

[1] – Accuracy is indicating the raw score, calculated out of 38 items in each condition. ** $p \leq .01$, * $p \leq .05$

Table5.6

Raw score and Percentage of Errors based on the Error Classifications for Cognate (C) and Non-cognate (NC) Picture Names in Bengali and English for both BWA and BHA Groups

Error type	**BWA (*N* =6)**						**BHA (*N* =6)**					
	Bengali		English		Total		Bengali		English		Total	
	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC
Target language error												
Semantic	18 (41%)	12 (29%)	11 (24%)	12 (24%)	29 (33%)	24 (26%)	11 (55%)	6 (27%)	14 (52%)	14 (50%)	25 (53%)	20 (40%)
Formal	6 (14%)	4 (9.5%)	6 (13%)	4 (8%)	12 (13%)	8 (8.5%)	0	0	0	0	0	0
Mixed	1 (2%)	0	0	0	1 (1%)	0	0	0	0	1 (3.6%)	0	1 (2%)
Non-word	0	1 (2%)	1 (2%)	1 (2%)	1 (1%)	2 (2.1%)	0	0	0	0	0	0
No response	18 (41%)	21 (50%)	27 (59%)	32 (64%)	45 (50%)	53 (58%)	8 (40%)	14 (64%)	11 (41%)	13(46.4%)	19 (40%)	27 (54%)
Unrelated	0	4 (9.5%)	1 (2%)	1 (2%)	1 (1%)	5 (5.4%)	1 (5%)	2 (9%)	2 (7%)	0	3 (7%)	2 (4%)
Descriptive	1 (2%)	0	0	0	1 (1%)	0	0	0	0	0	0	0
Total	44(100%)	42 (100%)	46(100%)	50 (100%)	90(100%)	92 (100%)	20(100%)	22 (100%)	27(100%)	28(100%)	47(100%)	50(100%)
Cross-linguistic error												
Semantic	6 (86%)	2 (6%)	1 (20%)	2 (9%)	7 (58%)	4 (7%)	2 (100%)	1(6.7%)	0	0	2 (100%)	1 (5%)
Formal	0	1 (2.5%)	0	0	0	1 (2%)					0	0
Translational equivalents	1 (14%)	31 (89%)	2 (40%)	19 (91%)	3 (25%)	50 (89%)	0	14(93.3%)	0	6 (100%)	0	20 (95%)
unrelated	0	1 (2.5%)	2 (40%)	0	2 (17%)	1 (2%)	0	0	0	0	0	0
Total	7 (100%)	35(100%)	5 (100%)	21(100%)	12(100%)	56(100%)	2 (100%)	15 (100%)	0	6 (100%)	2 (100%)	21(100%)

Table5.7

Accuracy and RT of Cognate (Cog) and Non-cognate (Non-cog) Picture Names in Bengali (B) and English (E) for Bilingual Healthy Adults (BHA) and each Bilinguals with Aphasia (BWA) and the Statistical Results of the Dependent Variables.

Participants	**Accuracy**[1]				**Reaction Time (msec)**			
	Cog	Non-cog	Findings[3]	RSDT[4]	Cog	Non-cog	Findings[3]	RSDT[4]
BHA[2]								
E	34(3)	33(4)			890 (206)	1007(218)		
B	34(3)	32(2)			944 (83)	1011(125)		
BWA								
BWA1								
E	28	24	$\chi2\ (1) = .31, p = .58$	*t*(7)=.66, *p*=.53	1416.3	1403.3	*t*(50)=.10, *p*=.92	*t*(7)=1.6, *p*=.16
B	28	27	$\chi2\ (1) = .02, p = .89$	*t*(7)=.13, *p*=.90	816.4	1019.7	*t*(38.1)= -1.6, *p*=.12	*t*(7)=-1.2, *p*=.26
BWA2								
E	CNP[5]				CNP[4]			
B	25	27	$\chi2\ (1) = .07, p = .78$	*t*(7)=.74, *p*=.48	1662.9	2270.2	*t*(43.2)=-2.3, *p*=.02*	*t*(7)=-1.1, *p*=.29
BWA4								
E	35	37	$\chi2\ (1) = .05, p = .81$	*t*(7)=.82, *p*=.43	801.23	892.8	*t*(70)=-1.9, *p*=.06	*t*(7)=.19, *p*=.85
B	33	32	$\chi2\ (1) = .02, p = .90$	*t*(7)=.42, *p*=.69	846.06	932.3	*t*(63)=-1.5, *p*=.14	*t*(7)=.42, *p*=.68
BWA5								
E	29	29	$\chi2\ (1) = 0, p = 1$	*t*(7)=.50, *p*=.63	1948.4	2552.7	*t*(43.4)=-2.4, *p*=.02*	*t*(7)=3.8, *p*=.006**
B	34	30	$\chi2\ (1) = .25, p = .62$	*t*(7)=.67, *p*=.52	1885.9	2106.4	*t*(62)=-1.2, *p*=.22	*t*(7)=1.9, *p*=.09
BWA6								
E	29	25	$\chi2\ (1) = .30, p = .59$	*t*(7)=.70, *p*=.50	1657.8	1711.9	*t*(52)=-.77, *p*=.44	*t*(7)=1.1, *p*=.34
B	29	15	$\chi2\ (1) = 4.4, p = .03*$	*t*(7)=4.7, *p*=.002**	1519.1	2127.7	*t*(17.5)=-1.1, *p*=.29	*t*(7)=1.5, *p*=.16
BWA7								
E	34	34	$\chi2\ (1) = 0, p = 1$	*t*(7)=.27, *p*=.79	1098.5	1228.4	*t*(66)=-1.7, *p*=.08	*t*(7)=.01, *p*=.98
B	34	26	$\chi2\ (1) = 1.1, p = .30$	*t*(7)=2.2, *p*=.06	1286.97	1206.2	*t*(58)=.60, *p*=.55	*t*(7)=1.9, *p*=.09
BWA8								
E	22	8	$\chi2\ (1) = 6.5, p = .01*$	*t*(7)=3.2, *p*=.01*	1256.45	1743.9	*t*(7.8)=-1.6, *p*=.14	*t*(7)=3.2, *p*=.01**
B	19	21	$\chi2\ (1) = .1, p = .75$	*t*(7)=.09, *p*=.93	1277.94	1259.9	*t*(38)=.08, *p*=.93	*t*(7)=1.2, *p*=.28

[1] – Accuracy indicating raw score, calculated out of 38 items in each condition, [2] – Means and SD of BHA group, [3] – Chi-square goodness of fit test for the accuracy and Student's independent sample t-test for RT comparing cognates vs. non-cognates, [4] – Revised Standardised Difference Test (Crawford, Garthwaite, & Porter, 2010) to compare cognate advantage of each BWA with BHA group mean, [5] – Could Not Perform, ** $p \leq .01$, * $p \leq .05$

Table5.8

Summary of Cognate Effects at Group (BWA, N =8 and BHA, N =7) and Individual level (BWA), Aphasia Severity, Naming Accuracy (%) and Self-rated Language Proficiency (Pre-and-Post Stroke) in Both Bengali (B) and English (E).

	Accuracy[1]		**RT[1]**	
Group	B	E	B	E
BWA	**Yes**	**Yes**	**Yes**	**Yes**
BHA	No	No	**Yes**	**Yes**

	RSDT Analysis[2]				**Aphasia severity[3]**		**Naming accuracy[4]**		**Proficiency (Pre-stroke)[5]**		**Proficiency (Post-stroke)[5]**	
	Accuracy		RT									
	B	E	B	E	B	E	B	E	B	E	B	E
BWA1	No	No	No	No	Moderate	Moderate	93.3	73.3	7	6.5	5	4.4
BWA2	No	CNP[6]	No	CNP[6]	Moderate	CNP[6]	76.7	6.7	7	3.8	4.5	2.2
BWA4	No	No	No	No	Mild	Mild	96.7	96.7	7	6	5.2	4.1
BWA5	No	No	No	**Yes**	Mild	Moderate	96.7	80	7	5.6	4.5	4
BWA6	**Yes**	No	No	No	CNP[6]	Severe	33.3	76.7	5.5	7	3.5	4.8
BWA7	No	No	No	No	Mild	Mild	96.7	96.7	6	7	4.5	3
BWA8	Yes	**Yes**	No	**Yes**	Moderate	CNP[6]	73.3	50	7	4.2	4.2	2.7

[1] – **Yes** indicates cognate advantage and No indicates cognate vs non-cognate difference is not significantly different.[2] – Revised Standardised Difference test (Crawford, Garthwaite, & Porter, 2010) to compare cognate advantage of each BWA with BHA group mean. [3] – Aphasia severity rating obtained from Western Aphasia Battery in English (Kertesz, 2006) and its adapted Bengali version (Keshri & Kumar, 2012). [4] – naming subtest from Croft's test battery (Croft, 2008), a higher score indicates better performance. [5] – On a scale of zero to seven (0 = no proficiency, 7 = native like proficiency), greater score means greater proficiency in that language. [6] – Could not perform due to poor language ability in that language.

Table5.9

Item-wise Analysis (Accuracy) for Cognate and Non-cognate Picture Names in BWA and BHA Groups and the Statistical Results of the Dependent Variables.

Variables	**BWA (N=6)**		**BHA (N=6)**		**Statistical analysis**	
	Cognate[1]	Noncognate[1]	Cognate[1]	Noncognate[1]	**BWA**	**BHA**
Both languages correct					$F(1,75)= 7.8$, $p=.007^*$, $\eta_p^2= .09$	$F(1,75)= 6.53$, $p=.01^*$, $\eta_p^2= .08$
M	4	3.1	5	4.2		
SD	1.4	1.5	1.2	1.6		
Range	0-6	0-6	1- 6	0-6		
Bengali correct					$F(1,75)= 3.7$, $p=.06$, $\eta_p^2= .05$	$F(1,75)= 3$, $p=.09$, $\eta_p^2= .04$
M	4.7	3.9	5.4	4.9		
SD	1.5	1.6	0.9	1.4		
Range	0-6	0-6	2-6	1-6		
English correct					$F(1,75)= 4.8$, $p=.03$, $\eta_p^2= .06$	$F(1,75)= 4.2$, $p= .04$, $\eta_p^2= .05$
M	4.7	4.1	5.3	4.8		
SD	1.1	1.1	1	1.2		
Range	3-6	2-6	2-6	1-6		

[1] – accuracy for each word (cognates and non-cognates) across participants. Correct score gets one score for each participant. The maximum score possible for each condition (cognate and non-cognate) was the number of participants in each group (6). Separate scores were calculated for each variable, and separate statistical tests were performed. * $p \leq .02$.

Table5.10

Correlation Coefficients amongst the Executive Control Measures and the Cognate Variables by Groups and Language (Bengali, English).

Executive control measures		Cognate picture naming measures							
		Accuracy difference [1]		RT difference[1] (msec)		Proportion difference score.accuracy		Proportion difference score.RT	
		Bengali	English	Bengali	English	Bengali	English	Bengali	English
BWA (N =7)									
Stroop ratio	rs^2	-.38	.82	.18	-.07	-.39	.77	.29	.07
	p	.40	.02*	.70	.88	.38	.04*	.53	.88
TMT difference	rs^2	-.42	.76	.39	.57	-.39	.72	.36	.50
	p	.35	.05*	.38	.18	.38	.07	.43	.25
BHA (N =8)									
Stroop ratio	rs^2	.43	.65	.15	.56	.43	.74	.15	.57
	p	.29	.08	.72	.14	.29	.04*	.72	.14
TMT difference	rs^2	.44	.81	.25	.40	.44	.87	.25	.40
	p	.27	.01*	.55	.32	.27	.005*	.55	.32

[1] – Accuracy and RT difference were measured by subtracting cognate accuracy and RT from non-cognate accuracy and RT, [2] – Spearman's correlation coefficients, * $p \leq .05$

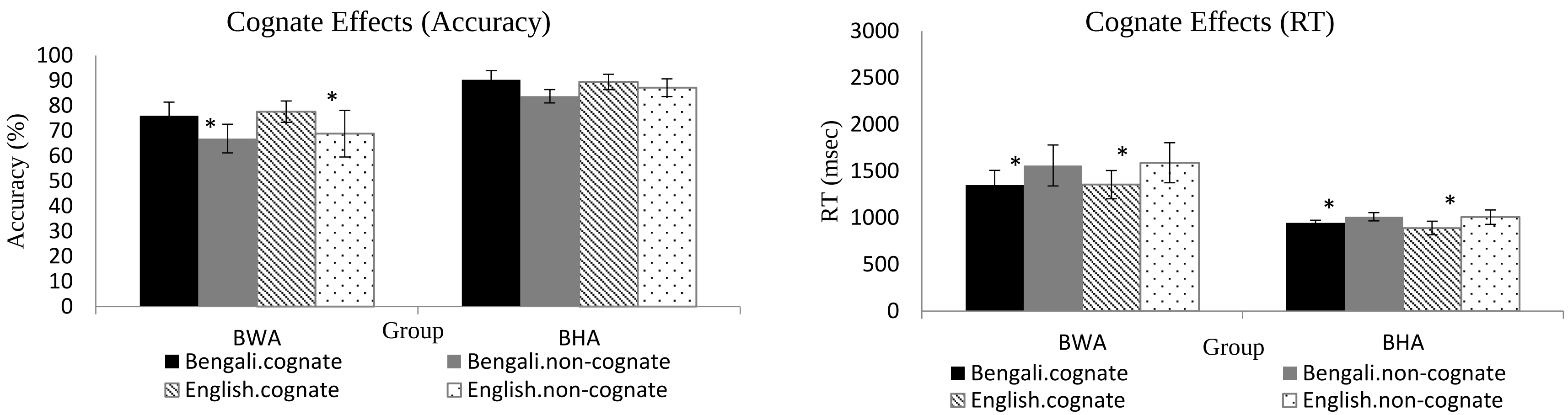


Figure 5.2 Cognate effects regarding accuracy (%, left panel) and RT (msec, right panel) for the BWA and BHA group. Error bars represent standard error of the means. * $p \leq .05$

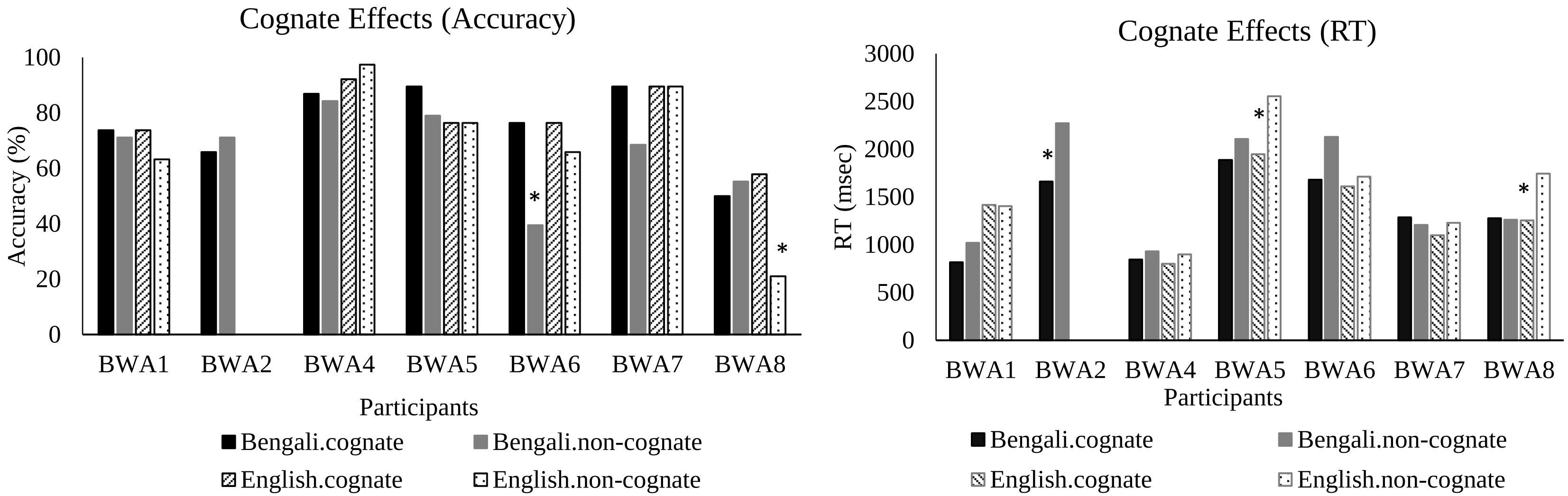


Figure 5.3 Cognate effects regarding accuracy (%, left panel) and RT (msec, right panel) for each BWA individual. * $p \leq .05$.

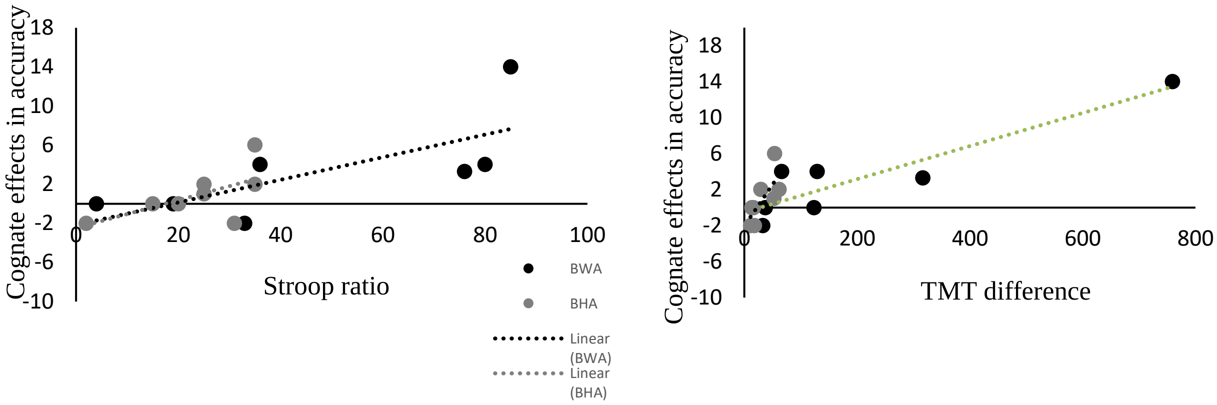


Figure 5.4 Correlation plots for the significant correlations amongst the executive control measures (left panel: Stroop ratio; right panel: TMT difference) and cognate effects in accuracy (English) for the two groups. However, the significant correlation for BWA between TMT difference and cognate effects in accuracy was no longer significant (p = .15) when we excluded the data of BWA8 (TMT difference: 759, cognate effects in accuracy: 14).

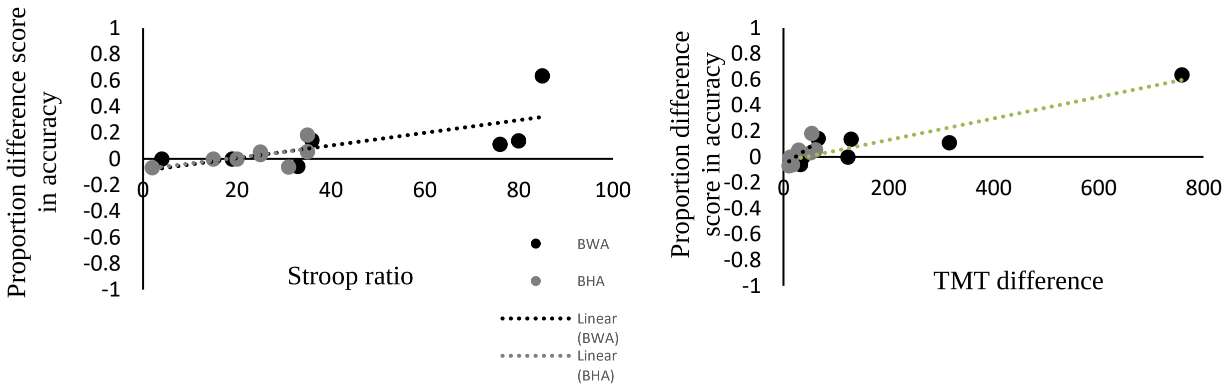


Figure 5.5 Correlation plots for the significant correlations amongst the executive control measures (left panel: Stroop ratio; right panel: TMT difference) and proportion difference score in accuracy (English) for the two groups.

5.6.1 Cognate Effects at the Group Level

As expected, differences between the BWA and BHA regarding the main effect of Group were observed for both accuracy and RT (see Table 5.4). On accuracy, BWA group made significantly fewer correct responses compared to BHA (BWA: *M* =27, *SD* = 5; BHA: *M* = 33, *SD* = 5) and the BWA group (*M* = 1421, *SD* = 338) were significantly slower than BHA group (*M* = 983, *SD* = 338).

Regarding cognate facilitation, we also found the main effect of Condition for both accuracy and RT. Cognates were produced more accurately (cognates: *M* = 31.7, *SD* = 4.4; non-cognates: *M* = 28.9, *SD* = 5.6) and faster (cognates: *M* = 1132, *SD* = 293.9; non-cognates: *M* = 1272.5, *SD* = 386.2) compared to non-cognates suggestive of cognate facilitation for both BWA and BHA. However, we did not find any main effect of language or any two-and three-way interactions either for accuracy or RT.

5.6.2 Cognate Effects at the Within-Group Level

Cognate effects at the within-group level for both BWA and BHA regarding accuracy and RT are presented in Table 5.5. For the BWA group, there was a main effect of Condition for both accuracy and RT (see *Figure 5.2*), that is cognates were produced more accurately with large effect size of 0.7 (cognates: *M* = 29, *SD* = 4; non-cognates: *M* = 26, *SD* = 5) and faster with large effect size of 0.8 (cognates: *M* = 1353, *SD* = 269; non-cognates: *M* = 1575, *SD* = 464) compared to non-cognates. There was no main effect of language or any two-way interactions for both accuracy and RT.

For the BHA group, there was a main effect of Condition, only for RT (see *Figure 5.2*). There were no significant differences between cognate naming accuracy and non-cognate naming accuracy (cognates: *M* = 34, *SD* = 3; non-cognates: *M* = 32, *SD* = 3; *p* = .58), however cognates were produced faster compared to non-cognates with large effect size of

0.8 (cognates: *M* = 917, *SD* = 124; non-cognates: *M* = 1009, *SD* = 135). There was no main effect of language or any two-way interactions for both accuracy and RT.

5.6.3 Cognate Effects on Naming Error

Error classifications at the group level are presented in Table 5.6. Overall, semantic, no response, and cross-linguistic errors most frequently occurred error types. For BWA, no response errors were more common than semantic errors in both cognate (50% no response and 33% semantic) and non-cognate condition (58% no response and 26% semantic). For BHA, semantic errors were more common than no response errors in the cognate condition (53% semantic and 40% no response), and no response errors were more common than semantic errors in the non-cognate condition (40% semantic and 54% no response). In terms of cross-linguistic errors, translational equivalents errors were the most common type of error for both groups and were more common in the non-cognate condition compared to the cognate condition (BWA: 89% in the non-cognate condition and 25% in the cognate condition; BHA: 95% in the non-cognate condition and no errors in the cognate condition).

In summary, BHA group produced word closer to the target word (semantic errors) while naming cognates suggestive of cognate facilitation. However, BWA group produced more number of no responses while naming cognates which implies BWA group faced greater interference from the cognate words which is just opposite to the BHA group.

5.6.4 Individual Level Analysis

On individual level analysis (see Table 5.7), not all the BWA showed cognate facilitation. Four out of seven BWA showed cognate facilitation either in accuracy or RT only in their nondominant language except BWA2 who showed cognate facilitation in dominant language (Bengali) for RT (see *Figure 5.3*). BWA5 showed cognate facilitation in L2 (English) for RT (cognate = 1948.4 msec, non-cognate = 2552.7 msec), BWA6 showed cognate facilitation in

L2 (Bengali) for accuracy (cognate = 29, non-cognate = 15), and BWA8 showed cognate facilitation in L2 (English) for accuracy (cognate = 22, non-cognate = 8).

Further, to determine whether the cognate advantage of each BWA is significantly different from BHA group, we performed RSDT analysis (Crawford et al., 2010) for each BWA. Findings are consistent with the individual level analysis (except BWA2) that is the difference in naming between cognates and non-cognates showed by BWA5, BWA6, and BWA8 were significantly different from the differences observed in BHA group. Overall, balanced BWA (except BWA5) did not show cognate facilitation; only the unbalanced BWA showed cognate facilitation which was significantly different from the BHA group (see Table 5.8).

5.6.5 Item-wise Analysis

On item-wise analysis (see Table 5.9), cognate pictures were more often correctly named in both languages than the non-cognate pictures. There was a significant effect of cognateness (accuracy) only for 'both languages correct' for both BWA, $F(1, 75) = 7.8$, $p=.007$ with a moderate effect size of 0.3 and BHA, $F(1, 75) = 6.53$, $p=.01$ with a small effect size of 0.2.

5.6.6 Cognate Variables and Executive Control Measures

Table 5.10 presents the correlation coefficients amongst the cognate variables and executive control measures for BWA and BHA. *Figure 5.4* and *Figure 5.5* provides the scatter plots for the significant correlations. Correlation analyses revealed better executive control correlated with lesser cognate facilitation and lesser proportion difference score for both groups

Significant positive correlations were observed for both the executive control measures (Stroop ratio and TMT difference) and cognate facilitation regarding accuracy in English (see *Figure 5.4*). Participants (BWA) with smaller Stroop ratio and lesser TMT difference (BWA and BHA) illustrated lesser cognate facilitation in their nondominant language (English) indicating that the participants with better inhibitory control and task switching ability could restrict the cross-linguistic activation (i.e., less cognate facilitation). However, the significant correlation between TMT difference and cognate facilitation for BWA went away (*p* =.15) when we excluded the data from BWA8 (TMT difference: 759, accuracy difference: 14). Therefore, the significant correlations between TMT difference and cognate facilitation in English should be treated cautiously.

For proportion difference score, significant positive correlations were observed with Stroop ratio for BWA and significant positive correlations were observed with TMT difference for BHA (see *Figure 5.5*). However, the significant results were observed only for accuracy in English similar to cognate difference score. Participants with smaller Stroop ratio (BWA) and lesser TMT difference (BHA) illustrated lesser proportion difference score in their nondominant language (English) indicating that the BWA participants with better inhibitory control and BHA participants with better task switching ability could restrict the cross-linguistic activation (i.e., less cognate facilitation).

5.7 Discussion

The present study investigated the group differences in naming of cognate and non-cognate nouns in two languages of BWA and BHA and explored the executive control measures that mediate the performance difference between them. Overall, we found cognates were named faster and more accurately compared to non-cognates on both languages. BWA were slower and more error-prone as compared to BHA on both cognate and non-cognates. BWA showed cognate facilitation in both accuracy and RT, whereas BHA group showed cognate facilitation only for RT. Error patterns revealed BHA group performed better while naming cognates compared to non-cognates. However, BWA who had more difficulty in cognates produced more number of no response errors. On the individual analysis, only unbalanced BWA showed cognate facilitation in their non-dominant language. Item-wise analysis revealed cognate advantage on both languages with a greater effect size for BWA compared to BHA.

On the correlation analysis, both groups showed significant correlations between executive control measures (Stroop ratio and TMT difference) and accuracy regarding cognate effects and proportion difference score in their nondominant language (English).

Compared to BHA, BWA were less accurate and took more time to respond to the picture naming task irrespective of the word status (cognate and non-cognate). Both groups showed cognate facilitation which corroborates with the literature (Detry et al., 2005; Lalor & Kirsner, 2001; Roberts & Deslauriers, 1999). Cognate facilitation observed at the group level for both BWA and BHA supports the language non-selective hypothesis that even when bilinguals are speaking in one language; both languages are activated (Abutalebi & Green, 2007; Green, 1998). Regarding performance differences between languages, BWA showed no cross-linguistic difference which is consistent with the findings in the aphasia literature involving picture naming tasks (Detry et al., 2005; Roberts & Deslauriers, 1999). Comparable cross-linguistic performance in the picture naming task involving cognate and non-cognates is also consistent with the findings observed in Chapter 4 where BWA as a group did not show any cross-linguistic difference on the verbal fluency task as well as on Croft's materials.

However, cognate facilitation for both BHA and BWA in our study is in contrast with studies where cognate facilitations were not observed (Boersma et al., 2016; Kurland & Falcon, 2011; Tiwari & Krishnan, 2015; Verreyt et al., 2013). Boersma et al. (2016) tested English-dominant, Welsh-dominant and balanced BHA on a picture naming task. They found cognate interference for the English-dominant group in their non-dominant language and cognate facilitation for the Welsh-dominant and balanced BHA in both languages. BHA participants in the present study were balanced bilinguals. Therefore, findings from the healthy adults of our study are in line with Boersma et al.'s study. Future research should look into the different type of bilinguals regarding language combinations and proficiency to find out the role of cognates in word production.

Kurland and Falcon (2011) found cognate interference when they tested a severe non-fluent BWA on a picture naming task following an intensive semantic naming treatment. They showed improved naming accuracy for non-cognates compared to cognates. Similarly, Tiwari and Krisnan (2015) tested a self-reported balanced BWA on a picture naming task and found naming difficulty in cognates. Verreyt et al. (2013) tested a non-fluent BWA on a selective and generalised picture naming task. They did not observe cognate facilitation on the selective picture naming where the task demand was higher compared to the generalised naming task. These three studies tested only single participant. Therefore, we cannot generalise their findings to our BWA group findings.

Individual analysis of BWA aimed to shed further light on whether individual patients would show cognate interference or no cognate facilitation. Our individual level analysis indeed supported the findings observed from the previously mentioned studies. Three out of 7 BWA did not show cognate facilitation, especially who were balanced BWA based on the severity of aphasia in both languages and self-rated language proficiency (pre- and post-stroke). Error analysis of BWA further provided valuable insight into the debate of cognate facilitation vs no cognate facilitation. Error analysis revealed cognate interference for BWA, but BHA showed cognate facilitation. Cognate interference for BWA are in agreement with the notion that cognate words compared to non-cognates, face greater response conflict due to larger feature overlap (Acheson et al., 2012). No cognate facilitation for BWA in our study supports the findings of Verreyt et al. (2013) who attributed no cognate facilitation to greater cross-linguistic competition when the task demand was higher. However, for healthy balanced BHA, Broersma et al. (2016) found cognate facilitation. They attributed this facilitation to the ability of balanced bilinguals to take advantage of the larger feature overlap at the phonological level as the cross-linguistic competition is lesser compared to non-balanced bilinguals. Therefore, findings from the error analysis involving the healthy adults of our study are in line with Boersma et al.'s study.

Hence, the present study has provided evidence for cognate advantage as well as no difference between cognates and non-cognates in BWA. The present study also signifies the importance of including more number of patients, individual level analysis, and extensive language background measures. Future studies may look into the cognate effects (facilitation or not) involving different types of aphasia population regarding type (fluent vs non-fluent), severity, nature of bilingualism (balanced vs unbalanced).

Correlation analysis from the present study provide further evidence of greater competition faced by cognate words compared to non-cognates and the role of executive control to resolve this competition. Both groups from the present study showed significant correlations between the executive control components and picture naming variables. Participants with better inhibitory control and mental-set shifting abilities showed lesser cognate facilitation in their non-dominant language. This is the first study to investigate the relationship between executive control abilities and cross-linguistic interference faced during cognate word production in a group study involving BWA.

Verreyt et al. (2013) tested a French-Dutch BWA on a cognate picture naming task (generalized and selective) and a flanker task. Verreyt et al. linked the poorer performance in the flanker task with the cognate facilitation. Linck et al. (2008) tested healthy bilinguals and found better inhibitory control in terms of smaller Simon effect leads to smaller cognate facilitation. Present study confirms the role of executive control abilities in cognate word production in both BWA and BHA population and extends the literature by including a range of executive control measures. In addition to inhibitory control, we found mental-set shifting abilities also mediate the performance difference between cognate word production and non-cognate words production. Future studies should include different types of executive control measures to further establish the role of executive control abilities during cognate word production.

Overall, we found evidence of both cognate facilitation and interference for BWA population in a picture naming task. Language proficiency and executive control abilities modulated the cognate effects. Findings from the present study support the language non-selective hypothesis and inhibitory control model of lexical access. The present study has provided evidence of both cognate facilitation and interference, therefore therapy treatment plan focusing only on cognate words should take into consideration of other factors such as language proficiency, severity of aphasia, and executive control abilities of BWA.

Chapter 6: General Discussion

6.1 General Discussion

The overarching goal of this research project was to examine the contribution of linguistic and executive control processes to word production in healthy monolinguals and bilinguals (healthy and aphasia). This was explored in two phases: Phase I (Chapters 2 and 3) and II (Chapters 4 and 5). The Phase I explored the differences between young healthy monolingual and bilingual speakers residing in UK. These two groups of participants were matched on age, years of education, and receptive vocabulary measures. All the participants performed two linguistic experiments (verbal fluency, Chapter 2 and blocked-cyclic picture naming, Chapter 3) in English and three measures of executive control tasks (Stroop test, colour-shape switch task, and backward digit span test). Bilingual participants were characterized in both languages for the bilingualism related variables (acquisition history, language of instruction during education, proficiency, usage, dominance, and language switching habits).

Phase II explored the word production impairments in both languages of bilinguals with aphasia (BWA) and compared the differences with age-, gender-, education- and language background- matched bilingual healthy adults (BHA). All BWA participants were characterized comprehensively in both languages for the following variables: language impairments (severity and type of aphasia); word production impairments across various modalities (word-to-picture matching, naming, repetition, and reading); pre-and post-stroke bilingualism characteristics (acquisition history, language of instruction during education, proficiency, usage, and dominance). Both groups performed two linguistic experiments (verbal fluency in Chapter 4, and picture naming involving cognates and non-cognates in Chapter 5) in both languages and completed three executive control tasks (Stroop test, Trail Making Test, and backward digit span test). Table 6.1 below summarises the main findings from the four experimental studies.

Table6.1

Summary of all Experimental Chapters with their Research Questions, Methodology, and Results.

Chapter 2. Verbal fluency and executive control in healthy monolingual and bilingual speakers		
Specific research questions	**Methods**	**Results**
To determine the relative contribution of linguistic and executive control processes during word production in healthy monolingual and bilingual speakers by using verbal fluency task.	*Participants*: 25 healthy young adult Bengali-English bilinguals and 25 healthy young adult English monolinguals. Groups were matched on age, years of education, and receptive vocabulary. *Linguistic tasks*: Verbal fluency tasks (semantic and letter) in English *Variables*: Quantitative: (number of correct responses, fluency difference score), Time-course (1st RT, sub-RT, initiation, slope), Qualitative (cluster size, number of switches, within-cluster pauses, between-cluster pauses) *Executive control measures*: Inhibitory control (Stroop test: Stroop ratio), Mental-set shifting (colour-shape task switch: switch cost for accuracy and RT), and working memory (backward digit span test: backward digit span)	*Linguistic tasks:* • Bilinguals outperformed monolinguals on measures where executive control demands were higher such as number of correct responses in letter fluency, fluency difference score, sub-RT, slope in letter fluency, cluster size in letter fluency, and BCP in letter fluency. • On the correlation analysis, bilinguals showed significant correlations between inhibitory control (Stroop ratio) and verbal fluency slope. *Executive control measures:* Bilinguals showed superior inhibitory control (smaller Stroop ratio) compared to monolinguals. There was no difference on switch cost RT between the two groups, but bilinguals performed significantly better compared to monolinguals in terms of switch cost accuracy. Both groups performed similarly on the working memory measure (backward digit span).
Chapter 3. Semantic contexts effects and executive control in healthy monolingual and bilingual speakers		
Specific research questions	**Methods**	**Results**
To determine the relative contribution of linguistic and executive control processes during word production in healthy monolingual and bilingual speakers by using a paradigm where executive control demands can be varied from low to high.	*Participants*: Same as Chapter 2 *Linguistic tasks*: Blocked-cycling picture naming in English *Variables*: Context effect (RT difference between the homogeneous and heterogeneous context) for all cycles, excluding first presentation cycle, and excluding cycle 2-4. Slope (changes in RT across cycles) *Executive control measures*: Same as Chapter 2	*Linguistic tasks:* • Bilinguals showed lesser semantic context effect compared to monolinguals • On the first presentation cycle bilinguals showed semantic facilitation • On the correlation analysis, we did not find any significant correlation between any of the executive control measures with any of the blocked-cyclic naming variables.

Chapter 4. Verbal fluency and executive control in bilingual aphasia (BWA) and bilingual healthy adults (BHA)		
Specific research questions	**Methods**	**Results**
To determine the relative contribution of linguistic and executive control processes during word production in bilinguals with aphasia and bilingual healthy adults by using verbal fluency task.	*Participants*: Eight Bengali-English BWA and eight Bengali-English BHA. Both groups were matched on age, sex, years of education and other bilingualism related variables. All BWA speakers sustained a single left hemisphere CVA and had mild to moderate non-fluent type aphasia in both languages. *Linguistic tasks*: Verbal fluency tasks (semantic and letter) in both languages. *Variables*: Same as in Chapter 2. *Executive control measures*: Inhibitory control (Stroop test: Stroop ratio), mental set-shifting (Trail Making Test: RT difference between trial B and A), and working memory (backward digit span test: backward digit span)	*Linguistic tasks:* • Overall, BHA performed better compared to BWA group on both linguistic (number of correct responses, 1st –RT, and initiation) and executive control components of the task (fluency difference score, slope, number of switches, and between-cluster pauses) • BWA showed no cross-linguistic differences. BHA performed better in their dominant language (Bengali) on the semantic fluency but on letter fluency they performed better in English which was the medium of instruction during education. • Correlation analysis revealed significant relationship between executive control and verbal fluency measures for BWA. BWA with better inhibitory control and mental-set shifting abilities made more number of correct responses, were faster to initiate the first response, had more linguistic resources to begin with, and made more number of switches in the verbal fluency tasks. *Executive control measures*: BWA showed poorer inhibitory control (larger Stroop ratio) and mental-set shifting (larger TMT difference) abilities compared to BHA. However, both groups performed similarly on the working memory measure (backward digit span)
Chapter 5. Cognate production and executive control in bilinguals with aphasia (BWA) and bilingual healthy adults (BHA)		
Specific research questions	**Methods**	**Results**
To examine the cross-linguistic interference/activation using a picture naming task with cognates and non-cognates in BWA and BHA. In addition, we also aimed to investigate whether the differential cognate/non-cognate naming abilities were influenced by their executive control.	*Participants*: Same as Chapter 4 *Linguistic tasks*: Picture naming tasks in both languages (cognates and non-cognates) in both languages. *Variables*: Accuracy and RT for cognate and non-cognate pictures *Executive control measures*: Same as Chapter 4	• Both groups showed cognate facilitation at group level in terms of accuracy and RT. However, individual analysis and error analysis revealed no cognate advantage for balanced BWA. • Correlation analysis revealed inhibitory control and mental-set shifting abilities correlated significantly for both the groups with the accuracy difference between cognate and non-cognate pictures. Better inhibitory control and mental-set shifting abilities lead to lesser cognate facilitation in both groups.

In the following section, we will discuss the summary and contribution of these studies in terms of theoretical and clinical understanding of bilingual populations. The chapter ends with the limitations of the current project and suggested future directions.

6.1.1 Review and Contribution from the Experimental Chapters

Previous studies have shown bilingual disadvantage in various linguistic tasks such as picture naming (Roberts et al., 2002; Gollan et al., 2005), verbal fluency (Rosselli et al, 2000), lexical decision tasks (Ransdell & Fischler, 1987), word identification through noise task (Rogers et al., 2006), etc. There are various explanations in the literature to account for the bilingual disadvantage in the linguistic domain. According to the weaker link hypothesis, the reason for bilingual disadvantage in the linguistic domain is the lesser usage of each language of a bilingual speaker resulting in weaker link between the two languages (Michael & Gollan, 2005). Sensorymotor account (Hernandez & Lee, 2007) attribute the bilingual disadvantage to the delay in age of acquisition of the second language.

As can been seen from Figure 1.2 (Chapter 1), bilinguals face greater lexical competition compared to monolinguals as both languages are active during language processing (Costa & Caramazza, 1999) and the poorer performance in the linguistic domain can be attributed to this increased lexical competition (Inhibitory control model, Green, 1998). Consequently, bilinguals have to inhibit one language while speaking another language and this exercise of inhibition reflects bilingual's superiority in non-linguistic executive control tasks over monolinguals (Bialystok, 2009). For Phase I, we formulated our hypothesis from these theoretical accounts (weaker link hypothesis, inhibitory control model) described earlier. Bilingual participants from Phase I were matched in vocabulary with the monolingual group. Further, bilingual participants in Phase I used English in their day-to-day life more often than Bengali. We predicted that controlling for these factors (vocabulary and usage), bilingual would be able to perform at par with the monolinguals if bilinguals can resolve their increased cros-linguistic competition with the help of their executive control mechanisms. Further bilingual's advantage in the non-linguistic domain is relatively well establised (Bilaystok, 2009). Therefore, it might be possible to extend the bilingual's superiority in the non-linguistic domain to the linguistic domain if both language vocabulary and usage can be controlled for and the chosen linguistic task require higher executive control processing. To test this hypothesis, in Phase I, we chose a task (verbal fluency) and a paradigm (blocked-cyclic naming) where executive control demands can be manipulated (e.g., greater executive demand in letter fluency). As expected, in both the linguistic tasks, bilinguals outperform the monolinguals where executive control demands were higher (e.g., greater number of CR in the letter fluency, smaller FDS score, lesser blocking effect in blocked-cyclic naming, etc.), and bilinguals performed at par with the monolinguals where executive control demands were comparatively lesser (e.g., no difference in CR for the semantic fluency). In addition, correlation analysis from the present study further supported the statement above (significant positive correlations between Stroop ratio and verbal fluency slope for bilinguals).

Therefore, bilingual disadvantage in the linguistic domain could be negated if vocabulary and language usage are controlled for. Also, bilingual advantage in the non-linguistic domain can be extended to the linguistic domain if the linguistic tasks were made more challenging by increasing the executive control demands. In Phase I, we provided evidence for bilingual advantage in the linguistic domain and the relationship between linguistic and executive control mechanism during word production. Our findings support the theoretical models which explain bilingual disadvantage in linguistic domain (Michael & Gollan, 2005) and advantage in the non-verbal executive control domain (Bialystok, 2009; Green, 1998). However, to explain our findings there is a need of an integrative model which would take contribution of executive control mechanisms in linguistic domain into consideration. Future studies may consider exploring the relationship between linguistic and executive control mechanism at various linguistic levels (lexical level, phonological level, etc.) and coming up with a theoretical model which could explain the bilingual advantage in the linguistic domain by taking executive control mechanisms into consideration.

In Phase II, we aimed to extend our understanding of the relationship between the linguistic and executive control mechanisms from healthy bilinguals to bilinguals with aphasia. In contrast to research on linguistic and executive control processes in healthy bilinguals, studies investigating linguistic manifestation of a breakdown in the two languages in BWA are limited (see Kiran & Gray, 2018 for a review). We described the nature and extent of language breakdown following a stroke in bilingual individuals. We also investigated whether bilingualism related variables (pre- and post-stroke) and executive control profile of individuals could explain the linguistic manifestation of a breakdown in the two languages in BWA.

As expected, we found evidence of linguistic and executive control impairments at the group level for BWA individuals. Similar to the monolingual group in Phase I, we found BWA had more difficulty in the linguistic tasks where executive control demands were higher (e.g., larger FDS, fewer number of switches, longer BCP). However, the underlying executive control deficits in the linguistic tasks may not be visible with the usual analysis techniques (e.g., number of CR). Therefore, we argued in favour of including a more fine-grained analysis of linguistic tasks. In terms of cross-linguistic impairment, our results showed similar impairment in both the languages and the post-stroke language ability (e.g. better performance in Bengali) mirrored their pre-stroke language ability (Bengali dominant). In both (verbal fluency and cognate/non-cognate picture naming) the linguistic tasks, we found strong evidence of executive control involvement that is BWA who performed poorly in the executive control measures also performed poorly in the linguistic tasks.

Findings from the linguistic tasks revealed that despite showing deficits in lexical access, BWA still mirrored the BHA in terms of the underlying language processing mechanism which is required to perform in the linguistic tasks. For example, BWA showed similar clustering strategy as BHA while generating items in the verbal fluency task. Like BHA, BWA showed cognate facilitation at the group levels.

Executive control impairment was evident across the inhibitory control and task switching domain, however not all the BWA individuals showed executive control impairment across the two measures. Individuals with more severe aphasia showed poorer executive control abilities, as expected. However, we did not have site of lesion information to support our claim for the relationship between extent of lesion/or severity and the executive control impairments. Future studies may consider investigating the relationship between the extent of lesion/or severity and executive control impairment.

In the following section, we provide summary of results from each experimental chapter and the implications.

In Chapter 2, verbal fluency task investigated the relative contribution of linguistic and executive control processes during word production using a wide range of variables (quantitative, time-course, and qualitative), a relatively homogeneous group of bilinguals (i.e., all were Bengali-English, equally proficient and dominant in both languages), and separate measures of executive control. Previous studies comparing healthy monolinguals and bilinguals on verbal fluency tasks have shown mixed results ranging from bilingual advantage (Bialystok et al., 2008; Luo et al., 2010) to disadvantage (Gollan et al., 2002; Paap et al., 2017) to no differences (Paap et al., 2017). Nevertheless, all these studies have relied only on the number of correct responses as a dependent variable (except Luo et al., 2010). For example, Paap et al (2017) did not find any difference between bilinguals and monolinguals on the difficult letter fluency condition. The results were inconsistent with the notion of bilingual's enhanced executive control abilities help them to outperform monolinguals on the more demanding letter fluency condition. Paap et al. also refuted the claim that compared to semantic fluency, letter fluency requires greater executive control functioning and suggested to support this claim by independent and direct tests of executive control abilities. Similarly, Whiteside et al. (2016) in an exploratory factor analysis study have argued that the contributions of linguistic processes are greater in verbal fluency compared to executive control processes. They found number of correct responses in the verbal fluency loaded onto the language factor only and not the executive control factor. The Chapter 2 addressed these irregularities in the literature by including a wide range of variables and separate measures of executive control abilities. We found that vocabulary matched healthy bilinguals performed similarly to monolinguals in semantic fluency, which are thought to have higher linguistic demands. However, bilinguals outperformed the monolinguals in the difficult letter fluency task which are assumed to have higher executive control demands. Differences between the two groups were observed only on the variables where executive control demands were higher such as, number of CR in the letter fluency, fluency difference score, slope, cluster size, and BCP in the letter fluency. Independent executive control measures (Stroop ratio) correlated only for the variable (slope) that tapped into executive control component of the verbal fluency task.

Importantly, traditional analysis approaches (e.g. number of correct responses) would not have revealed this pattern of results. Both Paap et al. and Whiteside et al.'s study argued against the fact that letter fluency condition requires greater executive control demands, however their claim was made based on only number of correct responses as a variable. When a broad range of variables and separate executive control measures were included, we found evidence of executive control involvement in the letter fluency condition. Present study found differences between bilingual and monolingual groups mainly where the executive control demands were higher. We found bilinguals are not at a disadvantage on linguistics measures if matched for vocabulary. Present study highlights that to explain advantage, disadvantage, and no differences between bilinguals and monolinguals, it is necessary to use a range of verbal fluency variables and independent executive control measures.

In Chapter 3, we tested both the same monolingual and bilingual healthy adult groups on blocked-cyclic picture naming task to test how increasing or decreasing lexical competition affects their picture naming abilities. To the best of our knowledge, this is the first study to investigate the lexical competitions in bilinguals compared to monolinguals using experimental paradigm of blocked-cyclic naming. This manipulation allowed testing how bilinguals manage their two lexical systems and how their executive control mechanisms resolve this competition. We have argued in Chapter 1 (pp. 15-16) that three possible conditions that can arise while comparing bilinguals and monolinguals on the blocked-cyclic naming task:

Condition 1: Compared to monolinguals, bilingual's executive control advantage outweighs the bilingual's increased lexical competition (disadvantage). Therefore, bilinguals will have lesser semantic context effect than monolinguals.

Condition 2: Compared to monolinguals, bilingual's increased lexical competition (disadvantage) outweighs the bilingual's executive control advantage. Therefore, bilinguals will have greater semantic context effect than monolinguals.

Condition 3: Bilingual's increased lexical competition (disadvantage) and the executive control advantage are of similar magnitude. Therefore, both groups will have comparable semantic context effects.

We found bilinguals had lesser semantic interference (i.e., lesser semantic context effect) compared to monolinguals and only bilinguals showed semantic facilitation in the first cycle. Lesser semantic context effect for bilinguals supports the claim that bilinguals' better executive control helped them to overcome their disadvantage of having increased lexical competition (within-language and between-language competition). Absence of semantic facilitation in the first cycle for monolinguals is consistent with the literature when homogeneous and heterogeneous sets were presented in alternative manner as in the present study (see Belke, 2017 for a review). Belke (2017) observed that semantic facilitation in monolinguals were reported in studies where stimuli sets were presented in a blocked fashion and participants could use their executive control to bias their responses. However, semantic facilitation for bilinguals even when sets were presented in an alternated manner can be attributed to the superior executive control in bilinguals which helped them to bias their responses.

Overall, both studies from Phase I found evidence of bilingual advantage in linguistic domain where executive control demands were higher, and on separate executive control measures, especially on inhibitory control. We also showed that inhibitory control measure was correlated with certain variables of the linguistic measures (slope of verbal fluency), especially where task demands were higher.

Phase II explored the linguistic breakdown in BWA and compared the differences with BHA using verbal fluency and picture naming task involving cognates and non-cognates words. The results of Phase II make significant contribution to the bilingual aphasia literature. We present very well characterized bilingual aphasia participants on their background language abilities (see Section 4.4.2, Chapter 4), relatively homogenous group of non-fluent aphasia, cross-linguistic comparison, individual and group level analysis and research in a language combination (i.e., Bengali-English) where only handful of studies exist (see Beveridge & Bak, 2011). We also explained the linguistic impairments of BWA in terms of their executive control abilities by administering separate measures of executive control tasks.

In the verbal fluency task, we found that BWA had difficulty in both the linguistic and executive control component of the verbal fluency task; however, the impairment was greater where executive control demands were higher. Correlation analysis provided further support to the role of executive control abilities in verbal fluency performance. Independent executive control measures were correlated with the verbal fluency measures where task demands were higher, especially for BWA. Similar to Chapter 2, this research highlights the importance of using a full range of verbal fluency measures to tap into the linguistic as well as executive control abilities of BWA. This is also the first study to address how the executive control abilities mediated the verbal fluency performance differences between BWA and BHA. This type of evidence is currently lacking in the literature.

In Chapter 5, we found cognate facilitation for both BWA and bilingual healthy adults (BHA) at the group level. BWA performed similarly in both languages despite showing differences in their pre-morbid language abilities. At the individual level analysis of BWA, we found inhibitory effect for cognates especially for balanced BWA and individuals with better inhibitory control abilities showed lesser cognate facilitation. Previous studies have shown both cognate facilitation (Detry et al., 2005; Roberts & Deslauriers, 1999; Kohnert, 2004) and inhibition (Broersma et al., 2016; Kurland & Falcon, 2011; Tiwari & Krishnan, 2015) in bilinguals (healthy and aphasia). Most of the studies involving BWA were of individual case studies and had participants mostly from Germanic (English) and Romance (Spanish, Italian, French) language families (except Tiwari & Krishnan, 2015 who tested two Dravidian languages). Previous studies have argued the role of executive control abilities in cognate production but there are no studies involving BWA which have linked the role of executive control in cognate word production. This is the first study to investigate the lexical activation/competition process in two different language combinations that is Bengali (Indo-Aryan) and English (Germanic) and to link the lexical activation/competition processes with separate executive control measures. These findings highlight the importance of including detailed language background measures, individual and group level analysis and separate executive control measures before focusing therapeutic treatment on shared structure of language (cognates).

Overall, both studies from Phase II provide evidence of linguistic impairments in BWA in both their languages and these impairments were manifested by their executive control impairments. The present study emphasises the importance of characterising the BWA participants in terms of their linguistic impairments in both languages, bilingualism related variables, separate linguistic and executive control measures and involved analysis approaches.

6.1.2 Study Limitations and Future Directions

6.1.2.1 Participants groups and characteristics. In Phase I, bilingual participants were highly proficient in both languages and high skilled immigrants which can be a reason of bilingual advantage in executive control measures (Paap et al., 2015). However, previous studies have shown advantageous effect of bilingualism irrespective of the immigration status (Alladi et al., 2013). In addition, we matched both the groups on non-verbal intelligence measure and number of years of education. Bilingual healthy adults from Phase II who were non-immigrant bilinguals residing in India also showed evidence of executive control involvement while performing linguistic tasks. Taken all these factors into account, we do not expect immigration status of our bilinguals (Phase I) was a confounding factor for the bilingual advantage. Another variable that would have better characterized the bilingual participants in our project was the nature of code-switching (mixing of languages) in day-to-day life. Recent studies have shown that bilinguals with different code-switching habits showed different executive control abilities (Hofweber, Marinis, Treffers-Daller, 2016). Though we reported the language switching habits of our bilingual participants in Phase I, but we did not consider their code-switching abilities and how that can be related to the performance differences in the linguistic and executive control domains. Future studies might consider examining the different aspects of bilingual experience such code-switching to inform the debate on bilingual “advantage” in executive control.

Both the groups in Phase I performed almost at the ceiling level in the objective vocabulary tasks (BPVS III and OPT). Based on the tests results from these vocabulary measures, we should be careful to claim that both groups were matched on vocabulary. Future studies may consider taking a more challenging vocabulary task to describe the vocabulary knowledge of the experimental groups. Another limitation of the present project was that both the vocabulary tasks were receptive in nature and the experimental tasks were expressive. Therefore, future studies should take expressive vocabulary tasks into consideration while characterizing and matching the bilingual population with the monolingual group.

Due to cultural differences, we did not compare bilinguals from Phase II with the monolinguals and bilinguals from Phase I. The debate on monolinguals vs bilinguals could be extended by testing BWA vs. monolinguals with aphasia (MWA). In Phase II, we could not compare our results with MWA as bilingualism is the norm in a country like India (Bak & Alladi, 2014). Future studies should consider investigating the bilingualism debate from the clinical perspective by comparing BWA vs MWA across various linguistic and executive control domains.

In Phase I, we tested 25 participants in each group. Paap, Johnson, and Sawi (2015) argued that small sample size ($n < 30$) could be a confounding factor for studies showing bilingual advantage. We acknowledge that it was difficult to recruit relatively homogeneous bilinguals from England who were matched on the languages they speak (all bilingual participants were Bengali-English speakers), proficiency, age, education, non-verbal intelligence, gender and other bilingualism related factors. Future studies should aim to replicate the present findings with large sample size to provide further support for the findings reported in the present project. Similarly, in Phase II, we recruited eight BWA participants, therefore caution must be taken while interpreting and generalizing the findings from the present study. One possibility for future studies would be to replicate the present findings with a large sample of BWA population to provide further support to our findings. However, the project involved an extensive background test battery along with several experimental tasks and executive control measures. Our focus was to recruit BWA participants who would be as homogeneous as possible in terms of aphasia type and severity, language combinations, educational background, and background language profile. Therefore, recruitment of relatively homogeneous group of BWA participants provided an advantage in terms of robustness of the findings.

As mentioned in Chapter 1, according to Beveridge and Bak, research on aphasia can only make a significant contribution to the debate on language universals vs language variation if we consider testing participants from different language families. Present study made an effort to address this issue. Future studies might consider providing further insight into the debate on language universals vs language variation by including participants from other Indian language families, such as Dravidian language family (Tamil, Kannada) or other languages from the same Indo-Aryan family (Hindi, Assamese, Punjabi).

In Phase II, our findings were based on relatively homogeneous group of aphasia participants that is all of them were non-fluent aphasia with mild to moderate level of severity in both languages. Therefore, we cannot generalize our findings to participants with different type and severity of aphasia. Systematic investigation of other types and severity of aphasia would provide would provide further insight into the effect of bilingualism and neurological status on linguistic and executive control processes. For example, we found verbal fluency to be an effective measure when full range of variables were considered for understanding the linguistic and executive control impairments in non-fluent aphasia. Future studies with different types of neurological population would provide diagnostic validity of the task to other populations.

We could not get the exact details about the neurological profile of our BWA participants (medical scan reports for the site and extent of lesion) and therefore could not relate our findings with the nature and site of lesion. Though this was not the aim of our project, but future studies may consider investigating the effect of lesion status (site and extent) on linguistic and executive control measures.

6.1.2.2 Experimental tasks. We had three experimental tasks (verbal fluency, blocked-cyclic picture naming, and picture naming task involving cognates and non-cognates) to investigate the interaction of linguistic and executive control processes in bilingual (healthy and aphasia) speakers. All these tasks were simple yet powerful tasks to investigate the research question of the present study, but they were at the level of single word production. In Phase I, we found evidence of bilingual advantage in linguistic tasks at the single word level where executive control processes were involved. Future studies should consider moving beyond single word production to connected speech and more naturalistic linguistic paradigms, such as analyzing various aspects of conversational speech (code-switching), and narratives. A possible extension of the present study would be to look at the performance differences in a linguistic task at the sentence level between bilinguals and monolinguals and whether these differences between the two groups can be explained by their executive control abilities. The results will provide further understanding of the bilingual language processing in more naturalistic context. In Phase II, we found evidence of linguistic impairments in both languages at the single word level. Investigation of the cross-linguistic impairments at the sentence level would provide further insight to the effect of neurological impairment (aphasia) on linguistic processing in bilinguals. Further, we found evidence of executive control involvements in linguistic impairments at the single word level. Based on these results, we highlighted the importance of assessing executive control abilities in BWA population. Involvement of executive control abilities at the sentence level would provide further support to this claim and will provide valuable information for designing appropriate assessment and treatment protocols.

6.1.2.3 Executive control tasks. Present research included only one task of executive control for each domain (inhibition: Stroop test, mental-set shifting: colour-shape switch task in Phase I and TMT in Phase II, and working memory: backward digit span), restricting the convergent validity for the present findings. Shao et al (2014) found mental-set shifting abilities (operation span task) to correlate with the number of correct responses in both semantic and letter fluency condition for healthy speakers. However, we did not find any relationship between the number of correct responses and any of the executive control measures for the healthy participants. Therefore, including a broad range of executive control measures in future would provide greater insights into the relationship between linguistic and executive control processes in healthy bilinguals as well as in BWA.

Nigg (2000) reported four different types of inhibitory control mechanism, such as interference control (Stroop task, Flanker task), cognitive interference (negative priming), behavioural inhibition (go/no-go task), and oculomotor inhibition (anti-saccade tasks). We tested the inhibitory control abilities of our participants by administering verbal Stroop test which measured the interference control or the ability to suppress the interference from the non-target stimuli. We chose the Stroop test which was more closely linked to the type of executive control abilities required in our experimental linguistic measures. However, future studies might consider exploring the involvement of different types of inhibitory control mechanism to explain the differences in performances in these populations. All of our executive control tasks (except colour-shape switch task) were verbal in nature which might be a reason of significant correlation with the different variables of experimental linguistic measures. However, we did not any significant correlation between the executive control measures and the objective vocabulary measures. Future studies should consider investigating the role of non-linguistic executive control tasks to inform the linguistic and executive control processing in bilinguals. Conducting such studies will provide valuable information regarding executive control impairments in BWA in the linguistic and non-linguistic domains.

6.1.3 Conclusion

This research systematically investigated the relationship between linguistic and executive control measures in bilingual population using different type of linguistic tasks, broad range of variables, different participant groups, different analysis approaches, and separate executive control tasks. Results of this study provide critical understanding of the nature of linguistic and executive control processing in bilingual population (healthy and aphasia). First, the findings confirmed the relationship between linguistic and executive control measures. Second, we highlighted the importance of using simple yet powerful linguistic tasks with broad range of variables, detailed characterisation of bilingual participants, detailed characterisation of aphasia in both languages, and using separate executive control measures to explain the differences in linguistic and executive control abilities in healthy bilinguals as well as in BWA. Third, in terms of linguistic factors, language proficiency, usage, and instruction of educations showed greater impact on the performance differences between groups. In terms of executive control factors, inhibitory control showed greater impact on the performance differences between groups.

This project has improved our understanding of the language processing and impairments in an Indian language (Bengali) which is underreported in the literature (Beveridge & Bak, 2011) despite having a large number of speakers in this world (180.5 million speakers, Ethnologue: Languages of the World, 2005).

Appendices

Appendix 2.1. Example of an Information Sheet and Consent Form

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INFORMATION SHEET

Title: Word production in bilingual speakers: effect of linguistic context and cognitive control

This research is investigating how word production is affected by linguistic context (For example, if we see pictures that all belong to the same category e.g. animals - cat, dog, tiger etc., it might be harder to name them than naming pictures from different category) and cognitive control (a mechanism which controls the operation of various processes like memory, thinking etc) in monolingual and bilingual speakers. This research will inform us what helps people to produce words more correctly. This information will help us to understand the mechanism of word production in monolingual and bilingual speakers.

We will be glad to involve you in this research as a participant. This research will use a simple language assessment of naming pictures, reading words or repeating words presented on a laptop screen. The testing may take 2-3 one-hour sessions to complete and will be scheduled on different days depending on your availability. We will ensure that frequent breaks are provided during testing to avoid fatigue and frustration, and if needed a session can be stopped and resumed on a later date.

Participant's data will be kept confidential and securely stored, with only a number attached to each participant, and therefore it will not be possible to link any set of data with any individual. All information collected for the project will be destroyed after five years in accordance with the University's procedures.

Your participation in this experiment is completely voluntary. You may withdraw at any time without giving any reason. This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.

Thank you for your help.

Consent Form

I, ……………………………………… agree to take part in this study. It is about how monolingual and bilingual speakers name pictures and what helps them to name pictures easily. It is being carried out by Mr. Abhijeet Patra and Dr. Arpita Bose at The University of Reading.

- I have seen and read a copy of the Participant's Information Sheet
- I was able to ask questions about the study. They have been answered.
- I understand that personal information is confidential and only a number will identify my data.
- I understand that the whole study will take 2-3 one-hour sessions to complete.
- I know the information will be stored in secure locked cabinets.
- I know the information will be kept for five years.
- I understand that taking part in this study is voluntary.
- I can withdraw at any time without having to give an explanation.
- I am happy to participate.

Signature ---

Name (in capitals) ---

Date ---

Appendix 2.2. Language Background Questionnaire

a. Language Acquisition History

SCALE:

1. Spoke mostly Bengali
2. Spoke both English and Bengali in a single context
3. Spoke mostly English

LANGUAGE ACQUISITION

AS A CHILD:

What language did you speak at home?	1	2	3
What language was spoken mostly by others at home?	1	2	3
What other language did you speak at home?	1	2	3
What was your father's native language?	1	2	3
What other language did he speak?	1	2	3
What language did he speak to you most often?	1	2	3
What language did you speak with him?	1	2	3
What other language did your mother speak at home?	1	2	3
What was your mother's native language?	1	2	3
What other language did she speak?	1	2	3

What language did she speak to you most often?	1	2	3
What language did you speak to her most often?	1	2	3
What language did you speak with your siblings?	1	2	3

Did anyone else take care of you? YES NO

What was his/her native language?	1	2	3
What language did he/she speak to you most often?	1	2	3
What other language did your he/she speak at home?	1	2	3
What language did you speak with the relatives you saw most often?	1	2	3
What language did you speak most with friends?	1	2	3
Which language did you prefer to speak?	1	2	3

Did you take Bengali classes? YES NO

If so, which grades?

How many years?

b. Educational History

How many years of education did you have?

LESS THAN 6 6 TO 9 9 TO 12 SOME COLLEGE COLLEGE

What was the language:

IN ELEMENTARY?	1	2	3
IN HIGH SCHOOL?	1	2	3
IN COLLEGE?	1	2	3

What language did the other students speak:

IN ELEMENTARY	1	2	3
IN HIGH SCHOOL	1	2	3
IN COLLEGE	1	2	3

Which language did you prefer to speak:

IN ELEMENTARY	1	2	3
IN HIGH SCHOOL	1	2	3
IN COLLEGE	1	2	3

Were you taught in any other languages? YES NO

If so, which languages

At what age did you first learn English?

How did you learn English?

c. Language Proficiency Rating

Please rate your language proficiency ability based on the following scale (1 = nonfluent, 7 = native fluency)

L1_________________

	Nonfluent						Native fluency
Speaking in casual conversation	1	2	3	4	5	6	7
Listening in casual conversation	1	2	3	4	5	6	7
Speaking in formal situation	1	2	3	4	5	6	7
Listening in formal situation	1	2	3	4	5	6	7
Reading	1	2	3	4	5	6	7
Writing	1	2	3	4	5	6	7

L2_________________

	Nonfluent						Native fluency
Speaking in casual conversation	1	2	3	4	5	6	7
Listening in casual conversation	1	2	3	4	5	6	7
Speaking in formal situation	1	2	3	4	5	6	7
Listening in formal situation	1	2	3	4	5	6	7
Reading	1	2	3	4	5	6	7
Writing	1	2	3	4	5	6	7

d. Language Use

Describe the language(s) you use in conversations with the following people and in the following contexts. Circle the number that best represents your language use with the individuals or in the context indicated.

SCALE:

1 Speak mostly your first language (BENGALI)

2 Speak both ENGLISH and your first language (BENGALI)

3 Speak mostly ENGLISH

LANGUAGE USE—PEOPLE

spouse	1	2	3
children:			
__________________	1	2	3
__________________	1	2	3
__________________	1	2	3
__________________	1	2	3
__________________	1	2	3
__________________	1	2	3
grandchildren:			
__________________	1	2	3
__________________	1	2	3
brothers/sisters:			
__________________	1	2	3
__________________	1	2	3
__________________	1	2	3
__________________	1	2	3

__________________	1	2	3
__________________	1	2	4

other relatives:

__________________	1	2	3
__________________	1	2	3
__________________	1	2	3
__________________	1	2	3

friends:

__________________	1	2	3
__________________	1	2	3
__________________	1	2	3
__________________	1	2	3

co-workers

__________________	1	2	3
__________________	1	2	3
__________________	1	2	3
__________________	1	2	3

LANGUAGE USE-- SITUATIONS

at home	1	2	3
at work	1	2	3
grocery store	1	2	3
bank	1	2	3
church/ synagogue	1	2	3

clubs	1	2	3
shopping	1	2	3
reading for pleasure	1	2	3
writing for pleasure	1	2	3
reading for work/school	1	2	3
writing for work/school	1	2	3
watching television	1	2	3
when listening to the radio	1	2	3
other			
__________________	1	2	3
__________________	1	2	3
__________________	1	2	3

LANGUAGE USE—CONTENT

expressing emotion	1	2	3
discussing the news	1	2	3
discussing the past	1	2	3
discussing work	1	2	3

discussing family	1	2	3
discussing hobbies	1	2	3
discussing coursework	1	2	3
other			
_________________	1	2	3
_________________	1	2	3
_________________	1	2	3

Which language, if any, would you are most comfortable using? Why?

How has your language use patterns changed in the last five years?

What language do you hear most frequently?

e. Bilingual Language Dominance Questionnaire

Please answer the following questions to the best of your knowledge.

1. At which age did you first learn these languages (please tick the correct one):

Language	0-5 years	6-9 years	10-15 years	16 years and above
Bengali				
English				

2. At which age did you feel comfortable speaking these languages:

Language	0-5 years	6-9 years	10-15 years	16 years and above
Bengali				
English				

3. Which language do you predominantly use at home?

Bengali ____

English ____

Both ______

4. When doing maths in your head which language do you calculate the numbers in?

Bengali ___

English ___

Both ____

5. If you have a foreign accent, which language (s) is it in?
   ____

6. If you had to choose which language to use for the rest of your life, which language would it be?

____

7. How many years of schooling did you have in:

Bengali ______

English ______

8. Do you feel that you have lost any fluency in a particular language?

If yes, which one ___________________

9. What country/ region do you currently live in?

____

f. Language Switching Questionnaire

Please answer the following questions to the best of your knowledge.

1. I do not remember or I cannot recall some Bengali words when I am speaking in Bengali (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

2. I do not remember or I cannot recall some English words when I am speaking in English (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

3. I tend to switch between languages during a conversation (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

4. When I cannot recall a word in Bengali, I tend to immediately produce it in English (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

5. When I cannot recall a word in English, I tend to immediately produce it in Bengali (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

6. I do not recall when I switch between languages during a conversation or when I mix the two languages; I often realize it only if I am informed of the switch by another person (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

7. When I switch languages, I do it consciously (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

8. It is difficult for me to control the language switch I introduce during a conversation (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

9. Without intending to, I sometimes produce the Bengali word faster when I am speaking in English (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

10. Without intending to, I sometimes produce the Bengali word faster when I am speaking in English (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

11. There are situations in which I always switch between the two languages (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

12. There are certain topics or issues for which I normally switch between the two languages (please tick as appropriate)

__ never, __ very infrequently, __ occasionally, __ frequently, __ always

Appendix 2.3. Stroop Ratio Calculation Example

	Neutral (RT in msec)	Incongruent (RT in msec)	Overall mean latency (Incongruent + Neutral) ÷ 2	Stroop ratio in percentage (Stroop difference ÷ Overall mean latency) × 100
Example 1	400	800	(800+400) ÷2 = 600	(400÷600) × 100 = 66.67
Example 2	800	1200	(1200+800) ÷2 = 1000	(400 ÷ 1000) × 100 = 40

Appendix 2.4. Subcategory Classification for the Semantic and Letter Fluency

1. Semantic Fluency

a. **Animal**

Africa: aardvark, antelope, buffalo, camel, chameleon, cheetah, chimpanzee, cobra, eland, elephant, gazelle, giraffe, gnu, gorilla, hippopotamus, hyena, impala, jackal, lemur, leopard, lion, manatee, mongoose, monkey, ostrich, panther, rhinoceros, tiger, wildebeest, warthog, zebra

Australia: emu, kangaroo, kiwi, opossum, platypus, Tasmanian devil, wallaby, wombat, koala bear

Arctic/ Far North: auk, caribou, musk ox, penguin, polar bear, reindeer, seal

Farm: chicken, cow, donkey, ferret, goat, horse, mule, pig, sheep, turkey

North America: badger, bear, beaver, bobcat, caribou, chipmunk, cougar, deer, elk, fox, moose, mountain lion, puma, rabbit, raccoon, skunk, squirrel, wolf

Aquatic animal: alligator, auk, beaver, crocodile, dolphin, fish, frog, lobster, manatee, muskrat, newt, octopus, otter, oyster, penguin, platypus, salamander, sea lion, seal, shark, toad, turtle, whale

Marine fish: gold fish, lion fish, clown fish

Beasts of Burden: camel, donkey, horse, llama, ox, bull, alpaca, cow

Fur: beaver, chinchilla, fox, mink, rabbit

Pets: budgie, canary, cat, dog, gerbil, golden retrieval, guinea pig, hamster, parrot, rabbit

Arboreal: panda, sloth, bear, red panda, monkey, koala bear

Bird: budgie, condor, eagle, finch, kiwi, macaw, parrot, parakeet, pelican, penguin, robin, toucan, woodpecker, hawk

Big cats: cheetah, cougar, jaguar, leopard, lion, snow leopard, tiger

Anthropoids: spider

Flightless birds: ostrich, emu, kiwi, penguin

Aquatic birds: duck, goose, swan

Small birds: sparrow, pigeons,

Big birds: flamingo, ostrich, vulture, peacock

Bovine: bison, buffalo, cow, musk ox, yak, bull

Canine: coyote, dog, fox, hyena, jackal, wolf

Deer: antelope, caribou, eland, elk, gazelle, gnu, impala, moose, reindeer, wildebeest

Feline: bobcat, cat, cheetah, cougar, jaguar, leopard, lion, lynx, mountain lion, ocelot, panther, puma, tiger

Fish: bass, guppy, salmon, trout, barracuda

Insect: ant, beetle, cockroach, flea, fly, praying mantis, termite

Insectivores: aardvark, anteater, hedgehog, mole, shrew

Mollusc: slug, snail,

Primate: ape, baboon, chimpanzee, gibbon, gorilla, human, lemur, marmoset, monkey, orang-utan, shrew

Rabbit: Coney, hare, pika, rabbit

Reptile/ Amphibian: alligator, chameleon, crocodile, frog, gecko, iguana, lizard, newt, salamander, snake, toad, tortoise, turtle

Rodent: beaver, chinchilla, chipmunk, gerbil, gopher, ground hog, guinea pig, hedgehog, marmot, mole, mouse, muskrat, porcupine, rat, squirrel, woodchuck

Young animals: kitten, cubs

Weasel: badger, ferret, marten, mink, mongoose, otter, polecat, skunk, meerkat

Xenarthral: anteaters, armadillo, sloths

Occurs together: cat, mouse; snake, mongoose; horse, elephant; tiger, bear;

Winged mammals: Bat

Extinct animals: Dinosaur

b. Fruits and Vegetables

Tree fruits: apple, pear, apricot, peach, plum, nectarine, damson, cherry

Tropical: banana, pineapple, mango, kiwi, guava, pears, watermelon, jackfruit, star fruit, ladies finger, coconut, papaya, apple, custard apple, passion fruit, Sharon fruit, grape fruit,

Root & tuberous vegetables: carrot, radish, turnip, potato, sweet potato, parsnip, swede, beetroot,

Gourds & squashes: squash, cucumber, pumpkin, butternut squash, courgettes, marrow, cushaw squash, gherkin, zucchini

Berries: strawberry, raspberry, blueberry, blackberry, rowanberry, gooseberry, lychee

Fifteen+ seeds: jackfruit, pomegranate, dragon fruit,

One seeded: date, cherries, grapes, avocado, *Two to ten seeds*: mangosteen

Leafy & salad vegetables: spinach, cauliflower, broccoli, red cabbage, Brussel sprout, cilantro, cucumber, celery, parsley, mint, coriander, lettuce, asparagus, kale, rocket, tomato

Fungi: mushroom, prune

Bulb & stem vegetables: onion, garlic, ginger, spring onions, leek, artichoke,

Fruits eaten as vegetables: brinjal, tomato, eggplant, zucchini, ladies finger

Vegetables in pods: beans, runner beans, string beans, peas, lentils, sweet corn, broad beans, French beans, legumes, pitipua, kidney beans,

Citrus: lemon, orange, lime, tangerine, clementine, satsuma, amlaki

Chilli peppers: chillies, red pepper, green pepper, yellow pepper, bell pepper,

Dry fruits: dates, cashew, raisins, grapefruit,

Commonly occurred together: onion, potato, brinjal, cauliflower

c. Clothing

Winter wear: jacket, coat, sweater, thermal, shawl, muffler, sweater, blazer, cardigans, pullover,

Summer wear: t-shirt, tops, tanks,

Clothing wore on the upper body: shirt, tops, t-shirt,

Clothing wore on the lower body: trouser, pant, shorts, slacks, jeans, skirts,

Underwear: bra, boxers, underwear, lingerie, trunk, vest, blouse,

Headgear: cap, hat, toupee, headscarf

Dresses: gown, sari, burqa, kimono, wrapper, lehenga, dresses

Footwear: sandal, shoes, socks, flipflops, trainers

Commonly associated: glove, mitten, hat, cap, tuke

Traditional wear: shawl, saree, dhoti, salwar, Punjabi, quilt, kimono, dishdash

Accessories: belt, towel, handkerchief,

Neckwear: bow tie, scarf, tie,

Formal wear: shirt, pant, tie, coat, suit

2. Letter fluency

a. Words that begin with the same first two letter (church/change)

b. Differ only by their vowel sounds (fit/fat)

c. Words that rhyme (stand/sand)

d. Homonyms (some/sum)

Appendix 2.5. Raw Data of Each Individual on the Demographic Variables and Objective Language Tests

	Age/Sex	Years of education	Occupation	Immigration (years)	IQ	OPT	BPVS-III
Bilinguals (B)							
B1	45/M	18	Lecturer	5	50	55	164
B2	28/M	20	Student	2	41	52	144
B3	29/M	19	Student	4	45	54	157
B4	28/F	16	Homemaker	6	47	52	152
B5	31/F	17	Homemaker	7	43	49	159
B6	28/F	16	Accountant	8	44	58	164
B7	29/M	16	Engineer	9	50	57	161
B8	35/M	16	Engineer	3	45	53	160
B9	38/M	17	Business	8	41	55	161
B10	38/F	17	Homemaker	8	44	57	163
B11	38/M	17	Sales	6	51	50	161
B12	38/F	19	Homemaker	8	40	51	153
B13	27/M	16	Student	10	38	57	156
B14	38/M	16	Engineer	11	40	52	157
B15	27/M	17	Engineer	12	44	55	160
B16	34/M	20	Doctor	13	45	49	161
B17	40/M	19	Homemaker	15	41	51	154
B18	37/M	18	Clerk	1	42	52	155
B19	29/M	17	Business	12	51	51	159
B20	30/M	17	Engineer	4	44	52	162
B21	31/F	17	Housemaker	3	40	54	163
B22	31/F	16	Housemaker	7	42	57	160
B23	30/F	16	Engineer	9	39	53	161
B24	31/F	17	Student	10	40	43	150
B25	31/F	18	Student	6	41	57	161

	Age/Sex	Years of education	Occupation	Immigration (years)	IQ	OPT	BPVS-III
Monolinguals (M)							
M1	44/F	20	Student	N/A	40	57	164
M2	23/M	18	Student	N/A	38	55	162
M3	23/M	17	Student	N/A	39	54	165
M4	27/F	17	Student	N/A	54	57	159
M5	32/M	18	Accountant	N/A	47	58	161
M6	24/F	17	Student	N/A	33	55	167
M7	23/M	17	Student	N/A	42	48	166
M8	27/F	17	Engineer	N/A	35	58	160
M9	23/M	18	Student	N/A	43	57	161
M10	26/F	18	Student	N/A	44	57	167
M11	28/F	18	Engineer	N/A	49	55	149
M12	22/M	17	Student	N/A	42	58	158
M13	32/M	18	Engineer	N/A	50	56	165
M14	22/M	17	Student	N/A	40	52	157
M15	22/F	17	Student	N/A	41	51	154
M16	32/M	18	Business	N/A	43	48	160
M17	30/F	18	Student	N/A	38	49	157
M18	22/M	17	Student	N/A	50	55	164
M19	27/F	17	Student	N/A	44	48	157
M20	38/M	15	Lab manager	N/A	48	49	154
M21	38/F	17	Technician	N/A	54	54	157
M22	45/F	16	Administrator	N/A	42	54	157
M23	40/M	15	Property maintenance	N/A	41	55	154
M24	45/M	15	Sales	N/A	40	57	161
M25	45/F	15	Support worker	N/A	38	56	160

Appendix 2.6. Raw Data of Each Individual on the Subjective Language Measures

	Bilinguals (B)																								
Bengali	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**	**B17**	**B18**	**B19**	**B20**	**B21**	**B22**	**B23**	**B24**	**B25**
Language acquisition	15	17	17	9	16	15	9	17	12	14	14	12	14	17	15	15	17	14	17	10	10	15	17	15	15
Language of instruction	3	8	1	6	9	6	3	6	5	4	6	8	3	6	5	5	6	6	8	2	6	5	6	6	5
Speaking	5.5	7	6	6	7	6	6	7	6	6.5	6	7	7	7	6	7	6	7	7	5	5	7	7	6	6
Comprehension	6	7	7	6	7	6	6.5	7	7	6.5	7	7	7	7	7	7	7	7	7	6	6	7	7	7	7
Reading	6	7	7	7	7	6	7	7	7	7	7	7	5	7	7	7	7	7	7	7	5	6	7	7	6
Writing	4	7	6	7	7	4	6	7	6	6	6	5	5	7	6	6	6	7	7	6	4	6	7	6	6
Usage	8	16	12	10	11	8	11	13	12	13	11	14	8	14	12	12	13	12	14	13	14	12	14	12	12
Dominance	11	20	11	18	20	11	16	20	14	20	20	20	11	17	17	17	20	20	20	17	15	17	20	17	17
Switching habits	9	9	7	9	9	9	10	8	11	9	9	9	9	5	9	9	8	8	8	10	9	9	8	8	9
English	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**	**B17**	**B18**	**B19**	**B20**	**B21**	**B22**	**B23**	**B24**	**B25**
Language acquisition	9	0	3	8	2	4	3	0	3	3	3	3	10	0	3	3	0	3	0	0	0	3	0	3	3
Language of instruction	7	2	9	9	3	9	9	4	5	9	4	2	7	6	6	6	4	4	2	9	9	6	4	6	6
Speaking	7	6	7	7	6	7	6.5	6.5	7	7	6	5	7	7	6	7	6	6.5	5	5.5	6	7	6.5	6	6
Comprehension	7	6	7	7	6	7	7	6.5	7	7	6	5	7	7	7	7	7	6.5	6	6	7	7	6.5	7	7
Reading	7	6	7	7	6	7	7	7	7	7	7	6	7	7	7	7	7	6	6	7	6	7	6	7	7
Writing	7	6	7	7	6	7	6	7	7	7	7	5	7	7	6	6	6	6	6	6	6	6	6	6	6
Usage	42	15	22	22	21	24	20	22	21	22	18	21	16	20	20	20	22	21	20	24	20	21	21	20	21
Dominance	24	12	19	22	12	24	21	10	20	21	16	17	24	21	18	18	17	16	16	19	18	18	16	18	18
Switching habits	4	12	5	8	9	4	8	9	11	6	6	8	4	5	8	8	9	9	10	9	9	8	9	8	7

Appendix 2.7. Raw Data of Each Individual on the Executive Control Measures

	Bilinguals (B)																								
Executive control tests	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**	**B17**	**B18**	**B19**	**B20**	**B21**	**B22**	**B23**	**B24**	**B25**
Stroop congruent	629	412	668	628	811	742	481	612	870	642	830	700	618	934	534	657	903	903	562	543	443	595	520	670	744
Stroop incongruent	795	616	810	795	1042	1060	675	683	919	773	1007	845	864	1066	777	897	1141	1141	671	723	560	733	675	750	874
Stroop difference	166	205	142	167	231	318	193	70	49	131	177	146	246	132	243	240	238	238	109	180	117	138	155	80	130
Stroop ratio	23	39	19	23	25	35	33	10	5	18	19	18	33	13	37	30	23	23	18	28	23	21	25	12	16
Switch cost (accuracy)	-2.8	4.1	2.8	0	1.4	-2.7	1.4	0	-1.5	2.7	1.2	-2.8	1.8	-1.4	-6.9	-1.3	-2.7	6.9	3.1	2.8	-6.9	2.8	0	-2.8	1.4
Switch cost (RT)	238	314	103	197	137	488	89	110	177	48	302	52	469	301	229	655	177	198	154	272	319	512	259	90	162
Digit span backward	5	7	7	6	6	7	5	7	6	4	5	6	7	6	6	6	6	4	4	7	7	6	6	7	7
	Monolingual (M)																								
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**	**M12**	**M13**	**M14**	**M15**	**M16**	**M17**	**M18**	**M19**	**M20**	**M21**	**M22**	**M23**	**M24**	**M25**
Stroop congruent	458	441	457	453	581	451	529	428	495	496	583	424	425	934	903	469	448	629	460	761	745	725	759	934	938
Stroop incongruent	722	563	722	676	758	577	793	650	617	600	750	643	642	1066	1141	745	581	795	670	553	587	606	604	576	712
Stroop difference	264	123	265	223	177	127	264	222	121	104	167	218	217	131	238	276	133	166	210	207	158	119	155	358	226
Stroop ratio	45	24	45	40	26	24	40	41	21	18	25	40	41	13	23	45	26	23	37	32	24	18	23	47	27
Switch cost (accuracy)	4.2	1.4	2.8	-7.4	2.8	-4.1	15.2	0	0	-1.4	2.8	4.1	11.1	-1.4	-2.8	5.5	6.9	-2.8	3.2	5.5	5.6	3.2	4.5	4.8	5.2
Switch cost (RT)	113	151	227	221	116	380	428	116	94	243	345	49	366	301	177	373	177	238	270	268	269	253	249	227	241
Digit span backward	6	7	4	6	7	6	5	4	7	6	7	6	5	6	6	4	5	5	6	5	6	5	5	5	5

Appendix 2.8. Correlation Between Executive Control and Vocabulary Measures

Executive control measures	Vocabulary measures		
		OPT	BPVS-II
Stroop ratio	*rs*[1]	.16	.20
	p	.26	.16
	N	50	50
Switch cost (RT)	*rs*[1]	-.18	.12
	p	.21	.41
	N	50	50
Digit span backward	*rs*[1]	.12	-.13
	p	.39	.36
	N	50	50

[1] – Spearman's rho

Appendix 4.1 Example of Information Sheet and Consent Form

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Information Sheet

Title: Word production in bilingual speakers: effect of linguistic context and cognitive control

- This study looks at how people with neurological conditions produce the names of pictures, read and repeat words, and what helps them to produce words.
- You will perform simple language tasks, like naming pictures, repeating and reading words.
- You will be asked to tell me the names of pictures or read written words or repeat words shown on the computer screen.
- It might take up to 4-5 sessions of about an hour each. The sessions will be conducted on at a time of your ease.
- You can take a break when you need one.
- You will be compensated with £25 (2500INR) upon completion of the study for your time.
- The information you give will be private and stored safely. We don't use your name. A number will be put on your form. For future research we will use only this number. All the documents will be destroyed after 5 years.
    - You can decide if you want to do this. You may stop at any time. You don't have to give a reason. You can ask questions about this study at any time.
    - This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.
    - The researchers have been checked to confirm that they do not have any criminal record

Thank you for your help.

Abhijeet Patra, PhD student (3rd year)

Consent Form

I, …………………………………… agree to take part in this study. It is about how bilingual speakers name pictures and what helps them to name pictures easily. It is being carried out by Mr. Abhijeet Patra and Dr. Arpita Bose at The University of Reading, Reading, United Kingdom.

- I have seen and read a copy of the Participant's Information Sheet
- I was able to ask questions about the study. They have been answered.
- I understand that personal information is confidential and only a number will identify my data.
- I understand that the whole study will take 4-5 one-hour sessions to complete.
- I know the information will be stored in secure locked cabinets.
- I know the information will be kept for five years.
- I understand that taking part in this study is voluntary.
- I can withdraw at any time without having to give an explanation.
- I am happy to participate.

Signature --

Name (in capitals) ---

Date ---

Appendix 4.2 Raw Data of Each BWA and BHA on the Executive Control Measures

Executive control parameters	**BWA**							
	BWA1	BWA2	BWA3	BWA4	BWA5	BWA6	BWA7	BWA8
Stroop incongruent (msec)	3688.05	7390	2929.86	1293.01	1724.68	6148.39	1266.58	4000
Stroop congruent (msec)	2555.22	3321.23	1633.75	925.63	1659	2636.69	1014.77	1608.66
Stroop difference (msec)	4068.77	4068.77	1296.11	363.38	65.78	3511.70	251.81	2391.34
Stroop ratio	36.29	75.97	56.80	33.12	3.88	79.95	18.90	85.27
TMT-A	37	45	86	56.53	69	70	21.9	134
TMT-B	103	361	168	89.16	192	199	59.03	893
TMT difference	66	316	82	32.63	123	129	37.13	759
Backward digit span	4	3	3	4	4	5	5	3
	BHA							
	BHA1	BHA2	BHA3	BHA4	BHA5	BHA6	BHA7	BHA8
Stroop incongruent (msec)	720	1232	933.49	658.74	774.52	1444.42	830.86	560.4
Stroop congruent (msec)	617.97	896.54	654.53	508.33	538.54	1118.3	676.48	545
Stroop difference (msec)	102.03	335.46	278.96	150.41	235.98	326.12	154.38	15.4
Stroop ratio	15.25	31.52	35.13	25.78	35.94	25.45	20.48	2.79
TMT-A	22.02	33.2	39.8	30.8	28.9	50.8	32.8	21.04
TMT-B	38.2	50.8	93.5	60	90.1	103	43.7	34.15
TMT difference	16.18	17.6	53.7	29.2	61.2	52.2	10.9	13.11
Backward digit span	7	4	3	4	4	3	4	7

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