ABSTRACT

Title of Thesis:	THE EFFECT OF LANGUAGE MIXING ON WORD RETRIEVAL IN BILINGUAL ADULTS WITH APHASIA
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Lexical retrieval deficits are a common feature in aphasia, and while much research has been done on bilingual aphasia and on the processes involved in language mixing by healthy bilingual adults, it is not clear whether it may be beneficial for bilingual people with aphasia to change languages in moments of lexical retrieval or if it is more effective to continue the lexical search in one language. The primary aim of this project was to determine whether bilingual people with aphasia demonstrate global and local effects of language mixing. Grammatical categories (i.e., nouns and verbs) were examined separately, and participant- and stimulus-related factors were considered. Based on preliminary analyses of participants' accuracy and response onset latencies, it appears that participants tended to benefit from mixing in terms of speed and accuracy and that their results may be related to their language proficiency and dominance.

THE EFFECT OF LANGUAGE MIXING ON WORD RETRIEVAL IN BILINGUAL ADULTS WITH APHASIA

by

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Introduction: The Effect of Language Mixing on Word Retrieval in Aphasia

Aphasia is a language disorder that results from cortical or subcortical damage (e.g., stroke, traumatic brain injury) to areas responsible for language processing and production. Aphasia is one of the most common and persistent deficits following stroke, affecting 30 to 34 percent of stroke survivors in acute facilities (Flowers et al., 2016). Aphasia results in impaired communication as well as decreased functional outcomes and quality of life (Boheme, 2016). Given its prevalence, deficit patterns and intervention methods for aphasia have been the subject of much study.

While aphasia in bilingual speakers has been the subject of increased research in recent years, the mechanisms underlying deficit patterns in bilingual aphasia and effective treatment interventions for bilingual people with aphasia (BPWA) are less understood. Current data suggest that 22 percent of households in the United States speak a language other than English in the home, and the rising rate of bilingualism in the U.S. highlights an increased need for effective aphasia intervention for the bilingual population (U.S. Census Bureau, 2019).

Language mixing, defined as the use of two languages while speaking, is a complicated process requiring bilinguals to analyze the speaking environment to make decisions regarding language selection. Bilinguals are required to restrict their lexicon to the selected language and inhibit their other lexicon in order to speak in a monolingual context, and when they mix languages, bilinguals require cognitive control in order to make decisions on what words they will switch and when switching is appropriate based on their understanding of their listener and the language context (de Bruin et al., 2018; Green & Wei, 2014). Despite the complexity of language mixing, most healthy bilinguals are highly accurate when mixing languages, suggesting a high level of control of the bilingual's lexicons (de Bruin et al., 2020).

Language mixing studies in healthy adults have examined global effects of language mixing (i.e., effects on response times in single-language conditions versus mixed-language conditions) as well as local effects of language mixing (i.e., effects on response times for *switch* (L1 to L2 or L2 to L1) trials versus *non-switch* (L1 followed by L1 or L2 followed by L2 trials) trials). Such studies have demonstrated that for healthy bilinguals, mixing two languages may be less effortful than being restricted to using one language (de Bruin et al., 2018; Green & Abutalebi, 2013). In healthy bilinguals, language mixing studies have also largely found local switch costs (i.e., increased naming time for switch trials as compared to non-switch trials) for both cued and voluntary language mixing tasks, suggesting that switching languages may be a cognitively taxing process (de Bruin et al., 2018; Gollan & Ferreira, 2009).

This process of language mixing is further complicated in bilingual people with aphasia (BPWA). A central characteristic of all aphasias, including bilingual aphasia, is lexical retrieval deficits, which result in difficulty with naming (Kiran et al., 2014). While patterns in language mixing have been identified for healthy bilingual populations, literature on lexical access and language mixing in bilingual aphasia is lacking, and no clear guidelines exist directing assessment and treatment of lexical access deficits in BPWA. For instance, it is not clear if it is more helpful to switch to another language in the event of the word retrieval challenge, or if it is better to continue the lexical search in the same language. This is because switching to another language requires the speaker to inhibit the current language and activate the other language, which may be cognitively taxing to an already compromised lexical system in BPWA. This thesis proposes to examine this unresolved question by comparing word retrieval success in mixed language versus single language conditions in BPWA.

In order to answer this question, we first present current literature on bilingual language mixing, particularly highlighting key differences in study design that are correlated with global and local effects of language mixing. We then provide an overview of theories and key concepts that explain why particular patterns have emerged in bilingual language mixing research. We discuss lexical access, cognitive control, and language use and proficiency as they relate to known patterns in bilingual language mixing and possible applications to language mixing in PWA. Finally, we detail current literature on grammatical categories and aphasia to justify our approach of separating nouns and verbs in our study of language mixing.

Language Mixing in Neurotypical Adults

Language mixing is a relatively common practice when two bilingual speakers communicate with each other. In addition to its cultural and linguistic implications, language mixing provides important insight into neural and cognitive mechanisms that underlie bilingual language control and use. Language switching (i.e., the process of changing from one language to another) involves switching between response sets, which requires multiple processes of control. As such, language switching involves the interaction of multiple neural networks, including the dorsolateral prefrontal cortex (required for decision making, executive functions, and inhibition), the inferior parietal cortex (required for working memory) as well as the anterior cingulate cortex (needed for identification of conflict; Abutalebi & Green, 2008). In addition, subcortical structures, such as the basal ganglia and the caudate nucleus, aid in sequence planning required for cognitive control. Thus, the study of language mixing provides important insight on neural networks that govern its underlying cognitive processes in neurotypical adults. The study of language mixing in BPWA is especially valuable because understanding the neural mechanisms that underlie deficits in aphasia is a major component of better understanding neural plasticity (i.e., the brain's ability to change and adapt to experience) and patterns of language recovery in aphasia (Kiran & Thompson, 2019).

As mentioned previously, studies on language mixing have found both global (i.e., mixing) and local (i.e., switching) effects associated with language mixing. Studies on language mixing typically involve two conditions: blocked (i.e., where bilinguals are restricted to using one language) and mixed (i.e., where bilinguals use two languages during a naming task). Studies also feature one of two designs: cued mixing (i.e., participants are cued when to switch languages) or voluntary mixing (i.e., participants are free to switch when they choose during study tasks), which will be examined in detail in the following sections.

Global Effects of Language Mixing

Global effects (i.e., mixing costs or benefits, defined as overall slower or faster response times in bilingual contexts as compared to blocked, monolingual contexts) have been a central focus of studies on language mixing. In cued switching paradigms, where participants are cued as to which language they are to use on individual picture naming trials, healthy bilinguals demonstrate a mixing cost, as defined as longer response latencies on non-switch trials in the mixed condition (i.e., researchers examine specific trials within the mixed condition where participants were cued to name subsequent stimuli in the same language) than in blocked (monolingual) conditions (Rubin & Meiran, 2005; Gollan et al., 2014; de Bruin et al., 2018; Jetović et al, 2020). Rubin and Meiran (2005) examined the origins of this mixing cost using a four-experiment task-switching design that compared response times on mixed conditions (i.e. where participants were required to identify both colors and shapes in the same trial; bivalent) to blocked conditions (i.e. where participants were required to identify only color or shape; univalent). Experiments included three conditions: univalent without filtering (i.e. only one changing factor—all shapes presented in one color or all colors presented in the same shape), univalent with filtering (i.e. participants respond to one factor, shape or color, but the shapes or colors are presented in different forms, such as different colored shapes), and bivalent with filtering (i.e. participants are cued to switch between identifying color or shape within the same condition). Rubin and Meiran (2005) found that the mixing cost was significantly higher in the bivalent (mixed) condition than in the univalent (blocked) conditions, suggesting that when participants are required to actively monitor multiple factors with the knowledge that they may be required to switch tasks at any time, their response times overall are longer than when they know that they are required to respond to only one characteristic. In linguistic tasks, Rubin and Meiran (2005)'s findings suggest that actively maintaining two languages with the expectation of being asked to use any language on the next trial may be cognitively demanding.

In contrast, in voluntary switching paradigms, where participants are asked to name pictures in whichever language they choose, healthy bilinguals demonstrate a mixing advantage and name pictures faster in voluntary mixed (bilingual) conditions than in blocked (monolingual) conditions (de Bruin et al., 2018). To assess these mixing effects, Gollan et al. (2014) compared response times averaged across languages in the voluntary condition to the cued condition. Participants were asked to name images in four conditions: an English-only condition, a Spanish-only condition, a cued switching condition, and a voluntary switching condition. There was a mixing advantage when participants voluntarily switched into the non-dominant language compared to blocked conditions (i.e., where participants were required to name all pictures in one language). Additionally, de Bruin et al. (2018) found that bilinguals named pictures faster overall in the voluntary mixed condition than in the blocked condition (i.e. mixing benefit). These faster naming responses in voluntary mixing conditions provides a contrast to the mixing costs that have been found in cued language mixing tasks.

de Bruin et al. (2018) compared naming speed in the blocked condition to naming speed on non-switch trials of the cued and uncued conditions to examine global effects of cued versus voluntary picture naming. The fastest naming responses were in the voluntary non-switch trials followed by blocked trials (single language), and cued non-switch trials were the slowest. Jetović et al. (2020) aimed to replicate de Bruin et al. (2018)'s findings using a purely voluntary switch task, but in contrast to de Bruin et al. (2018), Jetović et al. (2020) used an intermixed mandatory-voluntary task design (participants were cued for each trial to either choose which language to use or to use one particular language) in order to control for effects of task complexity related to cue processing. As in the study by de Bruin et al. (2018), Jetović et al. (2020) employed two naming tasks: One task included a single-language blocked condition (participants named all images in one language) and a voluntary condition (participants named images in either language and switched freely, with the instruction to not use the same language for the entire condition); the other task used cues to indicate either the language that was to be used or that the participant could choose the language they wanted to use. Similar to the findings from de Bruin et al. (2018), Jetović et al. (2020) found a mixing benefit (participants named pictures faster during non-switch trials in the mixed condition than during the blocked condition. In the intermixed mandatory-voluntary task, participants named faster in voluntary switch trials than in cued switch trials, supporting the mixing benefit in voluntary compared to cued switching. Taken together, these findings suggest that voluntary mixing results in faster naming times overall (global mixing benefit) for healthy bilingual adults than cued mixing or blocked conditions. This finding has important implications for language mixing in the bilingual aphasia population. These findings imply that if similar word retrieval mechanisms operate in BPWA and healthy adults, voluntarily code switching may facilitate picture naming. However, the language system is impaired following aphasia, and as discussed in the following sections, the specific deficits to the language system and to cognitive control mechanisms that govern language mixing may influence bilingual PWA's benefit (or lack thereof) in voluntary language mixing.

Local Effects of Language Mixing: Switch Costs

Even though healthy bilinguals demonstrate a mixing benefit as a global effect of language mixing in voluntary switching paradigms, they have still been found to exhibit a local cost for switching, defined as longer response times for switch trials as compared to non-switch trials (de Bruin et al., 2018; Gollan and Ferreira, 2009). de Bruin et al. (2020) expanded on this finding and determined that while bilinguals demonstrated similar-sized global mixing effects in voluntary bilingual conditions and bilinguals across the lifespan demonstrated local switch costs, children and older adults demonstrated larger local switch costs than young adults. These findings suggest that the process of switching from one language to another may be more cognitively taxing than remaining in the same language from trial to trial even though overall, using two languages voluntarily has been found to be more efficient than being required to remain in one or being told when to use a second.

Grammatical Categories

Traditionally, picture naming studies in healthy adults and in people with aphasia have focused primarily on nouns. It is well documented that PWA tend to perform more poorly when naming verbs than when naming nouns (e.g., Nilipour et al., 2017; Hernàndez et al., 2008). Matzig et al. (2009) found that this pattern of noun-verb differences in picture naming was consistent despite differences in lesion sites and diagnoses. This finding was supported by Faroqi-Shah and Waked (2010), who found that noun-verb dissociation is possible across languages. It has been hypothesized that in both healthy bilinguals and BPWA, verbs may behave differently than nouns and that this categorical effect may in turn influence global effects associated with language mixing in picture naming tasks. Picture naming requires a high level of cognitive control, and bilinguals often perform more poorly on these tasks than monolinguals as bilinguals have dual lexicons to manage during naming tasks. Faroqi-Shah and Milman (2015) predicted that because bilinguals tend to demonstrate more cognitive control than monolinguals (Green & Wei, 2014), and because categorical naming requires a high level of cognitive control, bilinguals may demonstrate a smaller disadvantage when naming verbs than when naming nouns. They found that as expected, bilinguals scored lower than monolinguals on noun picture naming but that this effect was not present when bilinguals were naming actions, perhaps because the representations of verbs in the bilingual's mind are more complex than representations of nouns (Bultena et al., 2013). These findings support that grammatical category influences bilingual lexical organization and naming ability, and this is an important concept to consider in bilingual picture naming in PWA. If bilingual PWA perform similarly to healthy adults, they would be expected to be faster when naming verbs than when naming nouns. However, verb deficits and cognitive control deficits have been documented in aphasia, which may lead bilingual PWA to demonstrate the opposite global effects to healthy bilinguals when considering the effect of grammatical category on language mixing in bilingual aphasia.

Examining the effect of grammatical category on language mixing by people with aphasia is also interesting in light of prior literature that has found that code switching appears to be different psycholinguisitcally for nouns, verbs, and adjectives (Zeller, 2020) and that naturalistic code switches tend to occur most frequently on nouns when healthy bilinguals communicate (Van Gass, 2002). Given that studies on global and local language mixing using a picture-naming paradigm elicit lexical access code switches, applying this paradigm to a verb condition may not be entirely reflective of code switches that bilinguals produce in conversation. However, multiple interventions for aphasia (e.g., Semantic Feature Analysis, Verb Network Strengthening Training, picture-naming therapy) aim to improve lexical access, retrieval, and production in the hope of improving communication for people with aphasia (e.g., Conroy et al., 2010; Edmonds et al., 2014). Because multiple interventions for aphasia rely on paradigms that aim to improve lexical access and retrieval, understanding patterns in bilingual PWA's performance on lexical access code-switching tasks can provide a useful foundation for future studies on interventions that use these paradigms for bilingual PWA.

Factors that Influence Effects of Language Mixing

These global and local effects of language mixing have led researchers to examine the role of bottom-up and top-down processes of lexical access and cognitive control on bilingual language use. Global mixing benefits associated with voluntary switching suggest that bilinguals may rely on lexical access (i.e., the ease with which they can access lexical items) to guide their language mixing in a way that facilitates their communication (de Bruin et al., 2018), while local switch costs suggest that the inhibition that bilinguals require to manage two lexicons may contribute to the costly nature of switching between their languages (Lai & O'Brien, 2020).

Lexical Access

The finding that bilinguals name pictures more quickly in voluntary mixed conditions as compared to blocked conditions (global mixing benefit) was surprising given that traditional cued mixing studies had demonstrated significant costs associated with cued bilingual conditions as compared to monolingual conditions and that switching languages is costly according to patterns of local switch costs. This has led researchers to hypothesize that bilingual language mixing is controlled at least in part by the bottom-up process of lexical access (i.e., the ease with which bilinguals access words in their mental lexicon). Based on the hypothesis that if lexical access drives language mixing, then bilinguals would switch languages only on trials where switching languages was easier than staying in the current language, two studies have confirmed the role of lexical accessibility in voluntary language switching (de Bruin et al., 2018; Gollan & Ferreira, 2009). Gollan and Ferreira (2009) found that Spanish-English unbalanced bilinguals named easier-to-name pictures (e.g., higher-frequency or shorter syllable length words) in their non-dominant language. In a group of Spanish-Basque speakers, de Bruin et al. (2018) analyzed the items in voluntary switch trials for their naming ease (i.e., response time) in blocked naming trials. They found that words that were slow to be named in any language were more frequently named in the other language.

Although both studies showed lexical accessibility effects, there were also switch costs for voluntary switch trials (de Bruin et al., 2018; Gollan & Ferreira, 2009). It is possible that cognitive control mechanisms are engaged in language switching, resulting in switch costs despite lexical accessibility. It is important to examine the interplay between lexical access and cognitive control because both processes can be compromised in BPWA (Faroqi-Shah et al., 2018). While Faroqi-Shah et al. (2018) found that cognitive control is weakened in PWA, it did not find a significant correlation between naming and cognitive control abilities, leaving open questions as to the interaction between this weakened cognitive control and language mixing.

Cognitive Control

While lexical access certainly plays a role in bilingual language mixing, bilinguals do not switch languages for every word they speak, and as detailed above, bilinguals tend to mix languages even though language mixing may be costly. These findings suggest that the bottom-up process of lexical access alone cannot fully account for the patterns observed in bilingual language mixing. This has led researchers to examine the top-down process of cognitive control and the impact that it may have on language mixing patterns. Cognitive control refers to the cognitive process that allows for goals or plans to govern behavior. Specifically, in bilingualism cognitive control refers to the cognitive mechanisms that allow bilinguals to manage their dual lexicon and to use it appropriately. Green and Abutalebi (2013) suggested that cognitive control is involved in language mixing as bilinguals must inhibit the non-target language when speaking in a target language and then switch to re-activate a language that was previously inhibited. The Adaptive Control Hypothesis (ACH) posits that as individuals work to accomplish their goals, cognitive control processes activate mental representations (verbal or nonverbal) that compete with their goals (e.g. when participants are presented with written names of colors and asked to identify only the color of the font, the name of the color interferes with accomplishing this task). They hypothesize that this interference is reduced when a following trial involves a stimulus that is completely different from the competitive one. Based on this principle, Green and Abutalebi (2013) suggest that in language mixing, the level of cognitive control required to communicate effectively varies, or "adapts," based on the task being completed. From a language mixing standpoint, this means that the context of language use implicates different neural and cognitive control mechanisms required to communicate in that context. They describe three primary contexts in which bilinguals communicate: single-language contexts (where bilinguals use only one language in a given environment), dual-language contexts (where bilinguals use two languages, but use each language with different speakers), and a highly mixed context in which bilinguals switch languages often while speaking). In a single-language context, cognitive control is argued to be low because languages are generally kept separate. In a dual-language context, cognitive control is argued to be relatively high because bilinguals must actively control both languages in order to use them separately within a conversation. In a dense-switching context, cognitive control is argued to be low as both languages are being used in a facilitative context rather than in a competitive context.

The ACH was tested by Lai and O'Brien (2020). They used a verbal Stroop (Stroop, 1935) task and a non-verbal Global-Local task to examine cognitive control across the three contexts of the ACH model (single-language, dual-language, and dense language switching contexts). These measures were selected in order to simulate bilingual language mixing as their stimuli require stimulus-stimulus inhibition (i.e., where stimuli are from the same category, such as words and colors, which creates conflict), which is similar to the conflict created by simultaneously activated language representations. Lai and O'Brien (2020) found that after accounting for bilingual proficiency, performance in the dual-language context (hypothesized to require the highest level of cognitive control; Green & Abutalebi, 2013) was correlated with their performance in the verbal cognitive control task (i.e., Stroop task).

People with aphasia perform more poorly on attention and cognitive measures as compared to healthy controls, and these cognitive deficits are correlated to their impaired language efficiency (Murray, 2012). In addition, researchers have hypothesized that word finding difficulties, which are classically associated with aphasia, may be indicative of associated deficits in cognitive control. Faroqi-Shah et al. (2018) compared six groups in their study on cognitive control and word finding in PWA: monolingual PWA, bilingual English-dominant PWA, bilingual Tamil-English PWA, monolingual neurologically healthy adults, bilingual English-dominant healthy adults, and bilingual Tamil-English healthy adults. They analyzed participants' response times on a non-verbal Stroop (MacLeod, 1991) task in order to draw conclusions on their cognitive control abilities. Faroqi-Shah et al. (2018) found that PWA scored worse in terms of accuracy and response time than age-matched healthy controls, implying that the presence of aphasia is correlated with worse performance on cognitive control tasks. However, they also found that bilinguals with and without aphasia demonstrated a bilingual advantage in cognitive control, suggesting that a cognitive control advantage, as suggested by Green and Wei (2014), may exist even following cortical damage associated with aphasia.

Language proficiency

In examining the role that lexical access plays on language mixing, language proficiency is an important consideration as many of the observed patterns in bilingual language mixing vary with language proficiency. de Bruin et al. (2018) examined the influence of lexical access in balanced (i.e., equally proficient in both of their languages) and unbalanced (i.e., more proficient in one language than another) bilinguals and found that individual lexical access played a role in language mixing as balanced bilinguals who had learned their languages simultaneously consistently named specific words in the same language. Similarly, Costa and Stantesteban (2004) compared the performance of highly proficient bilinguals to that of L2 learners on picture naming tasks. They evaluated local switch costs on picture naming tasks, and they found that for highly proficient bilinguals, switch costs were similar for L1 and L2 (i.e. the magnitude of the switch cost was similar regardless of the language into which bilinguals switched) whereas for L2 learners, switch costs were greater in magnitude when switching into L1 than into L2. Costa and Stantesteban (2004) suggested that these patterns in switch costs are related to the level of inhibition that must be applied to each language according to the speaker's proficiency in the language, as detailed above.

Gollan and Ferreira (2009) also found that language mixing had a larger effect on nondominant language production than on dominant language production. For example, for English-dominant bilinguals, voluntary mixing led to faster Spanish naming times in the mixed condition than in the blocked Spanish condition. To explain this trend, they studied the specific words that were named in each language by unbalanced bilinguals. They found that unbalanced bilinguals named mostly in one language (i.e., *matrix language*) and that unbalanced and balanced bilinguals switched languages for single trials before returning to the matrix language. This pattern demonstrates that language proficiency and language dominance influence voluntary language switching as bilinguals switch from the non-dominant language to the dominant one when they cannot lexically access the name for a presented stimulus.

Language Use and Code-Switching Tendencies

In addition to bilinguals' proficiency being an important factor in patterns of language mixing, researchers have found that the specific ways that bilinguals use their languages also impacts their language mixing. Language use changes depending on culture, community, and context. Bilingual speakers are constantly required to analyze their speaking environments and make choices on language use, and the communities that they live in often dictate general patterns in how they use their languages (e.g. a bilingual who lives with speakers of their L1 but uses L2 for work may have a different language use pattern than a bilingual who spoke their L1 as a child but now uses their L2 almost exclusively at work and at home). Green and Abutalebi (2013) suggest that the cognitive control governing language mixing adapts to the specific contexts in which the bilinguals use their languages. Thus, Green and Wei (2014) suggest that in order to truly understand bilingual language use and especially the impact of cognitive control on language mixing, we must examine bilinguals' language use and code switching (i.e., switching languages at the phrase or conversation level) tendencies. This notion is supported by Lai and O'Brien (2020) who assert that language use and mixing and code-switching tendencies must be evaluated in order to understand their impact on bilinguals' performance in studies of bilingual language use.

In addition, Green and Wei (2014) propose that because language mixing and code-switching involve neural and non-linguistic mechanisms that can be altered with experience, bilinguals who grew up in an environment where language mixing and code switching were highly prevalent may have advantages in code switching over monolinguals or bilinguals who did not code switch frequently. This idea is supported by Lai and O'Brien (2020), who assert that research should examine bilinguals' environments in order to identify conditions that improve language efficiency. This idea of a bilingual advantage has been studied in bilinguals with aphasia.

Lexical Frequency and Complexity

Associated with the study of the direction of each language switch made by bilinguals in picture naming studies is an analysis of the specific properties of the words for which bilinguals choose to switch languages. The frequency of stimuli (i.e., how often names of stimuli occur in given languages) is associated with the lexical access of those words (Alario et al., 2002), and picture naming studies often control for the frequency of stimuli used in order to draw conclusions on participants' language mixing patterns (e.g., Costa & Stantesteban, 2004; de Bruin et al., 2018). Words that occur more frequently or that are shorter in length are often assumed to be easier to name; however, de Bruin et al. (2018), found that word length and frequency did not predict healthy bilinguals' naming choices. Examining characteristics of words associated with their ease of lexical access is valuable in a language mixing study involving bilingual PWA as their lexical access abilities are impaired as compared to healthy bilinguals, and the influence of word length and frequency may present differently in this population.

To summarize, language mixing data in neurotypical adults show a global mixing benefit in voluntary mixed conditions, defined by faster naming times when bilinguals are free to mix languages voluntarily for picture naming tasks. This global mixing benefit is influenced by participants' language proficiency and cognitive control. While voluntarily switching is faster than naming in a blocked monolingual condition for healthy adults, local switch costs (i.e., longer naming time on switch trials than on stay trials) have been widely found in research on language mixing. In healthy adults, these local switch costs are also associated with cognitive control as well as language use and code-switching tendencies. Other factors often considered in language mixing studies in healthy adults are lexical frequency and complexity (i.e., length) and the direction of language switches. Finally, picture naming studies in aphasia have traditionally featured nouns, and while interventions for verb deficits in aphasia exist, they often are less successful than those for nouns, suggesting that nouns and verbs may behave differently in aphasia. For this reason, nouns and verbs are studied separately in the present study.

Research Questions & Hypotheses

This study examined the effect of language mixing on word retrieval in bilingual adults with aphasia. The following research questions were addressed:

1a. What is the global effect of a single-language versus mixed-language mode on word retrieval in bilingual adults with aphasia, as measured by accuracy and speed of picture naming? It was hypothesized that PWA would show a mixing benefit resulting in shorter picture naming latencies in mixed conditions as compared to blocked (monolingual) conditions, as had been observed in neurologically healthy bilingual adults participating in voluntary language switch tasks (de Bruin et al., 2018).

1b. Does the global mixing benefit differ by grammatical category, as measured by the naming of action and object pictures? People with aphasia are less accurate when naming verbs than when naming nouns (Nilipour et al., 2017). Given this greater difficulty with verbs, it was hypothesized that a potential mixing benefit would be smaller in magnitude when participants named verbs than when they named nouns.

1c. What factors influence bilingual PWA's global mixing benefit from single- versus mixed-language picture naming? The participant-related factors that were examined include cognitive control, language proficiency, translation ability, language use, and code-switching tendencies. It was predicted that increased language proficiency and cognitive control would be correlated with greater magnitude of mixing benefit, as hypothesized by the Adaptive Control Hypothesis (Green & Abutalebi, 2013). Additionally, it was hypothesized that participants who tended to codemix more frequently in daily life and had better translation scores would show larger mixing benefits. Both of these factors were predicted to promote stronger cross-language connections in bilinguals' mental lexicon, thus resulting in larger mixing benefits.

2a. In a mixed language mode, are there local switch costs? Local switch costs are defined as the response times of switch trials compared to the response times of non-switch trials. It was hypothesized that local switch costs would be observed in BPWA as the literature on language mixing in healthy bilinguals had found local switch costs even in the presence of an overall mixing benefit (de Bruin et al., 2018; Gollan and Ferreira, 2009).

2b. Do local switch costs vary based on the grammatical category of images named? The effect of the grammatical category on local switch costs was evaluated. It was hypothesized that switch costs would be greater for verbs than for nouns, consistent with the generally greater difficulty with verb naming experienced by PWA (Nilipour et al., 2017; Hernàndez et al., 2008).

2c. What factors influence local switch costs? The participant-related factors that were examined included cognitive control, language proficiency, translation ability, language use, code-switching tendencies. The stimulus-related factors that were examined include lexical frequency/length and direction of switch (L1 to L2 and L2 to L1). It was hypothesized that participant-related factors of cognitive control, language proficiency, translation ability, language use, and code-switching tendencies would be positively correlated with participants' language switching abilities. It was predicted that cognitive control would be a significant predictor in participants' picture naming ability given the ACH (Green and Abutalebi, 2013), which suggests that cognitive control is involved in task switching. Language proficiency and related translation ability were hypothesized to predict picture naming ability given findings that participants' language proficiency correlated with observed patterns in bilingual language mixing (de Bruin et al., 2018; Costa & Stantesteban, 2004). It was hypothesized that language use and code-switching tendencies would be positively related to participants' picture naming ability given findings that language use and code-switching tendencies are related to cognitive control and language mixing

(Green & Abutalebi, 2013; Green & Wei, 2014; Lai and O'Brien, 2020). With regard to stimulus-related factors studied, it was predicted that participants would demonstrate greater switch costs when switching to name longer, less frequent words, and words with lower name agreement (Costa & Stantesteban, 2004; de Bruin et al., 2018).

Methods

The methods for the present study, including study design, participants, baseline testing, experimental design, and analysis, are presented below. However, for the purposes of this thesis, note that only Spanish-English bilinguals were prioritized for recruitment, and only preliminary analyses on patterns in stimulus-related factors are presented given that the number of participants did not allow for collection of data in all balancing conditions.

Participants

Participants were recruited through the Aphasia Research Center, from the local community, and by advertisements to speech-language pathologists (SLPs) and professionals who work with PWA. To increase the sample size, bilingual speakers of any language will be eventually considered to participate in this study design; however, for this thesis, Spanish-speaking bilinguals were prioritized during recruitment.

Inclusion Criteria

Participants were considered if they were between the ages of 18 and 80 years and at least one-month post-stroke or brain injury. Participants were also required to be bilingual, with bilingualism defined in this study as high proficiency in English prior to the onset of aphasia and at least conversational proficiency in Spanish, which may have been a native language or an acquired second language.

In addition, participants were considered if they had no other neurological or cognitive impairments other than aphasia as determined by self- or caregiver report. This was to ensure that no neurological or cognitive factors other than aphasia influenced participants' performance. Participants were required to have typical or corrected vision and typical hearing or use a hearing aid per self- or caregiver report. In order to ensure that participants could complete study tasks, participants were also required to have received a combined score of at least 10 for the expressive and receptive components of the Quick Aphasia Battery (QAB; Wilson et al., 2018). Participants were also evaluated using an apraxia of speech (AOS) screener, and participants were required to have no more than mild apraxia (i.e., a score of 5 or less on section 3 of the AOS Rating Scale (Strand et al., 2014; distinguishes between AOS and aphasia) in order to qualify for the study. Finally, participants were required to have an electronic device that was compatible with a videoconferencing service (e.g., Zoom) as the study was conducted remotely using videoconferencing.

Participants in Current Study

Participants included two females and one male who were ages 55, 60, and 70 at the time of testing. Participants were all bilingual speakers of Spanish and English who learned Spanish from birth. All participants resided in the United States and used English most commonly in day-to-day life at the time of testing. Participants had no other neurological or cognitive impairments other than aphasia as determined by self-report. Participants had typical or corrected vision and had typical hearing or used a hearing aid per self- or caregiver report. Finally, participants all had an electronic device that was compatible with a video conferencing service (e.g., Zoom) as the study was conducted remotely using videoconferencing.

Study Design

The present study took place during two testing sessions. Prior to the first testing session, participants completed questionnaires on their language acquisition, use, proficiency, and code-switching tendencies. During the first session, participants completed language testing (i.e., Quick Aphasia Battery, Verb Naming Test, translation task) in English (L1) as well as in their L2. Participants also completed a Stroop task where the response mode was non-verbal (i.e., participants indicated the color of the font of printed words via key press on keyboard) in order to assess their cognitive control abilities. Preliminary exploration of observed patterns in participants' accuracy and response onset latencies (ROLs) were used to determine whether the factors studied (i.e., language proficiency, language use, code switching, cognitive control, and translation ability) might be valuable in understanding participants' language mixing benefit and switch costs, as detailed in the following section.

The main experimental task in the present study was a picture-naming task in which participants named images in two single language blocks (i.e., English, Spanish) and in a voluntary mixed-language condition. This task was administered during the second day of testing. Stimuli for the picture-naming task included both nouns and verbs in order to assess whether a mixed-language advantage presented differently in nouns than it did in verbs. This study used a within-participants design.

The picture naming condition (i.e., English versus Spanish versus mixed language) and grammatical category (i.e., noun versus verb) were the independent variables. Picture naming accuracy and ROLs were the dependent variables and were compared across language conditions and grammatical categories for the first research question. To address the second research question (regarding local switch costs), picture naming accuracy and ROLs were compared across trial types (i.e., switch versus non-switch trials), grammatical categories (i.e., nouns versus verbs) and across response languages (i.e., responses in English versus responses in Spanish) in order to determine whether local switch costs were present and whether they varied by grammatical category or linguistic direction of the switch or non-switch trials.

Language and Cognitive Assessments

Participants completed speech, language, and cognitive testing during the first day of the study prior to experimental task procedures. This session was used to ensure that the participants were eligible for the present study and to collect information on participants' language and cognitive abilities that may impact their performance on the main picture naming task. All assessments were administered virtually on a video conferencing platform (i.e., Zoom) and are detailed below. See Table 1 for a summary of background testing administered and each assessment's purpose. Both an English-speaking and bilingual Spanish-speaking clinician administered testing measures to participants.

Table 1

Background Testing Measures and their Purposes

Assessment	Response Mode	Purpose

Quick Aphasia Battery (Wilson et al., 2018)	English & Spanish	Language proficiency
Verb Naming Test (Cho-Reyes & Thompson, 2012)	English & Spanish	Verb naming ability
Translation Task	English & Spanish	Translation ability
Stroop Task (Stroop, 1935)	Non-verbal	Cognitive control
Bilingual Language Profile (Birdsong et al., 2012)	English & Spanish	Language use
Self-Assessment of Individual Differences in Language Mixing Tendencies (Rodriguez-Fornells et al., 2012)	English & Spanish	Code-mixing tendencies
Apraxia of Speech Rating Scale (Strand et al., 2014)	English & Spanish	Determining severity of apraxia of speech

The Quick Aphasia Battery

The Quick Aphasia Battery (QAB; Wilson et al., 2018) was administered to participants in English and in Spanish in order to assess their language proficiency. The QAB has been translated into Spanish, French, Danish, and Lebanese Arabic, and the Spanish translation was used to assess participants' Spanish language abilities. The QAB broke participants' scores into eight categories: word comprehension, sentence comprehension, word finding, grammatical construction, speech motor programming, repetition, reading, and QAB overall. The word and sentence comprehension subscores were combined to represent receptive language, and the word finding and grammatical construction subscores were combined to represent expressive language. To qualify for the present study, participants were required to receive a score of at least 10 out of a possible 20 on the expressive (i.e., Picture

Naming subtest & Connected Speech subtest) and receptive (i.e., Word Comprehension subtest & Sentence Comprehension subtest) composites.

Verb Naming Test

The Verb Naming Test (VNT; Cho-Reyes & Thompson, 2012) was administered in English and in participants' L2 in order to assess their verb naming ability. A separate verb naming test was required because the QAB did not include an assessment for verb naming. Stimuli images for the VNT included 22 black and white line drawings depicting actions. Participants were asked to say what action was depicted in each of the stimuli images.

Calculation of Language Proficiency

Participants' accuracy on the VNT was combined with their performance on the picture naming, repetition (single-word items only), and reading aloud (single-word items only) subscores on the QAB to represent participants' proficiency in English and Spanish.

Translation Task

Participants were asked to translate adjectives and adverbs that were non-cognates in English and Spanish (e.g., four, blue, pretty, slowly) in both directions: from English to Spanish and from Spanish to English. Adjectives and adverbs were selected as stimuli as these grammatical categories were not included in the main experimental task or in language testing. Target words were simple colors, numbers, descriptive words, etc. given that the aim of the task was to assess participants' translation ability and not their word finding ability. Stimuli were presented in print on the screen and were verbally read by bilingual Spanish-English clinicians. Participants were asked to translate the words into the language not presented (e.g., participants were asked to translate words presented in English into Spanish).

Stroop Task

A Stroop task (Stroop, 1935) was used to assess participants' cognitive control. The Stroop task was administered using the online platform Pavlovia (Pavlovia, n.d.) and is taken from Faroqi-Shah & Gehman (2021). Stimuli words were visually presented on the screen and belonged to one of three experimental categories: congruent (i.e., the color of the font matches the word on the screen; n = 60), incongruent (i.e. the color of the font does not match the word on the screen; n = 60), and neutral (i.e., the word on the screen is not a color word, meaning that participants do not need to cognitively inhibit the written color name while selecting the color of the font; n=60). Participants were asked to press buttons on their keyboard to indicate the color of the font on the screen, requiring them to selectively attend to the color of fonts rather than the meanings of words on screen. Participants' Stroop Effect was calculated as the difference in participants' accuracy and speed between incongruent and neutral trials (n=60) and was used as a measure of cognitive control. As in Faroqi-Shah & Gehman (2021), in order to account for individual differences in processing speed and response times, the Stroop effect was divided by the accuracy and response times of neutral trials to obtain the conflict ratio for statistical analysis. This cognitive control task was used to quantify participants' cognitive control abilities, which were used to determine whether or not there is a correlation between cognitive control and mixed-language advantage.

Bilingual Language Profile

The Bilingual Language Profile (BLP; Birdsong et al., 2012) was sent to participants via Google forms prior to initial testing. The BLP provides an overview of language history, use, proficiency, and attitudes as well as composite scores that represent participants' language dominance. Participants were asked to complete the BLP twice—once with responses that pertained to language history, use, proficiency, and attitudes prior to their injury and once with responses that pertained to their language at the time of the study (i.e., following their injury). Participants' pre-injury language use scores (i.e., average of the percentage of the week that participants use their language with family, friends, and at work/school) were evaluated as potential predictors of their performance in the main picture naming condition.

Language Switching Questionnaire

The Self-Assessment of Individual Differences in Language Switching (Rodriguez-Fornells et al., 2012) was sent to participants via Google forms prior to initial testing. This code-switching questionnaire provides an overview of participants' code-switching tendencies in four categories: from L2 to English (L1), switching from English (L1) to L2, contextual switching (i.e., switching in specific contexts), and unintentional switching (US). Participants were asked to complete the questionnaire twice—once with responses that pertained to code-switching tendencies prior to their injury and once with responses that pertained to their code-switching tendencies at the time of the study (i.e., following their injury). Participants' code-switching tendencies were quantified using a numerical scale (i.e., 1=never; 2=rarely; 3=occasionally; 4=frequently; 5=always), and responses to certain questions were combined to reflect participants' likelihood to switch into English and into Spanish where a higher number indicates a higher frequency of language switching. Participants' pre-injury mixing scores were used to determine whether or not code-switching practices predict their performance in the main experimental task. See Appendix A for a detailed list of questions included on the language switching questionnaire.

Apraxia of Speech Rating Scale

Participants were screened for apraxia of speech (AOS) using the Apraxia of Speech Rating Scale (Strand et al., 2014). Given that the present study relied on verbal responses during the picture naming task and given the high comorbidity of aphasia and motor speech disorders (e.g., apraxia), screening for apraxia was necessary in order to ensure that participants' responses were not influenced by motor speech impairment. Participants were required to have no more than mild apraxia (i.e., a score of 5 or less on section 3 of the AOS Rating Scale, which distinguishes between AOS and aphasia) in order to qualify for the study.

Experimental Task

The primary task was a picture-naming task, which was administered virtually to participants using PCIbex (Zehr & Schwartz, 2018), an online platform for behavioral research. The picture naming task asked participants to name pictures of nouns and verbs (in separate blocks) in three language conditions (i.e., English only, L2 only, mixed condition). In the mixed language condition, participants named pictures in either L1 or L2 but were asked to voluntarily use both languages while naming. The instruction to name in either language but to use both languages was to ensure that the bilingual condition was a mixed-language condition and that participants did not name all pictures in their more proficient language, following the model of Gollan & Ferreira (2009). This approach to elicit voluntary language mixes had been used by several authors (de Bruin et al., 2018; Gollan & Ferreira, 2009). Participants were not provided specific feedback about accuracy during trials. Each trial began with a "cross" symbol, which remained on the screen for 1 second. After 1 second, the cross disappeared, and a stimulus image appeared on the screen and remained on screen for 10 seconds. A media recorder within PCIbex, which was synchronized with the image presentation, recorded the participants' naming response and created an audio file for each individual trial. Thus, trials in the present experiment progressed at a set rate, regardless of the time required for the participant to generate a response.

Participants were given practice conditions with at least five noun and verb trials before the experiment. Participants were allowed to repeat practice trials until they were comfortable with the task. In addition, family members were allowed to assist participants on practice trials to aid in facilitating understanding of the experimental task. During the experimental task, an English-speaking and bilingual Spanish-speaking researcher were present and took notes about participant behaviors during specific trials that needed to be considered during data analysis. Test administrators also live-scored responses as accurate or inaccurate. Scores were later verified by a bilingual Spanish-English speaking research assistant. The sequence of naming conditions (L1, L2, mixed) and grammatical categories were counterbalanced across participants.

Stimuli

The stimuli for the picture naming task consisted of black-and-white line drawings from the International Picture Naming Project (IPNP; Szekely et al., 2005). Stimuli consisted of nouns and verbs, and cognates (i.e., words that are exactly the same in English and Spanish) were avoided. Each blocked condition consisted of 30 unique stimulus items, and the mixed condition consisted of 60 stimulus items (i.e., a combination of the two blocked condition stimulus lists). The lists of stimuli each consisted of low and high frequency names (i.e. high frequency=more than 40 per million in English; low frequency=less than 25 per million in English according to the IPNP database, which reports CELEX frequencies), and the lists were matched for frequency to analyze potential frequency effects (Research Question 1b) in English. English values were used to control stimuli given that the ultimate aim of the study is to test speakers of multiple languages, and controlling for all languages was not feasible. Because current participants are Spanish-English bilinguals only, future post-hoc evaluations may be used to evaluate stimuli by Spanish stimulus-related factors in order to understand how these factors may have impacted current participants' performances. Lists were also matched for syllable length in English to avoid confounding effects of articulation time (Bowers et al., 2010). Name agreement was also taken into consideration in stimuli selection, and nouns and verbs with higher agreement according to the IPNP database were selected. An overview of the stimuli for the experimental task is given in Table 2. Stimuli were broken into six lists: four lists for blocked conditions (i.e., two lists of nouns and two lists of verbs; each with 30 stimulus items) and two lists for mixed conditions (i.e., one list of nouns and one list of verbs; each list with the same 60 stimulus items from the blocked conditions) for a total of 120 unique stimuli.

Table 2

Overview of Stimuli in the Picture Naming Task

Grammatical category	Condition	Stimuli
Nouns (N=120)	Single language (L1)	N=30; 15 high-frequency and 15 low-frequency
	Single language (L2)	N=30; 15 high-frequency and 15 low-frequency

	Mixed language	N=60; 30 high-frequency and 30 low-frequency
Verbs (N=120)	Single language (L1)	N=30; 15 high-frequency and 15 low-frequency
	Single language (L2)	(N=30; 15 high-frequency and 15 low-frequency)
	Mixed language	N=60; 30 high-frequency and 30 low-frequency

Note: N refers to number of stimuli.

Data Analysis

Accuracy was defined as a response that accurately described the image presented, as determined by IPNP norms and the experimenters administering the task. Obvious phonemic paraphasias (i.e. sound substitutions within responses) were scored as correct as long as the word produced was not ambiguous (i.e. at least 50% of the phonemes are produced correctly); however, ambiguous responses and neologisms were scored as incorrect. Experimenters scoring participants' accuracy were instructed to accept responses that accurately described the stimulus item presented but may have been dialectal variations of the target words. Only correct trials without self-corrections (e.g., "dog..no.. cat") or false starts (e.g., "d...cat"; "um, cat") were included in response time analyses but were coded as correct if the response was judged as accurately describing the image presented by the experimenter administering the task.

Planned Statistical Analyses

Given the limited number of participants in the current study, accuracy data was descriptively analyzed at the single subject level, and the results were interpreted with caution. Analyses of participants' response onset latencies (ROLs) excluded one participant's data due to technical issues that resulted in lost data. Analyses of ROLs were also interpreted with caution given this limitation. To examine the first research question regarding global mixing benefit, a Kruskal-Wallis test (a non-parametric statistical test) will be used when more participants are run in order to compare accuracy across the three language conditions (English, Spanish and mixed) and the two grammatical categories (nouns and verbs). Significant K-W will be followed by pairwise comparisons using the Mann-Whitney U test. Response onset latencies (ROLs) were analyzed with linear mixed effects models (LMMs). To assess the effect of mixed versus blocked conditions, an LMM was conducted with condition (blocked versus mixed) and grammatical category (nouns versus verbs) as fixed factors and participants and stimulus items as random factors. Main effects and interactions were examined, and significant results were followed up with two-tailed t-tests to determine the nature of the effect of naming condition and grammatical category on response times. If there was a main effect of condition such that ROLs in the mixed condition were significantly shorter than ROLs in the blocked conditions, this would indicate a mixing benefit. If there was an interaction between grammatical category and condition, this would indicate that global mixing effects vary by grammatical category. To examine possible ROL effects in the blocked condition that were dependent on language profile, a second LMM was conducted with a fixed effect of condition where the blocked condition was split by language (English versus mixed, Spanish versus mixed, English versus Spanish) and a fixed condition of grammatical category (noun versus verb) and participants and stimulus items as random factors.

Main effects and interactions were examined. If there was a significant main effect of condition (English, Spanish, mixed), this was followed up with two-tailed unpaired t-tests. Interpretation of results examined whether global mixing effects (i.e., faster or slower naming times in the mixed condition as compared to blocked conditions) was driven by the language of the response in the blocked conditions. If there was an observed interaction between grammatical category and condition, this meant that the benefits of language mixing may be different for nouns versus verbs. The hypothesis that a mixing benefit would be greater in magnitude for nouns than for verbs would be supported if the difference in RTs between mixed- and single-language conditions was greater for nouns than for verbs.

To address research question 1c regarding participant and stimulus factors that influence picture naming performance, a multiple regression analysis is planned with each participant's mixing effect as the dependent variable and the following predictor variables: language proficiency, cognitive control, translation ability, language use, and code-switching tendencies. Separate mixing effects will be calculated for L1 and for L2 as the difference in average accuracy (later to be calculated using RTs) for the mixed vs single language conditions (Mixed-L1; Mixed-L2). Separate regressions are planned for each language. Logistic regressions are intended to be used for accuracy and simple linear regressions for response onset latencies. However, given the limited number of participants in the present study, only descriptive analyses were conducted.

To examine local switching costs (research question 2), individual trials in the mixed language condition were coded as non-switch and switch trials on the basis of the language used in the preceding trial. For example, if the languages used by the participant in successive trials were English, English, Spanish, Spanish, then the 2nd and 4th trials were non-switch trials and the 3rd trial was a switch trial. The first trial for each participant was obviously not coded as it had no preceding trial, and similarly any trials following a no-response trial were not coded. The switch trials were also coded for direction of the switch (i.e., English to Spanish or Spanish to English). It is planned that when more participant data is collected, accuracies of switch and non-switch trials will be compared using a Kruskal-Wallis in order to determine the effect of condition (switch versus non-switch) and category (nouns versus verbs), and significant results will be followed up with non-parametric Mann-Whitney U tests. Response onset latencies were analyzed using LMM with trial type (switch versus nonswitch) and grammatical category (noun versus verb) as the fixed factors and participants and items as random factors. If there was a main effect of condition, follow-up two-tailed t-tests were completed to identify patterns in response times. If longer response times on switch trials as compared to non-switch trials, this would indicate a switching cost. If there was an interaction between grammatical category and condition, this would indicate that switching costs are different for nouns versus verbs. Response onset latencies were also evaluated for the effect of linguistic direction. LMMs were completed with switch type (switch versus non-switch) and language of the response (English versus Spanish) as fixed factors and participants and stimulus items as random factors. Main effects and interactions were evaluated, and significant results were followed up with two-tailed t-tests. If there was a main effect of trial type such that follow-up t-tests demonstrated longer response times on switch trials than on stay trials, this indicates a switch cost. If there was an interaction between switch type and grammatical category, this indicates that local switching effects may be different depending on the linguistic direction of the switch.

Similar to analyses to address research question 1b, analyses to address research question 2b regarding participant factors that influence local switch costs, a multiple regression analysis was planned where each participant's average switch cost would function as the dependent variable with the following as predictor variables: language proficiency in L1, cognitive control, translation ability, language use, and code-switching tendencies. However, given the limited number of participants, only descriptive analyses were conducted. To complete an initial exploration of the effect of stimulus factors, calculations were completed on participants' switches into English and into Spanish in order to assess the percentage of switches into each language that occurred for high-frequency words and the percentage of words of various syllable lengths in English for which participants switched languages. Later, non-parametric analyses will be conducted with the average switch cost for each stimulus item (i.e., the response time for each stimulus item will be averaged across participants in order to yield an average switch cost value for each stimulus item) will be used as the dependent variable and the predictor variables will be syllable length, lexical frequency and name agreement (bilingual naming latency values will be derived from Faroqi-Shah, Kevas, & Li, 2021).

Results

Participant profiles

As mentioned previously, statistical analyses could not be computed for accuracy data of three participants. Hence individual participant profiles will be briefly presented first in order to facilitate presentation of the results of the experimental tasks. Analyses of ROLs are presented in conjunction with descriptive analyses on participants' accuracy and discussed with patterns observed in participants' accuracy in order to address the research questions. Demographic information is presented in Table 3, and scores from baseline language and cognitive testing are presented in Tables 4 and 5, respectively. Overall, participants were relatively homogenous in terms of their ages and in the fact that all three participants began learning Spanish at birth. Participants were also relatively similar in that they reported using English more than Spanish in their daily lives prior to their strokes on the BLP (Birdsong et al., 2012), and they reported similar code-switching tendencies on the Self-Assessment of Individual Differences in Language Mixing (Rodriguez-Fornells et al., 2012). In terms of their cognitive control, participants demonstrated overall increased accuracy on congruent trials as compared to incongruent trials and faster response times on congruent trials as compared to incongruent trials. Participants' conflict ratios on the Stroop task (i.e., Stroop effect divided by participants' accuracy and average response time on neutral trials) indicate that they did not demonstrate significant cognitive control deficits. Individual analyses of participants' baseline testing and demographic information is presented below.

Table 3

Participant Demographic Information.

Demographic information	AP164	AP167	AP168	Mean (SD)
Age	60	55	70	61.67 (7.64)
Time post-onset of stroke (in months)	63	8	24	31.67 (28.29)
Age participant began learning Spanish	0	0	0	0 (0)
Age participant began learning English	4	14	16	11.33 (6.43)
Participant's self-perceived proficiency in Spanish (0-24)*	15	24	24	21 (5.2)
Participant's perceived proficiency in English (0-24)*	24	24	24	24 (0)
Dominance Score (-182 to +182)*	74.11	25.16	-15.7	27.86 (44.97)

Note: Dominance scores of zero represent balanced bilingualism; positive dominance scores represent English dominance; and negative dominance scores represent Spanish dominance. Participants' perceived proficiency in Spanish and English and their dominance scores from the BLP (Birdsong et al., 2012).

*Pre-morbid values.

Table 4

Participants' Performance on Subjective and Objective Language Assessments.

	English				Spanish			
	AP164	AP167	AP168	Mean (SD)	AP164	AP167	AP168	Mean (SD)

Language Proficiency Composite (0-88)[1]	88	86	87	87 (1)	55	86	84	75 (17.35)
VNT (0-22)[2]	*22*	*20*	*21*	*21 (1)*	*10*	*20*	*18*	*16 (5.29)*
QAB Picture Naming (0-24)[3]	*24*	*24*	*24*	*24 (0)*	*13*	*24*	*24*	*20.33 (6.35)*
QAB Single-Word Repetition (0-16)[3]	*16*	*16*	*16*	*16 (0)*	*8*	*16*	*16*	*13.33 (4.62)*
QAB Single-Word Reading (0-16)[3]	*16*	*16*	*16*	*16 (0)*	*16*	*16*	*16*	*16 (0)*
Translation into Stated Language (0-10)	10	10	10	10 (0)	8	10	10	9.33 (1.15)
Language Use (0-50)[4]	37	38	28	37 (8.54)	7	12	17	12 (5)
Language Switching (0-40)[5]	21.66	22	16	21.67 (5.51)	25	24	16	21.67 (4.93)

1. Language proficiency composite=sum of participants' VNT, QAB-Picture Naming, QAB-Single-Word Repetition, & WAB-Single-Word Reading.
2. Verb Naming Test (VNT; Cho-Reyes & Thompson, 2012)
3. Quick Aphasia Battery (QAB; Wilson et al., 2018)
4. Bilingual Language Profile (BLP; Birdsong et al., 2012)

5. Self-Assessment of Individual Differences in Language Switching (Rodriguez-Fornells et al., 2018)

Table 5

Participants' Cognitive Control Scores.

Measure	AP164	AP167	AP168	Mean (SD)
Stroop effect: accuracy (in percentage)	10	5	5.14	6.88 (2.72)
Stroop effect: timing (in milliseconds)	-181	-155	-51	-129 (68.79)
Conflict ratio: accuracy	0.1	0.05	0.05	0.07 (0.03)
Conflict ratio: RT	-0.06	-0.07	-0.05	-0.06 (0.01)

Note: Participants' Stroop effect for accuracy is calculated as percent correct responses on congruent trials minus percent correct responses on incongruent trials. Participants' Stroop effect for timing is calculated as response time on congruent trials minus response time on incongruent trials. Participants' conflict ratio is calculated as Stroop effect divided by accuracy or RT on neutral trials.

AP164

Participant AP164 was an early bilingual, learning both languages before the age of 5 years. Her self-ratings of language proficiency (Birdsong et al., 2012), indicate a perfect proficiency for English but not for Spanish. This is also reflected in her language dominance score of 74.11, which shows a pre-morbid dominance for English. Of the three participants, she was the most unbalanced bilingual with a dominance score of 74.11 out of a possible 182, indicating high English dominance. Her test scores show overall, an unimpaired (non-aphasic) performance in English

(88/88 total score) but a moderate degree of impairment in Spanish (55/88). In Spanish, AP164's word finding abilities were slightly more impaired for verbs (45% accurate) than for nouns (54.2% accurate). AP164's translation ability into Spanish was only slightly lower than her translation ability into English (80% versus 100%). AP 164's Language Use composite on the BLP indicated that she used English more frequently than Spanish before her stroke. AP164 did report mixing languages in her daily life prior to her stroke (Rodriguez-Fornells et al., 2018); her score of 21 for switching to English and 25 for switching to Spanish indicates that she occasionally mixed languages prior to her stroke. Lastly, AP164 showed a typical Stroop effect for accuracy (10% more accurate on congruent compared to incongruent trials) and a Stroop effect of 181 milliseconds (RT for congruent trials minus incongruent trials). Her conflict ratios of 0.1 for accuracy and -0.06 for timing do not indicate a significant cognitive control deficit (Faroqi-Shah & Gehman, 2021).

AP167

Participant AP167 was a later bilingual than AP164. Like AP164, participant AP167 began learning Spanish from birth, but she did not begin learning English until age 14. Participant AP167 received a dominance score of 25.16 out of a possible 182 on the BLP (Birdsong et al., 2012). This score indicates that she had premorbid English dominance, but given that a dominance score of zero indicates balanced bilingualism, AP167 was closer to a balanced bilingual than AP164. Participant AP167 rated herself as having perfect proficiency in English and Spanish prior to her stroke on the BLP (Birdsong et al., 2012). Interestingly, AP167 received exactly the same scores in English and Spanish for all subtests administered during baseline language testing. In both English and Spanish, the only subtest on which she lost points was the VNT (Cho-Reyes & Thompson, 2012), on which she received a score of 20 out of a possible 22 (90% accurate), indicating that her verb naming was slightly more impaired than her noun naming. AP167's language use score on the BLP (Birdsong et al., 2012) indicates that she used English more frequently than Spanish before her stroke. AP167's language switching score (Rodriguez-Fornells et al., 2012) indicates that she switched into English and Spanish approximately equally, and her scores of 22 out of 40 for English hand 24 out of 40 for Spanish indicate that she switched languages occasionally before her stroke. Lastly, AP164 showed a 5% improvement in accuracy for congruent trials versus incongruent trials on the Stroop task, and she demonstrated a typical Stroop effect of 155ms for timing. AP167's conflict ratios of 0.05 for accuracy and -0.07 for timing do not indicate a significant cognitive control deficit (Faroqi-Shah & Gehman, 2021).

AP168

Similar to the other two participants, AP168 began learning Spanish from birth; however, AP168 began learning English latest of the three participants (age 16). Participant AP168 was the only participant who received a dominance score on the BLP (Birdsong et al., 2012) that indicated Spanish dominance prior to his stroke (-15.7 out of -182). Participant AP168's dominance score also suggests that he was the most balanced bilingual in the current study (i.e., AP168's dominance score was closest to zero). Similar to AP167, participant AP168 rated himself as having prefect proficiency in both English and Spanish prior to his stroke. Also similar to AP167, participant AP168 demonstrated a perfect (non-aphasic) performance on all subtests conducted during language testing with the exception of the VNT (Cho-Reyes & Thompson, 2012), indicating that his picture naming was within normal limits for nouns but mildly impaired for verbs. AP168 performed more accurately on the VNT in English (95%) than in Spanish (82%). AP168 received a language use score on the BLP (Birdsong et al., 2012) of 28 out of 50 for English and 17 out of 50 for Spanish, indicating that he used English more than Spanish in his daily life prior to his stroke. AP168 received the lowest language switching score of the three participants (16 out of 40 for English and Spanish), which indicates that before his stroke, AP168 switched between languages infrequently, but when he did so, he switched into Spanish and English with the same frequency. Lastly, AP168 demonstrated a typical Stroop effect (5.14% higher accuracy on congruent trials) for accuracy and a typical Stroop effect of 51ms for timing. His conflict ratios of 0.05 for accuracy and -0.05 for timing do not indicate a significant cognitive control deficit (Faroqi-Shah & Gehman, 2021).

Experimental task

In this section, first group trends will be discussed for each research question. This will be followed by an analysis of individual participant performance. For context, the reader is reminded that there were 60 stimuli in the bilingual naming condition, and hence a change in accuracy of 1.67% corresponds to one item.

Table 6

Global Effects in the Picture Naming Task: Percent Accuracy. Mixing effect= accuracy of mixed minus blocked conditions.

	AP164	AP167	AP168	Mean (SD)

Nouns				
Blocked-English	90	100	100	96.67 (5.77)
Blocked-Spanish	50	93.33	100	81.11 (27.15)
Mixed (Bilingual)	100	100	98.31	99.44 (0.98)
Mixing Effect (both languages)	30	3.34	-1.69	10.55 (17.03)
Mixing effect: bilingual minus English-only	10	0	-1.69	2.77 (6.32)
Mixing effect: bilingual minus Spanish-only	50	6.67	-1.69	18.33 (27.47)
Verbs				
Blocked English	93.33	96.67	93.33	94.44 (1.93)
Blocked-Spanish	16.67	80	96.67	64.44 (42.21)
Mixed (Bilingual)	89.29	95	100	94.76 (5.36)
Mixing Effect both languages	34.29	6.67	5	15.32 (16.45)
Mixing effect: bilingual minus English-only	-4.04	-1.67	6.67	0.32 (5.63)
Mixing effect: bilingual minus Spanish-only	72.62	15	3.33	30.32 (37.09)

Figure 1

Global Effects in the Picture Naming Task: Response Onset Latency (Mixed versus Blocked Condition)

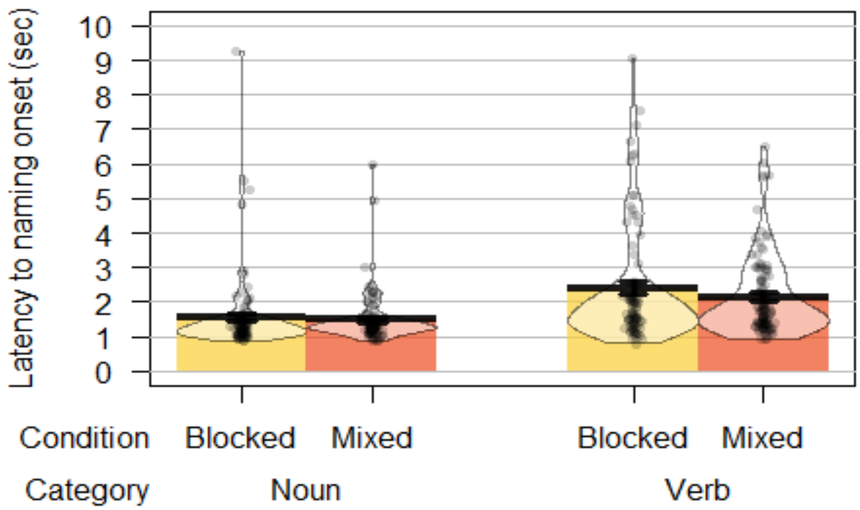
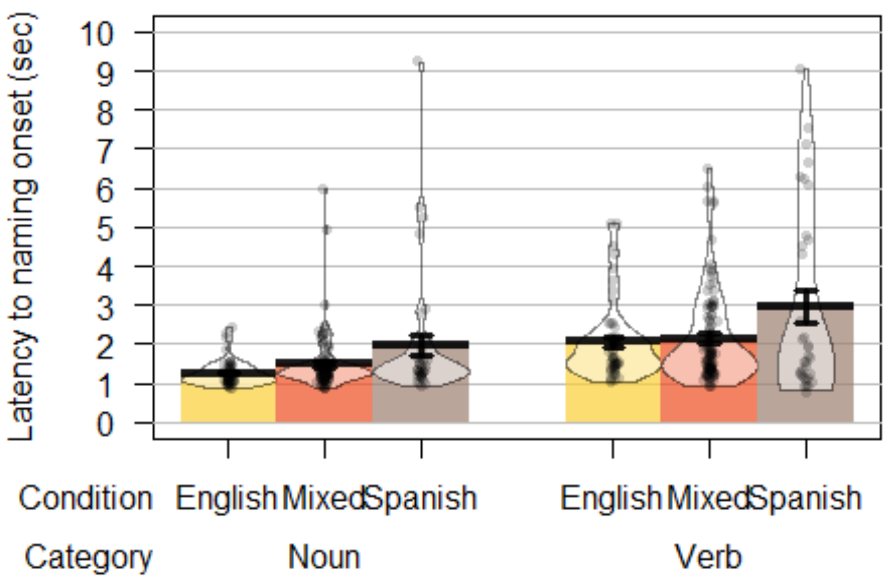


Figure 2

Global Effects in the Picture Naming Task: Response Onset Latency (Mixed versus Blocked Conditions, Separated by Language)



Global Effects of Language Mixing: Research Question 1

In Table 6, the global mixing effects across participants show a numerical mixing benefit, which was slightly smaller for nouns (10.55%) compared to verbs (15.32%). In addition, the mixing benefit appeared to be larger for Spanish (18.33% nouns and 30.02% for verbs) than it was for English (2.77% for nouns and 0.32% for verbs). The LMM of participants' ROLs revealed a main effect of category ($F(1,172)=0.871$, $p<.001$), no main effect of condition ($F(1,172)=-0.096$, $p=0.55$), and no interaction. Follow-up t-tests were conducted in order to explore the main effect of category on ROLs. These follow-up t-tests revealed that ROLs were significantly longer in the verb condition than ROLs in the nouns condition ($t(332)=-6.22$, $p<.001$). While the effect of condition (i.e., mixed versus blocked) was not significant, we see in the graphical representations of participants' ROL data (Figure 1) that response times in mixed conditions appear to be slightly shorter on average than response times on blocked conditions.

The picture naming accuracies in Table 6 show that all three participants received more accurate scores in English (96.67% on nouns and 94.44% on verbs) than in Spanish (94.44% on nouns and 64.44% on verbs). Similarly, a linear mixed effects model (LMM) of participants' response onset latencies (ROLs) found a main effect of condition ($F(1,170)=-0.843$, $p<.01$), and follow-up two-tailed t-tests showed that participants' ROLs in the Spanish condition were significantly longer than their ROLs in the English condition ($t(87)=-3.00$, $p<.01$) and the mixed condition ($t(83)=-2.44$, $p=.02$; Figure 2). Response times in the English and the mixed conditions were not significantly different from each other ($t(256)=-1.46$, *n.s.*). Participants also demonstrated higher accuracy overall in noun conditions (96.67% in English and

81.11% in Spanish) than in verb conditions (94.44% in English and 64.44% in Spanish). Individual participant performances will be discussed after presenting overall patterns in local switching effects.

Table 7

Participants' Overall Switching Tendencies during Picture Naming Task.

	AP164	AP167	AP168	Mean (SD)
Nouns				
Overall	43.1	51.7	62.7	52.5 (9.8)
Switch to Spanish	52	48.4	51.4	50.6 (1.9)
Switch to English	48	51.6	48.6	49.4 (1.9)
Verbs				
Overall	33.9	46.7	55.9	45.5 (11.1)
Switch to Spanish	52.6	53.6	48.5	51.7 (2.7)
Switch to English	47.4	46.4	51.5	48.4 (2.7)

Note: Overall refers to the percentage of trials for which participants switched languages. The number of trials for which participants switched to English and Spanish was then divided by the total number of trials for which participants switched languages in order to calculate percent of switches to English and Spanish.

Table 8

Local Effects in the Picture Naming Task: Accuracy Switching effect = accuracy of switch minus non-switch trials

	AP164	AP167	AP168	Mean (SD)
Nouns				
Non-switch	100	100	95	98.33 (2.89)
Switch	100	100	100	0
Switching effect:	0	0	5	1.67 (2.89)

both languages				
Switching effect: Spanish to English	0	0	5	1.67 (2.89)
Switching effect: English to Spanish	0	0	5	1.67 (2.89)
Verbs				
Non-switch	84.85	96.55	100	93.80 (7.94)
Switch	94.74	96.43	100	97.06 (2.69)
Switching effect: both languages	9.89	-0.12	0	3.26 (5.74)
Switching effect: English	15.15	3.44	0	6.19 (7.94)
Switching effect: Spanish	5.15	-3.22	0	0.64 (4.22)

Figure 3

Local Effects in the Picture Naming Task: Response Onset Latency (Switch versus Non-Switch Trials)

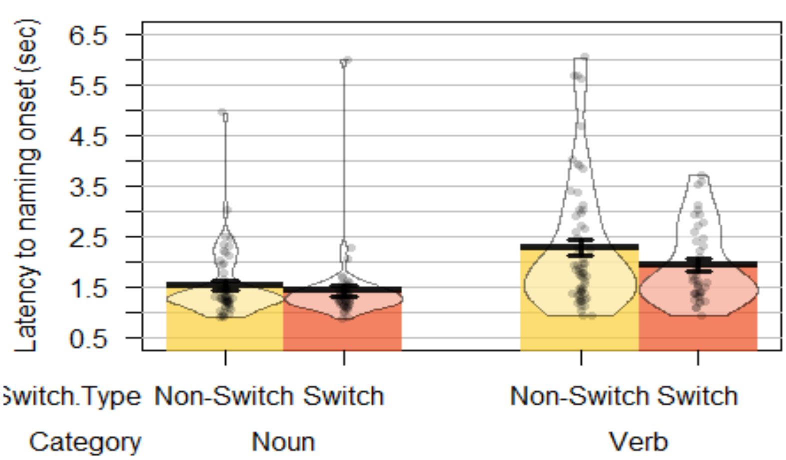
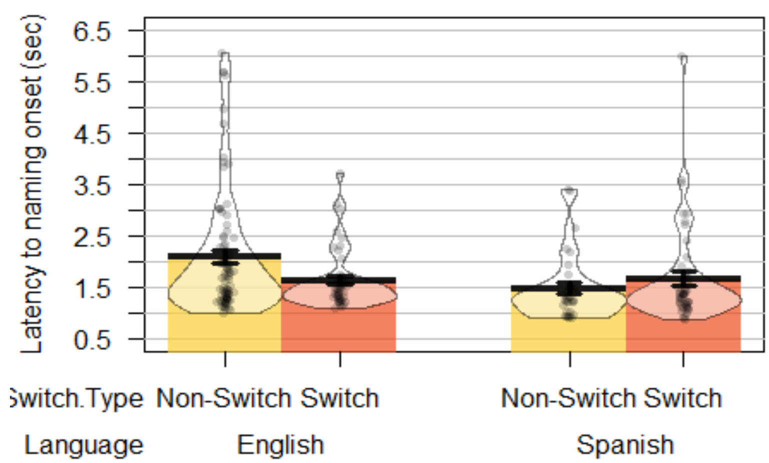


Figure 4

Local Effects by Language of the Response in the Picture Naming Task: Response Onset Latency (Switch-to-English, Switch-to-Spanish Non-Switch: English, Non-Switch: Spanish Trials)



Local Effects of Language Mixing: Research Question 2

During the main experimental task, participants switched languages on approximately 50% of trials for nouns and verbs. Participants' percentage of switch trials compared to their percentage of stay trials are presented in Table 7. The accuracies of the mixed language condition were split into switch and non-switch trials and presented in Table 8. The average switching effect was negligible (1.67% for nouns and 3.26% for verbs). The positive value, although negligible, suggests a local switching benefit. When naming verbs, switching into English resulted in slightly higher accuracy (6.16%) than switching into Spanish (0.64%). For nouns, there was no difference in magnitude of the switching effect based on switch direction. Participants' ROLs for switch trials were compared to their ROLs for non-switch trials (Figure 3). The LMM revealed a main effect of grammatical category ($F(1,3)=0.729$, $P=0.02$). The LMM did not result in a main effect of condition

($F(1,3)=-0.029$, $p=0.866$), and no interactions were observed (Figure 3). Follow-up t-tests assessing the nature of the relationship between participants' ROLs and grammatical category revealed significantly longer ROLs in the verbs category than the nouns category ($t(171.19)=-5.19$, $p<0.01$), similar to the finding for global mixing effects. A second LMM was conducted in order to assess potential asymmetries in local switching effects on the basis of the language of the response. This LMM did not reveal a main effect of switch type or the language of the response; however, the effect of the language of the response was marginal ($F(1,3)=-0.554$, $p=0.06$). In the graphical representation of this LMM (Figure 4), it appears that response times when the response language was Spanish are slightly lower than when the language of the response was English.

Table 9

Percent of participant language switches to English and Spanish by English frequency of stimulus words.

	AP164		AP167		AP168		Mean (SD)	
	High	Low	High	Low	High	Low	High	Low
Nouns								
Switch to English	50	50	63	37	50	50	54 (7.2)	46 (7.4)
Switch to Spanish	62	38	40	60	43	57	48 (11.8)	52 (11.8)
Verbs								
Switch to English	22	88	53	47	65	35	47 (22)	56 (28)
Switch to Spanish	80	20	54	46	56	44	63 (14)	37 (14)

Note: Values in Table 9 are calculated as number of switches to English for high-frequency nouns divided by total number of switches to English for nouns (and repeated for high- and low-frequency words and for switches to English and Spanish for nouns and verbs).

Table 10

Percent of time participants switched to English and Spanish for words of various syllable lengths (based on syllable lengths in English).

	AP164		AP167		AP168		Mean (SD)	
	English	Spanish	English	Spanish	English	Spanish	English	Spanish
Nouns								
1 Syllable	17	21	26	21	33	31	25 (8)	24 (5)
2 Syllables	29	21	21	29	14	36	21 (7)	29 (7)
3+ Syllables	25	25	50	50	50	25	42 (14)	33 (14)
Verbs								
1 Syllable	13	15	26	21	28	25	23 (8)	20 (5)
2 Syllables	29	0	14	29	29	43	24 (8)	24 (22)

Note: Calculated as number of switches to English for 1-syllable nouns divided by total number of 1-syllable nouns, etc.

Stimulus-Related Factors: Research question 2c

Participants' language switches were analyzed in order to calculate the percentage of their switches to English and to Spanish that were for high frequency words and words of various versus low-frequency words. Stimulus items were coded as high-frequency or low-frequency words based on data from the IPNP database, which reports CELEX frequencies (i.e., high frequency=more than 40 per million in English; low frequency=less than 25 per million in English). The frequency data is presented in Table 9. Each stimulus list featured an equal number of high- and low-frequency items; however, while lists were matched for number of syllables in English such that lists were comparable to one another in their distribution of syllable lengths (based on English targets for stimulus items), the number of one- versus two-versus three-plus-syllable words in each stimulus list varied greatly. In order to account for this variation, participants' switching patterns by word length were calculated as number of switches to English for one-syllable words divided by the total number of one-syllable words presented (the same calculation was completed for two- and three-plus-syllable words in English and for one- two- and three-plus-syllable words in Spanish). This data is presented in Table 10. Overall, participants switched languages approximately half of the time, and participants were relatively balanced in terms of the proportion of their switches to English and to Spanish that were for high and low frequency words for both nouns and verbs. No clear patterns could be drawn from data on participants' language switches by syllable length of stimulus words; further analyses will be conducted when more participant data is collected.

Individual participant profiles are presented next.

AP164

Participant AP164 was an early bilingual, learning both English and Spanish before 5 years of age. She was also the least balanced bilingual in the current study with high English dominance. Table 6 shows that AP164 scored better in English than in Spanish for both nouns and verbs during the main experimental task, which was consistent with her performance on baseline measures (Table 4) and her higher self-ratings of English proficiency (Table 3). While her noun naming was generally high in both languages (>90%), she was more impaired in verbs, particularly in Spanish (only 17% accuracy). In English, she did not show any substantial benefit of mixing languages for nouns (10%) or verbs (-4.04%). But because Spanish was her less proficient language, she showed substantial increases in accuracy in the mixed condition (50% when compared to nouns, 72% when compared to verbs) when only Spanish naming was considered.

AP164 switched languages on approximately half of trials in the mixed nouns condition; however, she demonstrated lower percentage of language switches in the mixed verbs condition (33.9%). Her proportion of switches to English and Switches to Spanish were approximately equal across grammatical categories. In terms of local switching effects in the mixed language condition, no patterns can be drawn for nouns because of ceiling performance. For verbs, switching into the more proficient language (i.e., from Spanish to English) resulted in more successful naming (15% switching benefit) than switching into the less proficient language (from English to Spanish, 5%). When naming nouns, AP164 was relatively balanced in terms of the percentage of her switches to English and Spanish that were for high versus low frequency words. However, when AP164 named verbs, she more frequently switched to Spanish for high-frequency words (80%) and switched to English for low-frequency words (88%). No patterns were observed in terms of AP164's language switches by complexity (i.e., syllable length) of stimulus items.

AP167

AP167 was a later bilingual than AP164, having started acquiring English at age 14. AP167 performed better in English than in Spanish for nouns and verbs during the main experimental task (Table 6), which is inconsistent with her baseline measures (Table 4) but consistent with her language dominance score on the BLP (Birdsong et al., 2012), which indicated that while she was a more balanced bilingual than AP164, English was AP167's dominant language prior to her stroke (Table 3). AP167 performed at or near ceiling (>90%) when naming nouns in English and Spanish and when naming verbs in English. She performed slightly better when naming nouns (100% in English and 93.33% in Spanish) than when naming verbs (96.67% in English and 80% in Spanish), which was consistent with her baseline testing (Table 4). AP167 was not significantly more accurate when naming nouns in the mixed condition versus the blocked condition (3.37%) or when naming verbs in the mixed condition versus the blocked condition (6.67%) for English or for Spanish.

In terms of local switching effects, no patterns were observed for nouns because of ceiling performance, and the magnitude of the switching effect was miniscule for verbs (3.44%) when switching to her dominant language (i.e., English) and -3.22% when switching to her non-dominant language (i.e., Spanish). AP167 switched languages on approximately half of all trials in the mixed conditions for nouns and for verbs, and the proportion of her switches to English and switches to Spanish were relatively balanced for nouns and verbs. AP167 switched to English slightly more often for high frequency nouns (63%), and she switched to Spanish slightly more often for low frequency nouns (60%). No patterns were observed in terms of AP167's language switches by complexity (i.e., syllable length) of stimulus items.

AP168

AP168 was the latest bilingual (i.e., began learning English at age 16). AP168 was also the most balanced bilingual in the present study and the only participant whose language dominance score on the BLP (Birdsong et al., 2012) indicated that he was Spanish dominant prior to his stroke (Table 3). In the experimental task, AP168 performed equally in English and Spanish when naming nouns, which was consistent with his baseline testing (Table 4). When naming verbs, AP168 performed slightly better in Spanish (96.67) than in English (93.33), which was inconsistent with his baseline testing but consistent with his language dominance score on the BLP (i.e., Spanish dominant). AP168 performed near ceiling (>90%) for nouns and verbs across language conditions, but he performed slightly better when naming nouns (100% for English and Spanish) than when naming verbs (93.33% for English and 96.67 for Spanish). AP168 demonstrated a negligible decrease in accuracy in the mixed condition when naming nouns (-1.69%). He demonstrated a slightly larger increase in accuracy when naming verbs in the bilingual condition (5%). The increase in accuracy in the mixed condition for verbs was slightly larger for his non-dominant language (6.67% for English) than for his dominant language (3.53% for Spanish).

In terms of local switching effects, no patterns can be drawn for verbs because of AP168's ceiling performance when naming verbs. When he was naming nouns, AP168 was more accurate by one trial on switch trials versus non-switch trials (5%),. AP168 switched languages for approximately half of the trials in the bilingual conditions for nouns and verbs. His language switches were balanced in terms of switches to English versus switches to Spanish. AP168's switches to English and Spanish were approximately equal in their proportions of high frequency versus low frequency nouns, and his switches to Spanish were balanced in terms of high versus low frequency verbs. However, AP168 switched to English slightly more for high frequency verbs (65%) than for low frequency verbs (35%).

Discussion

The goal of this thesis was to examine the effects of various language conditions on bilingual PWA's ability to name pictures. The design of this study is reflective of studies on global and local effects of language mixing in healthy adults (e.g., de Bruin et al., 2018; Jetovic et al., 2020; Gollan & Ferreira, 2009), and the research questions in this study aimed to examine whether or not global and local effects of language mixing observed in healthy bilingual adults might also apply to bilingual PWA. In addition, given that healthy bilinguals tend to perform differently when naming nouns and verbs (Faroqi-Shah & Waked, 2010; Matzig et al., 2009) and that people with aphasia tend to demonstrate larger verb deficits than nouns deficits (Nilipour et al., 2017), the present study examined the effect of grammatical category on bilingual PWA's picture naming ability by evaluating nouns and verbs separately. The three participants in the present study were relatively homogenous, in that they all began learning Spanish from birth and English before adulthood. All three participants also demonstrated high levels of accuracy across language conditions and grammatical categories, which is consistent with findings from language mixing studies on healthy adults that use a picture naming procedure (de Bruin et al., 2020), which have found that in general, bilinguals are highly accurate when picture naming.

In addition, initial analyses demonstrate that language condition and grammatical category as well as various participant- and stimulus-related factors may be related to participants' performances on picture naming tasks, warranting further evaluation involving a larger sample of participants.

Global Effects

Research question 1a asked whether various language conditions impacted global effects (i.e., mixing cost or benefit) in participants' picture naming accuracy. It was hypothesized that participants would be more accurate in voluntary bilingual conditions than in blocked conditions given that prior studies on bilingual language mixing have generally found a global mixing benefit for healthy bilinguals (de Bruin et al., 2018; Jetovic et al., 2020). When participants' data is averaged, they responded more accurately in the bilingual conditions than in the blocked conditions for nouns and verbs. This pattern aligns with the hypothesis of research question 1a that participants' accuracy would be higher in voluntary bilingual conditions than in blocked conditions. While response times for mixed and blocked conditions were not significantly different, participants' response times in the mixed condition appeared to be on average slightly shorter than response times in the blocked conditions in the graphical representation of the data, though these differences were not statistically significant; this pattern also aligns with the hypothesis of research question 1a.

Research question 1b asked whether global mixing effects might vary according to grammatical category (i.e., nouns versus verbs). Research question 1b hypothesized that a potential mixing benefit would be larger for nouns than for verbs given the documented difficulty that bilingual PWA have with naming verbs

(Nilipour et al., 2017). Participants responded more accurately in the mixed conditions than in blocked conditions, and the increase in accuracy in the mixed condition was larger for verbs (15.32%) than it was for nouns (10.55%), which is not supportive of the hypothesis for research question 1b but is consistent with prior literature on healthy bilinguals that has found that verb naming tasks can mitigate disadvantages of bilingual participants in noun-naming tasks. The finding that participants' response times were significantly longer for verbs than for nouns is consistent with prior literature on PWA, which has found that PWA tend to demonstrate more difficulty with verbs than with nouns (Nilipour et al., 2017). However, no patterns can be drawn regarding potential differences in magnitude of local switching effects in the present sample. While it was hypothesized that a mixing benefit would be smaller in magnitude for verbs than it would be for nouns because studies on healthy adults have found that bilinguals' language performance is aided by the specificity of verbs, it may be that because bilingual PWA are less accurate naming verbs, they benefited from the ability to switch languages as needed in order to increase their accuracy.

Research question 1c asked whether a potential mixing benefit was related to participant-related factors (i.e., cognitive control, language proficiency, translation ability, language use, code-switching tendencies). It was hypothesized that increased cognitive control, language proficiency, translation ability, language use, and code switching would be correlated with a mixing benefit in the bilingual condition. Each of these factors is addressed in the following paragraphs.

Results from the Stroop task demonstrated that all three participants in the current study had typical Stroop effects for accuracy and timing, and their conflict ratios did not indicate cognitive control deficits. It is therefore impossible to determine the impact of cognitive control on global mixing effects in the present study with the current number of participants.

Based on current results, language proficiency does appear to be an important participant-related factor to consider in evaluating participants' picture naming performances. Averaged results demonstrated increased accuracy in the mixed conditions which was larger when compared to Spanish-only conditions than when compared to English-only conditions; however, this average was highly influenced by participant AP164, who was the least balanced of the three bilinguals in the present study and who demonstrated much higher proficiency in English than in Spanish during baseline testing. In the main experimental task, AP164 demonstrated a significantly larger mixing benefit when only her less proficient language (i.e., Spanish) was considered (Table 6). These findings are consistent with findings from Costa and Stantesteban (2004), who suggested that language proficiency was correlated with language mixing effects in healthy bilinguals.

Language use and code-switching tendencies were selected as potentially important participant-related factors in the present study based on prior studies that have suggested that these factors may influence bilingual language performance (Green & Wei, 2014; Lai & O'Brien, 2020). However, all participants in the present study were relatively homogenous in terms of their language use and code-switching scores (Table 4), which yields conclusions on the influence of these factors impossible to draw with the current participant sample. Similarly, all three participants performed similarly on the translation task used during baseline testing; therefore, no conclusions can be drawn at this time regarding the influence of translation ability on participants' global mixing effects.

Language dominance was not a factor that was selected for study; however, participants' results suggest that language dominance may be an important participant-related factor for future evaluation in this study. Participant AP168 was the only Spanish-dominant bilingual according to the BLP (Birdsong et al., 2012) in the present study, and in the verb condition, he demonstrated increased accuracy in the mixed condition that was greater when compared to blocked conditions in his non-dominant language (i.e., English) than in his dominant language (i.e., Spanish). In contrast, participants AP164 and AP167, who were both English-dominant bilinguals according to the BLP (Birdsong et al., 2012), were less accurate in the mixed condition than when naming in their dominant language (i.e., English), but they were more accurate in the mixed condition than when they were naming in their non-dominant language only (i.e., Spanish). In addition, participants' ROLs were significantly longer in the Spanish condition than in the mixed English conditions, which may be reflective of participants' language dominance given that the two participants whose ROLs were included in the LMM were English-dominant bilinguals. These results demonstrate a possible relationship between participants' language dominance and their global mixing effects, such that increased accuracy in the mixed condition as compared to blocked conditions appeared to generally be larger when the mixed condition was compared to participants' non-dominant language than when it was compared to their dominant language. This is consistent with findings by Gollan and Ferreira (2009), who also found a larger mixing effect on participants' non-dominant language than on their dominant language.

Local Effects

Research question 2a asked whether language conditions affected participants' accuracy in terms of local switching effects. It was hypothesized that participants would be less accurate on switch trials than on non-switch trials (i.e., switch cost) given that prior studies involving healthy bilinguals that have found that even when healthy bilinguals demonstrate a global benefit of mixing languages in voluntary mixed conditions, they still demonstrate local switch costs, defined as slower response times on switch trials than on non-switch trials (de Bruin et al., 2018; Gollan & Ferreira, 2009). This hypothesis was not supported by the present data as participants demonstrated higher accuracy on switch trials than on non-switch trials for both nouns and verbs, indicating that participants were generally more accurate when they switched languages to name pictures than when they named consecutive pictures in the same language. This increase in accuracy on switch trials may be reflective of the fact that PWA consistently demonstrate picture naming difficulties (Kiran et al., 2014), and therefore the option to switch languages and the access to both of their lexicons may result in higher accuracy than being restricted to one language while picture naming. While switching languages appears to have benefitted participants in terms of their accuracy, participants did not respond significantly more quickly on switch trials than on stay trials. The difference in response times for switch versus stay trials is not significant, in looking at graphical representations of participants' ROLs (Figure 3), we see that ROLs for switch trials appear to be slightly smaller overall than ROLs for non-switch trials. More data involving more participants will be instrumental in exploring these patterns further.

Research question 2b asked whether observed local effects of language mixing might vary by grammatical category. It was hypothesized that local effects of language switching would be greater for verbs than for nouns, consistent with the generally greater difficulty with verb naming experienced by PWA (Nilipour et al., 2017; Hernàndez et al., 2008). The average increase in accuracy for switch trials as compared to non-switch trials that the current participants demonstrated was slightly larger in the verb category than it was in the noun category (Table 8), which aligns with the hypothesis of research question 2b. In addition, participants were significantly slower when naming verbs than when naming nouns. These patterns may indicate that because verb naming was generally more impaired than noun naming for the current participants, they demonstrated a larger benefit of switching languages in the verb condition than they did in the noun condition, in which most of them were relatively accurate in blocked conditions as well. Interestingly, participants AP164 and AP167, who were less balanced, English-dominant bilinguals demonstrated 100% accuracy in the bilingual condition when naming nouns and lower accuracy in the bilingual condition when naming verbs; however, participant AP168, who was the most balanced Spanish bilingual, demonstrated 100% accuracy in the bilingual condition when naming verbs and slightly less accurate naming when naming nouns. AP168's performance is reflective of findings by Faroqi-Shah and Milman (2015) that while healthy bilinguals demonstrated a disadvantage as compared to monolingual participants when naming nouns, this disadvantage was not present when healthy bilingual named verbs.

Research question 2c asked whether observed local effects of language switching may be related to various participant-related factors (i.e., cognitive control, language proficiency, translation ability, language use, code-switching tendencies) and stimulus-related factors (i.e., lexical frequency, complexity, and name agreement of stimulus items). It was hypothesized that higher scores on baseline assessments of participant-related factors may be correlated with participants' switching effects (Green and Abutalebi, 2013; de Bruin et al., 2018; Costa & Stantesteban, 2004; Green & Wei, 2014; Lai and O'Brien, 2020). As discussed in the prior section on global mixing effects, participants' scores for cognitive control, translation ability, language, use, and code switching were homogenous and therefore uninterpretable with the current sample size. Participants' language proficiency and language dominance appear to be related to their local switching effects on accuracy and will be discussed in this section. It was also predicted that switch costs would be larger when participants were naming less frequent, longer, words with lower name agreement (Alario et al., 2002; Costa & Stantesteban, 2004). Interpretation of the effect of stimulus-related factors on local switching effects will be more appropriately addressed with a larger sample size; however, preliminary analyses of participants' reveal patterns related to lexical frequency in English, which will be discussed below.

Language proficiency appears to be an important factor to consider in bilingual PWA's local switching effects, as has been suggested by prior studies on language switching in healthy adults (e.g., Costa & Stantesteban, 2004). While it was predicted that participants would be less accurate when they switched languages to name pictures as compared to when they named consecutive pictures in the same language, we see that in the verbs condition, participant AP164 demonstrated higher picture naming accuracy when she switched into her more proficient language (i.e., English). This is the opposite of the finding by Costa and Stantesteban (2004) who concluded that L2 learners (i.e., participants with lower language proficiency) demonstrated greater switch costs for switching into their more proficient language. These initial findings suggest that it may be that because word finding difficulties that result from aphasia (e.g., Kiran et al., 2014), bilingual people with aphasia name more accurately when they switch to their dominant language during naming tasks.

Similar to patterns observed in global mixing effects, participants' language dominance also appears to have played a role in local switching patterns. This pattern is reflective of prior findings by Gollan and Ferreira (2009). When naming verbs, AP167 and AP164 demonstrated higher accuracy on switch trials compared to non-switch trials when they switched to their dominant language (English) and lower accuracy or smaller effects on switch trials compared to non-switch trials when they switched to their non-dominant language (Spanish). This is similar to findings by Gollan and Ferreira (2009), who concluded that bilinguals switched languages only when switching languages either did not compromise or improved accuracy or when responses were relatively easy to access in their non-dominant language, as will be discussed next. In addition, the marginal effect of the language of the response on local switching effects which graphical representations of this model suggested that participants' responses in Spanish tended to be slightly shorter than responses in

English. This is interesting considering that the two participants whose data was included in this model were English-dominant, and it may be expected that their response times would trend toward being shorter in English than in Spanish. This finding of longer response times in the dominant language corresponds with prior studies that have found that healthy bilinguals demonstrate longer response times when switching into their dominant language given the increased inhibition required to inhibit their dominant language in order to name in their non-dominant language (Costa & Stantesteban, 2004); however, if this were the case for the present participants, we would expect that their increased response time when responding in English would be driven largely by their switch trials, but we see the opposite trend in the graphical representation of their data (Figure 4). This pattern will be further explored with more participant data and with analyses on stimulus-related factors.

Stimulus items' lexical frequency in English appears to a valuable factor to consider in examining participants' local switching effects during the picture naming task, supporting prior findings that stimulus-related factors are related to bilinguals' language switching (Alario et al., 2002; Costa & Stantesteban, 2004; de Bruin et al., 2018). AP164 switched to her less proficient and non-dominant language (i.e., Spanish) more often to name high-frequency words and switched to her more proficient and dominant language (i.e., English) more often to name low-frequency words. Given that AP164 was the least balanced bilingual and the least proficient in Spanish of the three participants, this pattern suggests that she may have switched languages in order to name more easily accessed words in her less proficient language and more difficult-to-access words in her more proficient language. AP168, who was the most balanced bilingual and the only Spanish-dominant bilingual, demonstrated the same pattern in the opposite linguistic direction—he switched to his non-dominant language (English) more often for high frequency words than for low frequency words. Both of these findings are consistent with prior studies on healthy bilinguals that have found that stimulus-related factors may be related to the lexical accessibility of stimulus items and that the ease with which words can be accessed may influence bilinguals' language switching when completing picture naming tasks.

Future Directions

Research on language mixing by bilingual people with aphasia is invaluable in our understanding of the ways that people with aphasia process and produce language similarly to and different from healthy bilingual adults. This information is also helpful in considering treatment methods for people with aphasia, which often draw on task designs similar to those employed in experimental research, and ways that these interventions may be beneficial for bilingual clients with aphasia. In 2021, ASHA represented a total of 213,115 speech-language pathologists, audiologists, and students. Of these members, only 17,373 (8.2%) of them report being bilingual clinicians (ASHA, 2021). Given that the vast majority of speech-language pathologists in the U.S. are monolingual, much of the speech therapy that bilingual PWA receive is conducted in English only. In addition, because much of the research on aphasia interventions involves monolingual patients, many of the interventions used with bilingual PWA are based on research on monolingual PWA. A better understanding of the impact of different language conditions on bilingual PWA's word finding abilities and overall communication patterns could inform future studies on intervention methods that modulate language conditions for treatment of bilingual PWA in order to ultimately contribute to our ability to develop effective interventions for this population.

Given the small sample size included in the current study, statistical analyses of global and local mixing effects based on participants' accuracy were unable to be completed, and timing analyses do not include a large enough sample of participants to be reliable. Recruitment for the current project is ongoing, and it is intended that more participant data will be collected in order to increase the sample size to allow for more detailed statistical analysis of global and local mixing effects on participants' accuracy and timing. These detailed analyses will allow for more reliable interpretation of participant data regarding the effects of various language conditions on the accuracy and response times of bilingual PWA during the picture naming task. When a larger sample is collected, regression analyses will also be conducted that will allow us to determine whether any participant-related factors (e.g., language proficiency, cognitive control, translation ability, language use, language mixing) are correlated with participants' picture naming ability in the main experimental task. This information will help us better understand what aspects of bilingual PWA's language and cognitive abilities are related to their picture naming performance, which will contribute to future studies on language mixing by bilingual PWA. Information on factors that contribute to bilingual PWA's performance could also aid clinicians working with this population in understanding bilingual PWA's unique language profiles by allowing them to integrate multiple types of information in their assessment of their patients.

As more detailed analyses of participant-related factors are conducted, language dominance may be a valid factor to incorporate into participants' language profiles to be evaluated in terms of its correlation with participants' global and local language mixing effects. In the pilot data presented, language dominance appears to be a contributing factor in participants' performance, which is consistent with findings in prior literature on the influence of language dominance on language mixing effects (e.g., Gollan & Ferreira, 2009).

Future analyses will also examine the impact of stimulus-related features (i.e., name agreement, lexical frequency, lexical complexity) on bilingual PWA's picture naming. Given that the study is currently recruiting Spanish-English bilinguals, these analyses may include data on lexical frequency and complexity in both English and Spanish, which would allow for some comparison of task complexity related to stimulus differences that exist between languages. One consideration that will also be explored with analyses on stimulus-related factors is cross-linguistic differences in stimulus names, particularly in the verbs condition as some verbs that are single-word verbs in English may be phrasal verbs in Spanish (e.g., vacuum). Analyses on stimulus-related factors will allow us to identify stimulus items that may influence accuracy and response time because of these factors in order to better understand participants' overall performance in terms of global and local mixing and switching effects.

As participants in this study were relatively homogenous in terms of language proficiency, experience, and age (i.e., highly proficient bilingual PWA who performed near ceiling in most language conditions), it is also intended that future participants in this study will be representative of a greater range of language abilities and backgrounds in order to draw conclusions that include a more representative sample of bilingual PWA. Recruiting and collecting data from participants with a range of language abilities and experiences will allow eventual conclusions to be more widely applicable to clinical work with bilingual PWA as it will include participants who are more typically treated by clinicians working with this population.

The collection of this preliminary data has highlighted some issues with task design that will be considered in future iterations of the project. The instruction given for mixed conditions in the main experimental task was "You can name pictures in English or Spanish, whichever language comes more easily to you. But try to use a mix of both languages." This instruction was informed by prior studies (e.g., de Bruin et al., 2018; Gollan & Ferreira, 2009); however, it led the current participants to attempt to switch languages on approximately half of the trials and to attempt to make their switches balanced in terms of the number of switches in each linguistic direction. This instruction may have facilitated language switching more in response to the instruction given and not in response to true lexical retrieval difficulties, which is an important consideration given that one of the intended purposes of the current research design is to understand whether language switching is beneficial for bilingual PWA in moments of lexical retrieval difficulty, but if participants' switches are more the product of task instructions than lexical retrieval difficulty, this question may not be answered with the current task design. A potential solution may be to explicitly state that participants do not need to think about using languages equally but should try to use both languages. This instruction may be more challenging for participants with cognitive control deficits and for less balanced bilinguals, but it may allow for switching to be reflective of lexical retrieval difficulties rather than interpreted task design.

Another related consideration in task design is that participants in the current study indicated that they switched languages infrequently prior to their strokes, and yet they switched on approximately half of the trials in the bilingual condition. This may again have been driven by task instructions; however, it also raises questions on whether or not the current task design, which elicits lexical access switching, is representative of or related to code switching. Task designs that attempt to elicit more naturalistic language switches in a communicative context may be more effective at evaluating code switching in bilingual aphasia, and the current task design may be more reflective of lexical access switching and may not be generalizable to overall communicative contexts for bilingual PWA. However, examining lexical access switching with the current task design is still valuable for bilingual PWA given that multiple interventions for aphasia (e.g., rapid picture naming, Verb Network Strengthening Treatment, Semantic Feature Analysis) focus specifically on lexical retrieval, and it is not well known whether the theoretical bases of these treatment approaches, when applied to bilingual people with aphasia, might reasonably facilitate language production in moments of lexical retrieval difficulties. Understanding these theoretical implications may also provide foundations for future intervention studies looking specifically at the effectiveness of the application of these types of interventions to the bilingual aphasia population.

Appendix A

Items included on the Self-Assessment of Individual Differences in Language Switching (Rodriguez-Fornells et al., 2012)

Item	Response options
I do not remember or cannot recall some English words when I am speaking in this language	Never, Rarely, Occasionally, Frequently, Always
I do not remember or I cannot recall some Spanish words when I am speaking in this language	Never, Rarely, Occasionally, Frequently, Always
I tend to switch languages during a conversation (for example, I switch from Spanish to English or vice versa)	Never, Rarely, Occasionally, Frequently, Always
When I cannot recall a word in English, I tend to immediately produce it in Spanish	Never, Rarely, Occasionally, Frequently, Always
When I cannot recall a word in Spanish, I tend to immediately produce it in English	Never, Rarely, Occasionally, Frequently, Always
I do not realize when I switch the language during a conversation (e.g., from English to Spanish) or when I mix the two languages; I often realize it only if I am informed of the switch by another person	Never, Rarely, Occasionally, Frequently, Always
When I switch languages, I do it consciously	Never, Rarely, Occasionally, Frequently, Always
It is difficult for me to control the language switches I introduce during a conversation (e.g., from English to Spanish)	Never, Rarely, Occasionally, Frequently, Always
Without intending to, I sometimes produce the Spanish word faster when I am speaking in English	Never, Rarely, Occasionally, Frequently, Always
Without intending to, I sometimes produce the English word faster when I am speaking in Spanish	Never, Rarely, Occasionally, Frequently, Always

There are situations in which I always switch between the two languages	Never, Rarely, Occasionally, Frequently, Always
There are certain topics or issues for which I normally switch between the two languages	Never, Rarely, Occasionally, Frequently, Always

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