Bilingualism: Language and Cognition

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Executive control in bilingual aphasia: a systematic review

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Review Article

Cite this article: Mooijman S, Schoonen R, Roelofs A, Ruiter MB (2021). Executive control in bilingual aphasia: a systematic review. *Bilingualism: Language and Cognition* 1–16. https://doi.org/10.1017/S136672892100047X

Received: 23 June 2020
Revised: 16 July 2021
Accepted: 17 July 2021

Keywords:
bilingualism; aphasia; executive control; bilingual advantage; systematic review

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Abstract

Much research has been dedicated to the effects of bilingualism on executive control (EC). For bilinguals with APHASIA, the interplay with EC is complex. In this systematic review, we synthesize research on this topic and provide an overview of the current state of the field. First, we examine the evidence for EC deficits in bilingual persons with aphasia (bPWA). We then discuss the domain generality of bilingual language control impairments. Finally, we evaluate the bilingual advantage hypothesis in bPWA. We conclude that (1) EC impairments in bPWA are frequently observed, (2) experimental results on the relationship between linguistic and domain-general control are mixed, (3) bPWA with language control problems in everyday communication have domain-general EC problems, and (4) there are indications for EC advantages in bPWA. We end with directions for experimental work that could provide better insight into the intricate relationship between EC and bilingual aphasia.

1. Introduction

With an ever-growing bilingual population, an increasing number of people who develop aphasia after neurological damage are bilingual (Ansaldo & Saidi, 2014). That is, they use or have used more than one language on a regular basis (Grosjean, 2013). Bilingualism has implications for the diagnosis and rehabilitation of aphasia. Treatment of both languages is not always feasible, and the likelihood of cross-linguistic transfer depends on many factors (Goral & Lerman, 2020). In addition, it is difficult to ascertain the premorbid level of proficiency in each language.

When a bilingual develops aphasia, this can result in different recovery patterns across languages (e.g., Fabbro, 2001; Paradis, 2001). Bilingual persons with aphasia (bPWA) may have parallel impairments in both languages or selective impairments in one of their languages. Recovery patterns are determined by a multitude of factors, including age of acquisition, language use and history, premorbid language proficiency, and stroke-related variables such as time post-onset as well as size and location of the lesion (Lerman, Goral & Obler, 2019). A meta-analysis investigated the relationship between these factors (Kuzmina, Goral, Norvik & Weekes, 2019), and showed that the general pattern is that bPWA perform better in their first-acquired language (L1) than in their other language (L2), an effect modulated by age of acquisition and, to a lesser extent, premorbid language proficiency and frequency of use (see Kuzmina et al., 2019, for a more extensive discussion).

Besides different recovery patterns, bilingual aphasia can lead to cross-language intrusions. Pathological language mixing is a rare phenomenon that refers to the unintended use of two languages within a single utterance, whereas switching happens between utterances (Fabbro, 2001). Although mixing and switching is frequently observed in all bilinguals, it becomes "a pathological behavior when it is inappropriately used within a context where speakers do not share both language codes" (Ijalba, Obler & Chengappa, 2004, p. 82). bPWA have been found to switch more frequently and their codeswitches result in miscommunication more often as compared to healthy bilinguals (Muñoz, Marquardt & Copeland, 1999).

Involuntary mixing or switching is caused by an impairment in bilingual language control, the set of functions necessary to use more than one language effectively (e.g., Abutalebi & Green, 2007). There is compelling evidence that both languages are active and compete for selection, either directly (e.g., Costa, Miozzo & Caramazza, 1999; Hermans, Bongaerts, de Bot & Schreuder, 1998; Kroll, Bobb & Wodniecka, 2006; van Heuven, Schriefers, Dijkstra & Hagoort, 2008) or indirectly by activating competitors in the target language (Roelofs, Piai, Garrido Rodriguez & Chwilla, 2016). One important model for bilingual language production is Green's Inhibitory Control model (1998), which argues that language selection is a competitive process in which interference is resolved by inhibitory control. This inhibition ability is hypothesized to be domain general: that is, it encompasses both linguistic and non-linguistic control.

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Inhibition is one of the often-postulated EXECUTIVE CONTROL (EC) functions. UPDATING of working memory and SHIFTING between mental sets are the other two components of an influential proposal about the taxonomy of EC (Friedman, Miyake, Young, DeFries, Corley & Hewitt, 2008; Friedman & Miyake, 2017; Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000a; Miyake & Friedman, 2012), although other models of EC have been put forward (e.g., Braver, 2012; Duncan, 2010). In this proposal, inhibition is defined as the ability to suppress dominant or prepotent responses, shifting refers to the ability to switch between mental sets, operations or tasks, and updating indicates the active manipulation of incoming information in working memory. Miyake et al. (2000a) found that updating, inhibition, and shifting are clearly distinguishable on the behavioral level, but share underlying commonality. EC functions are components of the attention system in the brain (e.g., Posner, 2012; Posner & Raichle, 1994), and together, they allow for complex and goal-directed behavior.

While Green (1998), among others, suggested that the mechanisms for resolving language interference rely on domain-general EC, there is considerable disagreement about the nature of bilingual language control. Another proposal is that bilingual language control relies on functions that are specific to the language domain. One line of research attempts to clarify this by looking for associations between tasks that rely on language control and domain-general EC. The findings of these behavioral studies are mixed. Some find that performance in the two domains correlates (Declerck, Grainger, Koch & Philipp, 2017; Prior & Gollan, 2011), suggesting overlap; while other evidence suggests that the overlap is only partial (Branzi, Calabria, Boscarino & Costa, 2016; Calabria, Branzi, Marne, Hernández & Costa, 2015; Calabria, Hernández, Branzi & Costa, 2012; Klecha, 2013). Secondly, evidence from neuroimaging research indicates that domain-general EC and language control share neural circuits (e.g., De Baene, Duyck, Brass & Carreiras, 2015; De Bruin, Roelofs, Dijkstra & FitzPatrick, 2014). A third approach is to investigate how bilingual language control demands in everyday life affect EC. For example, language switching experience has been found to predict non-linguistic switching performance (Barbu, Orban, Gillet & Poncelet, 2018; Prior & Gollan, 2011; Soveri, Rodriguez-Fornells & Laine, 2011; Verreyt, Woumans, Vandelanotte, Szmalec & Duyck, 2016).

The third approach is closely related to another lively debate in the bilingualism literature: the hypothesis that bilinguals exhibit enhanced EC due to a lifelong practice with managing two languages. Since the first article reporting evidence for improved performance on a non-linguistic inhibition task (Bialystok, Craik, Klein & Viswanathan, 2004), dozens of studies have been published on this topic, but the results are often inconsistent. Review articles and meta-analyses come to varying conclusions: from full support for an advantage (Adesope, Lavin, Thompson & Ungerleider, 2010), to partial support (Hilchey & Klein, 2011; Van den Noort, Struys, Bosch, Jaswetz, Perriard, Yeo, Barisch, Vermeire, Lee & Lim, 2019), to reviews concluding that there is no convincing evidence for an advantage (De Bruin, Treccani & Della Sala, 2015; Donnelly, 2016; Lehtonen, Soveri, Laine, Järvenpää, de Bruin & Antfolk, 2018; Paap, Johnson & Sawi, 2015). In other words, the status of the bilingual advantage hypothesis remains unclear to date.

Despite the inconclusive evidence, it could be argued that enhanced EC is especially beneficial for PWA. From monolingual populations with aphasia (mPWA) it is already known that they often experience deficits in EC (e.g., Christensen, Wright & Ratiu, 2018; Fridriksson, Nettles, Davis, Morrow & Montgomery, 2006; Hunting-Pompon, McNeil, Spencer & Kendall, 2015; Kuzmina & Weekes, 2017; Murray, 2012; Olsson, Arvidsson & Johansson, 2019). The prevalence of such impairments has led some researchers to suggest that aphasia reflects non-linguistic attentional impairments that negatively impact language processing (Hula & McNeil, 2008; McNeil & Pratt, 2001) and that EC can — at least in part — explain the inter- and intra-subject variation that is frequently observed in aphasia (Kolk, 2007).

Impairment in EC may lead to more severe aphasia symptoms because it prevents PWA from COMPENSATING for linguistic difficulties, which involves continuously recruiting relatively spared verbal and non-verbal communication skills. Therefore, EC has been shown to be important for functional communicative abilities and recovery of linguistic skills after stroke (Fridriksson et al., 2006; Olsson et al., 2019; Ramsberger, 2005). Moreover, evidence from neuroimaging research indicates that activation of brain regions responsible for domain-general EC correlates with recovery and language performance of mPWA (Brownsett, Warren, Geranmayeh, Woodhead, Leech & Wise, 2014).

Research discussed thus far evidently reveals open questions. We know that mPWA often suffer from non-linguistic EC impairments. For bPWA, these impairments could be particularly noticeable if they rely on these functions to manage their two languages effectively. In the literature on neurologically healthy bilinguals, two prominent debates concern the domain generality of bilingual language control and the bilingual advantage hypothesis. Because there is an increasing bilingual population with aphasia and an apparent link between aphasic symptoms and EC, it is worthwhile to investigate these issues in bPWA. In addition, advantages for bilinguals with aphasia could be particularly beneficial, as they may contribute to cognitive reserve and offer a protective effect (e.g., Craik, Bialystok & Freedman, 2010). Various researchers have started to pursue this line of research in the past decade, but findings are not always clear-cut.

In the present article, we synthesize the research published on this topic thus far. We first address the question whether non-linguistic EC deficits have been observed in bPWA. Secondly, we review the literature on domain generality of language control by investigating associations between impairments in bilingual language control and EC. Finally, we evaluate the evidence for bilingual advantages in EC for individuals with aphasia.

2. Methods

2.1 Literature search

Various bibliographic databases were searched: MLA International Bibliography, Linguistics and Language Behavior Abstracts, PubMed, CINAHL, Embase, MEDLINE, PsycINFO, ERIC, Web of Science. Construct- (EXECUTIVE CONTROL) and population-related (APHASIA and BILINGUALISM) search terms were used, which are presented in Appendix A. We included studies published between each database's coverage start date and March 2020. We inspected the *Aphasiology archives* separately for conference proceedings of the Clinical Aphasiology Conference. Lastly, bibliographies of previous reviews and studies were examined.

2.2 Inclusion and exclusion criteria

We included studies that reported on EC measures in bi- or multilingual individuals with aphasia. Studies were selected if they

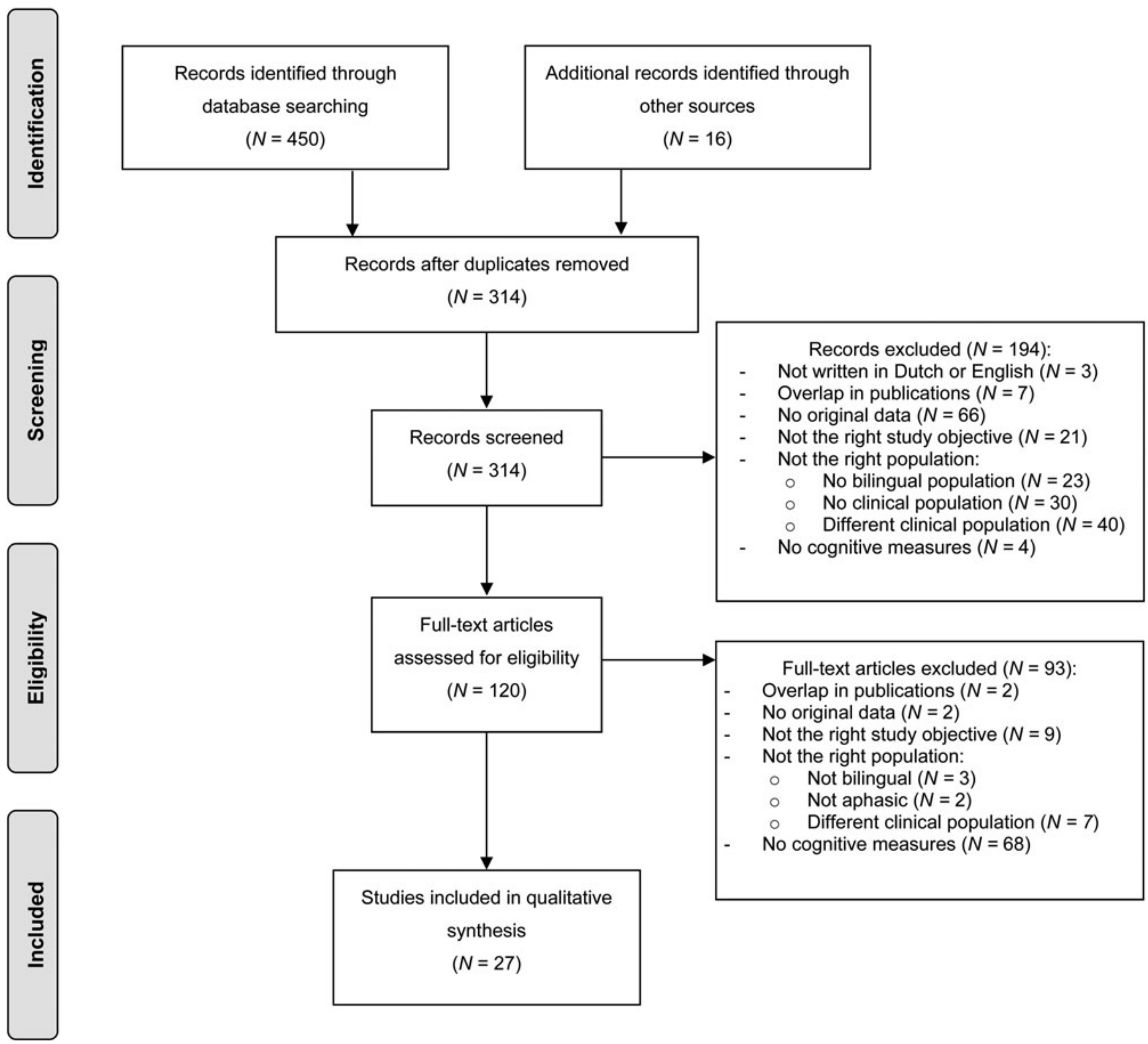

Figure 1. PRISMA flowchart of search process.

included participants who were adults (>18 years) with non-progressive aphasia due to acquired neurological damage of any etiology. Presence and severity of aphasia was determined using a standardized aphasia test or based on a clinician's evaluation. Participants had to be bi- or multilingual, but there were no specific restrictions regarding the type of bilingualism (such as AGE, MANNER OF ACQUISITION or PREMORBID PROFICIENCY). The studies had to be peer reviewed and include a measure of EC, either with standardized tests or compared to a matched control group of healthy participants. Finally, the article had to be written in English or Dutch. Studies were excluded if they failed to meet these criteria, if they did not include original data (e.g., meta-analyses, reviews), or if participants were duplicated in multiple studies.

2.3 Selection procedure

The literature search yielded 466 results in total. We checked the results and removed duplicates, resulting in 314 articles. The remaining papers were screened and assessed on eligibility based on their titles and abstracts. We retrieved the full text of the articles that were left in the final selection. There were 27 articles that met all requirements. The entire selection procedure is illustrated in a PRISMA-flowchart (Moher, Liberati, Tetzlaff, Altman & the PRISMA Group, 2009) given in Figure 1.

3. Results

3.1 Deficits in non-linguistic EC

All articles that included a comparison between bPWA and a healthy control group or that used standardized measures were suitable to evaluate whether EC impairments are observed in bPWA. Following Miyake et al. (2000a), we divided EC into INHIBITING, UPDATING, and SHIFTING, which have been shown to play a role in normal language performance (see Roelofs & Ferreira, 2019, for a review). The results for each study are presented in Table 1.

Table 1. Summary of studies reporting on non-linguistic EC impairments in bilingual aphasia. Abbreviations used in the table: TPO: time post-onset (acute: ≤2 weeks, subacute: ≤6 months, chronic: ≥6 months), AoA: Age of acquisition, TMT: Trail Making Test, WCST: Wisconsin Card Sorting Test.

Study	N	Lesion	Aphasia:TPO, severity	Bilingualism: languages, AoA, usage, proficiency	Inhibition	Updating	Shifting
Adrover-Roig et al. (2011)	1	Left basal ganglia	Chronic	Basque (L1) - Spanish (L2) Early, equal use, equal proficiency	Impairment (Stroop)	Impairment (digit span)	Impairment (TMT)
Aglioti et al. (1996)	1	Left basal ganglia	Chronic	Venetian (L1) - Italian (L2) L1 more frequent and proficient			No impairment (WCST)
Calabria et al. (2019)	11	Left hemisphere	Chronic Mild-moderate	Catalan – Spanish Early, equal use, equal proficiency	No impairment (flanker)		
Dash et al. (2020)	10	Left anterior regions	Chronic	French – English Varying AoA, usage and proficiency	Impairment (flanker)		
Dash & Kar (2014)	4	Left frontal/parietal	Chronic Mild/Moderate	Telugu, Hindi, Urdu (L1s) - English (L2) Varying AoA, usage and proficiency	Variable (flanker)		
Dekhtyar et al. (2020)	18	*Not specified*	Chronic	Spanish – English Highly proficient but English dominant	Impairment (triad task)		
Faroqi-Shah et al. (2018)	20	*Not specified*	Chronic Moderate	English (L1) – different L2s & Tamil (L1) – English (L2)	Impairment (manual Stroop)		
Gray & Kiran (2016)	10	Various	Chronic Varying severity	Spanish – English Varying AoA, usage and proficiency	No impairment (flanker)		
Gray & Kiran (2019)	13	*Not specified*	Chronic Mild-moderate/ Severe	Spanish - English Varying AoA, usage and proficiency	No impairment (flanker and triad task)		
Green et al. (2010)	2	Left subcortical/ parietal	Chronic	French/Spanish (L1s) - English (L2) Late, equal usage and proficiency	Both patterns (Stroop & flanker)		
Green et al. (2011)	1	Left temporo-parietal	Chronic	German-English-Spanish Early, equal usage and proficiency	No impairment (flanker), impairment (Stroop)		
Kambanaros et al. (2012)	1	Left parieto-occipital	Mild-moderate	Greek – English Early, L1 more frequent, varying proficiency	Impairment (Stroop)		
Keane & Kiran (2015)	1	Left frontal due to tumor	Chronic Moderate-severe	Amharic (L1) - English (L2) - French (L3) Early, L2 more frequent, equal proficiency	Impairment (flanker)		
Kohnert et al. (2004)	1	Left middle cerebral artery	Chronic Severe	Spanish (L1) - English (L2) Late, equal usage and proficiency			Impairment (WCST)
Kong et al. (2014)	1	Left frontal and temporoparietal	Severe	Cantonese (L1) - English (L2) - Mandarin (L3) Late, equal usage and proficiency	Impairment (Stroop)		Impairment (WCST)
Lee et al. (2016)	1	Right basal ganglia	Subacute Severe	Korean (L1) - Japanese (L2) Late, equal usage and proficiency		Impairment (digit span)	Impairment (TMT, WCST)
Leemann et al. (2007)	1	Left insula, upper temporal, frontal operculum	Subacute Severe	French (L1)-German (L2) Late, L2 not frequent, nor proficient		Impairment (not specified which test)	
Mariën et al. (2017)	1	Right cerebellum	Subacute Mild	English (L1), French (L2), German (L3), Slovene (L4), Serbo-Croat (L5), Hebrew (L6), and Dutch	Impairment (Stroop)		No impairment (WCST)

				(L7). Late, variable proficiency and usage			
Marini et al. (2016)	1	Whole left hemisphere affected	Chronic Severe	Romanian (L1) - Italian (L2) Early, equal usage and proficiency	Impairment (Tower of London)		Impairment (TMT)
Penn et al. (2010)	2	Left fronto-parietal, left temporo-parietal	Chronic Moderate	English (L1)-Afrikaans (L2) & Multilingual	No impairment (Stroop, Tower of London)	No impairment (self-ordered pointing)	No impairment (TMT - ratio B-A, WCST)
Penn et al. (2017)	10	Various	Subacute Severe	English (L2 or L3), various first languages	Impairment (Stroop)	Impairment (N-back)	Impairment (WCST)
Van der Linden et al. (2018b)	7	Differential aphasia	Subacute Mild (L1) - Moderate (L2)	Dutch (L1)- French/English (L2s) Varying AoA, L1 more proficient	Impairment (flanker)		
	8	Parallel aphasia	Subacute Mild	Dutch (L1)- French/English (L2s) Varying AoA, L1 more proficient	No impairment (flanker)		
Van der Linden et al. (2018a)	1	Left subcortical parietal	Chronic Severe	French (L1) -English (L2) Late, L2 more frequent, equal proficiency	Impairment (flanker)		
Verreyt et al. (2013)	1	Subcortical thalamic	Subacute	French (L1)-Dutch (L2) Early, equal usage and proficiency	Impairment (flanker)		

Inhibiting

INHIBITION turned out to be the most-often researched EC component in the included studies. Twenty studies investigated inhibition abilities in bPWA. Nine studies used the Stroop task (Stroop, 1935), in which a deficit is typically operationalized as the relative difference in reaction time (RT) or accuracy between congruent and incongruent conditions (e.g., say "red" to the red ink color of the word *red* or *green*, respectively). The Stroop task is taken to be a measure of PREPOTENT RESPONSE INHIBITION, a component of inhibition that involves the ability to suppress dominant or automatic responses (Friedman & Miyake, 2004; Miyake et al., 2000a; but see Roelofs, 2021; Shao, Roelofs, Martin & Meyer, 2015; Sikora & Roelofs, 2018, for evidence against this interpretation).

A large majority (37/39) of bPWA, reported on in eight studies, showed abnormally high interference in the Stroop task (Adrover-Roig, Galparsoro-Izagirre, Marcotte, Ferre, Wilson & Ansaldo, 2011; Faroqi-Shah, Sampson, Pranger & Baughman, 2018; Green, Grogan, Crinion, Ali, Sutton & Price, 2010; Green, Ruffle, Grogan, Ali, Ramsden, Schofield, Leff, Crinion & Price, 2011; Kambanaros, Messinis & Anyfantis, 2012; Kong, Abutalebi, Lam & Weekes, 2014; Mariën, van Dun, van Dormael, Vandenborre, Keulen, Manto, Verhoeven & Abutalebi, 2017; Penn, Barber & Fridjhon, 2017). Two bPWA, on the other hand, exhibited normal interference (Penn, Frankel, Watermeyer & Russell, 2010). Most studies report a case (series) design, except for Penn et al. (2017) and Faroqi-Shah et al. (2018), who conducted group studies. The results of the Stroop task indicate that most bPWA experience inhibition impairments. However, the linguistic nature of the task (i.e., naming and reading) complicates disentangling non-linguistic inhibition impairments from disordered language skills. In two studies, this validity issue is partially circumvented by administering an adapted version of the task, requiring a non-verbal response (Faroqi-Shah et al., 2018; Penn et al., 2017), but this does not reduce the reading demands. Moreover, the individuals who performed the adapted Stroop also showed impaired performance on this task.

The Eriksen flanker task (Eriksen & Eriksen, 1974) is another frequently used test. Here, participants manually respond to a visually presented target stimulus (e.g., >) while ignoring interference from flanked congruent (i.e., >>>>>) or incongruent (i.e., >><>>) non-target stimuli. This task is frequently used to assess RESISTANCE TO DISTRACTOR INTERFERENCE, a subcomponent of inhibition that involves the ability to resist or resolve interference from irrelevant information (Friedman & Miyake, 2004). Inhibition abilities in this task are operationalized as interference effects or ratios, which is the relative difference in RT or accuracy between incongruent and congruent conditions. A smaller difference typically points to more efficient conflict resolution. Therefore, impaired inhibitory control is generally defined as markedly larger conflict ratios. However, other authors have defined impaired inhibitory control as the absence of interference effects (Gray & Kiran, 2016, 2019).

bPWA also show impairments on the flanker task: 21 bPWA reported on in six studies experienced larger interference compared to healthy control participants (Dash, Masson-Trottier & Ansaldo, 2020; Green et al., 2010; Keane & Kiran, 2015; Van der Linden et al., 2018a, 2018b; Verreyt, De Letter, Hemelsoet, Santens & Duyck, 2013). However, a larger number of bPWA shows unimpaired performance on this task: 44 participants in six studies (Calabria, Grunden, Serra, García-Sánchez & Costa, 2019; Gray & Kiran, 2016, 2019; Green et al., 2010, 2011; Van der Linden et al., 2018b). The results of the putatively non-linguistic inhibition task thus show a more mixed pattern of impairments as compared to the Stroop task.

The results on the triad task, another test measuring resistance to distractor interference, were also found to be mixed. On this test, participants match stimuli on color or shape based on a cue while ignoring distractors. Eighteen bPWA showed impaired performance (Dekhtyar, Kiran & Gray, 2020), whereas 13 bPWA did not (Gray & Kiran, 2019). It is important to note, however, that impaired performance was operationalized differently in these studies. Dekhtyar et al. (2020) compared performance of the bPWA with a control group, whereas the presence of interference effects or ratios was indicative of unimpaired performance in Gray and Kiran (2019).

Four of the studies that did not find abnormal interference nevertheless found bPWA to be significantly slower and/or less accurate overall on tasks (Calabria et al., 2019; Gray & Kiran, 2016, 2019; Van der Linden et al., 2018b).[1] This shows that while the specific ability to resist interference from distractors may be intact, other cognitive abilities necessary to perform the task, such as processing speed or sustained attention, may be below normal performance.

Finally, the studies discussed above included bPWA who varied in their time post-onset and this may inform us about the transiency of inhibition impairments. The acute phase of recovery typically lasts two weeks, the subacute stage six months, followed by the chronic stage (Kiran, 2012). Three out of four studies that reported on inhibition in the SUBACUTE PHASE found abnormal scores (Mariën et al., 2017; Penn et al., 2017; Verreyt et al., 2013) and one study reported differences between bPWA with parallel and selective impairments (Van der Linden et al., 2018b). In the subacute phase, spontaneous and guided recovery is still expected, and these impairments may therefore resolve over time. Notably, one study that conducted a comparison between six- and twelve-weeks post onset found that inhibiting impairments persisted (Penn et al., 2017). Moreover, the remaining studies investigated bPWA with CHRONIC APHASIA and frequently observed inhibiting deficits, indicating that these impairments persist.

When we focus on inhibiting abilities, we can conclude that the majority of bPWA show impairments when measured with the Stroop task. On flanker and triad tasks, the majority of bPWA shows unimpaired inhibition abilities. These contradictory findings could be due to the difference in the linguistic demands of each task, or to the type of inhibition that was measured.

Updating

Four studies investigated UPDATING abilities in bPWA. Penn et al. (2010) found the performance of two chronic bPWA on a self-ordered pointing task to be within the normal range. In this task, stimuli are arranged differently across trials, and participants point to a different item in each trial (Petrides & Milner, 1982). Conversely, three studies found updating to be impaired in 12 bPWA. Adrover-Roig et al. (2011) and Lee et al. (2016) describe case studies in which patients showed impaired performance on backward digit and/or visual span tasks, in which stimuli must be recalled in reverse order. In a group study ($N = 10$), Penn et al. (2017) found that bPWA were impaired on a non-linguistic N-back task, in which pictures are presented successively and participants manually indicate whether a new stimulus is the same as the one N back. At first sight, the majority (12/14) of bPWA appear to have impairments in updating ability.

This observation, however, needs to be nuanced when we consider time post-onset. Most (11/12) bPWA with impaired updating ability were in the subacute phase of recovery (Lee et al., 2016; Penn et al., 2017). Results by Penn et al. (2017) show that updating improved over time, though significant differences with control participants remained at 12 weeks post-onset. Therefore, as updating appears to be susceptible to improvement, we cannot rule out the possibility that updating impairments will recover toward the chronic phase of recovery.

Besides time post-onset, the operationalization of updating should call for cautious interpretation of the results. Firstly, backward span tasks tap a broader working memory capacity than the more specific updating ability (Diamond, 2013). Still, latent-variable analyses have shown that working memory maintenance and updating appear to rely on similar underlying constructs (Schmiedek, Hildebrandt, Lövdén, Wilhelm & Lindenberger, 2009; Waris, Soveri, Ahti, Hoffing, Ventus, Jaeggi, Seitz & Laine, 2017) and performances on the N-back and backward span tasks overlap considerably (Byrne, Gilbert, Kievit & Holmes, 2019). Secondly, only the self-ordered pointing and N-back task are non-linguistic in nature, as backward span tasks require some linguistic processing. Taking these considerations into account, updating impairments are observed in bPWA, though the results appear to be mixed.

Shifting

Finally, there were nine studies that investigated SHIFTING ability in bPWA. Six studies, including 15 participants, found it to be impaired (Adrover-Roig et al., 2011; Kohnert, 2004; Kong et al., 2014; Lee et al., 2016; Marini et al., 2016; Penn et al., 2017), and three studies, including four participants, report unimpaired shifting abilities (Aglioti, Beltramello, Girardi & Fabbro, 1996; Mariën et al., 2017; Penn et al., 2010).

Like the findings for updating, most (11/15) of the bPWA with impaired switching ability were in the subacute phase of recovery, compared to one out of four bPWA with unimpaired shifting abilities. Again, Penn et al.'s (2017) study showed that shifting improves during recovery, indicating that shifting impairments may diminish over time.

It is important to consider the tasks that were used to measure shifting ability. The studies reported here administered the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948) and the Trail Making Test (TMT; Army Individual Test Battery, 1944). Only the WCST can be characterized as a non-linguistic task, as the TMT requires sequencing of letters and therefore relies on linguistic knowledge. When we eliminate the linguistic demands and only focus on the outcomes of the WCST, the majority (13/17) of bPWA are still found to be impaired.

Besides linguistic demands, both tasks require complex cognitive processing. Although shifting is an essential component of performance on the WCST (Miyake et al., 2000a), it is a multifactorial task that also requires other functions such as conceptual ability, problem solving, and attentional processing (Greve, Love, Sherwin, Mathias, Ramzinski & Levy, 2002; O'Donnell, Macgregor, Dabrowski, Oestreicher & Romero, 1994). The TMT is not only a measure of shifting ability, but also relies on visuo-perceptual abilities and working memory (Sánchez-Cubillo,

[1]For Gray and Kiran (2016, 2019), this claim is based on our calculation of *t*-scores and *p*-values based on the means, standard deviations, and samples sizes reported in these articles.

Periáñez, Adrover-Roig, Rodríguez-Sánchez, Rios-Lago, Tirapu & Barceló, 2009). As with the other EC components, operationalization of the constructs is challenging but crucial for the right interpretation of results. In conclusion, the literature suggests that most bPWA experience shifting problems.

3.2 Domain generality of bilingual language control impairments

This section of our review is about the nature of bilingual language control in PWA. If bilingual language control impairments are consistently paired with EC impairments, this may have implications for recovery because the integrity of EC is crucial for aphasia recovery and treatment (Olsson et al., 2019; Simic, Bitan, Turner, Chambers, Goldberg, Leonard & Rochon, 2020). Similarly, if language control relies on domain-general EC, training of the latter could lead to improvements in language (Kiran & Gray, 2018). Another reason to investigate domain generality in bPWA is that the selectivity of their impairments can inform us about associations and dissociations between cognitive functions (Calabria, Costa, Green & Abutalebi, 2018).

In what follows, we first examine studies that adopted an experimental design to compare EC and language control abilities. Next, we discuss studies that report problems with bilingual language control in functional communication, demonstrated by selective recovery or pathological switching and mixing of the two languages.

Domain generality: evidence from experiments

Nine studies directly investigated the relationship between EC and bilingual language control in controlled experiments (Table 2). The majority of studies focused on RECEPTIVE language control abilities measured with lexical decision tasks (Green et al., 2010, 2011; Van der Linden et al., 2018a, 2018b; Verreyt et al., 2013), semantic judgment tasks (Gray & Kiran, 2016, 2019), or a linguistic version of the flanker task (Dash & Kar, 2014; Gray & Kiran, 2019). One study measured EXPRESSIVE language control abilities using language switching tasks or picture naming tasks (Calabria et al., 2019). The Stroop task, used by Green et al. (2010, 2011), is a peculiar case, as it requires receptive language abilities (i.e., reading), expressive language abilities (i.e., naming colors), but only limited lexical or semantic knowledge.

The first study to explicitly investigate the overlap between language control and EC was conducted by Green et al. (2010). Two bPWA performed verbal lexical decision (LD), the Stroop task, and a non-linguistic flanker task. Their results indicated that, despite their parallel recovery pattern, both bPWA had problems managing interference. However, one participant's impairments were limited to the verbal domain, whereas the other participant demonstrated an association between linguistic and non-linguistic control impairments. Green and colleagues argue that overlap between the two processes can be explained by the localization of lesions. The first bPWA had left subcortical damage, which according to Green et al. (2010) is consistent with domain-specific language control problems. The other participant had extensive left parietal damage, explaining the domain-general control problems.

Subsequent studies also reported dissociations between language control and EC. Green et al. (2011) report on a case of a trilingual individual with parallel recovery of three languages. The PWA showed impaired LD and Stroop performance, but performed within normal limits on the flanker task, demonstrating that her language control difficulties were dissociable from non-linguistic control issues. Gray and Kiran (2016) made a similar observation in one of the few group studies that have been conducted ($N = 10$). They administered a semantic relatedness judgment task, measuring bilingual language control, and a flanker task. On the non-linguistic task, both the bPWA group and the control group showed interference effects. On the linguistic control task, though, the control group showed significant interference ratios whereas the bPWA group did not. According to the authors, these dissociations are indicative of a domain-specific impairment in bilingual language control.

Dash and Kar (2014) investigated four bPWA in a case series design. They relied on Braver's (2012) dual-mechanisms framework, in which variability in functions is explained in terms of the temporal dynamics of control. Braver distinguishes PROACTIVE CONTROL, measuring resistance to interference that is expected, and REACTIVE CONTROL, measuring resistance to interference after it has occurred. These were tested by looking at slow and fast trials, respectively. Dash and Kar used a non-linguistic negative priming task, and a linguistic (i.e., with letters instead of arrows) and non-linguistic version of the flanker task. RT analyses revealed that bPWA were impaired in proactive control and primarily used reactive control on the negative priming task. The participants showed effective control mechanisms on the non-linguistic flanker task. For the linguistic version, however, results were more variable both between participants, and within participants between languages. This variability not only demonstrates the inter-subject variance, but Dash and Kar argue that it also stresses the difference between language control and EC mechanisms. These findings are at odds with the results of another research group (Van der Linden et al., 2018a, 2018b; Verreyt et al., 2013). The latter compared bPWA's performance on flanker and LD tasks, and found that performances in both domains were associated.

Associations in impairments, however, may not be required to conclude that bilingual language control and executive control rely on the same underlying mechanism. Although the bPWA ($N = 11$) in a study by Calabria et al. (2019) did not exhibit deviant interference ratios on inhibitory control tasks, their performance on these tasks was significantly correlated with linguistic control (see Gray, 2020, for converging evidence). Due to small sample sizes, however, findings of correlational analyses should be interpreted with caution.

A final issue we address here is TASK COMPLEXITY as a potentially modulating factor for domain generality of language control. Gray and Kiran (2019) investigated this in a group of bPWA ($N = 13$) by contrasting relatively easy linguistic and non-linguistic flanker tasks with more complex linguistic and non-linguistic triad tasks. They found that bPWA and the control group scored similarly on easier tasks but performed differently on more complex tasks. On the non-linguistic triad task, both groups showed interference, but on the linguistic triad only the control group did. Furthermore, the control group showed significant interference ratios for all tasks, whereas the bPWA showed significant ratios only for the non-linguistic tasks. Consequently, Gray and Kiran propose that bPWA have selective impairments on complex tasks that require participants to manage and process more information simultaneously. This claim was supported by correlational analyses. However, it is important to note that on the linguistic flanker task, neither the control group nor the bPWA showed interference effects, complicating the interpretation of these results.

Table 2. Summary of studies reporting bilingual language control and EC measures. Abbreviations used in the table: TPO: time post-onset (acute: ≤2 weeks, subacute: ≤6 months, chronic: ≥6 months), BLC: bilingual language control.

Study	N	Lesion	TPO	Bilingualism	BLC	EC	Conclusion
Calabria et al. (2019)	11	Left hemisphere	Chronic	Catalan - Spanish, early bilinguals and highly proficient. Parallel impairment.	Impairments in non-dominant language (semantically blocked cyclic naming, bilingual word-picture matching)	No impairment (flanker), but slower	Evidence for partial overlap
Dash & Kar (2014)	4	Left frontal/ parietal	Chronic	Telugu, Hindi, Urdu (L1) - English (L2). Dominance comparable premorbidly. Parallel impairment	Two bPWA impaired for L1, one for L2, one unimpaired (linguistic flanker)	Variable: slower, but intact conflict cost (flanker and negative priming)	Varying patterns highlight dissociations
Gray & Kiran (2016)	10	Various	Chronic	Spanish - English, varying in dominance and proficiency. Parallel impairment.	Impairment (semantic relatedness judgment)	No impairment (flanker)	Dissociation between BLC and EC indicative of domain-specific BLC
Gray & Kiran (2019)	13	*Not specified*	Chronic	Spanish - English, varying in dominance and proficiency. Mostly parallel impairment.	Impairment (linguistic flanker and triad task)	No impairment (flanker) and impairment (triad task)	For complex tasks bPWA show selective impairment in BLC
Green et al. (2010)	2	Left subcortical / parietal	Chronic	French/Spanish (L1s) - English (L2), late learner, highly proficient. Parallel impairment.	Impairment (lexical decision), mixed results (Stroop)	Opposite results (flanker)	Overlap between EC and BLC depending on localization of lesion
Green et al. (2011)	1	Left temporo-parietal	Chronic	German-English-Spanish, early L2, highly proficient. Parallel impairment.	Impairment (lexical decision and Stroop)	No impairment (flanker)	Domain-specific problems with BLC
Van der Linden et al. (2018b)	15	Various	Subacute	Dutch (L1)- French/English (L2s), highly proficient though not completely balanced. Differential and parallel impairment.	No impairment (generalized and selective lexical decision)	Impairment for differential bPWA, no impairment for parallel bPWA (flanker)	Preserved cross-language interactivity, but impaired EC for bPWA with differential recovery
Van der Linden et al. (2018a)	1	Left subcortical parietal	Chronic	French (L1) -English (L2), late learner but highly proficient. Differential impairment.	Impairment for high-control setting (generalized and selective lexical decision)	Impairment (flanker)	BLC and EC are at least closely related
Verreyt et al. (2013)	1	Subcortical (thalamic)	Subacute	French (L1)-Dutch (L2), early acquisition, equal usage and proficiency. Differential impairment.	Impairment for high-control setting (generalized and selective lexical decision)	Impairment (flanker)	Deficit in EC may underlie differential language impairment

Nonetheless, task complexity appears to be an important factor to consider when investigating control abilities.

Our review of the experimental studies on the nature of bilingual language control reveals mixed findings. Several studies report dissociations between bilingual language control and EC impairments, suggesting that problems experienced by bPWA are restricted to language control (Dash & Kar, 2014; Gray & Kiran, 2016, 2019; Green et al., 2011). Other studies report overlap (Van der Linden et al., 2018a, 2018b; Verreyt et al., 2013), although differing regarding the extent of the overlap (Calabria et al., 2019; Green et al., 2010).

Domain generality: evidence from functional communication

Problems with bilingual language control can lead to symptoms such as translation difficulties or involuntary language switching, and differential recovery of languages. A frontal-basal ganglia connection, the ANTERIOR CONTROL LOOP, has been identified as a crucial circuitry for language control (Abutalebi & Green, 2007; Green & Abutalebi, 2008). It has been argued that language control impairments cause selective recovery patterns through inhibitory mechanisms (Green, 1986; Green & Abutalebi, 2008; Paradis, 1998). Languages can be inhibited to a similar degree (parallel recovery), one language can be inhibited more strongly (selective recovery), or inhibition can shift from one language to the other (antagonistic recovery). When inhibition cannot be selectively applied, this results in involuntary language switching and mixing. The question we address here is whether non-linguistic EC impairments are observed when bPWA show deviant recovery patterns or language control impairments in functional communication.

First, some studies report differential recovery of the L1 or the L2. Four studies report cases showing better recovery of the L2 (Adrover-Roig et al., 2011; Aglioti et al., 1996; Lee et al., 2016; Van der Linden et al., 2018a). Aglioti et al. (1996) report on a case of bilingual subcortical aphasia in which the participant's L2 was better preserved than her L1. In addition, translation abilities from L2 to L1 were worse than vice versa. This pattern is unexpected considering that premorbidly the L1 was used more frequently and proficiently. Aglioti et al. propose that a lesion in the left basal ganglia, a brain region also crucial for implicit memory systems, mainly impacts the L1. The L2, typically relying more heavily on explicit memory systems, is therefore better preserved. However, the bPWA's performance on EC tasks (updating and shifting) were within normal range, leading the authors to suggest that the impairment is predominantly linguistic.

Other studies describe, however, that differential recovery patterns co-occur with EC problems. Adrover-Roig et al. (2011) report on a case with damage to the left basal ganglia showing worse L1 production compared to the L2 and translation difficulties from L2 to L1, despite being equally proficient in both language premorbidly. The bPWA also experienced problems on the TMT, showing that the language control problems were part of a wider ranging impairment. Likewise, Van der Linden et al. (2018a) argue that their participant with subcortical damage shows differential recovery of the L2 due to a domain-general impairment, illustrated by deviant flanker task performance. Finally, Lee et al. (2016) describe differential impairment of the L1 in a case of crossed aphasia that resulted from subcortical damage to the right basal ganglia, which was accompanied by problems with EC. All four studies report selective recovery of the L2 following damage to subcortical areas. While Aglioti et al. (1996) did not find evidence for accompanying EC deficits, the other studies report that the participants in their studies experienced problems with EC.

Evidence for a more direct relationship between EC deficits and selective recovery of one language is provided by Verreyt et al. (2013) and corroborated by the group comparison of Van der Linden et al. (2018b). They investigated bPWA's language control and EC abilities and found that bPWA with differential recovery of their languages tentatively showed more difficulties with both linguistic control and inhibitory control, compared to bPWA with parallel recovery. Therefore, the authors conclude that a deficit in EC may underlie selective recovery of one language. The importance of the control network in recovery of two languages is confirmed by findings from an fMRI experiment (Radman, Mouthon, Di Pietro, Gaytanidis, Leemann, Abutalebi & Annoni, 2016). They found that although improvements in language control functions alone were not sufficient to fully explain recovery patterns, the involvement of the control network in recovery was nevertheless essential.

Problems with bilingual language control can also lead to pathological mixing and switching. This has been reported in several studies, and more recent case studies allow us to investigate the relationship with EC. In one case, Leemann, Laganaro, Schwitter and Schnider (2007) observed involuntary switching to the L2, which had never been fluent nor used after late acquisition in school. The authors suggest that this switching pattern is due to reliance on explicit memory systems used for L2 processing. Kong et al. (2014) report on a highly proficient trilingual with damage to frontal regions who showed involuntary switching across three languages. Lastly, Mariën et al. (2017) describe a multilingual PWA who involuntarily switched between languages when speaking in one of his several second languages, but not in his L1. This patient suffered a cerebellar stroke, and the authors hypothesize that this damage led to functional disruption of the dorsolateral prefrontal areas, causing control impairments. Importantly, these three cases showed co-occurring deficits in non-linguistic EC, indicating a connection between impaired language control and EC.

Two treatment studies provide additional evidence for this connection. Firstly, Kohnert (2004) conducted a cognitive and cognate-based treatment study in which a bPWA showed modest improvement on various language tests, after receiving training on a range of non-linguistic cognitive functions, including shifting and inhibiting. The transfer effect from the non-linguistic cognitive domain to the language domain is interpreted as indirect evidence for overlap between functions. Secondly, Keane and Kiran (2015) performed a semantic treatment study that further informs us on this relationship. The chronic trilingual PWA experienced lexical deficits that manifested as pathological switching during naming and, importantly, showed problems with EC. The individual received semantic treatment to improve naming deficits, which did not lead to cross-language generalization but instead resulted in an increase of cross-language intrusions from the treated language. Keane and Kiran argue that these are an effect of a failure to inhibit the non-target language and result from impairments in domain-general control mechanisms, which is supported by the finding that this PWA had EC impairments.

In summary, a convincing majority of studies that report differential recovery profiles or involuntary language mixing or switching find co-occurring deficits in EC (except Aglioti et al., 1996), indicative of domain-general control issues. Another prominent finding is that many of the individuals who show this behavior suffer from lesions in subcortical or frontal areas of the brain, parts of the anterior control loop (Abutalebi & Green, 2007; Green & Abutalebi, 2008). Lastly, transfer effects of EC training to language performance and lack of cross-linguistic generalization due to inhibition impairments also point to overlapping control domains.

3.3 Bilingual advantage for populations with aphasia

Research with healthy bilinguals suggests that their lifelong practice managing their languages may have favorable consequences for non-linguistic EC (e.g., Adesope et al., 2010; Bialystok & Martin, 2004). However, not all studies have replicated these results (e.g., Paap et al., 2015, 2017), leaving the status of the cognitive consequences of bilingualism uncertain. Here, we report on the studies that investigated whether bPWA experience EC advantages relative to mPWA. Therefore, only studies that included mPWA as a control group were reviewed.

Penn et al. (2010) were the first to conduct a study on the bilingual advantage for individuals with aphasia. EC abilities were measured with a test battery that included inhibition, updating, and shifting tasks. They compared two bPWA with eight mPWA. Penn et al. found that the bilinguals in their experiment had significantly better-preserved EC abilities and showed better conversation skills. While this is an important starting point for further enquiries, these findings should be regarded as preliminary due to the small sample size.

Perhaps more compelling evidence for a bilingual advantage in persons with neurological damage was provided by Alladi, Bak, Mekala, Rajan, Chaudhuri, Mioshi, Krovvidi, Surampudi, Duggirala and Kaul (2016). They evaluated the protective effect of bilingualism for cognitive outcome after stroke by examining data of over 600 patients from a stroke registry. They found that the incidence of aphasia was similar for mono- and bilinguals (12% versus 11%). However, bilinguals showed unimpaired performance on cognitive measures more often than monolinguals (41% versus 20%). The authors measured cognitive performance with the Addenbrooke's Cognitive Examination revised (ACE-R; Mioshi, Dawson, Mitchell, Arnold & Hodges, 2006). It is important to note that both the memory and attention tests of the ACE-R rely on verbal abilities (word repetition and recall, serial subtraction), which complicates separating non-linguistic cognitive abilities from language capacities. Alladi et al.'s results demonstrate that the protective effect of bilingualism for stroke survivors lies in the non-linguistic cognitive abilities rather than the linguistic domain.

If bPWA have benefits in the non-linguistic domain, their aphasic symptoms could be less severe when compared to mPWA. A recent study has demonstrated this pattern in a large group ($N = 68$) of bilingual and monolingual PWA (Paplikar, Mekala, Bak, Dharamkar, Alladi & Kaul, 2018), who were at least three months post stroke. The bPWA showed significantly better performance on language, attention, memory, and visuospatial subtests of the ACE-R. The authors conclude that bilingualism does not reduce the likelihood of developing aphasia after acquired neurological damage but can reduce impairment symptoms through enhanced EC. Strengthened EC may facilitate compensation for aphasic deficits. Paplikar et al.'s results point to the need to examine this relationship more systematically.

Faroqi-Shah et al. (2018) carried out an experimental investigation into the relationship between word retrieval and EC. They compared mPWA ($N = 18$) with two groups of bPWA ($N = 10$ in each group). One bilingual group was English dominant and had various L2s, the other bilingual group spoke Tamil as L1 and English as L2. Each group was matched for age and education level with healthy control groups. Their study showed a bilingual advantage in interference ratios on the Stroop task for the control groups and the English-dominant bPWA, but not the Tamil-English bPWA. The authors give two explanations for this difference. First, it could be due to opposing proficiency patterns for reading (necessary for the Stroop task) and speaking (necessary for word retrieval tasks). Tamil-English bilinguals may have stronger reading proficiency in their L2 and stronger speaking proficiency in their L1. The English-dominant bilinguals did not have such a potential confound. Second, the authors suggest that in Tamil-English bPWA, the EC advantage does not surpass the EC impairments following aphasia. To conclude, Faroqi-Shah et al.'s (2018) results show the importance of cross-linguistic replications but are inconclusive about the bilingual advantages for PWA.

Recently, two articles were published in which bilingual advantages were investigated with a similar approach. Dekhtyar et al. (2020) assessed inhibitory control abilities with a triad task in monolingual and bilingual groups with and without aphasia. The groups were matched on demographic variables, language abilities, and non-linguistic EC measured with a composite score of the Cognitive Linguistic Quick Test (CLQT; Helm-Estabrooks, 2001). The bPWA ($N = 18$) in their study showed significantly shorter RTs on incongruent trials of the triad task, compared to mPWA ($N = 18$). Such a difference was absent on congruent trials. Interestingly, bilingual advantages on the inhibitory control task were also absent in the healthy control group. Dekhtyar et al. (2020) suggest that bilingualism may contribute to cognitive reserve in bPWA, whereas its advantages do not surface in healthy individuals. Finally, the authors found that shorter RTs were not correlated with language or executive function scores, suggesting that cognitive advantages are subtle and may not be picked up by standardized diagnostic tests.

Other attentional mechanisms, in addition to EC, were investigated by Dash et al. (2020). They used the Attention Network Task (ANT; Fan, McCandliss, Sommer, Raz & Posner, 2002), an adaptation to the flanker task designed to disentangle alerting, orienting, and EC (i.e., resistance to interference) mechanisms of attention (Posner, 2011; Posner & Raichle, 1994) by providing warning cues for alerting or location cues for orienting. In addition to the analysis of the difference scores, Dash et al. examined the RT distributions with an ex-Gaussian analysis. While the group analysis did not reveal statistically significant differences in mean RT between the bPWA and mPWA groups ($N = 10$ and $N = 7$), a comparison based on the RT distribution revealed significant differences for ALERTING. For the Gaussian part of the distribution (faster responses, automatic processing) bilinguals outperformed monolinguals, whereas the opposite pattern was observed for the exponential part (slower responses, controlled processing). The authors interpret this as evidence that for bPWA, alerting is more automatized, whereas mPWA are more helped by the alerting cue in controlled processing. Furthermore, Dash and colleagues found significant correlations between language scores and EC abilities for bPWA, while this correlation was absent in the monolingual group. bPWA experienced no clear benefits on the other attentional mechanisms.

When we recapitulate the findings of a bilingual advantage for populations with aphasia, all studies published thus far seem to point in the direction of confirmation of the bilingual advantage hypothesis. Nonetheless, there are also some caveats. Some report on small sample sizes (Penn et al., 2010), others included rather coarse measures of linguistic and cognitive abilities (Alladi et al., 2016; Paplikar et al., 2018), and in other cleverly designed group studies researchers have observed contradicting findings (Dash et al., 2020; Faroqi-Shah et al., 2018).

4. Discussion

In our review of the literature, it appeared that, at first glance, a majority of bPWA shows impaired performance on inhibition tasks. However, some of these tasks partially rely on language processing, and when we only focused on studies that reported on an exclusively non-linguistic task, this pattern was weaker or absent. Studies on mPWA have also observed discrepancies between linguistic and non-linguistic EC, as the latter appears to be intact more often than the former (Christensen et al., 2018; Kuzmina & Weekes, 2017). Updating abilities, much less researched in this population, varied considerably between studies. Shifting impairments were found in most bPWA; but here too, the employed tasks are likely to recruit other cognitive functions, including language. We can conclude that, despite the variability, bPWA often suffer from deficits outside the linguistic domain. This is in accordance with the literature on mPWA, in which EC impairments are frequently observed (Murray, 2012; Olsson et al., 2019; Purdy, 2002).

Aphasia characteristics can partly explain the observed variability. Based on the available data on time post-onset, we found that inhibiting deficits are likely to persist, while most evidence for updating and shifting impairments was found in bPWA in the subacute phase. Aphasia severity may impact performance on EC tasks that rely more heavily on language processing. In addition, persons with more severe aphasia may have suffered larger lesions and may therefore experience more extensive cognitive deficits. Evaluating the influence of aphasia severity proved to be difficult, as this is operationalized differently across studies. But at first sight, it appears that all studies that included patients with (moderate to) severe aphasia also report deficits in EC (Keane & Kiran, 2015; Kohnert, 2004; Kong et al., 2014; Lee et al., 2016; Leemann et al., 2007; Marini et al., 2016; Penn et al., 2017; Van der Linden et al., 2018a).

However, severity of aphasia alone is not enough to predict EC performance, as the EC results for bPWA with mild aphasia are more mixed. In addition, the studies that directly investigated the influence of aphasia severity on EC also report opposing results. Dash et al. (2020) found that bPWA experience less interference if they have higher language scores. Other studies did not find performance on inhibition tasks to correlate with the degree of language impairment (Calabria et al., 2019; Dekhtyar et al., 2020; Gray & Kiran, 2019). Gray and Kiran (2019) found that aphasia severity did not correlate with the interference ratios for flanker and triad tasks, but it correlated with processing speed in the flanker task. More research on the relationship between aphasia severity and EC is needed to elucidate this matter.

Next, we discussed evidence for and against domain generality of bilingual language control, the set of mechanisms responsible for managing more than one language. An increasing number of studies investigated this by comparing performance on experiments tapping language control to tasks measuring EC. Results were found to be mixed, as the number of studies concluding overlap, partial overlap, or dissociations was essentially equally distributed. Contradicting findings are also reported in the literature on healthy participants (e.g., Declerck et al., 2017; Prior & Gollan, 2011; Branzi et al., 2016).

The conflicting results for bPWA cannot resolve the debate about domain generality of bilingual language control. bPWA may experience linguistic control problems in absence of non-linguistic control problems, which could be interpreted as evidence for a domain-specific nature of control in bPWA (Gray & Kiran, 2016, 2019). However, Gray and Kiran also acknowledge that more research is needed to provide definite conclusions. In addition, the question arises whether a dissociation between linguistic control and EC is necessary to explain patterns of impairments, or whether a domain-general EC problem could explain both patterns, an issue also raised by Green et al. (2010). EC always interacts with another function: it "manages, integrates, regulates, coordinates, or supervises other cognitive processes" (Valian, 2015, p. 5). In this view, EC would interact with language in tasks measuring linguistic control. Aphasic impairments are most pronounced in the language domain and, therefore, tasks tapping linguistic control will be relatively harder for PWA than tasks requiring non-linguistic EC. Consequently, if bPWA have difficulties with linguistic control tasks, a domain-general EC impairment may underlie these problems even if the control issues may not surface outside the linguistic domain in less demanding tasks (cf. Spearman, 1927). This way, selective impairments in linguistic control could nonetheless be the result of a domain-general EC problem.

The variability in findings for domain generality of control impairments in bPWA leads us to suggest a partial dissociation between language control and non-linguistic EC in bPWA (Murray, 1999, 2012; Villard & Kiran, 2017). This is supported by correlational analyses in Calabria et al. (2019), who also advocate partial overlap. More recently, Gray (2020) found an association between bilingual language control and non-linguistic EC for bPWA, but not for healthy bilinguals. Gray (2020) argues that this association may be due to the increased cognitive load bPWA experience in order to process language. Increased demands in language processing for bPWA requires them to rely more heavily on non-linguistic EC.

A partial dissociation is in line with the view that relatively spared EC can facilitate compensation for language deficits of persons with aphasia. EC has been identified as an important mediator in compensating for linguistic deficits in monolingual PWA. For example, research into mPWA has found a relationship between functional communication abilities and EC (Fridriksson et al., 2006), especially for persons with severe aphasia (Olsson et al., 2019). In addition, Simic, Rochon, Greco and Martino (2019) carried out a systematic review and argue that baseline EC ability is a robust indicator of language therapy outcome, independently of time post-onset.

We suspect that similar mechanisms are at play in bilingual populations. In addition, better-preserved EC could increase flexibility, efficient inhibition of the non-intended language, or more effective switching between languages – and, this way, improve functional communication. For example, it has been shown that language mixing in aphasia is associated with lexical retrieval problems (Lerman, Pazuelo, Kizner, Borodkin & Goral, 2019), and that individuals with more severe aphasia codeswitch more often (Goral, Norvik & Jensen, 2019). Similarly, Muñoz et al. (1999) suggested that mixing is an (un)conscious strategy to access a lexical item and could be a compensatory approach.

Our review of the literature showed that language control problems in functional communication – most notably, selective impairments or involuntary language switching – are consistently paired with non-linguistic EC deficits (Adrover-Roig et al., 2011;

Kong et al., 2014; Lee et al., 2016; Leemann et al., 2007; Mariën et al., 2017; Van der Linden et al., 2018a, 2018b; Verreyt et al., 2013). In most cases, such impairments follow damage to subcortical areas, part of the anterior control loop (Abutalebi & Green, 2007; Green & Abutalebi, 2008). Involuntary language switching in absence of aphasic deficits has also been observed (Fabbro, Skrap & Aglioti, 2000). In this case, the bilingual speaker suffered a lesion in parts of the anterior control loop, which resulted in a defective language control system while the rest of the language network remained intact. This is indicative of dissociations between aphasia in absence of involuntary switching (impairments to language network), aphasia with instances of involuntary switching (impairments to language and control network), and involuntary switching in absence of aphasia (impairments to control network). Considering that there is much variance in the specific lesion locations of these cases, more research is needed to shed light on this issue. However, it appears that in bilingual aphasia, if involuntary language switching is observed, it is often paired with EC deficits.

In the final part of the review, we addressed the bilingual advantage hypothesis for bPWA. Only a few studies investigated this issue in populations with aphasia, but all provide indications for the existence of such an advantage for bPWA. Yet, it is important to consider potential methodological weaknesses such as small sample sizes. In addition, in the literature on neurologically healthy bilinguals, researchers have started to cast doubt upon the validity of the bilingual advantage hypothesis, as there is evidence for a publication bias (De Bruin et al., 2015), an issue to consider when reviewing the aphasiology literature too. While there is controversy surrounding the bilingual advantage hypothesis, there are reasons to assume that beneficial effects may be larger for bPWA. Age appears to be a modulating factor for the bilingual advantage (Van den Noort et al., 2019) and advantages are more consistently demonstrated in older (Bak, Vega-Mendoza & Sorace, 2014; Kavé, Eyal, Shorek & Cohen-Mansfield, 2008; Perquin, Vaillant, Schuller, Pastore, Dartigues, Lair & Diederich, 2013) and vulnerable populations (Alladi, Bak, Shailaja, Gollahalli, Rajan, Surampudi, Hornberger, Duggirala, Chaudhuri & Kaul, 2017; Woumans, Santens, Sieben, Versijpt, Stevens & Duyck, 2015). This is in line with Dekhtyar et al.'s (2020) results, who found evidence for a bilingual advantage in bPWA, but not in matched control participants.

Reviewing bilingual advantages for populations with aphasia revealed promising findings. But how is superior performance on EC tasks helpful in a bPWA's daily life? mPWA with better EC show enhanced functional communication, recovery, and generalization of skills taught in therapy (Fridriksson et al., 2006; Helm-Estabrooks, 2002; Olsson et al., 2019). If EC is enhanced in bilinguals, this compensatory mechanism is more effective in bPWA compared to mPWA and, as a result, could lead to better functional communication. The results of Penn et al. (2010) can be regarded as first evidence: they showed that bPWA performed better on EC tasks and exhibited better conversational skills than mPWA.

In summary, bPWA appear to experience benefits as a consequence of their bilingualism and these benefits may have a positive impact on improvement of their language performance. Importantly, that is not the whole story. Findings in neurologically healthy populations show that bilinguals may be disadvantaged in lexical retrieval abilities (Bialystok, 2009). Similarly, Hope, Jones, Grogan, Crinion, Rae, Ruffle, Leff, Seghier, Price and Green (2015) assessed how suitable post-stroke prognostic models are to predict language impairments in bPWA when these models are trained with monolingual data. They found that models tend to be over-optimistic; bilinguals had worse language skills than expected based on the model. Again, this stresses the importance of careful separation of linguistic and non-linguistic skills and warrants the need to further investigate the contributions of each of these in functional communication of bilinguals with aphasia.

Tackling this validity issue is our first suggestion of how research on EC in bilingual aphasia should advance. Our review showed that many of the administered EC tasks also engage language processing and/or other cognitive functions. This is referred to as the IMPURITY PROBLEM, which has been particularly problematic in the investigation of EC (Burgess, 2004; Miyake et al., 2000a). The fact that EC interacts with other cognitive functions makes it difficult, if not impossible, to fully isolate EC from other abilities, including language. When investigating PWA, it is even more important to administer EC tests that allow for separation of linguistic and non-linguistic abilities, to ensure the possibility of drawing conclusions about the integrity of non-linguistic functions (Keil & Kaszniak, 2002). For example, the Stroop task measures prepotent response inhibition, but its verbal demands complicate administering and interpreting this task in populations with aphasia. In line with Miyake, Emerson and Friedman (2000b), we suggest using simpler EC tasks and making explicit which subcomponent of EC it is supposed to measure. Good examples of such tasks are flanker or triad tasks (tapping resistance to interference), while the WCST or the TMT are less suitable.

Furthermore, some studies found slower performance on EC tasks, in absence of impaired interference. Calabria et al. (2019) suggest that overall slower response speed indicates a deficit in conflict monitoring rather than resolution. However, being slower to perform any task may be caused by general cognitive slowing rather than a specific problem with EC (Purdy, 2002). Discrepancies between RTs and accuracy, as well as negative correlations between the two, can also be indicative of a difference in speed/accuracy trade-off. Participants may favor quick over accurate responding or vice versa. Faroqi-Shah et al. (2018) found that, in contrast to healthy participants, bPWA's Stroop performance was characterized by a negative correlation between RTs and accuracy. Therefore, reporting both RTs and accuracy is recommended.

Inter-individual variability is a key feature of research into bilinguals as well as studies involving PWA. Bilingual experience and aphasia-related factors can have profound (combined) effects on recovery and linguistic and non-linguistic control abilities (e.g., Green, 1998; Kuzmina et al., 2019). For example, Calabria et al. (2019) found evidence for a relationship between language dominance and control abilities, and Dash and Kar (2014) found language proficiency to influence language control. Due to the variation in the included studies of the current review, a systematic analysis of these factors proved to be difficult. Therefore, we advise to report these factors consistently and take these into consideration when interpreting results of bPWA.

Another recommendation for future research is to investigate expressive language control abilities. We have shown that many previous studies have focused on receptive linguistic control, for example, as involved in making lexical decisions. As anomia is one of the most pervasive problems for PWA (e.g., Goodglass & Wingfield, 1997), a next step is to investigate bilingual language control in language production. A final way to advance research on bilingual aphasia is to investigate whether the positive findings for a bilingual advantage in PWA can be replicated and extended to benefit everyday functional communication.

5. Conclusion

We systematically reviewed the literature on the role of EC in bilingual aphasia. Our first finding was that bPWA's impairments are not limited to the linguistic domain and that non-linguistic EC impairments are frequently observed. Next, we examined domain generality of bilingual language control by reviewing whether linguistic control impairments were associated with EC impairments and found that the experimental results were mixed. However, bPWA who show problems with bilingual language control in everyday communication, such as differential recovery or pathological switching and mixing, nearly always show problems with EC, indicative of overlapping mechanisms. Finally, research on bilingual advantages in bPWA published thus far points to beneficial effects for this population.

Acknowledgments. We thank three anonymous reviewers for helpful comments.

References

Abutalebi J and Green DW (2007) Bilingual language production: The neurocognition of language representation and control. *Journal of Neurolinguistics* **20**, 242–275. https://doi.org/10.1016/j.jneuroling.2006.10.003

Adesope OO, Lavin T, Thompson T and Ungerleider C (2010) A systematic review and meta-analysis of the cognitive correlates of bilingualism. *Review of Educational Research* **80**, 207–245. https://doi.org/10.3102%2F0034654310368803

Adrover-Roig D, Galparsoro-Izagirre N, Marcotte K, Ferre P, Wilson MA and Ansaldo AI (2011) Impaired L1 and executive control after left basal ganglia damage in a bilingual Basque-Spanish person with aphasia. *Clinical Linguistics & Phonetics* **25**, 480–498. https://doi.org/10.3109/02699206.2011.563338

Aglioti S, Beltramello A, Girardi F and Fabbro F (1996) Neurolinguistic and follow-up study of an unusual pattern of recovery from bilingual subcortical aphasia. *Brain* **119**, 1551–1564. https://doi.org/10.1093/brain/119.5.1551

Alladi S, Bak TH, Mekala S, Rajan A, Chaudhuri JR, Mioshi E, Krovvidi R, Surampudi B, Duggirala V and Kaul S (2016) Impact of bilingualism on cognitive outcome after stroke. *Stroke* **47**, 258–261. https://doi.org/10.1161/STROKEAHA.115.010418

Alladi S, Bak TH, Shailaja M, Gollahalli D, Rajan A, Surampudi B, Hornberger M, Duggirala V, Chaudhuri JR and Kaul S (2017) Bilingualism delays the onset of behavioral but not aphasic forms of frontotemporal dementia. *Neuropsychologia* **99**, 207–212. https://doi.org/10.1016/j.neuropsychologia.2017.03.021

Ansaldo AI and Saidi LG (2014) Aphasia therapy in the age of globalization: cross-linguistic therapy effects in bilingual aphasia. *Behavioural Neurology*, 603085. https://doi.org/10.1155/2014/603085

Army Individual Test Battery. (1944) *Trail Making Test. Manual of Directions and Scoring*. Washington, DC: War Department, Adjutant General's Office.

Bak TH, Vega-Mendoza M and Sorace A (2014) Never too late? An advantage on tests of auditory attention extends to late bilinguals. *Frontiers in Psychology* **5**, 485. https://doi.org/10.3389/fpsyg.2014.00485

Barbu C, Orban S, Gillet S and Poncelet M (2018) The impact of language switching frequency on attentional and executive functioning in proficient bilingual adults. *Psychologica Belgica* **58**, 115–127. https://doi.org/10.5334/pb.392

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

Bialystok E, Craik FIM, Klein R and Viswanathan M (2004) Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology and Aging* **19**, 290–303. https://doi.org/10.1037/0882-7974.19.2.290

Bialystok E and Martin MM (2004) Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental Science* **7**, 325–339. https://doi.org/10.1111/j.1467-7687.2004.00351.x

Branzi FM, Calabria M, Boscarino ML and Costa A (2016) On the overlap between bilingual language control and domain-general executive control. *Acta Psychologica* **166**, 21–30. https://doi.org/10.1016/j.actpsy.2016.03.001

Braver TS (2012) The variable nature of cognitive control: A dual mechanisms framework. *Trends in Cognitive Sciences* **16**, 106–113. https://doi.org/10.1016/j.tics.2011.12.010

Brownsett SLE, Warren JE, Geranmayeh F, Woodhead Z, Leech R and Wise RJS (2014) Cognitive control and its impact on recovery from aphasic stroke. *Brain* **137**, 242–254. https://doi.org/10.1093/brain/awt289

Burgess PW (2004) Theory and methodology in executive function research. In Rabbitt P (ed), *Methodology of frontal and executive function*. London: Psychology Press, pp. 87–121.

Byrne EM, Gilbert RA, Kievit R and Holmes J (2019) *Evidence for separate backward recall and n-back working memory factors: A large-scale latent variable analysis*. PsyArXiv. https://doi.org/10.31234/osf.io/bkja7

Calabria M, Branzi FM, Marne P, Hernández M and Costa A (2015) Age-related effects over bilingual language control and executive control. *Bilingualism: Language and Cognition* **18**, 65–78. https://doi.org/10.1017/S1366728913000138

Calabria M, Costa A, Green DW and Abutalebi J (2018) Neural basis of bilingual language control. *Annals of the New York Academy of Sciences* **1426**, 221–235. https://doi.org/10.1111/nyas.13879.

Calabria M, Grunden N, Serra M, García-Sánchez C and Costa A (2019) Semantic processing in bilingual aphasia: evidence of language dependency. *Frontiers in Human Neuroscience* **13**, 205. https://doi.org/10.3389/fnhum.2019.00205

Calabria M, Hernández M, Branzi FM and Costa A (2012) Qualitative differences between bilingual language control and executive control: evidence from task-switching. *Frontiers in Psychology* **2**, 399. https://doi.org/10.3389/fpsyg.2011.00399

Christensen SC, Wright HH and Ratiu I (2018) Working memory in aphasia: Peeling the onion. *Journal of Neurolinguistics* **48**, 117–132. https://doi.org/10.1016/j.jneuroling.2018.02.001

Costa A, Miozzo M and Caramazza A (1999) Lexical selection in bilinguals: do words in the bilingual's two lexicons compete for selection? *Journal of Memory and Language* **41**, 365–397. https://doi.org/10.1006/jmla.1999.2651

Craik FIM, Bialystok E and Freedman M (2010) Delaying the onset of Alzheimer disease. *Neurology* **75**, 1726–1729. https://doi.org/10.1212/WNL.0b013e3181fc2a1c

Dash T and Kar BR (2014) Bilingual language control and general purpose cognitive control among individuals with bilingual aphasia: evidence based on negative priming and flanker tasks. *Behavioural Neurology* **2014**, 679706. https://doi.org/10.1155/2014/679706

Dash T, Masson-Trottier M and Ansaldo AI (2020) Efficiency of attentional processes in bilingual speakers with aphasia. *Aphasiology* **34**, 1363–1387. https://doi.org/10.1080/02687038.2020.1719970

De Baene W, Duyck W, Brass M and Carreiras M (2015) Brain circuit for cognitive control is shared by task and language switching. *Journal of Cognitive Neuroscience* **27**, 1752–1765. https://doi.org/10.1162/jocn_a_00817

De Bruin A, Roelofs A, Dijkstra T and FitzPatrick I (2014) Domain-general inhibition areas of the brain are involved in language switching: FMRI evidence from trilingual speakers. *NeuroImage* **90**, 348–359. https://doi.org/10.1016/j.neuroimage.2013.12.049

De Bruin A, Treccani B and Della Sala S (2015) Cognitive advantage in bilingualism: an example of publication bias? *Psychological Science* **26**, 99–107. https://doi.org/10.1177/0956797614557866

Declerck M, Grainger J, Koch I and Philipp AM (2017) Is language control just a form of executive control? Evidence for overlapping processes in language switching and task switching. *Journal of Memory and Language* **95**, 138–145. https://doi.org/10.1016/j.jml.2017.03.005

Dekhtyar M, Kiran S and Gray T (2020) Is bilingualism protective for adults with aphasia? *Neuropsychologia* **139**, 1–7. https://doi.org/10.1016/j.neuropsychologia.2020.107355

Diamond A (2013) Executive functions. *Annual Review of Psychology* **64**, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Donnelly S (2016) *Re-Examining the Bilingual Advantage on Interference-Control and Task-Switching Tasks: A Meta-Analysis*. Ph.D. dissertation, City University of New York.

Duncan J (2010) The multiple-demand (MD) system of the primate brain: Mental programs for intelligent behaviour. *Trends in Cognitive Sciences* **14**, 172–179. https://doi.org/10.1016/j.tics.2010.01.004

Eriksen BA and Eriksen CW (1974) Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics* **16**, 143–149. https://doi.org/10.3758/BF03203267

Fabbro F (2001) The bilingual brain: Cerebral representation of languages. *Brain and Language* **79**, 211–222. https://doi.org/10.1006/brln.2001.2481

Fabbro F, Skrap M and Aglioti S (2000) Pathological switching between languages after frontal lesions in a bilingual patient. *Journal of Neurology, Neurosurgery, and Psychiatry* **68**, 650–652. https://doi.org/10.1136/jnnp.68.5.650

Fan J, McCandliss BD, Sommer T, Raz A and Posner MI (2002) Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience* **14**, 340–347. https://doi.org/10.1162/089892902317361886

Faroqi-Shah Y, Sampson M, Pranger M and 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

Fridriksson J, Nettles C, Davis M, Morrow L and Montgomery A (2006) Functional communication and executive function in aphasia. *Clinical Linguistics & Phonetics* **20**, 401–410. https://doi.org/10.1080/02699200500075781

Friedman NP and Miyake A (2004) The relations among inhibition and interference control functions: a latent-variable analysis. *Journal of Experimental Psychology: General* **133**, 101–135. https://doi.org/10.1037/0096-3445.133.1.101

Friedman NP and Miyake A (2017) Unity and diversity of executive functions: Individual differences as a window on cognitive structure. *Cortex* **86**, 186–204. https://doi.org/10.1016/j.cortex.2016.04.023

Friedman NP, Miyake A, Young SE, DeFries JC, Corley RP and Hewitt JK (2008) Individual differences in executive functions are almost entirely genetic in origin. *Journal of Experimental Psychology: General* **137**, 201–225. https://doi.org/10.1037/0096-3445.137.2.201

Goodglass H and Wingfield A (1997) *Anomia: Neuroanatomical and Cognitive Correlates*. San Diego: Academic Press.

Goral M and Lerman A (2020) Variables and mechanisms affecting response to language treatment in multilingual people with aphasia. *Behavioral Sciences* **10**, 144. https://doi.org/10.3390/bs10090144

Goral M, Norvik M and Jensen BU (2019) Variation in language mixing in multilingual aphasia. *Clinical Linguistics & Phonetics* **33**, 915–929. https://doi.org/10.1080/02699206.2019.1584646

Grant DA and Berg EA (1948) A behavioral analysis of degree of reinforcement and ease of shifting to new responses in Weigl-type card-sorting problem. *Journal of Experimental Psychology* **38**, 404–411. https://doi.org/10.1037/h0059831

Gray T (2020) The relationship between language control, semantic control and nonverbal control. *Behavioral Sciences* **10**, 169. https://doi.org/10.3390/bs10110169

Gray T and Kiran S (2016) The relationship between language control and cognitive control in bilingual aphasia. *Bilingualism: Language and Cognition* **19**, 433–452. https://doi.org/10.1017/S1366728915000061

Gray T and Kiran S (2019) The effect of task complexity on linguistic and non-linguistic control mechanisms in bilingual aphasia. *Bilingualism: Language and Cognition* **22**, 266–284. https://doi.org/10.1017/S1366728917000712

Green DW (1986) Control, activation, and resource: A framework and a model for the control of speech in bilinguals. *Brain and Language* **27**, 210–223. https://doi.org/10.1016/0093-934X(86)90016-7

Green DW (1998) Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition* **1**, 67–81. https://doi.org/10.1017/S1366728998000133

Green DW and Abutalebi J (2008) Understanding the link between bilingual aphasia and language control. *Journal of Neurolinguistics* **21**, 558–576. https://doi.org/10.1016/j.jneuroling.2008.01.002

Green DW, Grogan A, Crinion J, Ali N, Sutton C and Price CJ (2010) Language control and parallel recovery of language in individuals with aphasia. *Aphasiology* **24**, 188–209. https://doi.org/10.1080/02687030902958316

Green DW, Ruffle L, Grogan A, Ali N, Ramsden S, Schofield T, Leff AP, Crinion J and Price CJ (2011) Parallel recovery in a trilingual speaker: The use of the Bilingual Aphasia Test as a diagnostic complement to the Comprehensive Aphasia Test. *Clinical Linguistics & Phonetics* **25**, 449–512. https://doi.org/10.3109/02699206.2011.560990

Greve KW, Love JM, Sherwin E, Mathias CW, Ramzinski P and Levy J (2002) Wisconsin Card Sorting Test in chronic severe traumatic brain injury: Factor structure and performance subgroups. *Brain Injury* **16**, 29–40. https://doi.org/10.1080/0269905011008803

Grosjean F (2013) Bilingualism: A short introduction. In Grosjean F and Li P (eds), *The psycholinguistics of bilingualism*. Hoboken, NJ: John Wiley & Sons, Ltd, pp. 5–25.

Helm-Estabrooks N (2001) *Cognitive Linguistic Quick Test*. San Antonio, TX: Pearson.

Helm-Estabrooks N (2002) Cognition and aphasia: A discussion and a study. *Journal of Communication Disorders* **35**, 171–186. https://doi.org/10.1016/S0021-9924(02)00063-1

Hermans D, Bongaerts T, de Bot K and Schreuder R (1998) Producing words in a foreign language: Can speakers prevent interference from their first language? *Bilingualism: Language and Cognition* **1**, 213–229. https://doi.org/10.1017/S1366728998000364

Hilchey MD and Klein RM (2011) Are there bilingual advantages on nonlinguistic interference tasks? Implications for the plasticity of executive control processes. *Psychonomic Bulletin & Review* **18**, 625–658. https://doi.org/10.3758/s13423-011-0116-7

Hope TMH, Jones OP, Grogan A, Crinion J, Rae J, Ruffle L, Leff AP, Seghier ML, Price CJ and Green DW (2015) Comparing language outcomes in monolingual and bilingual stroke patients. *Brain* **138**, 1070–1083. https://doi.org/10.1093/brain/awv020

Hula WD and McNeil MR (2008) Models of attention and dual-task performance as explanatory constructs in aphasia. *Seminars in Speech and Language* **29**, 169–187. https://doi.org/10.1055/s-0028-1082882

Hunting-Pompon RH, McNeil MR, Spencer KA and Kendall DL (2015) Intentional and reactive inhibition during spoken-word Stroop task performance in people with aphasia. *Journal of Speech, Language, and Hearing Research* **58**, 767–780. https://doi.org/10.1044/2015_JSLHR-L-14-0063

Ijalba E, Obler LK and Chengappa S (2004) Bilingual aphasia. In Bhatia TK and Ritchie WC (eds), *The handbook of bilingualism*. Chichester: Blackwell Publishing, pp. 71–89.

Kambanaros M, Messinis L and Anyfantis E (2012) Action and object word writing in a case of bilingual aphasia. *Behavioural Neurology* **25**, 215–222. https://doi.org/10.3233/BEN-2012-119006

Kavé G, Eyal N, Shorek A and Cohen-Mansfield J (2008) Multilingualism and cognitive state in the oldest old. *Psychology and Aging* **23**, 70–78. https://doi.org/10.1037/0882-7974.23.1.70

Keane C and Kiran S (2015) The nature of facilitation and interference in the multilingual language system: Insights from treatment in a case of trilingual aphasia. *Cognitive Neuropsychology* **32**, 169–194. https://doi.org/10.1080/02643294.2015.1061982

Keil K and Kaszniak AW (2002) Examining executive function in individuals with brain injury: A review. *Aphasiology* **16**, 305–335. https://doi.org/10.1080/02687030143000654

Kiran S (2012) What is the nature of poststroke language recovery and reorganization? *international scholarly research notices*, 786872. https://doi.org/10.5402/2012/786872

Kiran S and Gray T (2018) Understanding the nature of bilingual aphasia: diagnosis, assessment and rehabilitation. In Miller D, Bayram F, Rothman J and Serratrice L (eds), *Bilingual Cognition and Language: The State of the Science across Its Subfields*. Amsterdam: John Benjamins Publishing Company, pp. 371–400.

Klecha A (2013) Language and task switching in Polish-English bilinguals. *Psychology of Language and Communication* **17**, 17–36. https://doi.org/10.2478/plc-2013-0002

Kohnert K (2004) Cognitive and cognate-based treatments for bilingual aphasia: A case study. *Brain and Language* **91**, 294-302. https://doi.org/10.1016/j.bandl.2004.04.001

Kolk H (2007) Variability is the hallmark of aphasic behaviour: Grammatical behaviour is no exception. *Brain and Language* **101**, 99–102. https://doi.org/10.1016/j.bandl.2007.04.002

Kong APH, Abutalebi J, Lam KSY and Weekes B (2014) Executive and language control in the multilingual brain. *Behavioural Neurology* **2014**, 27951. https://doi.org/10.1155/2014/527951

Kroll JF, Bobb SC and 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

Kuzmina E, Goral M, Norvik M and Weekes B (2019) What influences language impairment in bilingual aphasia? A meta-analytic review. *Frontiers in Psychology* **10**, 445. https://doi.org/10.3389/fpsyg.2019.00445

Kuzmina E and Weekes BS (2017) Role of cognitive control in language deficits in different types of aphasia. *Aphasiology* **31**, 765–792. https://doi.org/10.1080/02687038.2016.1263383

Lee B, Moon HI, Lim SH, Cho H, Choi H and Pyun SB (2016) Recovery of language function in Korean-Japanese crossed bilingual aphasia following right basal ganglia hemorrhage. *Neurocase* **22**, 300–305. https://doi.org/10.1080/13554794.2016.1141966

Leemann B, Laganaro M, Schwitter V and Schnider A (2007) Paradoxical switching to a barely-mastered second language by an aphasic patient. *Neurocase* **13**, 209–213. https://doi.org/10.1080/13554790701502667

Lehtonen M, Soveri A, Laine A, Järvenpää J, de Bruin A and Antfolk J (2018) Is bilingualism associated with enhanced executive functioning in adults? A meta-analytic review. *Psychological Bulletin* **144**, 394–425. https://doi.org/10.1037/bul0000142

Lerman A, Goral M and Obler LK (2019) The complex relationship between pre-stroke and post-stroke language abilities in multilingual individuals with aphasia. *Aphasiology* **34**, 1319–1340. https://doi.org/10.1080/02687038.2019.1673303

Lerman A, Pazuelo L, Kizner L, Borodkin K and Goral M (2019) Language mixing patterns in a bilingual individual with non-fluent aphasia. *Aphasiology* **33**, 1137–1153. https://doi.org/10.1080/02687038.2018.1546821

Mariën P, van Dun K, Van Dormael J, Vandenborre D, Keulen S, Manto M, Verhoeven J and Abutalebi J (2017) Cerebellar induced differential polyglot aphasia: A neurolinguistic and fMRI study. *Brain and Language* **175**, 18–28. https://doi.org/10.1016/j.bandl.2017.09.001

Marini A, Galetto V, Tatu K, Duca S, Geminiani G, Sacco K and Zettin M (2016) Recovering two languages with the right hemisphere. *Brain and Language* **159**, 35–44. https://doi.org/10.1016/j.bandl.2016.05.014

McNeil MR and Pratt SR (2001) Defining aphasia: Some theoretical and clinical implications of operating from a formal definition. *Aphasiology* **15**, 901–911. https://doi.org/10.1080/02687040143000276

Mioshi E, Dawson K, Mitchell J, Arnold R and Hodges JR (2006) The Addenbrooke's Cognitive Examination Revised (ACE-R): A brief cognitive test battery for dementia screening. *International Journal of Geriatric Psychiatry* **21**, 1078–1085. https://doi.org/10.1002/gps.1610

Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A and Wager TD (2000a) 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

Miyake A, Emerson MJ and Friedman NP (2000b) Assessment of executive functions in clinical settings: Problems and recommendations. *Seminars in Speech and Language* **21**, 169–183. https://doi.org/10.1055/s-2000-7563

Miyake A and Friedman NP (2012) The nature and organization of individual differences in executive functions: four general conclusions. *Current Directions in Psychological Science* **21**, 8–14. https://doi.org/10.1177/0963721411429458

Moher D, Liberati A, Tetzlaff J, Altman DG, & the PRISMA Group. (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of Internal Medicine* **151**, 264–269. https://doi.org/10.7326/0003-4819-151-4-200908180-00135

Muñoz ML, Marquardt TP and 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

Murray LL (1999) Review Attention and aphasia: Theory, research and clinical implications. *Aphasiology* **13**, 91–111. https://doi.org/10.1080/026870399402226

Murray LL (2012) Attention and other cognitive deficits in aphasia: presence and relation to language and communication measures. *American Journal of Speech-Language Pathology* **21**, 51–64. https://doi.org/10.1044/1058-0360(2012/11-0067)

O'Donnell JP, Macgregor LA, Dabrowski JJ, Oestreicher JM and Romero JJ (1994) Construct validity of neuropsychological tests of conceptual and attentional abilities. *Journal of Clinical Psychology* **50**, 596–600. https://doi.org/10.1002/1097-4679(199407)50:4<596::AID-JCLP2270500416>3.0.CO;2-S

Olsson C, Arvidsson P and Johansson MB (2019) Relations between executive function, language, and functional communication in severe aphasia. *Aphasiology* **33**, 821–845. https://doi.org/10.1080/02687038.2019.1602813

Paap KR, Johnson HA and Sawi O (2015) Bilingual advantages in executive functioning either do not exist or are restricted to very specific and undetermined circumstances. *Cortex* **69**, 265–278. https://doi.org/10.1016/j.cortex.2015.04.014

Paap KR, Myuz HA, Anders RT, Bockelman MF, Mikulinsky R and Sawi OM (2017) No compelling evidence for a bilingual advantage in switching or that frequent language switching reduces switch cost. *Journal of Cognitive Psychology* **29**, 89–112. https://doi.org/10.1080/20445911.2016.1248436

Paplikar A, Mekala S, Bak TH, Dharamkar S, Alladi S and Kaul S (2018) Bilingualism and the severity of poststroke aphasia. *Aphasiology* **33**, 58–72. https://doi.org/10.1080/02687038.2017.1423272

Paradis M (1998) Language and communication in multilinguals. In Stemmer B and Whitaker HA (eds), *Handbook of Neurolinguistics*. San Diego: Academic Press, pp. 417–430. https://doi.org/10.1016/B978-012666055-5/50033-2

Paradis M (2001) *Bilingual and Polyglot Aphasia*. Amsterdam: Elsevier Science Publishers.

Penn C, Barber N and Fridjhon P (2017) Early recovery profiles of language and executive functions after left hemisphere stroke in bilingualism. *Aphasiology* **31**, 741–764. https://doi.org/10.1080/02687038.2016.1258538

Penn C, Frankel T, Watermeyer J and Russell N (2010) Executive function and conversational strategies in bilingual aphasia. *Aphasiology* **24**, 288–308. https://doi.org/10.1080/02687030902958399

Perquin M, Vaillant M, Schuller AM, Pastore J, Dartigues JF, Lair ML and Diederich N (2013) Lifelong exposure to multilingualism: new evidence to support cognitive reserve hypothesis. *PLoS ONE* **8**, e62030. https://doi.org/10.1371/journal.pone.0062030

Petrides M and Milner B (1982) Deficits on subject-ordered tasks after frontal-and temporal-lobe lesions in man. *Neuropsychologia* **20**, 249–262. https://doi.org/10.1016/0028-3932(82)90100-2

Posner MI (2012) *Attention in a Social World*. New York: Oxford University Press.

Posner MI and Raichle ME (1994) *Images of Mind*. New York: Scientific American Library.

Prior A and Gollan TH (2011) Good language-switchers are good task-switchers: evidence from Spanish–English and Mandarin–English bilinguals. *Journal of the International Neuropsychological Society* **17**, 682–691. https://doi.org/10.1017/S1355617711000580

Purdy M (2002) Executive function ability in persons with aphasia. *Aphasiology* **16**, 549–557. https://doi.org/10.1080/02687030244000176

Radman N, Mouthon M, Di Pietro M, Gaytanidis C, Leemann B, Abutalebi J and Annoni JM (2016) The role of the cognitive control system in recovery from bilingual aphasia: a multiple single-case fMRI study. *Neural Plasticity* **2016**, 8797086. https://doi.org/10.1155/2016/8797086

Ramsberger G (2005) Achieving conversational success in aphasia by focusing on non-linguistic cognitive skills: A potentially promising new approach. *Aphasiology* **19**, 1066–1073. https://doi.org/10.1080/02687030544000254

Roelofs A (2021) How attention controls naming: Lessons from Wundt 2.0. *Journal of Experimental Psychology: General*. https://doi.org/10.1037/xge0001030

Roelofs A and Ferreira VS (2019) The architecture of speaking. In Hagoort P (ed), *Human Language: From Genes and Brains to Behavior*. Cambridge, MA: MIT Press, pp. 35–50.

Roelofs A, Piai V, Garrido Rodriguez G and Chwilla DJ (2016) Electrophysiology of cross-language interference and facilitation in picture naming. *Cortex* **76**, 1–16. https://doi.org/10.1016/j.cortex.2015.12.003

Sánchez-Cubillo I, Periáñez JA, Adrover-Roig D, Rodríguez-Sánchez JM, Rios-Lago M, Tirapu J and Barceló F (2009) Construct validity of the Trail Making Test: Role of task-switching, working memory, inhibition/interference control, and visuomotor abilities. *Journal of the International Neuropsychological Society* **15**, 438–450. https://doi.org/10.1017/S1355617709090626

Schmiedek F, Hildebrandt A, Lövdén M, Wilhelm O and Lindenberger U (2009) Complex span versus updating tasks of working memory: The gap is not that deep. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **35**, 1089–1096. https://doi.org/10.1037/a0015730

Shao Z, Roelofs A, Martin RC and Meyer AS (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. https://doi.org/10.1037/a0039363

Sikora K and Roelofs A (2018) Switching between spoken language-production tasks: The role of attentional inhibition and enhancement. *Language, Cognition and Neuroscience* **33**, 912–922. https://doi.org/10.1080/23273798.2018.1433864

Simic T, Bitan T, Turner G, Chambers C, Goldberg D, Leonard C and Rochon E (2020) The role of executive control in post-stroke aphasia treatment. *Neuropsychological Rehabilitation* **30**, 1853–1892. https://doi.org/10.1080/09602011.2019.1611607

Simic T, Rochon E, Greco E and Martino R (2019) Baseline executive control ability and its relationship to language therapy improvements in post-stroke aphasia: A systematic review. *Neuropsychological Rehabilitation* **29**, 395–439. https://doi.org/10.1080/09602011.2017.1307768

Soveri A, Rodriguez-Fornells A and Laine M (2011) Is there a relationship between language switching and executive functions in bilingualism?. Introducing a within group analysis approach. *Frontiers in Psychology* **2**, 183. https://doi.org/10.3389/fpsyg.2011.00183

Spearman C (1927) *The Abilities of Man*. London: Macmillan.

Stroop JR (1935) Studies of interference in serial verbal reactions. *Journal of Experimental Psychology* **18**, 49–60. https://doi.org/10.1037/h0054651

Valian V (2015) Bilingualism and cognition. *Bilingualism: Language and Cognition* **18**, 3–24. https://doi.org/10.1017/S1366728914000522

Van den Noort M, Struys E, Bosch P, Jaswetz L, Perriard B, Yeo S, Barisch P, Vermeire K, Lee SH and 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

Van der Linden L, Dricot L, De Letter M, Duyck W, de Partz M.-P., Ivanoiu A and Szmalec A (2018a) A case study about the interplay between language control and cognitive abilities in bilingual differential aphasia: Behavioral and brain correlates. *Journal of Neurolinguistics* **46**, 37–68. https://doi.org/10.1016/j.jneuroling.2017.12.011

Van der Linden L, Verreyt N, De Letter M, Hemelsoet D, Mariën P, Santens P, Stevens M, Szmalec A and Duyck W (2018b) Cognate effects and cognitive control in patients with parallel and differential bilingual aphasia. *International Journal of Language & Communication Disorders* **53**, 515–525. https://doi.org/10.1111/1460-6984.12365

van Heuven WJB, Schriefers H, Dijkstra T and Hagoort P (2008) Language conflict in the bilingual brain. *Cerebral Cortex* **18**, 2706–2716. https://doi.org/10.1093/cercor/bhn030

Verreyt N, De Letter M, Hemelsoet D, Santens P and Duyck W (2013) Cognate Effects and Executive Control in a Patient with Differential Bilingual Aphasia. *Applied Neuropsychology: Adult* **20**, 221–230. https://doi.org/10.1080/09084282.2012.753074

Verreyt N, Woumans E, Vandelanotte D, Szmalec A and Duyck W (2016) The influence of language-switching experience on the bilingual executive control advantage. *Bilingualism: Language and Cognition* **19**, 181–190. https://doi.org/10.1017/S1366728914000352

Villard S and Kiran S (2017) To what extent does attention underlie language in aphasia? *Aphasiology* **31**, 1226–1245. https://doi.org/10.1080/02687038.2016.1242711

Waris O, Soveri A, Ahti M, Hoffing RC, Ventus D, Jaeggi SM, Seitz AR and Laine M (2017) A latent factor analysis of working memory measures using large-scale data. *Frontiers in Psychology* **8**. https://doi.org/10.3389/fpsyg.2017.01062

Woumans E, Santens P, Sieben A, Versijpt J, Stevens M and Duyck W (2015) Bilingualism delays clinical manifestation of Alzheimer's disease. *Bilingualism: Language and Cognition* **18**, 568–574. https://doi.org/10.1017/S136672891400087X

Appendix A: Search strings

Construct-related terms	Population-related terms
executive function* OR executive control OR cognitive function OR cognition OR cognitive control OR inhibition OR inhibitory OR inhibitory control OR switching OR shifting OR memory OR attention OR updating	aphasia OR dysphasia
	bilingual OR multilingual OR polyglot OR bilingualism OR multilingualism OR trilingual OR quadrilingual