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Verbal fluency as a measure of lexico-semantic access and cognitive control in bilingual aphasia

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VERBAL FLUENCY AS A MEASURE OF LEXICO-SEMANTIC ACCESS AND COGNITIVE CONTROL IN BILINGUAL APHASIA

by

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ABSTRACT

The research on bilingual language processing explores two main avenues of relevance to the present study: lexico-semantic access and cognitive control. Lexico-semantic access research investigates the manner in which bilingual individuals retrieve single words from their lexical system. Healthy bilingual individuals can manipulate their lexico-semantic access to accommodate settings in which code- or language-switching is expected. Alternatively, they can manipulate their lexico-semantic access to speak only their first (L1) or second (L2) languages. Cognitive control, also known as executive functioning, is closely related to lexico-semantic access. Specifically, bilingual individuals maintain and switch between their languages through a mechanism known as cognitive control. Both cognitive control and lexico-semantic access are important for language processing in healthy bilingual individuals as well as bilingual persons with aphasia (BPWA). However, the extent to which BPWA utilize each of these processes in the production of single words is still unknown. The present study used a method of verbal fluency in the form of a novel modified category generation task to assess the relative contributions of lexico-semantic access and cognitive control in bilingual healthy controls and BPWA.

Table of Contents

List of Tables

List of Figures

Introduction

There are a number of models that aim to explain how a bilingual speaker processes language. Two of the most models frequently cited in the bilingual literature are the bilingual interactive activation (BIA) model (Dijkstra & Van Heuven, 1998) and the revised hierarchical model (RHM; Kroll & Stewart, 1994). The BIA model describes bilingual lexical activation. It hypothesizes that when a proficient bilingual individual sees a word, representations of the word and semantically and orthographically related words are activated in both languages. In contrast, the RHM model describes the links between both of a speaker's languages in terms of lexical access and translation. In this model, Kroll & Stewart (1994) argue that the lexical representations of the first language (L1) are better established than the lexical representations of the second language (L2). They also propose that the connection from L2 to L1 is stronger than L1 to L2. In contrast to the BIA model which describes lexical activation only in proficient bilinguals, the RHM model accounts for varying levels of proficiency, as the relative strengths of the L1/L2 connections can change with proficiency levels. Both the RHM and the BIA models provide theoretical foundations for bilingual performance on tasks of word retrieval and recognition. However, they do not provide a complete picture of the processes behind language processing in bilingual individuals.

Language processing in bilingual speakers differs greatly from processing in monolingual speakers due to the switches bilingual speakers can make between their languages. Ansaldo, Saidi, and Ruiz (2010) define these switches (also known as cross-linguistic transfers) as the "reciprocal influence that one language exerts on another."

These inter-language effects are dependent on the similarities between a person's languages and the speaker's proficiencies. In healthy bilingual individuals, cross-language interferences are intentionally used to achieve a pragmatic goal (Ansaldo, Marcotte, Scherer, & Raboyeau, 2008). In fact, unintentional cross-language interferences are rare and difficult to elicit in healthy bilingual individuals (Ansaldo et al., 2008). While models of bilingual processing such as the BIA model or the RHM can partially explain the presence of cross-linguistic switches, they do not account for the underlying cognitive processes required to switch between languages (Soveri, Rodriguez-Fornells, & Laine, 2011).

Cognitive control has been used to explain a variety of different language processes in bilingual speakers. The term "cognitive control" has been used interchangeably in the literature with the terms "executive function", "executive ability", and "executive control". All three terms have been defined in a variety of ways and have been used to encompass a variety of different processes. However, for the purposes of this study, the term "cognitive control" will be defined as the mechanisms behind (1) how we **shift** mental representations of actions, (2) **update** working memory representations, and (3) consciously **inhibit** preponent responses (Miyake et al., 2000). These three aspects of cognitive control are separate yet closely related, and each plays an important role in bilingual language processing (Miyake et al., 2000). Given the significant role of inhibition when producing words in one language compared to another in both spontaneous speech and during language assessments, more detail regarding the inhibitory aspect (3) of cognitive control is provided below.

Friedman and Miyake (2004) explained three kinds of inhibition processes within cognitive control. The first, defined in their previous work, is prepotent response inhibition, or the ability to suppress a natural, more obvious behavior in favor of a less likely behavior. Prepotent response inhibition capabilities can easily be measured using a Stroop task, in which the salient behavior of reading the word on the page must be suppressed in favor of saying the font color. The second type of inhibition comes in the form of resistance to distractor interference, where information irrelevant to a task must be suppressed. Resistance to distractor interference is frequently measured via Flanker tasks, in which participants are asked to focus only on the highlighted, middle arrow and inhibit the direction and color of surrounding arrows. Finally, the third form of inhibition defined by Friedman and Miyake (2004) is the resistance to proactive interference. This type of inhibition reflects the ability to suppress information that was once relevant to a task but is no longer relevant. Together, these three types of inhibition control are a piece of the overall cognitive control mechanism and are likely engaged when an individual is involved in bilingual language processing due to the constant selective competition between a speaker's languages.

Green's (1998) inhibitory control model links inhibitory control and bilingual language processing. He argues that to produce a target language (TL), the non-target language (NL) must be inhibited. Because an individual's L2 is generally weaker than L1 as explained in the RHM model, Green (1998) argues that lower levels of cognitive control are needed to inhibit a person's L2 in favor of L1 than vice versa. In other words, even though an individual's languages are constantly in selective competition, it is easier for a speaker to produce language in L1 than in L2.

Green's (1998) inhibitory control model consists of language task schemas, or plans for the execution of language tasks. Schemas compete for language output control, and the winning schema modulates outputs by changing the baseline activation levels of a person's L1 and L2 until the goal is achieved or the schema is changed. When a schema requires the production of a certain word, semantic representations activate the concept's lemma, or lexical entry. Each lemma is tagged by language, but both languages' lemmas are initially activated. Similar to the simultaneous activation of both languages described in the Dijkstra & Van Heuven (1998) BIA model, Green (1998) argues that lemma-level control is reactive, that lemmas with the incorrect language tags are suppressed *after* all of the lemmas linked to a lexical concept are activated. This ability to inhibit active lemmas is influenced by previous lemma suppression and the connection between an individual's L1 and L2. Green's (1998) model, combined with the relative inter-language strengths theorized in the RHM model (Kroll & Stewart, 1994), can explain how cognitive control plays a role in bilingual language processing through the inhibition of a speaker's L1 or L2 to produce the target language.

Verbal fluency is a language processing task that engages the three types of inhibition outlined by Friedman and Miyake (2004), and is therefore frequently used to measure cognitive control and/or lexico-semantic access in bilingual individuals (Shao, Janse, Visser, & Meyer, 2014). There are two types of traditional verbal fluency tasks: category generation, in which participants are given one minute to name items within a given category, and letter fluency, in which participants are given one minute to generate items starting with a given letter. While similar, these two tasks have important differences. First, the manner in which the items are retrieved varies between the tasks. In the category generation task, semantically related items are selected via spreading activations through relevant subcategories (Gruenewald & Lockhead, 1980). Alternatively, the letter fluency task requires a serial search of words based on the initial letters (Rende et al., 2002). Due to this difference, Shao et al. (2014) posits that letter verbal fluency tasks are less realistic (and therefore, more difficult) than category generation tasks for older adults, since accurate performance on letter fluency tasks requires the inhibition of semantically related words in favor of less traditional word retrieval methods.

Due to the nature of the two verbal fluency tasks, research has explored the extent to which the tasks reflect cognitive control abilities in the manner explored above and the extent to which performance is explained by language processing. While the evidence supporting the relative contributions of cognitive control and lexical access to letter and category fluency varies greatly, recent research supports the idea that verbal fluency tasks are a reflection of both cognitive control and overall language processing. Shao et al. (2014) found that vocabulary size, a general measure of lexical knowledge, was positively correlated with performance on category generation tasks but not letter fluency tasks in healthy bilingual adults. In contrast, however, Luo, Luk, and Bialystok (2010) found the opposite effect: vocabulary size was positively related with letter fluency but not category generation task performance in healthy bilingual adults. Neither group found an association between letter fluency tasks and executive functioning skills, even though in theory, the required inhibition of semantically related words in the letter fluency task would indicate an increased need for cognitive control processes (Perret, 1974).

The above finding was supported by Whiteside et al. (2016) where an exploratory factor analysis method was used to determine the relationship between various language (BNT, WAIS-III), cognition (Wisconsin Card Sorting Test, Trail Making Test, Part B), and verbal fluency (animal fluency, Controlled Oral Word Association Test) tests. As expected, the analysis yielded two separate factors: a language factor that had significant loadings from the BNT, WAIS-III, and both verbal fluency tasks, and a cognitive control factor that had significant loadings from the Wisconsin Card Sorting Test and the Trail Making Test, Part B. These findings demonstrate that language processing and cognitive control play a significant role in verbal fluency performance, but verbal fluency performance may better align with tasks of language processing.

In sum, research and theory in healthy bilingual language processing has demonstrated a relationship between language processing, cognitive control, and performance on verbal fluency tasks. These variables have also been explored in the bilingual aphasia literature. Aphasia is commonly defined as "a language deficit following brain damage or disease" (Gazzaniga et al., 2014). According to the National Aphasia Association (NAA), over two million Americans are currently affected with various forms of the syndrome, and 200,000 more people are diagnosed with the disorder every year (Aphasia, n.d.). Bilingual aphasia can be defined as the presence of aphasia in individuals who speak one or more languages. Because of the rising number of bilingual speakers around the globe, it can be presumed that there will be a proportional increase of bilingual BPWA with aphasia (BPWA). In fact, Paradis (2001) estimated there would be around 45,000 new cases of multilingual aphasia annually in the U.S. alone. Thus, it is important to understand the language and cognitive control mechanisms behind bilingualism in BPWA with aphasia as well.

Research in bilingual aphasia has also been focused on language and cognitive control processes and the way in which they can be measured. Given Green's (1998) inhibition control model, it is evident that bilingual language processing and language maintenance requires some cognitive control. Ansaldo, Saidi, and Ruiz (2010) analyzed the case of E.L., a bilingual Spanish-English speaking male with transcortical mixed aphasia secondary to an embolic left internal capsule stroke within this inhibition control framework. E.L.'s speech was characterized spontaneous switches between Spanish and English in which he would produce speech in both languages even when cued to speak only in one language. They argue that E.L.'s involuntary language switching occurred because he had insufficient activation of target words coupled with insufficient inhibition of non-target translations of the target word, which caused an spontaneous mixing of languages in connected speech. In preliminary testing, E.L. completed confrontation naming tests in both Spanish (L1) and English (L2). Analysis of his performance revealed that he made involuntary language switches into English on 20% of the Spanish trials and made language switches into Spanish on 22% of the English trials. EL's performance on this task reveals that there is a relationship between his cognitive control capabilities and his lexico-semantic access resulting in cross-linguistic transfers at the word level. Specifically, Ansaldo et al. (2008) argue that aphasia causes disruption in the cognitive capabilities required to control languages, therefore causing unintentional language switching and borrowing.

As demonstrated with the case of E.L., one of the landmark features of bilingual aphasia is pathological language switching, in which bilingual speakers have difficulty preventing interferences from one language when speaking another (Fabbro, 2001). On an everyday basis, such interferences can have an impact on a patient's ability to communicate effectively, especially in circumstances where linguistic interferences occur in conversations with individuals who do not speak the interfering language (Ansaldo et al., 2008). However, not all bilingual individuals with aphasia demonstrate pathological switches. Green et al. (2010) found that two bilingual persons with aphasia (BPWA) who demonstrated parallel language recovery (as defined in Fabbro, 1999) and no pathological switches still demonstrated diminished verbal and non-verbal cognitive control. Interestingly, the BPWA demonstrated dissociated patterns of cognitive control such that one patient demonstrated greater impairment in verbal cognitive control as measured by Stroop and lexical decision tasks than non-verbal cognitive control as measured by a flanker task. The other patient demonstrated the opposite pattern of cognitive control impairment. These findings demonstrate that while pathological switching is an indicator of cognitive control deficits in BPWA, it is not necessarily present in all individuals with BPWA.

As mentioned before, verbal fluency tasks are often used as a measure of both lexico-semantic access and cognitive control (Schmidt et al., 2017). Research by Kiran, Balachandran, & Lucas (2014) demonstrated that, though healthy bilingual control participants named more items accurately than bilingual persons with aphasia on a category generation task, BPWA and controls made similar error patterns. Specifically, error analysis reveals that controls had the same strategies to group semantic clusters as BPWA. This finding demonstrates that even though BPWA' performance on category generation tasks indicates impaired lexico-semantic access and cognitive control, their ability to cluster items within the correct semantic subcategories remains intact.

The findings of Kiran et al. (2014) therefore calls into question the extent to which cognitive control and lexico-semantic access contributes to performance on verbal fluency tasks in BPWA. A study of 38 persons with aphasia (BPWA) examined the relationship between cognitive control via a Stroop task and language processing via category generation and picture naming in BPWA and controls (Faroqi-Shah, et al., 2016). BPWA belonged to one of three groups of individuals with aphasia: a monolingual group, a bilingual English-Tamil group, and a bilingual Tamil-English group. As expected, researchers found that all individuals with aphasia performed worse on the tasks than healthy control individuals. Additionally, researchers found a strong correlation between picture naming and category generation performance, but neither of these word retrieval tasks were related to performance on the Stroop task of cognitive control. Faroqi-Shah et al. (2016) theorize that the lack of correlation between the verbal fluency task and the cognitive control task may be due to one of two potential factors: first, it is possible that the weakened cognitive control system in BPWA may no longer be able to simultaneously support word retrieval and inhibition control, indicating that word retrieval and inhibition control are competing for cognitive resources in BPWA.

The alternative explanation refers back to Friedman and Miyake's (2004) hypothesis of three distinct inhibition control mechanisms and posits that it is possible that Stroop tasks and tasks of verbal fluency both measure different aspects of inhibition control such that Stroop tasks measure more explicit inhibition while verbal fluency is a measure of automatic inhibition. Either way, it is evident that the exact type of cognitive control measured by verbal fluency tasks such as category generation is still unclear.

Statement of Purpose and Rationale

In sum, research in healthy bilingual individuals and bilingual persons with aphasia demonstrates the strong relationship between cognitive control processes and lexico-semantic access. Specifically, it shows that inhibition as explained by Green et al. (1998) and Friedman and Miyake (2004) is required to some extent in order to select and produce a target word in the correct language. Due to the nature of this interaction, the integrity of cognitive control and lexico-semantic access processes are often measured together with tasks of verbal fluency such as category generation or letter fluency. However, the extent to which each of these processes contributes to verbal fluency performance is still contested, and how this relationship may be affected in bilingual aphasia is unknown. Thus, given past research, the present study aimed to investigate the nature of the relationship between cognitive control, lexico-semantic access, and performance on verbal fluency in bilingual persons with aphasia compared to healthy bilingual individuals. In the present study, the level of cognitive control and the type of lexico-semantic access required was manipulated to measure differences in category generation performance. This was accomplished by adding various conditions to the category generation task in which participants were required to maintain their first or second language (No Switch; NS-L1 or NS-L2), switch between languages for each item (Forced Switch; FS), or were allowed to switch between languages as they liked (Self-Switch; SS).

The different category generation conditions were designed to vary the amount of cognitive control required. The No-Switch in L1 (NS-L1) condition was expected to require the least amount of cognitive control since it was most reflective of everyday use. Highly automatized processes such as speaking in L1 or code switching require less cognitive control than non-automated tasks (Green, 1989). In contrast, the No-Switch in L2 (NS-L2) condition was expected to require moderate cognitive control. Keeping the connections between L1 and L2 from the revised hierarchical model in mind, it was hypothesized that completing the NS-L2 condition would require inhibitory control of prepotent L1 translations of the intended L2 words. Next, the Self-Switch (SS) condition was expected to require minimal cognitive control like the NS-L1 condition since it did not require inhibition of any language-tagged lemmas. Finally, the Forced Switch (FS) condition of the category generation task was expected to require the most cognitive control to complete. In this condition, participants had to not only inhibit prepotent responses in the wrong language, but accurate performance also required greater capacity to task switch and update working memory representations (Miyake et al., 2000).

The present study was designed as both a within-subjects and a between-group experimental study. Participants were compared with themselves on performance on the different category generation conditions, and controls were compared to BPWA on overall performance on the task. There were three distinct independent variables in this study: language (Spanish or English, identified as each participant's first (L1) or second (L2) language), category generation condition (No Switch in L1, No Switch in L2, Self-Switch, and Forced Switch), and group (control or bilingual person with aphasia). Language proficiency in each language based on an extensive language use questionnaire served as a quasi-independent variable in the study. Finally, dependent variables included: Total number and proportion of accurate of words produced, number of semantic switches, semantic cluster size, and the number of direct language translations for each condition. Given these variables, the following research questions and corresponding hypotheses were proposed.

1. *How do bilingual persons with aphasia (BPWA) perform on the different conditions compared to healthy bilingual adults?*

   Given findings of past research (Kiran et al., 2014), it was expected that bilingual healthy control (HC) subjects would produce more words with greater accuracy than BPWA. However, it was expected that both groups of participants would perform better on the NS and SS conditions than on the FS conditions because of the increased amount of cognitive control required to accurately complete the FS condition.

2. *What is the difference in the nature and efficiency in the responses to the four conditions between BPWA and healthy controls?*

   It was hypothesized that BPWA would have larger semantic cluster sizes and fewer semantic switches than HCs in the FS condition, since switching semantic clusters requires greater cognitive control capabilities (Bose, Wood, & Kiran, 2016). Additionally, it was hypothesized that the responses produced by BPWA would have a greater proportion of direct translations to accurate responses than HCs due to decreased inhibition of the non-target language in the FS condition as the cognitive control demand for the task increases.

3. *Can language use history and measures of lexical retrieval predict performance on the various category generation conditions?*

   It was hypothesized that language use history and language assessments would better predict performance on the NS and SS conditions compared to the FS conditions due to the likely increased cognitive demands of the FS context. If supported, these results would indicate the likely presence of a language-switching cost with increased cognitive control as described by Faroqi-Shah et al., 2016.

Overall, it was expected that healthy control individuals will outperform BPWA, but the manner in which they perform on the different conditions of the category generation task would be similar. These hypotheses are summarized in **Tables 1** and **2**.

Condition	Controls	BPWA
No Switch in L1 (NS-L1)	1	1
No Switch in L2 (NS-L2)	3	2
Self-Switch (SS)	2	3
Forced Switch (FS)	4	4

Table 1. Hypothesized performance of BPWA and controls on each condition. *Note:* 1 denotes condition with the hypothesized highest accuracy within the group, and 4 denotes the condition with the hypothesized lowest accuracy within the group.

Dependent Variables	Controls	BPWA
Total # Words	more	fewer
Accuracy	greater	less
Semantic Switches	more	fewer
Semantic Cluster size	smaller	larger
Direct Translations	fewer	more

Table 2. Hypothesized performance of controls compared to BPWA on the dependent variables in this study.

Method

Participants

Participants included 17 Spanish-English healthy bilingual HCs (13 female) and ten Spanish-English BPWA (six female) with aphasia secondary to stroke (n = 9) or traumatic brain injury (n = 1). Fluent multilingual participants were excluded from this study, as were individuals who were bilingual in languages other than English and Spanish. BPWA who could not complete a standard category generation task were also excluded from participation.

HCs were between the ages of 18 and 82 (mean age = 43, *SD* = 18). Sixteen of the HCs cited being native Spanish speakers who learned English between the ages of four and forty (mean English age of acquisition = 16, *SD* = 11). One HC was a native English speaker who learned Spanish during adolescence. Additionally, nine of the HCs reported exposure to additional languages at some point in their lifetime (e.g. Italian, French, Japanese), but none reported fluency in these languages. All HCs were given $15 for their participation. See **Table 3** for complete control demographic and language use information.

BPWA were between the ages of 24 and 82 (mean age = 49, *SD* = 18). Eight BPWA were native Spanish speakers who learned English between the age of five and 35 (mean age of English acquisition = 11, *SD* = 5). The other two BPWA cited being native English speakers with a mean age of Spanish acquisition of 5.5 years. None of the BPWA reported exposure to any languages other than English or Spanish. See **Table 4** for complete BPWA demographic and language use information.

Control	Age	Sex	Education (years)	AoA		Language ability rating (%)		Confidence (%)		Current Exposure (%)		Family Proficiency (%)		Education History (%)	
				Eng.	Sp.	Eng.	Sp.	Eng.	Sp.	Eng.	Sp.	Eng.	Sp.	Eng.	Sp.
HC1	53	F	20	6	0	77	97	62	93	87	13	50	100	6	94
HC2	18	M	14	0	0	100	80	89	49	97	3	63	100	78	22
HC3	36	M	12	20	0	89	91	41	96	58	42	63	75	28	72
HC4	18	F	15.5	4	0	74	100	55	79	72	28	92	100	39	61
HC5	47	F	25	28	0	80	100	40	100	83	17	33	100	11	89
HC6	36	F	21	26	0	100	100	34	100	53	47	25	100	17	83
HC7	45	M	27	12	0	91	100	57	100	100	0	25	100	6	94
HC8	30	F	23	7	0	80	100	75	100	72	28	33	100	0	100
HC9	48	F	21	15	0	86	100	72	100	91	9	25	100	17	83
HC10	39	F	21	36	0	97	100	18	100	78	22	92	42	0	100
HC11	30	M	26	7	0	91	100	55	94	79	21	25	100	11	89
HC12	27	F	18	6	0	100	80	61	76	81	19	67	92	89	11
HC15	21	F	20	7	0	89	100	47	100	18	82	42	100	22	78
HC16	73	F	11	23	0	37	100	20	100	13	87	0	100	0	100
HC18	63	F	14	7	0	43	100	15	100	3	97	58	100	0	100
HC19	33	F	18	0	19	100	83	98	67	50	50	100	13	94	6
HC20	82	F	12	40	0	49	100	0	100	0	100	33	100	0	100

Table 3. Demographic information for bilingual healthy control (HC) participants. Note. HC: Healthy Control. AoA: Age of Acquisition. Eng.: English. Sp.: Spanish.

Patient	Age	Sex	Education (years)	AoA		Language ability rating (%)		Confidence (%)		Current Exposure (%)		Family Proficiency (%)		Education History (%)	
				Eng.	Sp.	Eng.	Sp.	Eng.	Sp.	Eng.	Sp.	Eng.	Sp.	Eng.	Sp.
BPWA1	82	M	16	35	0	80	100	38	62	38	62	17	100	11	89
BPWA2	54	F	17	6	0	54	100	46	55	46	55	67	100	11	89
BPWA3	25	F	13	0	5	100	74	71	29	71	29	50	100	100	0
BPWA4	44	M	16	0	6	86	66	99	1	99	1	100	100	50	50
BPWA5	63	F	12	25	0	60	60	24	76	24	76	42	100	0	100
BPWA6	24	F	16	5	0	100	89	86	14	86	14	58	75	28	72
BPWA7	24	F	13	5	0	60	80	4	96	4	96	75	92	56	44
BPWA8	58	F	18	10	0	100	70	87	13	87	13	100	100	50	50
BPWA9	48	M	16	5	0	60	80	4	96	65	35	75	92	56	44
BPWA10	66	M	16	25	0	100	100	96	4	96	4	25	100	17	83

Table 4. Demographic information for bilingual persons with aphasia. Note. BPWA: Bilingual Person with Aphasia. AoA: Age of Acquisition. Eng.: English. Sp.: Spanish

Materials

All bilingual healthy control (HC) participants and bilingual persons with aphasia (BPWA) completed an extensive language use questionnaire (LUQ), a picture naming screener, two verbal fluency tasks, and a battery of standardized language assessments in both Spanish and English. Of note, the results of the picture naming screener will not be reported in this study. Assessments were administered entirely in one language before switching to the other. Within each language, the order of the assessments was arranged to minimize potential cross-assessment priming effects. See **Table 5** for the order of the tasks for HCs and BPWA.

Language use questionnaire. An extensive language use questionnaire (LUQ) was administered to each participant at the start of the study (Kastenbaum et al., in press). Components of the LUQ included confidence and exposure to Spanish and English in contexts of speaking, listening, reading and writing over the lifespan. Participants were asked to evaluate each metric in three-year increments until the age of thirty and one "30 and up" increment. Additionally, participants were asked to complete a daily language use input and output summary on an hour-by-hour basis for weekdays and weekends. Additional metrics included: family language history, family proficiency for each language, years of education (total and in each language), and language ability self-rating across various contexts (e.g. listening in formal situations). BPWA were asked to complete two versions of the questionnaire: one to reflect their language use pre-stroke and one to reflect language use post-stroke.

Assessment	Controls	BPWA
Informed consent	x	x
Participant History	x	x
Language Use Questionnaire	x	x
HIPAA release form		x
History	x	x
	English	
Category Generation Task	x	x
Letter Fluency Task	x	x
Naming Screener	x	x
PALPA 29		x
PALPA 51	x	x
PALPA 47	x	x
PALPA 49	x	x
BAT	Semantic Categories, Synonyms, Antonyms	Parts B & C
PALPA 50	x	x
PALPA 48	x	x
BNT	x	x
WAB	Picture Description	Parts I and II
	Spanish	
Category Generation Task	x	x
Letter Fluency Task	x	x
EPLA 28		x
EPLA 49	x	x
EPLA 45	x	x
EPLA 47	x	x
BAT	Semantic Categories, Synonyms, Antonyms	Part B
EPLA 48	x	x
EPLA 46	x	x
BNT	x	x
WAB	Picture Description	Parts I and II
Naming Screener	x	x

Table 5. Order of assessments for controls versus BPWA. *Note:* PALPA: Psycholinguistic Assessment of Language in Aphasia, EPLA: Evaluación del Procesamiento Lingüístico en la Afasia, BAT: Bilingual Aphasia Test, BNT: Boston Naming Test, WAB: Western Aphasia Battery, PAPT: Pyramids and Palm Trees, CLQT: Cognitive Linguistic Quick Test, PBJ: Peanut Butter and Jelly Task.

Verbal fluency. Each participant completed two tests of verbal fluency: a modified category generation task and a letter fluency test.

Category generation. Each participant was given five trials of the category generation task. Four trials were administered in the participants' L1 (two no-switch (NS) conditions, one self-switch (SS) condition, and one forced-switch (FS) condition) and the NS trials were administered again in the participants' L2. SS and FS conditions were not administered consistently in L2 due to the mixed-language context of the task. Categories for the generative naming task included animals, clothing, food, modes of transportation. The order of conditions was NS-NS-SS-FS for each participant to reduce potential biases of the FS condition on the SS condition. The category-to-condition assignments were counterbalanced across participants to account for the potential impact of semantic category knowledge on condition performance (See **Table 4**). No restrictions were given for cross-language (direct) translations in the FS or SS categories.

Letter fluency. After completing the four trials of the category generation task in the first language, each participant completed a letter verbal fluency task in the same language. After approximately a 1-hour delay, the participants completed the task in the second language. Prompts for the English letter verbal fluency task were F, A, and S, as traditionally used in the Controlled Oral Word Association Test (COWAT; Benton & Hamsher, 1976) and prompts for the Spanish task were P, M, and R (Peña-Casanova et al., 2009). Each participant was given one minute to name as many items as they could that started with the given letter in the given language. Of note, performance on letter fluency tasks were not discussed in these results.

Standardized measures. Each participant completed a battery of standardized language measures in English and Spanish that included: the Western Aphasia Battery - Revised *Picture Description Scene* (WAB; Kertesz, 2006), Boston Naming Test – Second Edition (BNT-2; Kaplan, Goodglass, & Weintraub, 2000), Psycholinguistic Assessment of Language Processing in Aphasia subtests *(*PALPA; Kay, Coltheart, & Lesser, 1992), Bilingual Aphasia Test *Semantic Categories, Synonyms, Antonyms I*, and *Antonyms II* subtests (BAT; Paradis, 1989); Pyramids and Palm Trees (PAPT; Howard & Patterson, 1992), and a picture naming screener.

Procedure

All participants completed a diagnostic evaluation consent form under the Boston University Institutional Review Board. The form and explanations were presented to participants in their preferred language. After obtaining consent, each participant completed the measures explained above. The order of language administration (English-Spanish or Spanish-English) was counterbalanced across participants such that half the participants completed testing in English first and the other half completed testing in Spanish first.

Bilingual healthy control participants. The seventeen bilingual healthy control participants were recruited from a variety of Spanish-language groups in the Greater Boston area and online email groups from across the country. Two participants were recruited from universities in Spain. Upon expressing interest in participation, all participants were given an electronic version of the consent form and language use questionnaire (LUQ) to complete and return via email. They were then scheduled to participate in the study. Fifteen of the participants completed the study online via GoToMeeting, a videoconferencing platform. The remaining five participants completed the study in person. The complete battery of language assessments took approximately two hours to complete. All but two participants completed the assessments in one session; the other two completed the assessments in two sessions due to time constraints. Participants who were administered the study online were given control over the researcher's keyboard and mouse so they could point to things as required in the PALPA/EPLA subtests. Recordings of the videoconferences were made via GoToMeeting and Audacity for reliability purposes. All participants were given a $15 online or physical gift card for their participation.

Bilingual persons with aphasia. Ten BPWA were recruited from medical centers in the Greater Boston area, referrals from ASHA Special Interest Groups, and the Gray Matter Lab at San Francisco State University. Upon expressing interest in the study, BPWA were given the consent form and LUQ to complete either in person or electronically. Assessments were administered in one to four sessions per participant. Nine BPWA completed the testing in-person, while the remaining BPWA completed the testing over videoconference.

Data scoring. All data were recorded as being in the participants' first language (L1) or second language (L2), as self-identified in the LUQ. All responses for the category generation and letter fluency tasks were recorded and transcribed during the session. Transcriptions were re-checked for accuracy after the session. Total number of productions and overall accuracy were calculated for each condition in each task. BPWA responses were counted as accurate if they matched an accurate target response and contained no more than one phonemic substitution, omission, or addition (Kiran, et al., 2014). In the NS conditions, any productions that were in the non-target language were scored as incorrect. In the SS condition, all real words in either language were counted as correct. In the FS condition, items that were produced in the same language as a previous item were scored as incorrect. The proportion of accurate responses was calculated by dividing the number of accurate responses by the total number of responses produced for each participant in each condition.

Next, the number of semantic switches and the average semantic cluster size were calculated. Semantic switches were calculated by tallying the number of times participants switched from semantic sub-group within each category, as outlined by Kiran et al. (2014). For example, if a participant listed the animals: *dog*, *cat*, *flamingo*, *rabbit*, *shark*, *jellyfish*, and *octopus*, they would have made a total of three semantic switches (*domestic animals* to *birds*, *birds* to *small outdoor mammals*, and *small outdoor mammals* to *underwater animals*). Similarly, average semantic cluster size was calculated by averaging the number of items in each of the semantic sub-categories. In this example, *domestic animals* had a cluster size of two, *birds* had a cluster size of one, *small outdoor mammals* had a cluster size of one, and *underwater animals* had a cluster size of three. These numbers would be averaged to produce an average semantic cluster size of 1.75.

Finally, the number of direct translations (e.g. apple, *manzana* in the forced switch condition) within a condition were tallied but marked as correct for overall accuracy. A proportion of direct translations was calculated by dividing the number of direct translations by the total number of accurate items produced for each participant in each condition.

Reliability and attrition. Responses for all participants were transcribed twice by the researcher. Questions about scoring were addressed in a group research meeting. Attrition was not a factor in this study, since data were only collected at a single time point.

Statistical Analysis

Statistical analysis were conducted using the platform *SPSS*. On average, healthy control participants produced 19.82 items (*SD* = 7.02) in the NS- L1 condition, 15.94 items (*SD* = 6.66) in the NS- L2 condition, 20.29 items in the SS condition (*SD* = 6.52), and 15.16 items (*SD* = 5.98) in the FS condition. In contrast, BPWA produced fewer items with greater variance in the NS- L1 condition ($\bar{x}$ = 13.23, *SD* = 9.06), NS- L2 condition ($\bar{x}$ =12.09, *SD* = 8.05), SS ($\bar{x}$ = 11.76, *SD* = 8.83), and FS ($\bar{x}$ = 10.25, *SD* = 8.26) conditions. These results are summarized in **Table 6**. Results were further analyzed in terms of accuracy in L1 and L2.

Group		No Switch; L1	No Switch; L2	Self-Switch	Forced Switch
H.C.	*Mean*	19.82	15.94	20.29	15.17
	St. Dev.	7.02	6.66	6.52	5.98
BPWA	*Mean*	13.23	12.09	11.81	12.19
	St. Dev.	9.06	8.05	8.18	6.25

Table 6. Total items produced by condition and group. Healthy control participants produced more items with less variability than BPWA. Note. H.C.: Healthy Controls. L1: First language. L2: Second language.

Group by Condition Comparisons

The first set analyses aimed to answer Research Question 1: *How do bilingual persons with aphasia (BPWA) perform on the different conditions compared to healthy bilingual adults?* A repeated measures ANOVA was conducted to compare the proportion of accurate responses across conditions (NS- L1, NS- L2, SS, and FS) for BPWA and HCs. Proportion of accurate responses was used to determine accuracy rather than the overall number of accurate items produced spontaneously. Results of the repeated measures ANOVA violated Mauchly's Test of Sphericity (χ^2 (5) = 15.603, p = .008), so Greenhouse-Geisser estimates of sphericity were used to correct the degrees of freedom (ε = .730). The results demonstrated that there was a significant group effect (F(1, 1.424) = 9.366, p = .005), indicating that the healthy controls and BPWA differed significantly in their overall accuracy on the tasks. However, there was a non-significant effect of condition (F(2.190, .063) = 1.262, p = .293), indicating that participants did perform differently across conditions. Condition by group analyses were also non-significant (F(2.190, .021) = .417, p = .679), indicating that there were no significant differences between groups across conditions.

Because the overall analysis was not significant and the sphericity tests indicated unequal variances, one-way (independent variable : group) ANOVAs were conducted for each condition and revealed significant group differences for the NS- L1 (F(1, 25) = 6.415, p = .018), NS-L2 (F(1, 25) = 4.713, p = .040), and FS conditions (F(1, 25) = 7.107, p = .013) such that controls produced a more accurate proportion of items compared to BPWA in these three conditions. HCs and BPWA did not significantly differ in the SS condition ($F(1, 25) = 3.713$, $p = .065$), though this difference was trending toward significance. Proportion accuracy by condition and group can be seen in **Figure 1**.

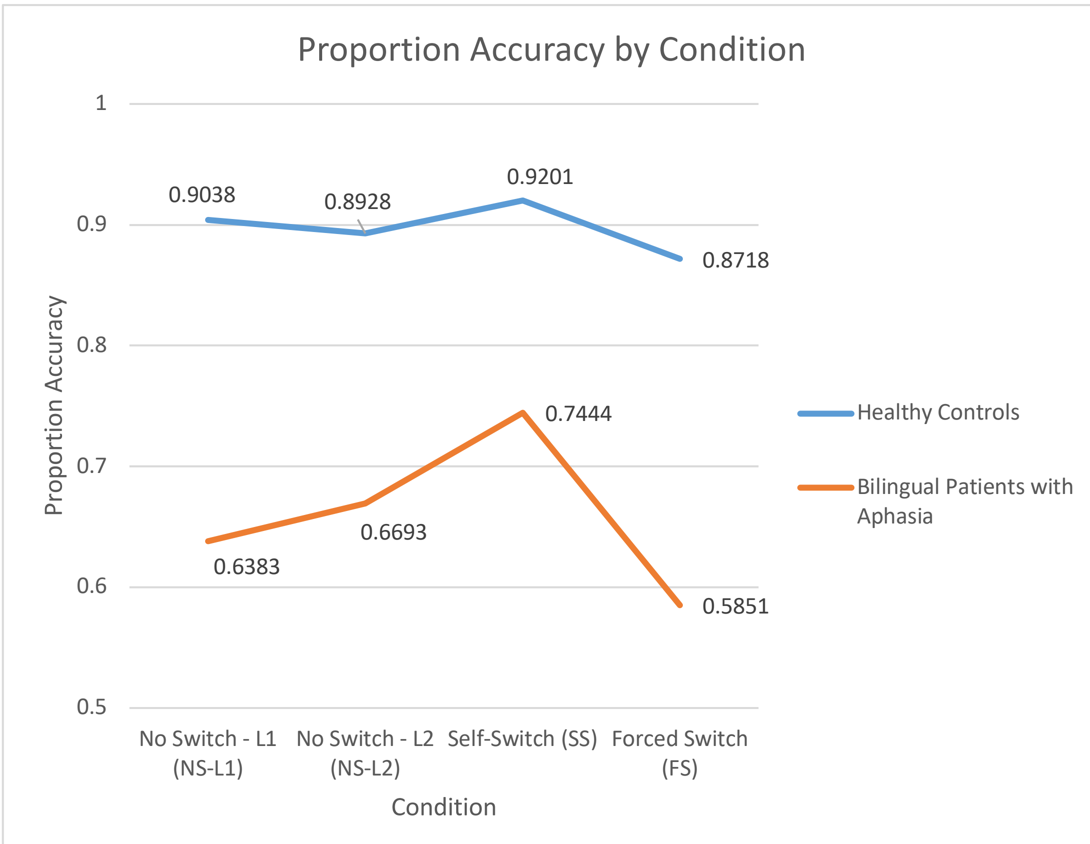

Figure 1. Proportion of accurate items produced over total items produced by group and condition. Healthy controls produced significantly more items than bilingual persons with aphasia (BPWA) in the NS-L1, NS-L2, and FS conditions.

Direct Translations

The second research question (*What is the difference in the nature and efficiency in the responses to the four conditions between BPWA and healthy controls?*) was tested using a repeated-measures ANOVA with proportion of direct translations over total accurate productions in each condition as the within-group dependent factors and group as a between-group quasi-independent factor. Results of the repeated measures ANOVA violated Mauchly's Test of Sphericity (χ^2 (5) = .046, *p* = .000), so Greenhouse-Geisser estimates of sphericity were used to correct the degrees of freedom (ε = .543). Results revealed a significant effect of condition (*F*(1.630, .232) = 12.024, *p* = .000), but not a significant effect of group (*F*(1, .000) = .012, *p* = .912) or condition by group (*F*(1.630, .007) = .382, *p* = .642), indicating that BPWA and controls demonstrated similar trends in the usage of direct translations across conditions. Additionally, the proportion of direct translations differed across condition when collapsed across group.

Because group : condition effects were not significant and sphericity tests indicated unequal variances, pairwise comparisons were used to analyze condition differences. Results demonstrated a nonsignificant difference between NS-L1 and SS (*p* = .049) when results were collapsed across group. In contrast, participants produced a greater proportion of direct translations in the FS condition when compared to the NS-L1 (*p* = .000), NS-L2 (*p* = .001), SS (*p* = .003) conditions. There was no significant difference in the proportion of direct translations between NS-L1 and NS-L2 or NS-L2 and SS conditions. Overall, these results demonstrate that the most direct translations were used in the FS condition. The proportion of direct translations by group and condition is shown in **Figure 2**.

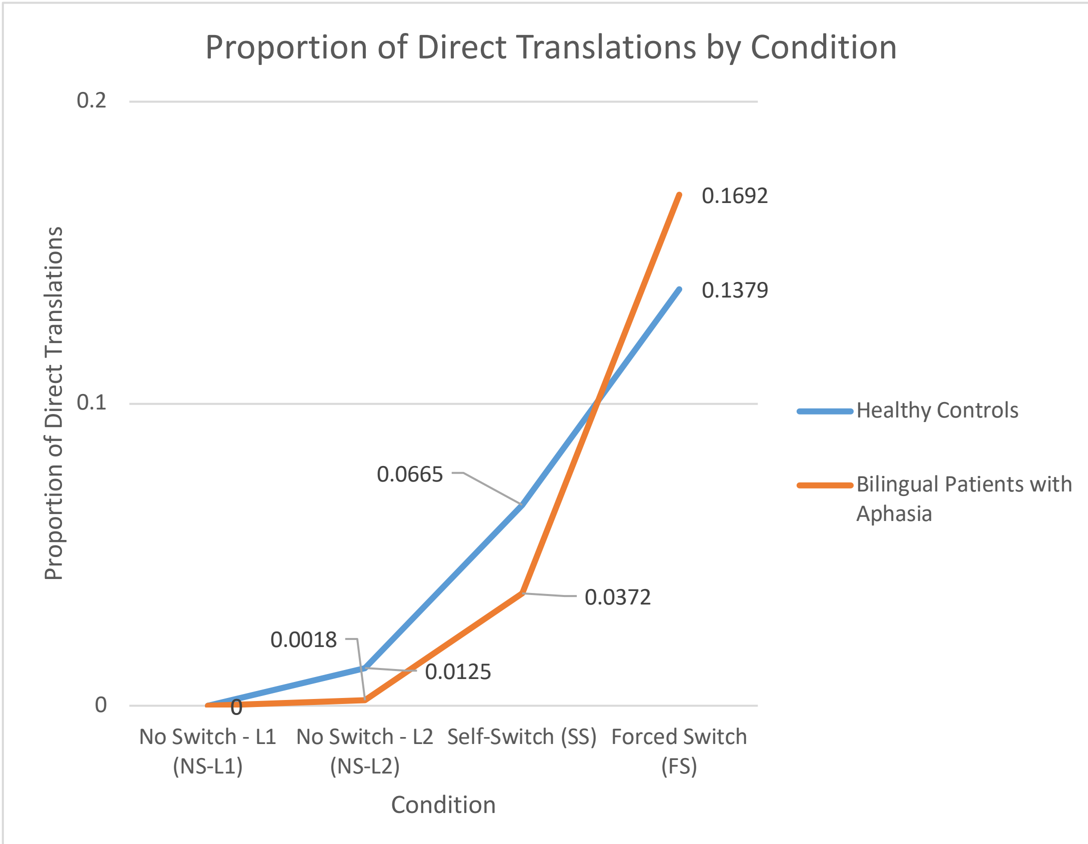

Figure 2. Proportion of direct translations produced over total number of accurate items produced by condition and group. Participants produced a greater proportion of direct translations in the FS condition compared to the NS-L1, NS-L2, and SS conditions.

Semantic Clusters and Semantic Switches

Additional repeated measure ANOVAs were conducted to analyze the relationship between semantic switches, semantic cluster sizes, and performance on each of the four conditions. The first repeated measures ANOVA was conducted using the number of semantic switches made for each condition as within-subject factors and group as the between-group factor. Mauchly's Test of Sphericity was not violated in this analysis (χ^2 (5) = 6.324, p = .276), so sphericity was assumed. Results demonstrated a significant group effect (F(1, 25) = 128.050, p = .000) and a trend toward a condition effect (Wilks' Lambda: $F(3, 23) = 2.494$, $p = .085$). Because group : condition effects were not significant, a one-way ANOVA was conducted to further investigate the significant effect of group on number of semantic switches in each condition. Results demonstrated that healthy controls made significantly more semantic switches compared to BPWA in all conditions (NS-L1 ($F(1, 25) = 25.285$, $p = .000$), NS-L2 ($F(1, 25) = 20.164$, $p = .000$), SS ($F(1, 25) = 18.631$, $p = .000$), and FS ($F(1, 25) = 13.400$, $p = .001$)). **Figure 3** shows the number of semantic switches made per condition for each group.

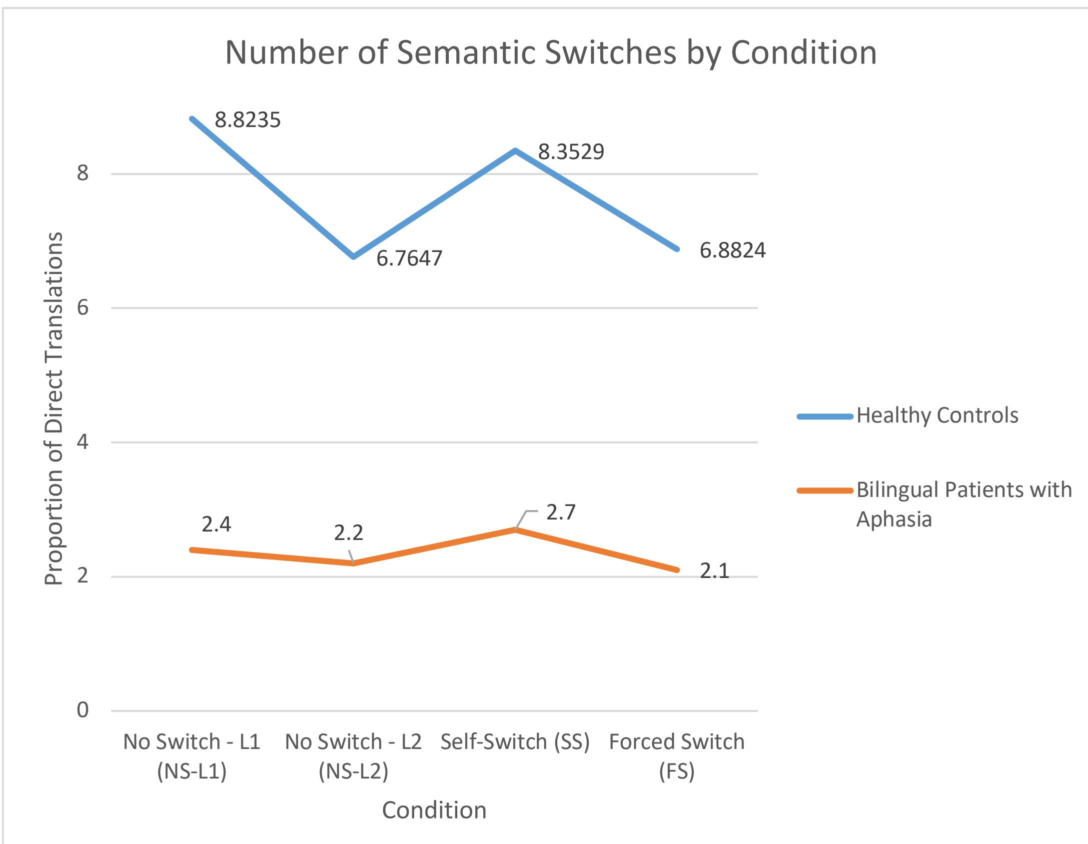

Figure 3. Number of semantic switches made by group in each condition. Results demonstrated a significant group difference for all conditions such that healthy controls made more semantic switches than BPWA. There was a trend toward condition differences, but it was non-significant.

Next, the relationship between the average size of semantic clusters, condition, and group was analyzed through a repeated measure ANOVA with average cluster size for each condition as within-subject factors and group as the between-subject factor. Mauchly's Test of Sphericity was not violated in this analysis (χ^2 (5) = 4.358, p = .499), so sphericity was assumed. Results demonstrated only a significant group effect such that healthy controls had larger average semantic cluster sizes than BPWA (F(1, 25) = 4.800, p = .040), but no condition (F(3, .266) = .467, p = .706) or condition by group (F(3, .239) = .419, p = .740) effects on performance. Semantic cluster results are shown in **Figure 4**.

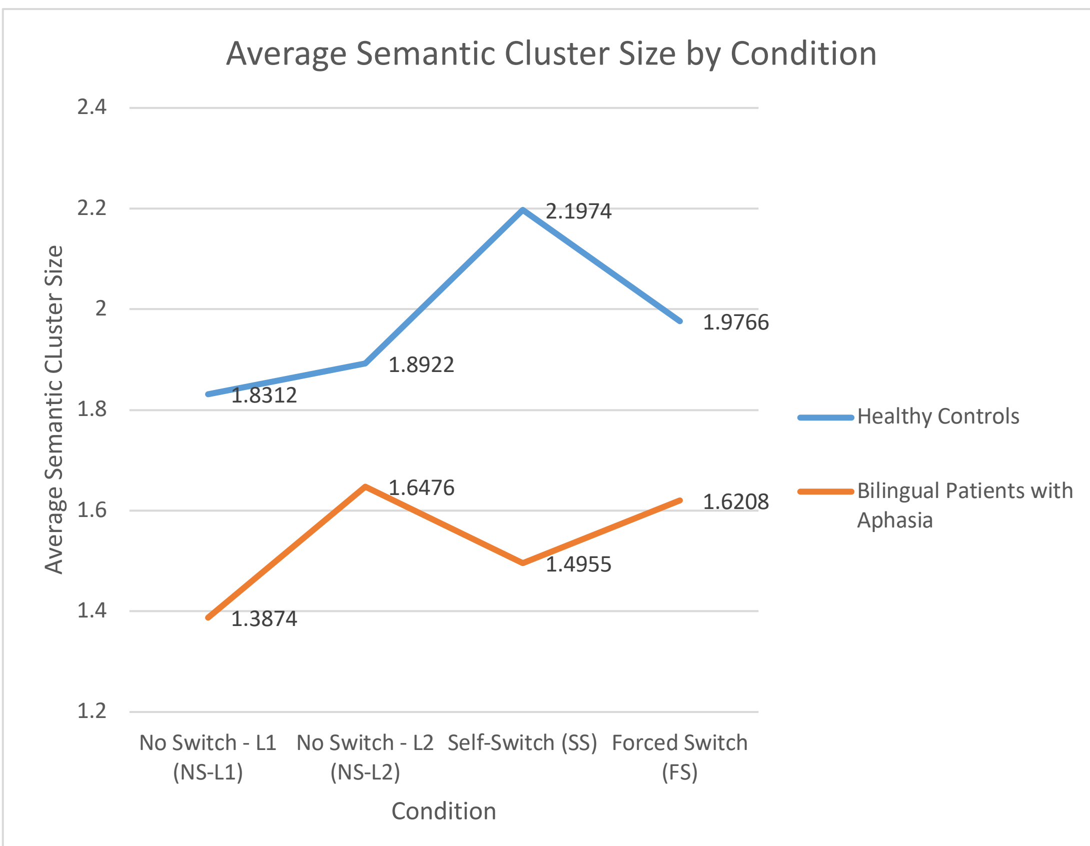

Figure 4. Average size of semantic clusters per condition by group. There was a trending difference between healthy controls and BPWA in the NS-L1 and SS condition, but no other within- or between-group differences were found.

Language Use History and Language Assessments

The third question explored the relationship between language use history, performance on standardized language assessments, and overall accuracy on the category generation task. A correlation matrix of two-tailed Pearson correlations was conducted to determine the areas of the Language Use Questionnaire (LUQ) and standardized assessments that were most related to performance on the category generation task. Significantly correlated LUQ and language assessment factors were then used as independent factors in individual linear regressions with proportion accuracy in each condition as the dependent factor. Of the LUQ variables, only the Language Ability Self-Rating (LAR) and Lifetime Confidence in L1 were significantly correlated with performance on the performance on the category generation task. Of the language assessments, the picture naming screener in L1 and L2, *PALPA* subtests in L1 and L2, *BNT-2* in L1, and an aggregate of performance on the *BAT* in L1 were significantly correlated with performance. Significant correlations can be found in **Table 7**.

Condition		L1 LAR	L1 Lifetime Confidence	L1 Screener	L2 Screener	L1 PALPA 47	L2 PALPA47	L1 BAT
NS-L1	*r*	***0.447***	***.611***	***.587***	***.448***	*.353*	***.471***	***.470***
	p	**.019**	**.001**	**.005**	**.042**	.099	**.027**	**.024**
NS-L2	*r*	*.087*	***.048***	***.744***	***.689***	***.675***	***.877***	***.715***
	p	.664	**.813**	**.000**	**.001**	**.000**	**.000**	**.000**
SS	*r*	***0.385***	***.316***	***.800***	***.772***	***.757***	***.845***	***.820***
	p	**.047**	**.109**	**.000**	**.000**	**.000**	**.000**	**.000**
FS	*r*	***0.487***	***.588***	***.804***	***.759***	***.586***	***.742***	***.704***
	p	**.010**	**.001**	**.000**	**.000**	**.003**	**.000**	**.000**

Table 7. Pearson correlation values and significance values for key correlations by condition. *Note. r:* Pearson correlation value. *s*: significance values. NS-L1: No Switch, L1. NS-L2: No Switch, L2. SS: Self-Switch. FS: Forced Switch. LAR: Language Ability Rating from the Language Use Questionnaire. PALPA: *Psycholinguistic Assessment of Language Processing in Aphasia*. PALPA 47: a measure of spoken word-picture matching. BAT: *Bilingual Aphasia Test,* a measure of semantic knowledge. Correlations reaching significance are highlighted in **bold**.

Many of the language use history and language assessment variables that were correlated with performance on the category generation task were significantly intercorrelated. Factors were selected to represent a variety of domains and reduce redundancies within the analyses. The redundant variables are explained below. Subtests of the *PALPA* were highly intercorrelated with *BAT* and *BNT* scores, so only scores on the *BNT* were used in the regression analyses. There was also a high correlation between L1 LAR/L1 Lifetime Confidence ($r = .804$, $p <.05$), so L1 LAR was chosen for the analyses. After omitting the highly inter-correlated items, the factors that were included in the subsequent regression analyses included L1 *BNT* and L1 language ability self-rating.

Four regression analyses were run using the above factors to determine how well performance on the four category generation task conditions (NS-L1, NS-L2, SS, and FS) could be explained by severity as measured naming severity, and language ability rating in L1. Overall regression equations were significant, indicating that L1 responses to the LUQ and performance on assessments of picture naming moderately explained performance on the NS-L2 ($F(2, 20) = 6.690$, $p = .006$, $R^2 = .401$), SS ($F(2, 20) = 7.967$, $p = .003$, $R^2 = .443$), and FS conditions ($F(2, 20) = 5.463$, $p = .013$, $R^2 = .353$). These results suggested that the majority of the variance on each of the category generation conditions was explained by subjective language ability rating, and lexical retrieval. Interestingly, these variables did not predict variance on the NS-L1 condition ($F(2, 20) = .001$, $p = .999$, $R^2 = .000$).

The relationship between language use history, performance on assessments, and variance of performance on each condition was then analyzed by looking at the beta coefficients of each factor in each regression to determine if language ability rating better predicted the FS condition compared to the other conditions. Language Ability Rating in L1 was a significant contributor to the NS-L2 regression (B = -1.706, p = .012) and SS regression (B = -1.055, p = .016), but not the FS regression. Performance on the *BNT-2* in L1 was a significant contributor to the models of the NS-L2 (B = .847, p = .002), SS (B = .616, p = .001), and FS (B = .569, p = .012) regressions. Beta and significance values for the relative contributions of each factor on each condition's model are included in **Table 8.**

	NS-L1		NS-L2		SS		FS	
Factor	*B*	*p*	*B*	*p*	*B*	*p*	*B*	*p*
L1 Language Ability Rating	.012	.980	**-1.706**	**.012**	**-1.055**	**.016**	-.028	.959
L1 Boston Naming Test	-.007	.973	**.847**	**.002**	**.616**	**.001**	**.569**	**.012**

Table 8. Beta coefficients and significance values for factors in the regression analyses for each condition. Note. NS-L1: No Switch; L1 condition. NS-L2: No Switch; L2 condition. SS: Self-Switch condition. FS: Forced Switch condition. B: beta coefficient from the regression model. p: significance value of the beta coefficient.

Discussion

The purpose of this study was to further investigate the relationship between cognitive control and lexical retrieval through a category generation task that was modified to include conditions requiring varying levels of cognitive control. Performance was assessed using the within-group factors of total number of items produced, proportion accuracy, proportion of direct translations, and average semantic cluster size in L1 and L2. Performance was compared within- and between- groups. Research questions and corresponding results are presented below.

The first research question asked: *How do bilingual persons with aphasia (BPWA) perform on the different conditions compared to healthy bilingual adults?* It was hypothesized that HC would produce more items with greater accuracy than BPWA. This hypothesis was supported, as HCs performed significantly more accurately than BPWA across the NS-L1, NS-L2, and FS conditions. The non-significant difference between groups in the SS conditions may reflect a relative strength of lexical retrieval in BPWA compared to HC in unconstrained language contexts (e.g. SS condition). These results support the findings of previous research that suggested that BPWA may make greater errors in contexts of spontaneous language production compared to healthy adults given a disruption in lexical access and/or cognitive control (Kiran et al., 2014; Ansaldo, Saidi, & Ruiz, 2010).

Next, it was hypothesized that both groups of participants will perform better on the NS and SS conditions than on the FS condition due to a language processing cost. This hypothesis was not supported by the results, likely due to underpowered analyses and large variability in responses across conditions. However, given the nonsignificant group difference in the SS condition and the relatively stable performance of controls across conditions, it appears that there is something unique in BPWA' performance on the SS condition compared to their performance on other conditions. These subtle changes in mean proportion correct between conditions for BPWA warrant further attention future studies with greater power.

The second question posited: *What is the difference in the nature and efficiency in the responses to the four conditions between BPWA and healthy controls?* First, it was hypothesized that BPWA would have larger average semantic cluster sizes and fewer semantic switches between semantic subcategories than HCs in the FS condition given increased cognitive control demands. This hypothesis was partially supported by the data. First, the number of semantic switches between semantic subcategories was analyzed. Results showed that BPWA had fewer semantic switches than HC in all conditions, likely due to the small number of items produced by BPWA overall. However, performance across conditions was not significantly different, though Figure 3 demonstrates some subtle differences in the mean number of semantic switches in controls that warrant further investigation.

Next, the average cluster size was analyzed. BPWA had smaller average semantic cluster sizes when compared to HC across conditions. Though there was not a significant difference across conditions, Figure 4 demonstrates possible trends in the average semantic cluster size produced across conditions and groups that warrant further investigation.

Additionally, it was hypothesized that the responses produced by BPWA would have a greater proportion of direct translations to accurate responses than HCs due to decreased inhibition of the non-target language in the FS condition as the cognitive control demand for the task increases. This hypothesis was not supported by the data. Specifically, results showed no significant difference between the proportion of direct translations to accurate items produced by BPWA and controls. These findings suggest that BPWA and HC demonstrated similar patterns of direct translation across conditions when the number of items produced was controlled for. These results support the findings of Kiran et al., (2014) which demonstrated that, though bilingual HCs produced more items than BPWA, the groups did not significantly differ in terms of approach to the task. Additionally, a significant condition effect was found such that participants produced a greater proportion of direct translations in the FS category compared to all other categories. This finding suggests that participants relied more on the simultaneous lexical activation of L1 and L2 words explained by the Green (1998) and RHM (Kroll & Stewart, 1994) models to produce items in contexts requiring greater cognitive control.

The final question addressed in this study was: *Can language use history and measures of lexical retrieval predict performance the tasks?* It was hypothesized that language use history and language assessments would better predict performance on the NS and SS conditions compared to the FS conditions due to a switching cost induced by increased cognitive demands of the language task. This hypothesis was partially supported. Results from regression analyses revealed that language use history and naming severity as assessed by the *BNT-2* significantly predict the performance on the NS-L2, SS, and FS conditions. Interestingly, these two assessments explained more variance in the SS condition compared to the NS-L2 condition, and more variance in the NS-L2 condition compared to the FS condition. The increase in variance explains corresponds to a decrease in variance explained by other factors, such as cognitive control. As such, these findings support the idea that the SS condition requires the least cognitive control of the modified conditions, followed by the NS-L2 condition which requires moderate cognitive control and the FS condition which requires the most cognitive control of the four conditions. Of note, performance on the NS-L1 condition was likely not explained by a significant regression due a ceiling effect of accurate responses.

Conclusions

Overall, the modified conditions of the category generation task were sensitive to the difference between BPWA and controls. Though performance across conditions was not significantly different, trends indicate that performance may decrease as expected cognitive control demand increased. Additionally, the results demonstrated that though HC produced significantly more items accurately than BPWA in the NS-L1, NS-L2, and FS conditions, both groups approached the task similarly by making more frequent direct translations when given a task of greater cognitive control.

Additionally, the various conditions (NS-L1, NS-L2, SS, and FS) appeared to require differing amounts of cognitive control and lexical access. The pattern in which lexical access and language use history predicted variance across conditions demonstrated that the SS condition may require the least amount of cognitive control, followed by the NS-L2 condition and the FS condition. Additionally, severity in naming significantly predicted variance in the NS-L2, SS, and FS conditions, but language ability was only significantly related to variance in the NS-L2 and SS conditions, indicating that confrontation naming may be a better predictor of performance in contexts of greater cognitive demand.

Implications of these findings include a greater understanding of the role of lexical access in semantic verbal fluency tasks and the introduction of a modified category generation task that may better capture the nuances of cognitive control and lexical access deficits in BPWA. With additional research, a modified category generation task with increasing cognitive control demands may help identify language contexts in which the BPWA may succeed (e.g. contexts with no constraint or highly constrained contexts) given the role of cognitive control in the errors of linguistic intrusion frequently made by BPWA in spontaneous conversation.

Limitations to this study include a limited sample size of BPWA compared to controls and the potential floor effect found for BPWA in analyses that considered the approach to performance. First, a smaller number of BPWA were included in this study compared to healthy controls. In the analyses that looked at condition and condition : group effects, subtle differences in the means of BPWA were found, but none approached significance. With a greater number of BPWA, it would be possible to increase the power of the results and further explore these nuances. Next, though BPWA who could not perform the task were excluded from participation in the study, the performance of BPWA who were included may reflect a ceiling effect for analyses that only considered accurate items (e.g. proportion of direct translations, number of semantic switches, average cluster size). Specifically, though BPWA may have produced five or six items, they may have only produced one item accurately. Therefore, in analyses that involved the accurate number of responses, BPWA may have had limited opportunity to demonstrate skill in using direct translations, semantic switches, or maintenance of semantic sub-category. Additionally, given the limited sample size of this study and the diverse nature of BPWA responses and severities, it is possible that outliers may have unduly influenced the more nuanced results (e.g. semantic cluster and direct translation analysis).

Future studies can expand on results of the present study with a larger number of participants to analyze the subtle condition differences found in this study. Next, future research can extend the varying conditions introduced in this study to performance on letter fluency test. Given the different nature of processing required to complete tasks of letter fluency and the dissociation found by previous research between letter and semantic fluency, it is possible that letter fluency performance may demonstrate greater need for cognitive control in the SS and FS conditions (Shao et al., 2014; Luo, Luk, & Bialystok, 2010). Finally, the relative contributions of cognitive assessments of verbal and nonverbal inhibition control can be compared to the contributions of traditional tests of lexical access across conditions. These results could better determine the presence of a greater language switching cost with given greater cognitive control.

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