Semantic context effects in monolingual and bilingual speakers

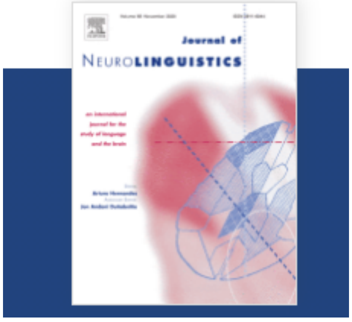
Article

Accepted Version

Patra, A., Bose, A. ORCID: https://orcid.org/0000-0002-0193-5292 and Marinis, T. (2021) Semantic context effects in monolingual and bilingual speakers. Journal of Neurolinguistics, 57. 100942. ISSN 0911-6044 doi: https://doi.org/10.1016/j.jneuroling.2020.100942 Available at https://centaur.reading.ac.uk/93293/

To link to this article DOI: http://dx.doi.org/10.1016/j.jneuroling.2020.100942

Publisher: Elsevier



Title: Semantic Context Effects in Monolingual and Bilingual Speakers (accepted version)

Citation:

Patra, A., Bose, A., & Marinis, T. (2020). Semantic context effects in monolingual and bilingual speakers. Journal of Neurolinguistics, 57, 100942. https://doi.org/10.1016/j.jneuroling.2020.100942

Semantic Context Effects in Monolingual and Bilingual Speakers

Abhijeet Patra[1,2]

Arpita Bose[1]

Theodoros Marinis[1,3]

[1]School of Psychology and Clinical Language Sciences, University of Reading, UK.

[2]Moss Rehabilitation Research Institute, Elkins Park, USA.

[3]Department of Linguistics, University of Konstanz, Germany.

Word count: 8133

Corresponding Author:

Arpita Bose, Ph.D.
School of Psychology and Clinical Language Sciences
University of Reading, Reading, UK.
Phone: +44-118-378-6105
Email: a.bose@reading.ac.uk

Acknowledgments
We are indebted to all our participants for their enthusiasm and time. This research was funded by the Felix Trust, UK.

Abstract

Most models of word production converge on the assumption that selecting a specific word to name is a competitive process. Monolingual speakers experience lexical competition in their spoken language (i.e., within-language competition), but bilingual speakers who constantly juggle two sets of lexical items face within- and between-language competition. It has been argued that one of the reasons bilingual speakers perform poorly in linguistic tasks compared to monolinguals is the interference from the non-target language. However, this constant juggling of two languages has also been proposed to lead to better executive control abilities in bilinguals. The aim of this research was to determine the relationship between increased lexical competition as induced by semantic context manipulation in the blocked-cyclic picture naming paradigm, and executive control processes in bilingual and monolingual speakers. We implemented the blocked-cyclic picture naming paradigm to induce increased lexical competition and employed independent executive control tasks to understand its role in reducing increased lexical competition. We also computed delta plots – size of interference effects as a function of naming latencies – to investigate the type of inhibition involved in the blocked-cyclic picture naming paradigm. In this paradigm, objects to be named were presented in close succession, either from the same semantic categories (homogeneous: elephant, lion, deer, tiger, and cat) or different ones (heterogeneous: pear, shoes, lips, saw, and deer). Naming latencies are longer in the homogeneous context due to the heightened activation of competitors, and the difference in latencies between the homogeneous and heterogeneous contexts is referred to as semantic context effect. The participants were 25 young, healthy Bengali-English bilinguals and 25 healthy, age-, gender- and education-matched English monolinguals. All participants performed a blocked-cyclic naming task in English as well as three independent executive control tasks, tapping into their inhibitory control (Stroop task), mental-set shifting (colour-shape switch task), and working memory (backward digit span task). The key group differences were as follows: bilinguals showed less semantic context effect and more semantic facilitation on the first presentation cycle, applied more selective inhibition in both blocked-cyclic picture naming and Stroop tasks as measured by delta plots, showed better inhibitory control (Stroop task) and shifting abilities, but showed comparable working memory span. The correlation findings for both groups were as follows: slope of the slowest delta segment correlated with the magnitude of the semantic context effect in the blocked-cyclic naming task, no correlation between the slope and interference effect in the Stroop task, no correlation between slope of the two tasks, and no correlations between the semantic context effect with any of the measures derived from the independent executive control tasks. This is the first study to establish that bilinguals are less affected by semantic context manipulation and show a reduced interference effect for the longest naming latencies, compared to monolinguals. It also illustrates that even in a challenging linguistic task that heightens lexical competition, bilinguals performed better than monolinguals. This challenges the notion that bilinguals are disadvantaged compared to monolinguals in linguistic tasks, and we conclude that this study provides evidence for the advantage of bilingualism in linguistic tasks where executive control demands are higher.

Key words: semantic blocking, naming, Bengali, delta plots, bilingual, executive control

1. Introduction

Psycholinguistic models of word production incorporate, among other things, the following representation levels: a preverbal, a conceptual, and a lexical level (e.g., Caramazza, 1997; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Levelt, Roelofs, & Meyer, 1999). Irrespective of the differences between the models in terms of levels and mechanisms of retrieval, all models converge on the assumption that, during lexical-semantic encoding, several conceptually related lexical entries are activated and a process is undertaken to select the most activated entry. For example, if the target is *dog*, items such as *cat, fish* and *horse* will also compete for selection. This situation is typical of monolingual speakers, who face lexical competition in their spoken language (i.e., within-language competition). In contrast, speakers of two languages – bilinguals – must resolve the lexical competition from their target language while also preventing interference from the non-target language, since research has shown that both languages are always active (Dijkstra, Grainger, & Van Heuven, 1999; Kroll, Bobb, & Wodniecka, 2006; Thierry & Wu, 2007). Bilinguals are constantly juggling both within- and between-language competition (Lee & Williams, 2001; Starreveld, De Groot, Rossmark, & Van Hell, 2014). Thus, increased lexical competition is a default condition for bilinguals, and some researchers have argued that this leads to an executive control *advantage* (Bilaystok, 2009; Struys, Woumans, Nour, Kepinska, & Van den Noort, 2018; for a review see Van den Noort et al., 2019; see Kousaie & Phillips, 2012; Nichols et al., 2020 ; Paap & Greenberg, 2013; Paap et al., 2017 for contrasting evidence).

Research has suggested that executive control mechanisms – especially inhibitory control – help to resolve this lexical competition (Crowther & Martin, 2014; Shao, Roelofs, Martin, & Meyer, 2015). The current literature is unclear regarding the effect of increased lexical competition on bilingual and monolingual speakers, as well as its relationship to executive control processes. This is an interesting puzzle worth solving, as these two populations have been shown to differ in their use of executive control and are differentially affected by lexical competition (Bilaystok, 2009; Lee & Williams, 2001; Prior & MacWhinney, 2010; Paap & Sawi, 2014; Patra, Bose, & Marinis, 2020; Prior & MacWhinney, 2010). Picture naming experiments using manipulations of the semantic context have been proven to be a powerful tool for investigating lexical competition (Abdel Rahman & Melinger, 2007; Belke, 2008; Belke, Brysbaert, Meyer, & Ghyselinck, 2005; Damian & Als, 2005; Kroll & Stewart, 1994). Therefore, keeping these two threads of findings in mind – that is, differences in lexical competition and differences in executive control abilities between monolinguals and bilinguals – the central goal of the present research was to investigate the interaction of lexical competition and executive control in these two populations. We implemented the blocked-cyclic picture naming paradigm to determine the relationship between increased lexical competition as induced by semantic context manipulation, and executive control processes in bilingual and monolingual speakers. To our knowledge, this is the first study to implement this paradigm in order to comparatively investigate the interaction of lexical competition and executive control in healthy bilingual and monolingual speakers.

Picture naming experiments using manipulations of the semantic naming context typically show that repeated access to the same semantic category induces substantial semantic interference. This interference is thought to arise during the selection of a target entry from among coactivated semantically related lexical entries. This is assumed to be more difficult when many semantically related lexical entries are named in close succession than when unrelated lexical entries are named (Belke & Steilow, 2013; Belke, Meyer, & Damian, 2005; Damian, Vigliocco, & Levelt, 2001).

The blocked-cyclic picture naming paradigm is a simple but robust way of manipulating the semantic context: by changing the semantic activation and increasing lexical competition.

It has been successfully implemented in healthy as well as neurologically impaired populations (e.g., Belke et al., 2005; Damian et al., 2001; Schnur, Schwartz, Brecher, & Hodgson, 2006). In the blocked context manipulation, participants name lists of objects from the same semantic category (homogeneous context, e.g., *duck, fish, horse, mouse, cat*) or from different semantic categories (heterogeneous context, e.g., *duck, palm, sock, grapes, saw*, see *Figure 1*). Usually, a small set of objects is presented in a sequence of stimulus cycles, with each cycle featuring all members of the set once in varying orders (homogeneous sets, e.g., cycle 1: *duck, fish, horse, mouse, cat;* cycle 2: *mouse, duck, fish, cat, horse*; cycle 3: *cat, mouse, duck, horse, fish*; cycle 4: *horse, cat, mouse, fish, duck*; cycle 5: *fish, horse, cat, duck, mouse*; heterogeneous sets, e.g., cycle 1: *duck, beard, vest, pear, lock*; cycle 2: *beard, vest, lock, duck, pear*; cycle 3: *vest, lock, pear, beard, duck*; cycle 4: *lock, pear, duck, vest, beard*; cycle 5: *pear, duck, beard, lock, vest*).

<< Insert Figure 1 about here >>

In healthy speakers, naming latencies are consistently longer and accuracy is lower in homogeneous compared to heterogeneous contexts (Belke & Steilow, 2013; Belke et al., 2005; Damian et al., 2001). This effect is called semantic context effect or semantic blocking effect and has been linked to the heightened activation of competitors in the homogeneous context (Belke et al., 2005; Schnur et al., 2006). The semantic context effect typically develops from the second presentation cycle onwards and does not increase thereafter (Belke et al., 2005; See Belke & Steilow, 2013 for a review). The magnitude of the semantic context effect has been found to be long-lasting – that is, the semantic context effect survives the manipulation of time between trials (Schnur et al., 2006) as well as the addition of filler trials (Damian & Als, 2005). Belke and Stielow (2013) conducted a power analysis to examine the cumulative semantic interference in a group of healthy adults, using a blocked-cyclic naming design with 17 sets of data collected from previous cyclic naming experiments. They found an absence of cumulative semantic interference when the first cycle was excluded from the analysis. According to the authors, after the first cycle, participants could bias the level of activation to make the task easier and thus memorise the task set – especially in the heterogeneous context.

Interestingly, several studies have also shown either semantic facilitation (better performance in the homogeneous context compared to the heterogeneous context) or no semantic context effect in cycle one depending on the order of presentation (Abdel Rahman & Melinger, 2007; see Belke, 2017 for a review). Abdel Rahman and Melinger (2007) tested German monolingual speakers and found semantic facilitation rather than interference in the first presentation cycle. Naming was slower in the heterogeneous condition compared to the homogeneous condition in the first presentation cycle; however, semantic context effect was present for the rest of the cycles. In a review article, Belke (2017) investigated the semantic facilitation effect in the first cycle by reviewing 18 blocked-cyclic naming experiments. She concluded that a minor change in the experimental design could lead to the presence or absence of the semantic facilitation effect in the first presentation cycle. In seven out of the 10 blocked-cyclic naming experiments, in which the context lists were presented in a blocked manner (homogenous-homogeneous-homogeneous-homogeneous-heterogeneous-heterogeneous-heterogeneous-heterogeneous), there was an effect of semantic facilitation. However, when the context lists were presented in an alternating order (homogenous-heterogeneous-homogenous-heterogeneous-homogenous-heterogeneous-homogenous-heterogeneous), the semantic facilitation effect disappeared. The reason behind the presence of the semantic facilitation effect in the first condition is assumed to be strategically driven. Participants can prepare themselves in the blocked design due to the nature of the design, and therefore use their executive control to facilitate the processing of semantic items in the homogeneous context. At present, there are no studies comparing bilingual and monolingual speakers on the strategic use of their executive control mechanisms in a blocked-cyclic naming paradigm where context lists are presented in a blocked manner.

Studies involving the blocked-cyclic naming task have employed within-task manipulation of executive control as well as independent measures of executive control to shed light into the relationship between the magnitude of the semantic context effects and executive control. In such a within-task manipulation of executive control, Belke (2008) tested 20 undergraduate German monolingual speakers to investigate the relationship between semantic context effects (i.e., RT difference between homogeneous and heterogeneous contexts) and working memory load. In the no-load condition, participants were tested only on the blocked-cyclic picture naming task and in the load condition, blocked-cyclic picture naming task was combined with a digit retention task. The author found that the semantic context effect was larger in the working memory load condition compared to the no-load condition. Results were interpreted to be in line with the biased-selection account of lexica access, which predicts lexical-semantic encoding during picture naming can be biased by not only in a bottom-up fashion but also by modulating the capacity of the executive control mechanisms.

Crowther and Martin (2014) attempted to establish the relationship between semantic context and executive control measures by employing independent executive control tasks tapping inhibitory control (verbal Stroop measuring response-distractor inhibition; recent negatives measuring proactive interference) and working memory (word span) in 41 younger and 42 older monolingual English speakers. In addition to reaffirming established effects of semantic context – semantic facilitation in the first presentation cycle and no cumulative semantic interference after cycle two – they found significant relationships between context effects and executive control measures. Specifically, individuals with better working memory showed reduction in cumulative increase of naming latency across trials in both the homogeneous and heterogeneous contexts. Larger effects in the Stroop task were related to greater interference (longer naming latency) across cycles in the homogeneous context. However, larger interference effects in the recent negative task were associated with faster naming latency in the heterogeneous context. The authors attributed the differences in correlation (i.e., semantic interference in the homogeneous context and Stroop effect, and semantic facilitation in the heterogenous context and recent negative task) to the separate mechanism activated in the homogeneous context (semantic interference) and heterogenous context (semantic facilitation) during a blocked-cyclic naming task.

The above two studies investigated the role of executive control in semantic context effects by either manipulating the executive control load within-task (Belke, 2008) or by employing independent measures of executive control (Crowther & Martin, 2014). In a more recent study, Shao, Roelofs, Martin and Meyer (2015) examined the relationship between semantic context effects and executive control in a group of 25 healthy young Dutch monolingual speakers by investigating the type of inhibition (i.e., selective inhibition, described below) that is involved in attenuating the semantic context effects in the blocked-cyclic naming task. In addition, the authors also tested participants on an independent measure of inhibitory control (i.e., Stroop task). Selective inhibition is a type of inhibition that helps to lower the activation of the competitors when selecting a target response. Selective inhibition takes time to build up and has been shown to be more pronounced on slower than on faster responses (Ridderinkhof, 2002; Roelofs, Piai & Rodriguez, 2011; Shao, Meyer & Roelofs, 2013). To characterize the dynamics of selective inhibition, delta plots were performed on both the blocked-cyclic naming task and the Stroop task. Delta plots were constructed in the following way: a) first, rank-ordered RTs for each condition (homogeneous and heterogenous for blocked-cyclic naming; incongruent and congruent for the Stroop) were divided into quintiles (20% bins), b) second, size of the interference or delta (differences in RT between the two conditions) was calculated for each quintile. Delta slope for each successive quintile x and y were calculated according to the following formula (De Jong et al., 1994; Ridderinkhof, 2002):

$$slope\ (x, y) = \frac{delta(quintile\ y) - delta\ (quintile\ x)}{average\ (quintile\ y) - average\ (quintile\ x)}$$

According to the selective inhibition literature (de Jong et al., 1994; Ridderinkhof, 2002), individuals with greater selective inhibition abilities show reduced interference effect and such relationship is more pronounced at the slowest segment of the delta slope (e.g., quintile 4 to 5). Therefore, the slopes of the slowest delta segment have been shown to provide an indication of one's inhibition ability. Shao et al. (2015) predicted a positive correlation between the slope of the slowest delta segment of each task and the magnitude of the interference (semantic context effect in the blocked-cyclic naming and Stroop difference in the Stroop task). The authors found a significant correlation between the slope of the slowest delta segment and the magnitude of the semantic context effects, that is, individuals with a steeper delta slope (i.e., poorer selective inhibition) showed larger semantic context effects. The authors neither found any significant correlation between the slope of the slowest delta segment and the magnitude of the Stroop effect, nor did they find any relationship between the slope of slowest delta segment across tasks. They concluded that the Stroop task did not represent the selective inhibition it was widely believed to. This study was the first study to employ the delta plot technique in a blocked-cyclic picture naming task involving healthy monolingual adults and provided evidence that greater selective inhibition leads to reduced semantic context effects.

From the existing literature, it appears that there is a relationship between semantic context effects and executive control processes – at least in monolingual speakers (e.g., Belke, 2008; Crowther & Martin, 2014; Shao et al., 2015). To date, no published research has compared semantic context effects in monolingual vs. bilingual speakers or explored their relationship with executive control processes. Specifically, no study has compared how bilingual and monolingual speakers differ in their ability to employ selective inhibition to reduce semantic context effects in a blocked-cyclic naming task. Determining this relationship is topical, as there is a raging debate in the literature about the superiority of executive control abilities in bilingual speakers, especially inhibitory control and its effects on other cognitive tasks (e.g., Bilaystok, 2009, Patra et al., 2020; Prior & MacWhinney, 2010; however, see Paap & Greenberg, 2013; Paap & Sawi, 2014, Paap et al., 2017). The present study tackles these unresolved issues in the literature.

The Current Study, Research Questions and Predictions

The aim of this study was to establish and compare semantic context effects in bilingual and monolingual speakers, and to determine if these effects are modulated by their executive control processes. Using a blocked-cyclic naming task, we compared the performance of 25 young, healthy Bengali-English bilinguals and 25 age-, gender- and education-matched healthy English monolinguals. Bengali (also known as Bangla) is an Indo-European language spoken in South Asia by people from Bangladesh, Eastern States of India, and Bengali diasporic communities across the world. Although Bengali is currently ranked as the seventh most spoken language in the world, with more than 265 million people speaking Bengali as their first or second language and using it in their day-to-day communication, psycholinguistic research on Bengali remains limited. As such, this study also adds to research on bilingual speakers of non-European languages, which is much needed in the current literature.

To examine the relationship between the executive control (especially inhibitory control) and semantic context effects, we consider both within-task and independent measures of executive control. To identify the within-task involvement of executive control, we conducted delta plots (as discussed in the previous section) for both the blocked-cyclic naming task and Stroop task, which would establish the role of selective inhibition in these two tasks and how two groups differ based on these measures. In addition, participants were also tested with independent measures of executive control. We utilised Miyake et al's. (2000) framework for conceptualising the three domains of executive control. We tested inhibitory control (measured by Stroop task, Scott & Wilshire, 2010), mental set-shifting (measured by the colour-shape switch task, Prior & MacWhinney, 2010), and working memory (measured by backward digital span, Wechsler, 1997). The specific research questions and predictions read as follows:

1. Is the semantic context effect (i.e., RT difference between homogenous and heterogeneous context) smaller in bilinguals compared to monolinguals? Does the semantic context effect change between the groups as a function of number of cycles (i.e., context effects on first cycle; context effects including all cycles vs. excluding cycle 1)?

Increased lexical competition is a default condition for bilingual speakers, as they must constantly juggle between two sets of lexical items to prevent the interference from the non-target language during word production (Lee & Williams, 2001; Starreveld et al., 2014). In a blocked-cyclic naming task, semantic activation is increased by the repeated presentation of a small set of semantically related items. Therefore, we predict that bilinguals will be better at suppressing the interference generated by increased semantic activation, since their lexical system is attuned to lexically competitive situations. Executive control abilities have been shown to be linked to performance in semantic blocking. Therefore, if our bilingual speakers show better executive control abilities on the independent executive control measures and better selective inhibition based on the delta plot analysis compared to monolinguals, then we would expect bilinguals to perform better in the blocked-cyclic naming task compared to monolinguals.

Based on the literature, we also predict that both bilingual and monolingual participants in our study will show non-cumulative semantic interference from cycle two onwards – that is, no growth in semantic interference over cycles. Based on the review article from Belke (2017), we expect our monolingual speakers not to show any semantic facilitation in the first presentation cycle, as the present study uses an alternating blocked-cyclic naming design (homogeneous-heterogeneous-homogeneous-heterogeneous and so on). However, if executive control helps to facilitate the processing of the semantic items in the first presentation cycle in the homogeneous context, bilingual speakers may show semantic facilitation even in the alternating design (given bilingual speakers' better performance on the independent measures of executive control).

2. Is there a relationship between the magnitude of semantic context effects and executive control processes in bilingual and monolingual speakers?

For the inhibitory control, we derived our predictions based on the Shao et al.' (2015) study. We expect individuals with better selective inhibition (as measured by slope of the slowest delta segment) to demonstrate smaller semantic context effects. If the types of inhibition are different between the blocked-cyclic naming and the Stroop task, we do not predict to find a relationship between them. For working memory, we interpolate our hypothesis from Belke's (2008) study. We expect individuals with better working memory to show reduced semantic context effects. However, we would like to point to a fundamental difference between the present study and Belke's study. In Belke's study, working memory load was manipulated while participants performed the blocked-cyclic naming task, whereas in our study participants performed the working memory task separately. For the mental-set shifting variable, we do not have any a priori prediction as this is the first study to examine such a relationship. This is the first study to establish a relationship between executive control abilities and magnitude of semantic context effects from the blocked-cyclic naming design for bilingual speakers. Although our sample size is in line with the literature that have investigated the relationship between semantic blocking effects and executive functions (Belke, 2008, Crowther & Martin, 2014, Shao et al., 2015), we acknowledge that correlational analysis based on a sample size of 25 could be considered underpowered and interpretation needs to be approached with caution (see Brysbaert, 2019 for a review).

2. Methods

2.1 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) participated in this study. Participants reported themselves to be right-handed with normal or corrected vision, no history of hearing impairment, and no history of neurological illness. To measure their non-verbal IQ, they were administered the Raven's standard progressive matrices *plus* version (SPM *Plus*, Raven, 2008). To measure their English verbal abilities, they were administered two standardised language tests: The Oxford Placement Test (OPT, Oxford University Press and Cambridge ESOL, 2001), a language proficiency test, and the British Picture Vocabulary Scale III (BPVS-III; Dunn, 2009), a receptive vocabulary test. The groups were similar in age (Bilingual: M = 32.84, SD = 4.78; Monolingual: M = 30.4, SD = 8.2; $t(48) = 1.3$, p = .21), gender distribution (Bilinguals: 11 females, 14 males; Monolinguals: 12 females, 13 males; $\chi^2(1) = .08$, p = .78), years of education (Bilingual: M = 18.1, SD = 1.6; Monolingual: M = 17.1, SD = 1.2; U = 311.5, p = .98), and non-verbal IQ (Bilingual: M = 43.5, SD = 3.8; Monolingual: M = 43, SD = 5.4; U = 275.5, p = .47). They were also similar in English language proficiency (OPT, Bilingual: M = 53.1, SD = 3.4; Monolingual: M = 54.1, SD = 3.4;

U = 251.5, *p* = .23) and receptive vocabulary (BPVS-III, Bilingual: *M* = 157.8, *SD* = 4.8; Monolingual: *M* = 159.8, *SD* = 4.6; *U* = 269.5, *p* = .40). The BPVS-III is normed with monolinguals. To address whether the two groups scored within monolingual norms, we calculated the standard scores for both groups. These showed that both groups scored within monolingual norms (Bilingual: *M* = 106, *SD* = 7; Monolingual: *M* = 109, *SD* = 8). Taken together with the results from the OPT that show no difference between the groups in their English language proficiency, the results from the language tasks demonstrate that the bilingual group was performing at an advanced level and within monolingual norms. These participants took part in a larger study on language production, and further demographic details have been reported in Patra et al. (2020).

Bilingual participants were recruited from the local Bengali community (e.g., Bengali Cultural Society of Reading). Bilinguals were immigrants who have lived in the UK, ranging from 1 to 15 years of age (*M* = 7.48, *SD* = 3.58). They spoke Bengali and English fluently, with minimal or no knowledge of any other language. Monolingual participants were recruited from the university student population (received course credit for participation) or the local community. Monolingual participants used only English in their day-to-day communication. Participants provided written consent and their participation was voluntary. The University of Reading Research Ethics Committee approved the experimental procedures (Ethical approval code: 2014/060/AB).

2.2 Measures of Bilingualism

Bilingual participants were characterised according to the following variables: language acquisition history (Muñoz, Marquardt & Copeland, 1999), language of instruction during education (Muñoz et al., 1999), language proficiency (Muñoz et al., 1999), language usage (Muñoz et al., 1999), language dominance (Dunn & Tree, 2009), and language switching habits (Rodriguez-Fornells, Krämer, Lorenzo-Seva, Festman & Münte, 2012).

Interested readers can access the questionnaires used in this study in the Supplementary material section (Appendix S1) of Patra et al. (2020). Individual level data on bilingualism variables can be accessed in the data repository (http://dx.doi.org/10.17864/1947.207). Bilingual participants did not show any significant difference between Bengali and English on the language of instruction during education ($t(24) = -.6$, $p = .53$), subjective language proficiency ratings (speaking: $t(24) = -.1$, $p = .91$; comprehension: $t(24) = .7$, $p = .50$; reading: $t(24) = -.3$, $p = .80$; writing: $t(24) = -1.6$, $p = .13$) and language dominance ($t(24) = -.9$, $p = .37$). This indicated balanced bilingualism in these domains. As the bilingual participants were immigrants from a Bengali-speaking state (West Bengal) in India, exposure to Bengali during childhood was greater than exposure to English. This was confirmed by their language acquisition history, which showed greater input of Bengali than English ($t(24) = 14.9$, $p < .001$). On the other hand, living in the UK for several years resulted in the current language usage being predominantly English ($t(24) = -14.2$, $p < .001$) and more prone to switching from Bengali to English in day-to-day communication ($t(24) = -2.3$, $p = .03$). For detailed scores on the bilingualism variables, please see Table 3 in Patra et al. (2020).

In summary, bilingual participants were sequential (acquired Bengali first and learnt English when they started schooling) but were using English more in their daily life at the time of testing. Having said this, bilingual participants were balanced in terms of language of instruction during education, self-rated language proficiency, and dominance.

2.3 Executive control measures

All participants completed three executive control tasks – inhibitory control (Stroop task, Scott & Wilshire, 2010), mental-set shifting (colour-shape switch task, Prior & MacWhinney, 2010), and working memory (backward digit span, Weschler, 1997). We provide brief details about these tasks below (see Patra et al., 2020 for further detail).

Stroop task. The computerised Stroop task used in this study was adapted from Scott and Wilshire (2010). Participants were assessed under two conditions, neutral and incongruent. In the neutral condition, participants named a series of 50 colour rectangles, and in the incongruent condition, a series of colour words were presented with a different font colour (e.g., RED word in green font colour). Participants were asked to name the font colour (e.g., green) of the colour word (e.g., RED). All verbal responses were digitally recorded and RT was measured for the two trial types (Stroop incongruent and Stroop neutral). Dependent variables were Stroop difference and percentage Stroop ratio. Stroop ratio was measured to account for the overall slowness in response speed (Faroqi-Shah et al., 2018; Patra et al., 2020). Larger Stroop difference and percentage Stroop ratio meant that participants had poorer inhibitory control.

$$\text{Stroop Difference} = RT_{INCONGRUENT\ TRIAL} - RT_{NEUTRAL\ TRIAL}$$

$$\text{Percentage Stroop ratio} = \left[\frac{RT_{INCONGRUENT\ TRIAL} - RT_{NEUTRAL\ TRIAL}}{\frac{RT_{INCONGRUENT\ TRIAL} + RT_{NEUTRAL\ TRIAL}}{2}}\right] * 100$$

In addition to the above two variables, we also measured the slope of the slowest delta segment by conducting delta plot analysis as explained in the Introduction. Especially, for each participant, we sorted the naming RTs for each condition in ascending order and for each condition rank-ordered RTs were divided into five RT quintiles of equal size. Magnitude of the interference (or delta) was computed for each quintile by subtracting the quintile average in the neutral condition from the corresponding quintile average in the incongruent condition. Slope of the slowest delta segment (quintile 4 to 5) was calculated with the following formula:

$$slope\ (slowest\ delta\ segment) = \frac{delta(quintile\ 5) - delta\ (quintile\ 4)}{average\ (quintile\ 5) - average\ (quintile\ 4)}$$

Colour-shape switch task. Mental-set shifting was measured by using a colour-shape switch task adapted from Prior and MacWhinney (2010). Based on a cue (colour cue or shape cue), participants had to judge the colour (red or green) or shape of the target (circle or triangle). There were two types of trials: switch and non-switch. In the switch trials, participants had to switch between judging the colour and shape of the target, whereas in the non-switch trials, participants either named the colour or the shape of the target. There were in total 72 switch trials and 72 non-switch trials. RT was measured for the two trial types. Dependent variables were switch cost for RT and percentage switch cost ratio. Greater switch cost and percentage switch cost ratio indicate poorer mental-set shifting abilities.

$$Switch\ Cost_{RT} = RT_{SWITCH\ TRIAL} - RT_{NON-SWITCH\ TRIAL}$$

$$\text{Percentage switch cost ratio} = \left[\frac{RT_{SWITCH\ TRIAL} - RT_{NON-SWITCH\ TRIAL}}{\frac{RT_{SWITCH\ TRIAL} + RT_{NON-SWITCH\ TRIAL}}{2}}\right] * 100$$

Backward digit span task. Working memory was assessed using the subtest from the Wechsler Memory Scale (WMS 3, Wechsler, 1997). Participants were verbally presented with a sequence of digits (two to nine) in ascending order and were asked to repeat the sequence in reverse order. Dependent variable was the total number of lists reported correctly.

As can be seen in Table 1, there were significant differences between the two groups in inhibitory control (percentage Stroop ratio), and mental-set shifting (percentage switch cost ratio), but no difference in working memory (backward digit span). Bilinguals showed better inhibitory control and mental-set shifting abilities compared to monolinguals. In the Stroop task and the colour-shape switch task, bilinguals performed in lower ranges (e.g., Stroop ratio, Bilinguals: *Min 5, Max 39*; Monolinguals: *Min 13, Max 47.4*) compared to the monolinguals (see Table 1). Lower range in the ratio score indicates better executive control ability. On the delta plot analysis of Stroop task, there was a significant difference between the two groups. Bilinguals showed facilitation (better performance in the incongruent condition compared to the control condition) rather than interference for the slow responses as observed by the slope of the slowest delta segment (see Table 1 and upper panel of Figure 3).

<< Insert Table 1 here >>

2.4 Blocked-Cyclic Picture Naming Task

2.4.1 Materials. The materials consisted of 25 black-and-white line-drawings, including five pictures from five different semantic categories (animals, body parts, clothing, fruits and vegetables, and tools). The images were selected from various sources, including the Philadelphia Naming Test database (PNT; Roach, Schwartz, Martin, Grewal, & Brecher, 1996), the International Picture-Naming Project database (IPNP; Szekely et al, 2004), the Bank of Standardised Stimuli database (BOSS; Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010), the 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 for two (*banana* had three syllables and *onion* had two syllables). The objects from the semantic categories were combined to create five homogeneous sets and five heterogeneous sets (see *Figure 1*).

The heterogeneous sets contained one item 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 phonemes and there were no Bengali-English cognates.

2.4.2 Design. Context (homogeneous and heterogeneous) and presentation cycles (five levels) varied across subjects. From the five homogeneous sets and five heterogeneous set, ten lists of trials were created, each including five presentation cycles (25 trials). Each presentation cycle 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 consisting 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 (Homogeneous-Heterogeneous-Homogeneous-Heterogeneous-Homogeneous or Heterogenous-Homogeneous-Heterogenous-Homogeneous-Heterogenous) – that is, no two consecutive sets were from the same context.

2.4.3 Procedures. Picture naming responses were elicited in English. Participants were familiarised with the pictures and 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 (Crowther & Martin, 2014; Shao et al., 2015). Following the familiarisation, participants were shown the picture stimuli one at a time on a computer screen using the E-Prime software. Each trial started with a fixation cross for 250ms, then a blank screen for 100ms, followed by the target stimuli which was accompanied by a short beep sound of 150ms. The target stimuli remained on the screen for 2000ms. Following the target stimuli, a blank screen appeared for 500ms, before then beginning 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 were transcribed later.

2.4.4 Scoring. RT for correct naming responses were calculated after excluding errors such as naming the incorrect target word (e.g., key for lock), hesitation (e.g., umm yes that is a lock), and no response. The onset of each response was labelled manually to obtain greater accuracy and the RT was measured from the onset of the beep to the onset of the naming response using the PRAAT (Boersma & David, 2015). The dependent variables were RT in the homogeneous and heterogeneous context (to determine the semantic context effect) across the five cycles and slope of slowest delta segment as measured by delta plot analysis. Delta plots were conducted following the same procedure as in the Stroop task.

3. Statistical Analysis

Data from 2.36% of the experimental trials (295 trials out of 12500 total trials) were excluded due to incorrect response (28 trials, bilinguals: 19 trials, monolinguals: 9 trials) or to the presence of outliers (±2.5*SD for each condition for each participant, 267 trials, bilinguals: 164, monolinguals: 103). RTs were calculated for each participant, for each cycle, and in each context. For each group, the semantic context effect was calculated twice, separately: one included all the presentation cycles while the other excluded cycle 1. The context effect was the difference in mean RT between the homogeneous context and the heterogeneous context.

RTs for the correct responses were submitted to an analysis of variance (ANOVA), where the Context (homogeneous, heterogeneous) and presentation Cycles (five) were within-participants factors, and Group (bilingual, monolingual) was the between-participants factor. Another similar ANOVA was performed, excluding cycle 1, to investigate the cumulative semantic interference. Further, to determine if there was any facilitation in cycle 1, an ANOVA was conducted where Context was the within-participants factor and Group the between-participants factor. To compare the slope of slowest delta segment between groups, an independent sample t-test was conducted. 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 semantic context effects, we conducted two kinds of correlation. First, correlation was conducted based on the delta plot analysis. Within-task Pearson's correlations were performed for blocked-cyclic naming (between slope of the slowest delta segment and semantic context effects) and Stroop task (slope of slowest delta segment and Stroop interference: Stroop ratio and Stroop difference). Between-task Pearson's correlations were performed between slope of the slowest delta segment obtained from blocked-cyclic naming task with the slope of the slowest delta segment obtained from the Stroop task.

Second, we examined the relationship between the independent executive control variables and the semantic context effect (all cycles and excluding cycle 1). Pearson's correlations (between percentage Stroop ratio and semantic context effect) and Spearman's correlations (between the other two executive control variables and semantic context effect) were performed. All correlations were performed separately for each group. Given our moderate sample size for each group, we interpretation our results with caution (see Brysbaert, 2019 for a review). Given the nascency of this literature and previous studies that have employed correlational measures with blocked cyclic naming and executive measures have been in the range of 20 to 41 participants (Belke, 2008, Crowther & Martin, 2014, Shao et al., 2015), we report our findings. Moreover, bilingual participants in this study belongs to unreported language and are well characterized, which we believe adds to the strength of this research.

4. Results

The mean and standard deviation values for the blocked-cyclic naming variables for Groups (Bilinguals; Monolingual) and Context (Homogeneous; Heterogeneous) across the five cycles, averaged across participants, are presented in Table 2 (standard deviation reflects between-subject variation). Table 2 also contains the results of the statistical tests with all cycles included and cycle 1 excluded as well as the results from the slope of slowest delta segment. Findings from the delta plot correlation analyses are presented in Table 3. Findings for Group differences are presented first, followed by the findings on the correlation analysis. Figure 2 shows the RT in each context across the five presentation cycles (upper panel) and differences in RT between the two contexts (collapsing across all cycles, left lower panel;

collapsing across cycle 2-5, right lower panel) for both groups. Figure 3 shows the delta plot across the two groups for Stroop task (upper panel of Figure 3) and blocked-cyclic naming task (lower panel of Figure 3). Figure 4 represents the significant correlation findings. Individual participants' item level RT for the naming task and the Stroop task, along with demographic variables and means from other executive measures are available in the University of Reading data repository (http://dx.doi.org/10.17864/1947.251).

<< Insert Table 2 here >>

<< Insert Table 3 here >>

<< Insert Figure 2 here >>

<< Insert Figure 3 here >>

<< Insert Figure 4 here >>

4.1 Group Differences in Blocked-Cyclic Naming Performance

4.1.1 Semantic context effect (Cycles 1-5). The ANOVA revealed no Group differences in RT – that is, bilinguals (*M* = 629.8, *SD* = 86.5) overall took a similar length of time to name pictures when compared to monolinguals (*M* = 595.9, *SD* = 86.5, $p = .17$). There was a main effect of Context – that is, 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 Group X Context and Context X Cycle (see following section for explanation of this interaction). Pair-wise comparisons for the Group X Context interaction revealed a significant effect of Context for both groups ($p = .001$ for bilinguals; $p < .001$ for monolinguals). However, monolinguals showed a significantly greater semantic context effect compared to bilinguals (Monolinguals: mean difference between contexts = 38.1 msec; Bilinguals: mean difference between contexts = 15.3 msec; $t(48) = 3.67$, $p = .001$; see *left lower panel of Figure 2*).

4.1.2 Semantic context effect (Cycles 2-5). To investigate the cumulative semantic interference observed in the previous analysis (significant Context-by-Cycle), we excluded cycle 1 from the analysis. As expected, Context X Cycle interaction was no longer observed. However, the Group X Context interaction was still present. Pair-wise comparisons on the Group X Context interaction revealed a significant effect of Context for both groups, with monolinguals (Mean difference = 46.3 msec) showing a significantly greater semantic context effect compared to bilinguals (Mean difference = 25.5 msec; $t(48) = 3.28$, $p = .002$; see *right lower panel of Figure 2*).

4.1.3 Semantic facilitation (Cycle 1). In terms of facilitation in cycle 1, there was no main effect of Group (Bilingual: $M = 685.9$, $SD = 101.4$; Monolingual $M = 653.7$, $SD = 101.4$) – that is, both groups overall took a similar length of time on cycle 1 (see Table 2). However, there was a significant effect of Context and Group X Context interaction. Semantic facilitation was observed in cycle 1, naming was faster in the homogeneous context ($M = 664.8$, $SD = 106$) compared to the heterogeneous context ($M = 674.8$, $SD = 100$). Paired-wise comparisons revealed that bilinguals showed significant facilitation in the homogeneous context over the heterogeneous context (Mean difference = - 25.4 msec, $p = .001$), whilst monolinguals did not show any facilitation (Mean difference = 5.4 msec, $p = .45$; see first cycle in the *upper panel of Figure 2*).

4.1.4: Slope of the slowest delta segment. Figure 3 represents the delta plots showing the differences in RT between conditions (i.e, delta) as a function of quintile. As can be seen from the lower panel of Figure 3, the groups performed differently in the slowest delta segment (quintile 4 to 5). Statistical results showed a significant difference between the groups on the slope of slowest delta segment where bilinguals showed semantic facilitation ($M = -0.12$, $SD = 0.58$), whilst monolinguals showed semantic interference ($M = 0.15$, $SD = 0.31$).

4.2 Blocked-Cyclic Naming Performance and Executive Control Measures

Table 3 represents the correlation coefficients based on the delta plot analysis. For within-task correlation, we found significant correlation between semantic context effect and slope of the slowest delta segment for both groups (see *Figure 4*). Individuals with poorer selective inhibition (steeper slope) showed larger semantic context effects. However, such within-task correlations were not significant for the Stroop task suggestive of different kind of inhibition at play in the Stroop task. For between-task correlations, we did not observe any significant correlations between the slope of slowest delta segment of the blocked-cyclic naming task and the slope of slowest delta segment of the Stroop task, in both groups.

For the correlation between the semantic context effects (i.e., context effects all cycles, context effect excluding cycle 1) and independent executive control variables (Stroop ratio, switch cost ratio, digit span backward), we did not observe any significant correlations for either group. As explained in Section 3, group size was moderate to interpret the null results. In addition, previous research has shown that reliability of difference scores is low (Hedge, Powell, & Summer, 2018), which could lead to non-significant findings when correlating difference scores (e.g., Stroop difference and semantic context effect). Therefore, we do not discuss the null findings related to between-task correlations further and provide the results in the Appendix for future researchers interested in data mining or meta-analyses.

5. Discussion

<< Insert Table 4 here >>

The aim of this research was to determine the relationship between increased lexical competition as induced by semantic context manipulation through a blocked-cyclic picture naming paradigm, and executive control processes for bilingual and monolingual speakers. We achieved this by comparing semantic context effects between a group of balanced sequential Bengali-English adult bilinguals and age-, gender-, education-, non-verbal IQ- and vocabulary-matched monolinguals. The key findings from this research demonstrate that compared to monolinguals, bilinguals showed smaller semantic context effects (i.e., less affected by lexically competitive condition, homogeneous context), more semantic facilitation on the first presentation cycles, and better inhibitory control and shifting abilities, but comparable working memory span. We also found individuals with better selective inhibition (as indexed by slope of slowest delta segment) showed smaller semantic context effects but such relationship was not observed in the Stroop task. The summary of findings is presented in Table 4. In the following paragraphs, we discuss these findings in the context of the current literature, but we also delve into possible extensions of this line of work, in the aim of resolving outstanding issues in this exciting literature.

The strong and significant semantic context effects (i.e., longer RTs in homogeneous context than in heterogeneous context) and the stable non-cumulative nature of this semantic interference after cycle 2 (i.e., lack of growth in semantic interference) corroborate research by other groups (Abdel Rahman & Melinger, 2007; Belke et al., 2005; Damian & Als, 2005; Navarrete, Del Prato, Peressotti, & Mahon, 2014; Shao et al., 2015). This illustrates that irrespective of the type of participants, the homogeneous context was more lexically demanding than the heterogeneous context. In a computational model of word production (WEAVER++), Roelofs (2018) demonstrated that the results from the computational model could account for the non-cumulative nature of semantic interference in the blocked-cyclic naming task by increasing the magnitude of the executive control or by implementing a strategic bias in the model. The stable and non-cumulative nature of semantic interference observed in the present study provides further support to the assertion that in the blocked-cyclic naming paradigm, executive control mechanisms bias the lexical selection (Belke & Stielow, 2013, Roelofs, 2018).

A novel aim of this research was to determine semantic context effects in vocabulary-matched bilinguals and monolinguals. We found that bilinguals demonstrated smaller semantic context effects compared to monolinguals – that is, they were less affected by increased lexical competition as induced by blocked-cyclic naming. To the best of our knowledge, this is the first study to report this novel finding between well-matched healthy bilinguals and monolinguals. As proposed in the introduction, the bilinguals' lexical system is highly competitive by default, as they must constantly juggle within- and between-language competitions. Therefore, in the homogeneous context of the blocked-cyclic naming, they were more attuned to coping with increased lexical competition, thus resulting in less semantic interference. However, prior to asserting the conclusion of a bilingual advantage, it is prudent to focus our attention to some of the findings in this research that may lead to an alternative interpretation, namely that there is a bilingual disadvantage. Bilinguals were overall slower in the executive control measures (Stroop neutral trials, Stroop incongruent trials, switch trials, non-switch trials, all *p*s$<.05$) and blocked-cyclic naming (though it did not reach significance, $p = .17$) despite being matched with the monolingual group on background measures. Therefore, we do consider the alternative possibility that bilinguals were less able to profit from the easier heterogeneous condition due to having interference from the non-target language. However, bilinguals performed better in the executive control measures when controlled for overall speed as observed by ratio scores (Stroop ratio and switch cost ratio). Similarly, observations form the delta plot measures from both the Stroop and the blocked-cyclic naming task indicate better selective inhibition abilities (which is most prominent for slower responses) for bilinguals. This is the first study to compare bilinguals and monolinguals on delta plot measures on the Stroop and the blocked-cyclic naming task and provide evidence of bilingual advantage over monolinguals. Further support for better performance of bilinguals in the blocked-cyclic naming task is revealed from the observation that bilinguals showed significant semantic facilitation on the first presentation cycle. For these reasons, we believe that there is stronger evidence for a bilingualism advantage than for a disadvantage.

Despite meeting the predictions that bilinguals will be less affected by semantic context effects, the question remains: why were they less affected? It has been suggested that executive control plays an important role in reducing the semantic interference in a blocked-cyclic naming task (Belke, 2008; Crowther & Martin, 2014; Shao et al., 2015). Specifically, inhibitory control and working memory have been proposed to be the primary attributing factors involved in reducing semantic interference. In the monolingual literature, individuals with better inhibitory control demonstrated smaller semantic context effects (Crowther & Martin, 2014; Shao et al., 2015), and semantic context effects increased when participants performed the blocked-cyclic naming task with a concurrent working memory load (Belke, 2008). Recall that the bilingual participants in this study demonstrated significantly better inhibitory control (see Table 1). Better inhibitory control could then be a potential reason for bilinguals being less affected in the homogenous condition. The possibility that executive control might have played a role in the semantic context effects is further corroborated by the findings of semantic facilitation on the first cycle in bilinguals and delta plot analysis.

Semantic facilitation on the first presentation cycle has been attributed to strategic facilitation or better executive control abilities (Belke, 2017; Roelofs, 2018). As discussed in the Introduction, Belke (2017) reviewed studies with monolingual participants on two types of blocked-cyclic naming tasks, namely alternating (i.e., hom, het; homo, het; homo, het) and blocked (i.e., hom, hom, hom; het, het, het) design. Monolingual participants did not show semantic facilitation on the alternating design, which aligns with the findings from our monolingual group. However, Belke found that when homogeneous and heterogeneous sets were presented in blocks, monolingual participants developed awareness of the semantic category and used a strategy to perform better in the homogeneous context compared to the heterogeneous context on the first presentation cycle. Bilingual participants of the present study behaved similarly to the monolinguals on the blocked design – that is, even on the alternating design, bilinguals could bias the selection of items in the homogeneous context on the first presentation cycle. Therefore, the semantic facilitation in the first presentation cycle of the blocked-cyclic naming task as well as better performance in the executive control measures provide converging evidence of a bilingual advantage in executive control.

The results of the correlational analyses between the magnitude of the semantic context effects and the slope of the slowest delta segment showed a significant correlation for both groups but such results were not observed for the Stroop task. Further, we did not observe any significant correlations between the slope of the slowest delta segment of the blocked-cyclic naming task and the slope of the slowest delta segment of the Stroop. Our results corroborate with the findings from Shao et al.'s study involving monolingual participants. Shao et al. attributed the lack of a correlation between Stroop effects and semantic context effects to the differences in the nature of inhibition between these two tasks. According to Shao et al., the type of inhibition (selective inhibition) which helps to reduce semantic context effects in the blocked-cyclic naming task may not be triggered by the Stroop task (which require inhibiting the visual distractor). This study is the first study to show the relationship between selective inhibition and semantic context effects in a bilingual population in a blocked-cyclic naming task.

Conclusions, limitation and future directions

This is the first study to establish that bilinguals are less affected by semantic context manipulation compared to monolinguals. This is an important finding because it illustrates that even in a challenging linguistic task that heightens lexical competition, bilinguals perform better than monolinguals. This challenges the notion in the literature that bilinguals are disadvantaged to monolinguals in linguistic tasks. We propose that when participant groups are matched for relevant demographic variables (e.g., vocabulary, age, non-verbal IQ), bilinguals perform on a par with monolinguals. In addition, bilinguals were able to use a better strategy in the lexically competitive condition (e.g., first cycle of homogeneous condition), which enabled them to derive facilitation during naming. We conclude that this study provided evidence for a bilingual advantage in a linguistic task where executive control demands were higher. Future research should explore the relationship between semantic interference and executive control across different types of populations (e.g., bilinguals with different levels of proficiency, bilinguals with neurogenic disorder), spanning a wide range of executive control measures and using different blocked-cyclic naming paradigms (alternating vs. blocked), to test if our findings will hold true in a wide range of populations and subject to different manipulations.

References

Abdel Rahman, R., & Melinger, A. (2007). When bees hamper the production of honey: lexical interference from associates in speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*,*33*, 604–614. http://dx.doi.org/10.1037/0278-7393.33.3.604

Belke, E. (2008). Effects of working memory load on lexical-semantic encoding in language production. *Psychonomic Bulletin & Review*,*15*, 357–363. https://doi.org/10.3758/PBR.15.2.357

Belke, E. (2017). The role of task-specific response strategies in blocked-cyclic naming. *Frontiers in psychology*,*7*, 1955. https://doi.org/10.3389/fpsyg.2016.01955

Belke, E., & Stielow, A. (2013). Cumulative and non-cumulative semantic interference in object naming: Evidence from blocked and continuous manipulations of semantic context. *The Quarterly Journal of Experimental Psychology*, *66*, 2135–2160. http://dx.doi.org/10.1080/17470218.2013.775318

Belke, E., Brysbaert, M., Meyer, A. S., & Ghyselinck, M. (2005). Age of acquisition effects in picture naming: evidence for a lexical-semantic competition hypothesis. *Cognition*, *96*, B45–B54. https://doi.org/10.1016/j.cognition.2004.11.006

Belke, E., Meyer, A. S., & Damian, M. F. (2005). Refractory effects in picture naming as assessed in a semantic blocking paradigm. *The Quarterly Journal of Experimental Psychology*, *58*, 667–692. http://dx.doi.org/10.1080/02724980443000142

Bialystok, E. (2009). Bilingualism: The good, the bad, and the indifferent. *Bilingualism: Language and Cognition*,*12*, 3–11. https://doi.org/10.1017/S1366728908003477

Boersma, P., & Weenink, D. (2015) Praat version 5.4. 08. Doing phonetics by computer.

Brodeur, M. B., Dionne-Dostie, E., Montreuil, T., & Lepage, M. (2010). The Bank of Standardized Stimuli (BOSS), a new set of 480 normative photos of objects to be used as visual stimuli in cognitive research. *PloS one*, *5*, e10773. https://doi.org/10.1371/journal.pone.0010773

Brysbaert M. (2019). How Many Participants Do We Have to Include in Properly Powered Experiments? A Tutorial of Power Analysis with Reference Tables. *Journal of Cognition*, *2*, 1–38. https://doi.org/10.5334/joc.72

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology*, *14*, 177–208. http://dx.doi.org/10.1080/026432997381664

Crowther, J. E., & Martin, R. C. (2014). Lexical selection in the semantically blocked cyclic naming task: the role of cognitive control and learning. *Frontiers in Human Neuroscience*, *8*, 9. https://doi.org/10.3389/fnhum.2014.00009

Damian, M. F., & Als, L. C. (2005). Long-lasting semantic context effects in the spoken production of object names. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*, 1372–1384. http://dx.doi.org/10.1037/0278-7393.31.6.1372

Damian, M. F., Vigliocco, G., & Levelt, W. J. (2001). Effects of semantic context in the naming of pictures and words. *Cognition*, *81*, B77–B86. https://doi.org/10.1016/S0010-0277(01)00135-4

De Jong, R., Liang, C. C., & Lauber, E. (1994). Conditional and unconditional automaticity: a dual-process model of effects of spatial stimulus-response correspondence. *Journal of Experimental Psychology: Human Perception and Performance*, *20*, 731–750. https://doi.org/10.1037/0096-1523.20.4.731

Dell, G. S., Schwartz, M. F., Martin, N., Saffran, E. M., & Gagnon, D. A. (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological Review*, *104*, 801–838. https://dx.doi.org/10.1037/0033-295X.104.4.801

Dijkstra, T., Grainger, J., & Van Heuven, W. J. (1999). Recognition of cognates and interlingual homographs: The neglected role of phonology. *Journal of Memory and language*, *41*, 496–518. https://doi.org/10.1006/jmla.1999.2654

Dunn, A. L., & Tree, JE. F. (2009). A quick, gradient bilingual dominance scale. *Bilingualism: Language and Cognition*, *12*, 273–289. https://doi.org/10.1017/S1366728909990113

Dunn, L. M., & Dunn, D. M. (2009). The British picture vocabulary scale. GL Assessment Limited.

Faroqi-Shah, Y., Sampson, M., Pranger, M., & Baughman, S. (2018). Cognitive control, word retrieval and bilingual aphasia: Is there a relationship? *Journal of Neurolinguistics*, *45*, 95–109. https://doi.org/10.1016/j.jneuroling.2016.07.001

Hedge, C., Powell, G., & Sumner, P. (2018). The reliability paradox: Why robust cognitive tasks do not produce reliable individual differences. *Behavior Research Methods*, *50*, 1166–1186. https://doi.org/10.3758/s13428-017-0935-1

Kousaie, S., & Phillips, N. A. (2012). Ageing and bilingualism: Absence of a "bilingual advantage" in Stroop interference in a nonimmigrant sample. *The Quarterly Journal of Experimental Psychology*, *65*, 356–369. https://doi.org/10.1080/17470218.2011.604788

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, *33*, 149–174. https://doi.org/10.1006/jmla.1994.1008

Kroll, J. F., Bobb, S. C., & Wodniecka, Z. (2006). Language selectivity is the exception, not the rule: Arguments against a fixed locus of language selection in bilingual speech. *Bilingualism: Language and Cognition*, *9*, 119–135. https://doi.org/10.1017/S1366728906002483

Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 English words. *Behavior Research Methods*, *44*, 978–990. https://doi.org/10.3758/s13428-012-0210-4

Lee, M. W., & Williams, J. N. (2001). Lexical access in spoken word production by bilinguals: Evidence from the semantic competitor priming paradigm. *Bilingualism: Language and Cognition*, *4*, 233–248. https://doi.org/10.1017/S1366728901000426

Levelt, W. J., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, *22*, 1–38. https://doi.org/10.1017/S0140525X99001776

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100. https://doi.org/10.1006/cogp.1999.0734

Muñoz, M. L., Marquardt, T. P., & Copeland, G. (1999). A comparison of the codeswitching patterns of aphasic and neurologically normal bilingual speakers of English and Spanish. *Brain and language*, *66*, 249–274. https://doi.org/10.1006/brln.1998.2021

Navarrete, E., Del Prato, P., Peressotti, F., & Mahon, B. Z. (2014). Lexical selection is not by competition: Evidence from the blocked naming paradigm. *Journal of Memory and Language*, *76*, 253–272. https://doi.org/10.1016/j.jml.2014.05.003

Nichols, E. S., Wild, C. J., Stojanoski, B., Battista, M. E., & Owen, A. M. (2020). Bilingualism Affords No General Cognitive Advantages: A Population Study of Executive Function in 11,000 People. *Psychological Science*. https://doi.org/10.1177/0956797620903113

Paap, K. R., & Greenberg, Z. I. (2013). There is no coherent evidence for a bilingual advantage in executive processing. *Cognitive Psychology*, *66*, 232–258. https://doi.org/10.1016/j.cogpsych.2012.12.002

Paap, K. R., & Sawi, O. (2014). Bilingual advantages in executive functioning: problems in convergent validity, discriminant validity, and the identification of the theoretical constructs. *Frontiers in Psychology*, *5*, 1–15. https://doi.org/10.3389/fpsyg.2014.00962

Paap, K. R., Johnson, H. A., & Sawi, O. (2014). Are bilingual advantages dependent upon specific tasks or specific bilingual experiences? *Journal of Cognitive Psychology*, *26*, 615–639. http://dx.doi.org/10.1080/20445911.2014.944914

Patra, A., Bose, A., & Marinis, T. (2020). Semantic context effects in Bengali-English bilingual and English monolingual speakers. University of Reading. Dataset. http://dx.doi.org/10.17864/1947.251

Patra, A., Bose, A., & Marinis, T. (2019). Measures of performance difference in verbal fluency in Bengali-English bilingual and English monolingual speakers. University of Reading. Dataset. http://dx.doi.org/10.17864/1947.207

Patra, A., Bose, A., & Marinis, T. (2020). Performance difference in verbal fluency in bilingual and monolingual speakers. *Bilingualism: Language and Cognition*, *23*, 204–218. https://doi.org/10.1017/S1366728918001098

Prior, A., & MacWhinney, B. (2010). A bilingual advantage in task switching. *Bilingualism: Language and Cognition*, *13*, 253–262. https://doi.org/10.1017/S1366728909990526

Quick Placement Test. (2001). Oxford: Oxford University Press.

Raven, J. (2008) Ravens Standard Progressive Matrices–Plus Version. London: NCS Pearson.

Ridderinkhof, K. R. (2002). Activation and suppression in conflict tasks: Empirical clarification through distributional analyses. In W. Prinz & B. Hommel (Eds.), Attention and performance XIX: Common mechanisms in perception and action (pp. 494–519). New York: Oxford University Press.

Roach, A., Schwartz, M. F., Martin, N., Grewal, R. S., & Brecher, A. (1996). The Philadelphia naming test: scoring and rationale. *Clinical Aphasiology*, *24*, 121–133.

Rodriguez-Fornells, A., Krämer, U. M., Lorenzo-Seva, U., Festman, J., & Münte, T. F. (2012). Self-assessment of individual differences in language switching. *Frontiers in Psychology*, *2*, 1–15. https://doi.org/10.3389/fpsyg.2011.00388

Roelofs, A. (2018). A unified computational account of cumulative semantic, semantic blocking, and semantic distractor effects in picture naming. *Cognition*, *172*, 59–72. https://doi.org/10.1016/j.cognition.2017.12.007

Roelofs, A., Piai, V., & Garrido Rodriguez, G. (2011). Attentional inhibition in bilingual naming performance: evidence from delta-plot analyses. *Frontiers in psychology*, *2*, 184. https://doi.org/10.3389/fpsyg.2011.00184

Schnur, T. T., Schwartz, M. F., Brecher, A., & Hodgson, C. (2006). Semantic interference during blocked-cyclic naming: Evidence from aphasia. *Journal of Memory and Language*, *54*, 199–227. https://doi.org/10.1016/j.jml.2005.10.002

Scott, R. M., & Wilshire, C. E. (2010). Lexical competition for production in a case of nonfluent aphasia: Converging evidence from four different tasks. *Cognitive Neuropsychology*, *27*, 505–538. http://dx.doi.org/10.1080/02643294.2011.598853

Shao, Z., Meyer, A. S., & Roelofs, A. (2013). Selective and nonselective inhibition of competitors in picture naming. *Memory & Cognition*, *41*, 1200–1211. https://doi.org/10.3758/s13421-013-0332-7

Shao, Z., Roelofs, A., Martin, R. C., & Meyer, A. S. (2015). Selective inhibition and naming performance in semantic blocking, picture-word interference, and color–word Stroop tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*, 1806–1820. http://dx.doi.org/10.1037/a0039363

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of experimental psychology: Human learning and memory*, *6*, 174–215. https://doi.org/10.1037/0278-7393.6.2.174

Starreveld, P. A., De Groot, A. M., Rossmark, B. M., & Van Hell, J. G. (2014). Parallel language activation during word processing in bilinguals: Evidence from word production in sentence context. *Bilingualism: Language and Cognition*, *17*, 258–276. https://doi.org/10.1017/S1366728913000308

Struys, E., Woumans, E., Nour, S., Kepinska, O., & Van den Noort, M. (2019). A domain-general monitoring account of language switching in recognition tasks: Evidence for adaptive control. *Bilingualism: Language and cognition*, *22*, 606–623. https://doi.org/10.1017/S1366728918000342

Szekely, A., Jacobsen, T., D'Amico, S., Devescovi, A., Andonova, E., Herron, D., ... & Federmeier, K. (2004). A new on-line resource for psycholinguistic studies. *Journal of Memory and Language*, *51*, 247–250. https://doi.org/10.1016/j.jml.2004.03.002

Thierry, G., & Wu, Y. J. (2007). Brain potentials reveal unconscious translation during foreign-language comprehension. *Proceedings of the National Academy of Sciences*, *104*, 12530–12535. https://doi.org/10.1073/pnas.0609927104

Van den Noort, M., Struys, E., Bosch, P., Jaswetz, L., Perriard, B., Yeo, S., ... & Lim, S. (2019). Does the bilingual advantage in cognitive control exist and if so, what are its modulating factors? A systematic review. *Behavioral Sciences*, *9*, 27. https://doi.org/10.3390/bs9030027

Wechsler, D. (1997). WMS-III: Wechsler memory scale administration and scoring manual. Psychological Corporation.

Figure captions

Figure 1. 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.

Figure 2. Upper panel: Mean RT by context (homogeneous and heterogeneous) for each group (bilingual and monolingual) for each presentation cycle. Lower panel: Mean RT by context (homogeneous and heterogeneous) for each group (bilingual and monolingual) averaged across all the presentation cycles (left panel) and cycle 2-5 (right panel). The error bar represents standard error of the means.

Figure 3. Upper panel: Delta plots showing the condition (congruent and neutral) differences (deltas) as a function of quintile (1-5) in the Stroop task. Lower panel: Delta plots showing the condition (homogenous and heterogeneous) differences (deltas) as a function of quintile (1-5) in the blocked-cyclic naming task.

Figure 4. Scatter plots of the relationship between the magnitude of the semantic context effects and the slopes of the slowest delta segment in the blocked-cyclic naming task for each group; *rs* represents Pearson's correlation coefficient; $^*p \leq .05$

Figure 1

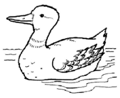
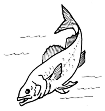
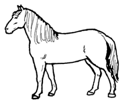
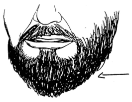
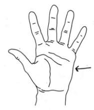
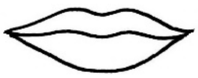
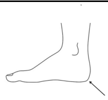
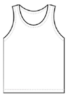
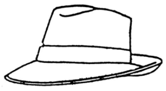
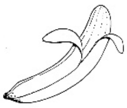
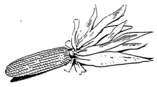
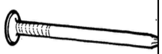
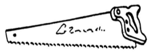
		Heterogeneous sets (Het)				
		Het 1	Het 2	Het 3	Het 4	Het 5
Homogeneous sets (Hom)	Hom 1 (Animals)	 Duck /hɑ̃s/	 Fish /matʃʰ/	 Horse /gʰoɽa/	 Mouse /ĩndur/	 Cat /biɽal/
	Hom 2 (Body parts)	 Beard /daɽi/	 Palm /hat̪/	 Lip /ʈʰoʈ/	 Heel /goɽali/	 Ear /kan/
	Hom 3 (Clothing)	 Vest /gendʒi/	 Hat /ʈupi/	 Sock /modʒa/	 Shirt /dʒama/	 Glove/dɔst̪ana/
	Hom 4 (Fruits and vegetables)	 Pear/naʃpat̪i/	 Banana /kɔla/	 Corn /bʰutta/	 Grapes /aŋur/	 Onion /p̃ɛadʒ/
	Hom 5 (Tools)	 Lock /t̪ala/	 Nail /pɛrek/	 Broom /d̠ʒʰaru/	 Key /tʃabi/	 Saw /kɔrat̪/

Figure 2.

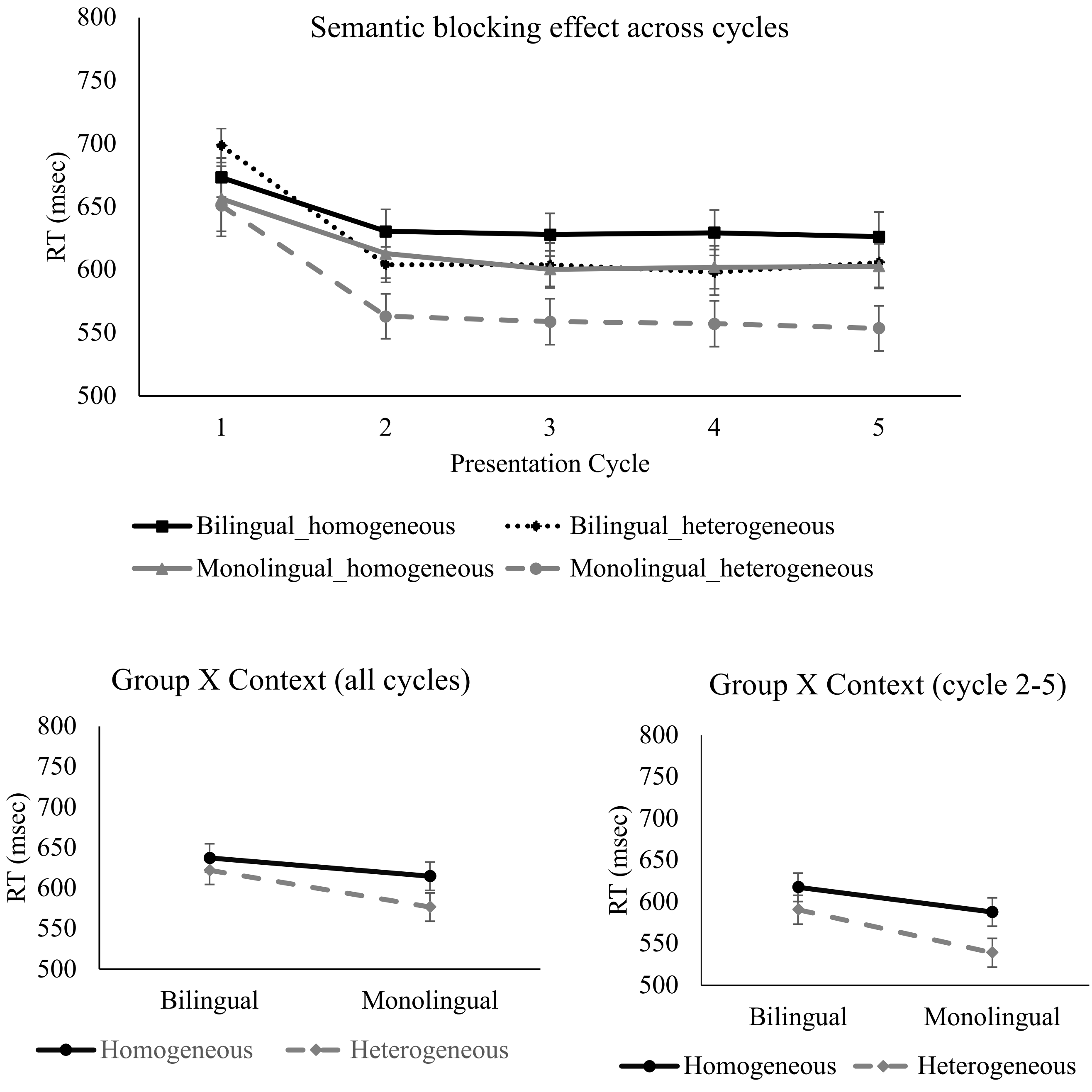

Semantic blocking effect across cycles
800
750
700
650
600
550
500
RT (msec)
1
2
3
4
5
Presentation Cycle
Bilingual_homogeneous
Bilingual_heterogeneous
Monolingual_homogeneous
Monolingual_heterogeneous
Group X Context (all cycles)
800
750
700
650
600
550
500
RT (msec)
Bilingual
Monolingual
Homogeneous
Heterogeneous
Group X Context (cycle 2-5)
800
750
700
650
600
550
500
RT (msec)
Bilingual
Monolingual
Homogeneous
Heterogeneous

Figure 3.

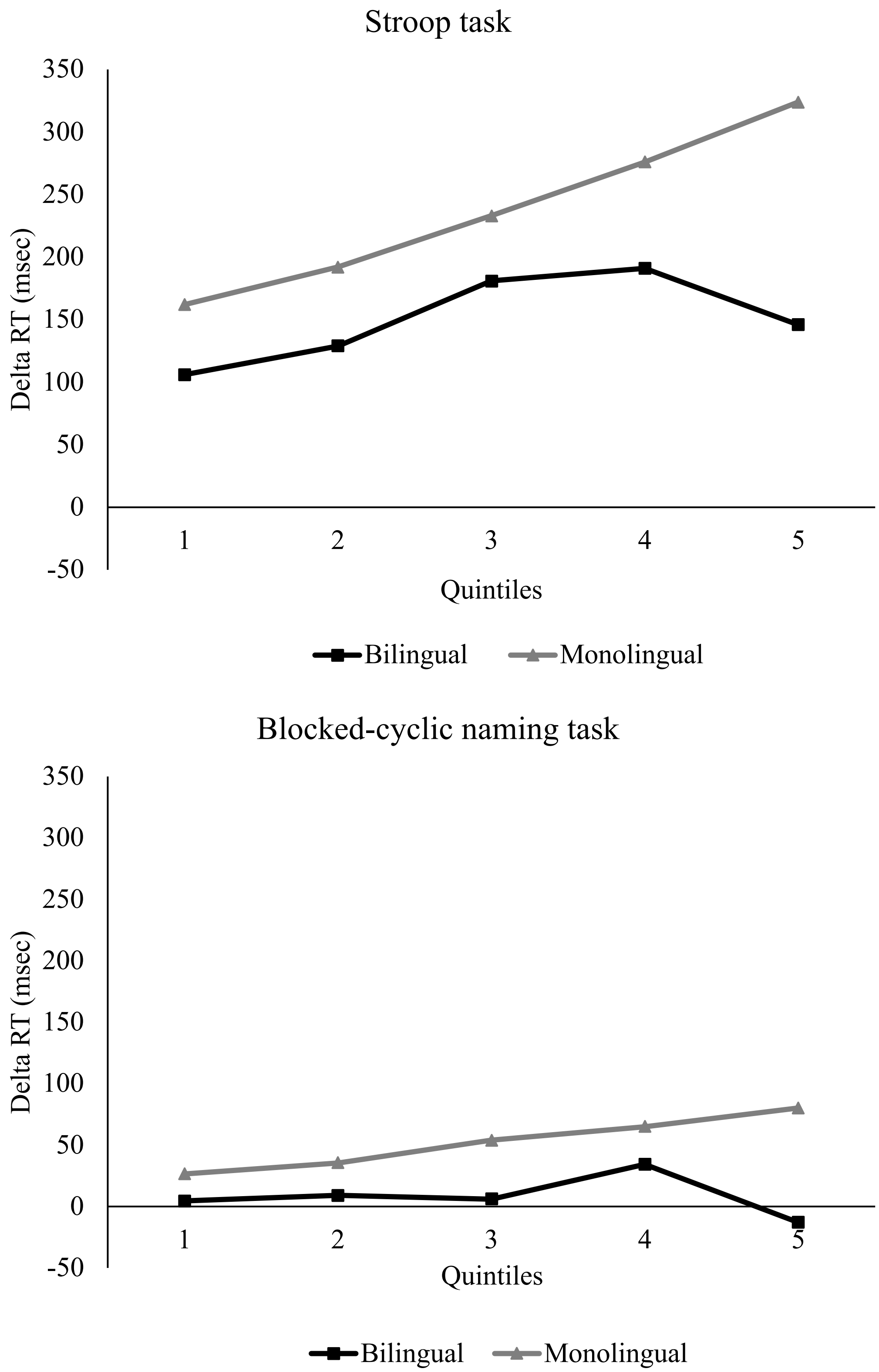
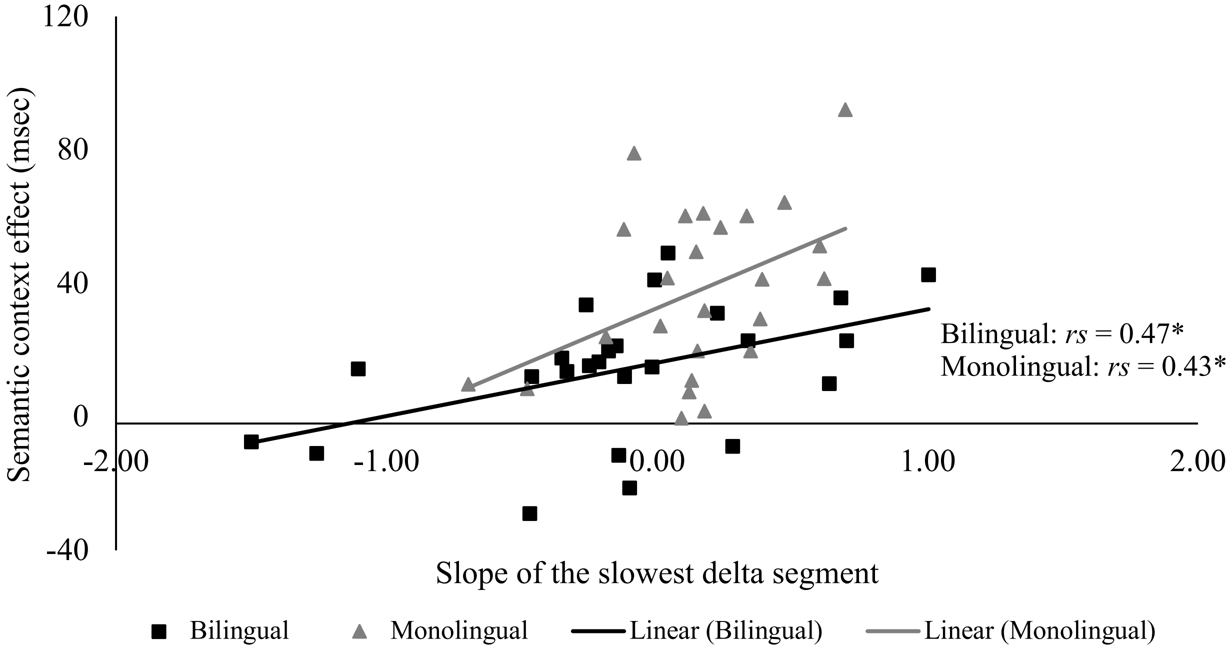

Stroop task
350
300
250
200
150
100
50
0
-50
Delta RT (msec)
1
2
3
4
5
Quintiles
Bilingual
Monolingual
Blocked-cyclic naming task
350
300
250
200
150
100
50
0
-50
Delta RT (msec)
1
2
3
4
5
Quintiles
Bilingual
Monolingual

Figure 4.



120
80
40
0
-40
Semantic context effect (msec)
-2.00
-1.00
0.00
1.00
2.00
Slope of the slowest delta segment
Bilingual: rs = 0.47*
Monolingual: rs = 0.43*
Bilingual
Monolingual
Linear (Bilingual)
Linear (Monolingual)

Table 1. *Means (M), Minimum (Min), Maximum (Max) and Standard Deviations (SD) values, and statistical results of executive control measures*

	Bilingual				Monolingual				
Measures	*M*	*Min*	*Max*	*SD*	*M*	*Min*	*Max*	*SD*	Statistical results
Stroop task[1]									
Percentage Stroop ratio (%)[2]	23	5	39	8	31	13	47	10	**$t(48) = -2.9$, $p = .005$**
Stroop difference (RT)[3]	170	49	318	64	195	104	358	63	$t(48) = -1.4$, $p = .17$
Stroop incongruent (RT)	836	560	1141	164	743	563	1141	145	**$t(48) = 2.1$, $p = .04$**
Stroop neutral (RT)	666	411	934	146	548	424	934	136	**$t(48) = 2.9$, $p = .005$**
Slope of the slowest delta segment	-0.03	-1.6	1.6	0.65	0.37	-.41	0.97	0.37	**$t(48) = -2.7$, $p = .01$**
Colour-shape switch task[4]									
Percentage switch cost ratio (%)[5]	20	4	44	11	27	6	53	12	**$t(48) = -2.1$, $p = .04$**
Switch cost (RT)[6]	242	48	655	154	252	49	499	130	$U^8 = 289.5$, $p = .65$
Switch trial (RT)	1331	736	1921	281	1036	716	1473	127	**$U^8 = 111$, $p < .001$**
Non-switch trial (RT)	1089	646	1723	242	783	565	1078	203	**$t(48) = 5.6$, $p < .001$**
Digit span test[7]									
Backward digit span	6.1	4	7	1	5.6	4	7	0.9	$U^8 = 226$, $p = .08$

[1] – Stroop task adapted from Scott and Wilshire, 2010; [2] – Percentage Stroop ratio (%) : smaller Percentage Stroop ratio indicates better inhibitory control; [3] – Stroop difference = Incongruent trial mean RT - Neutral trial mean RT; [4] – adapted from Prior and MacWhinney, 2010; [5] – Percentage switch cost ratio (%) : smaller Percentage switch cost ratio indicates better shifting ability; [6] – Switch cost (RT) = Switch trial mean RT - Non-switch trial mean RT; [7] – Digit span test (Wechsler, 1997); [8] – Mann-Whitney U test

Table 2. *Means (M), Standard Deviations (SD), and the Statistical Results of the Dependent Variables (Context, Cycles) for RT (msec) for all cycles, cycle 1 excluded, and cycle 1 only.*

	Bilingual (N =25)					Monolingual (N=25)				
	Homogeneous		Heterogeneous		Mean difference	Homogeneous		Heterogeneous		Mean difference
Cycles	*M*	*SD*	*M*	*SD*	(Hom-Het)	*M*	*SD*	*M*	*SD*	(Hom-Het)
1	673	77	699	67	-26	656	129	651	122	5
2	630	87	604	70	26	613	97	563	89	50
3	628	85	604	86	24	600	74	559	91	41
4	629	90	598	90	31	602	85	557	91	45
5	626	98	606	99	20	603	89	554	89	49
All cycles	637	87	622	87	15	615	87	577	87	38
Cycle 1 excluded	616	85	603	86	13	581	85	558	86	23

Statistical analysis	All cycles	Cycle 1 excluded	Cycle 1 only
Group	$F(1,48)=1.9, p=.17, \eta_p^2=.04$	$F(1,48)=2, p=.16, \eta_p^2=.04$	$F(1,48)=1.3, p=.27, \eta_p^2=.03$
Context	**$F(1,48)=71.6, p<.001, \eta_p^2=.60$**	**$F(1,48)=120.1, p<.001, \eta_p^2=.71$**	**$F(1,48)=4, p=.05, \eta_p^2=.08$**
Cycle	**$F(4,192)=83, p<.001, \eta_p^2=.63$**	$F(3,144)=.5, p=.65, \eta_p^2=.01$	
Group X Context	**$F(1,48)=13.1, p=.001, \eta_p^2=.21$**	**$F(1,48)=10.1, p=.003, \eta_p^2=.17$**	**$F(1,48)=9.5, p=.003, \eta_p^2=.17$**
Group X Cycle	$F(4,192)=.23, p=.92, \eta_p^2=.005$	$F(3,144)=.54, p=.65, \eta_p^2=.01$	
Context X Cycle	**$F(4,192)=21.6, p<.001, \eta_p^2=.31$**	$F(3,144)=.33, p=.80, \eta_p^2=.007$	
Group X Context X Cycle	$F(4,192)=.69, p=.60, \eta_p^2=.01$	$F(3,144)=.57, p=.64, \eta_p^2=.01$	

	Bilingual (N =25)		Monolingual (N=25)		
Slope of the slowest delta	*M*	*SD*	*M*	*SD*	Statistical analysis
segment (4^{th} to 5^{th} Quintile)	-0.12	0.58	0.15	0.31	$t(48) = -2.8, p = .04, d = .6$

Table 3. *Correlation coefficients within task (Blocked cyclic naming: slope of the slowest delta segment and semantic blocking effect; Stroop task: slope of the slowest delta segment and the Stroop effect) and between task (slope of the slowest delta segment for the blocked-cyclic naming and slope of slowest delta segment for the Stroop)*

Within-task correlation		Blocked-cyclic naming	Stroop
		Slope of the slowest delta segment	Slope of the slowest delta segment
Bilingual (*N* =25)			
Semantic context effect	*rs*	**0.47**	
	p	**.02***	
Stroop ratio	*rs*		0.34
	p		.10
Stroop difference	*rs*		0.27
	p		.20
Monolingual (*N* =25)			
Semantic context effect	*rs*	**0.43**	
	p	**.03***	
Stroop ratio	*rs*		0.23
	p		.26
Stroop difference	*rs*		0.30
	p		.14

Between-task correlation		Blocked cyclic naming task
		Slope of slowest delta segment
Stroop task		
Bilingual (*N* =25)		
Slope of the slowest delta segment	*rs*	-0.13
	p	.52
Monolingual (*N* =25)		
Slope of the slowest delta segment	*rs*	0.08
	p	.67

rs - Pearson's correlation coefficient; * $p \leq .05$

Table 4. *Summary of the results from the present study*

Variables	What it measures	Findings and Significance
Blocked-cyclic naming task		
Semantic context effect	Semantic interference	Bilinguals showed lesser semantic context effect and greater semantic facilitation (cycle1). In addition, the delta plot analysis revealed greater selective inhibition for the slower responses for bilinguals compared to monolinguals. The findings indicate greater recruitment of executive control in the blocked-cyclic naming task for bilinguals.
Semantic facilitation on cycle 1	Semantic facilitation	
Slope of the slowest delta segment	Selective inhibition	
Executive control measures		
Stroop ratio	Interference	Bilinguals showed significantly better inhibitory control and mental-set shifting abilities compared to monolinguals. Delta plot analysis revealed greater inhibitory abilities for the slower responses for bilinguals compared to monolinguals. These findings are consistent with the findings from the blocked-cyclic naming task.
Slope of the slowest delta segment in Stroop	Selective inhibition	
Switch cost ratio	Mental set-shifting	
Backward digit span	Working memory	
Relationship between selective inhibition and interference for within and between tasks		
Slope of the slowest delta segment and magnitude of the semantic context effect		Similar to Shao et al. (2015), for both groups we found that individuals with greater selective inhibition as denoted by shallower delta slopes showed lesser semantic context effect in blocked-cyclic naming. Participants' selective inhibition ability was unrelated to the Stroop effect, and between-task correlation was non-significant (suggestive of the type of inhibition is different in the blocked-cyclic naming task versus Stroop task).
Slope of the slowest delta segment and magnitude of the Stroop effect		
Slope of the slowest delta segment from the blocked-cyclic naming task and the Stroop task		

Authors Statement

Patra Abhijeet: Conceptualization, Methodology, Data-Collection, Data-Extraction, Data Analysis, Visualization, Software, Writing- Original draft preparation, Writing-Reviewing and Editing.

Bose Arpita: Conceptualization, Methodology, Data-Analysis, Visualization, Software, Writing-Reviewing and Editing, Supervision.

Marinis Theodoros: Methodology, Data-Analysis, Supervision, Writing- Reviewing and Editing.