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CHAPTER 8

Effects of cognitive control, lexical robustness, and frequency of codeswitching on language switching

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This study explores the effects of individual differences on the production of words when switching between a strong and significantly weaker language. Variables of interest included non-linguistic cognitive control, lexical robustness (i.e., the size and strength of the lexicon), and frequency of codeswitching in daily life. Seventy university students who were English (L1) speakers learning Spanish (L2) and French (L3) completed a language questionnaire and participated in: a Simon task; lexical robustness measures in all three languages; and a picture-naming task involving cued language switching between the L1 and L2. The results suggested that cognitive control and L2 lexical robustness had modulating effects on language switching, but only in limited cases. L3 lexical robustness did not affect L1-L2 language switching, however, both L1 and L2 lexical robustness had differential influences, with smaller differences between L1 and L2 switch costs being related to higher levels of L2. Counterintuitively, participants who reported more frequently codeswitching in daily life showed larger switch costs in both L1 and L2. We discuss the implications for these findings and emphasize the importance of examining a more comprehensive spectrum of variables that explain how multilingual experiences shape the networks that support cognition and language regulatory processes.

1. Introduction

When speaking, bilinguals activate both of their languages in parallel even when they are using only one. Overwhelming support for this has been found in a number of studies in speech comprehension (Bijeljac-Babic, Biardeau, & Grainger, 1997; Grainger & Dijkstra, 1992; Marian & Spivey, 2003; Spivey & Marian, 1999; Van Heuven, Dijkstra, &

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Grainger, 1998) and production (Calabria, Hernández, Branzi, & Costa, 2012; Chang, 2012; Colomé, 2001; Costa, & Caramazza, 1999; Costa, Caramazza, & Sebastián-Gallés, 2000; Costa, Miozzo, & Caramazza, 1999; de Groot & Starreveld, 2015; Giezen & Emmorey, 2015; Guo & Peng, 2006; Hermans, Bongaerts, De Bot, & Schreuder, 1998; Hoshino & Kroll, 2008; Kroll, Sumutka, & Schwartz, 2005; Poarch & van Hell, 2012; Starreveld, de Groot, Rossmark, & van Hell, 2014). Indeed, multilinguals are able to perform tasks such as speak in one language without letting their other language(s) interfere and to switch back and forth between their languages with what seems to be an apparent ease. Nonetheless, these seemingly simple tasks are not achieved without the support of a complex regulatory network.

There is ample evidence demonstrating that inhibitory control mechanisms facilitate bilingual speech production and language switching. However, we still know little about the cognitive control processes that mediate the ability to switch (Green & Wei, 2014). For instance, what is the exact functionality of the control mechanisms that allow multilinguals to regulate their languages? And are these mechanisms modulated by other aspects of language processing or individual differences such as proficiency, language experience, or cognitive control? In this study, we investigate whether cognitive control, lexical robustness, and the frequency of codeswitching in daily lives modulate the production of individual words when switching between a highly-proficient language (L1) and significantly weaker language (L2). In the upcoming sections, we provide a background on how multilinguals control their languages during speech production and the difficulties in operationalizing critical variables that have been shown to modulate control processes. We then discuss the present study including its research questions, participants, and experimental procedures. Finally, we present the results of the data analyses and comment on their implications for future work.

2. Background

Cognitive control mechanisms have been central in a number of bilingual models (Abutalebi & Green, 2007; Dijkstra & Van Heuven, 2002; Green, 1998; Schwieter & Sunderman, 2008; Van Heuven, Schriefers, Dijkstra, & Hagoort, 2008). Green's (1986, 1998) Inhibitory Control Model (ICM) posits that there are multiple levels of control which facilitate language production. Under the assumptions of this model, words in each language are marked with language tags specifying their belonging to one language over another (see Figure 1). With the intention to speak comes activation of words in both languages which compete for selection. These competitor words receive inhibition so that the correct word in the right language is accessed and produced. The ICM views bilingual speech production as a product of inhibition, control schemas, and a supervisory attentional system. As can be seen in Figure 1, when an

English-Spanish bilingual is asked to name a picture of a cat in English, the conceptualizer helps to build conceptual representations that are driven by the communicative goal. A supervisory attentional system and language task schemas help to mediate this procedure. Language tags identify words that are competing for selection and require inhibition. According to this model, at the conceptual level, the idea formed by mentally combining all characteristics of a particular concept takes place. At the lexical level, words in both languages are analyzed, and considered for selection. In the following example, let us consider an English-Spanish bilingual who wishes to say the word cat in his L1. This intention activates the concept of a cat in addition to related concepts in both languages (e.g., *dog*). *Cat* would receive more activation, as illustrated by the darker circles, but *dog* would also become activated. Language task schemas (i.e., inhibitory control) help to suppress and discard words in the irrelevant language. Because the word *cat* (compared to other activated words) maps on more closely to the concept *cat*, it is chosen for selection and subsequently phonetically encoded.

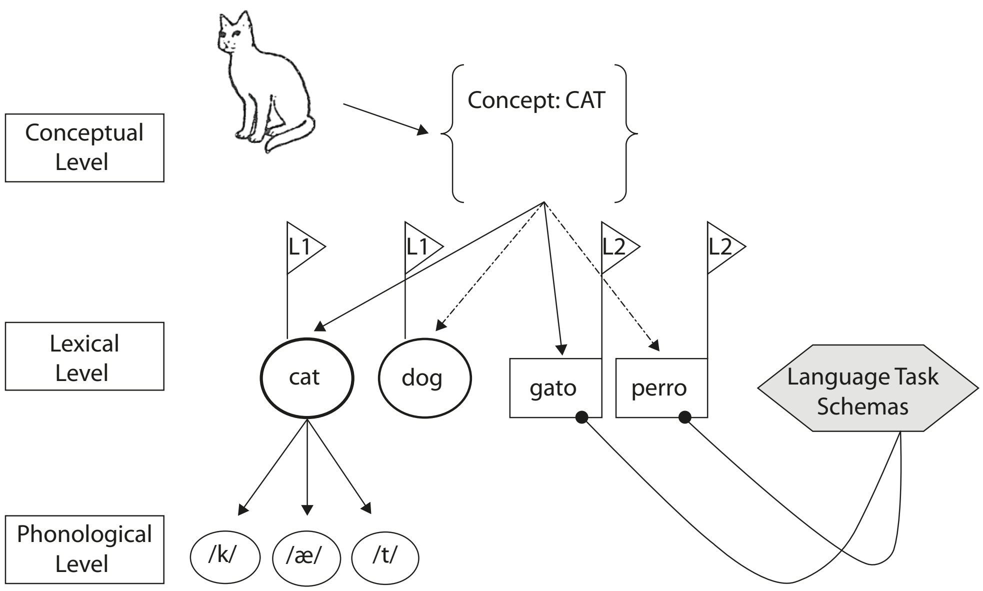

Figure 1. The Inhibitory Control Model (Green, 1986, 1998): An example of an English-Spanish bilingual naming a picture of a cat in English (adapted from Schwieter & Ferreira, 2013)

Empirical support for inhibitory control has been reported in psycholinguistic tasks in which participants name pictures or numerals while switching back and forth between two or more of their languages. One consistent finding is that it takes participants longer to switch into their more dominant language compared to switching into their less dominant language (Costa & Santesteban, 2004; Jackson, Swainson, Cunnington, & Jackson, 2001; Linck, Schwieter, & Sunderman, 2012; Meuter & Allport, 1999; Philipp, Gade, & Koch, 2007; Schwieter, 2010, 2013; Schwieter & Sunderman, 2008, 2011; Tarłowski, Wodniecka, & Marzecová, 2013; Verhoef, Roelofs, & Chwilla, 2009). Linck et al.'s study examined the relationship between the performance on the Simon task – a non-linguistic measure of inhibitory control and a trilingual switching task for a group of undergraduate English native speaker students. They assumed that "any relationship between performance on the Simon task and language switch costs would suggest that both tasks rely on a domain-general inhibitor control mechanism" (p. 653).

The results in Linck et al.'s (2012) study showed that better inhibitory control was related to reduced switch costs, but only when switching into or out of the L1, as switch costs were smaller for the L2 and L3, suggesting that there is a direct link between inhibitory control abilities and language switching capabilities. In this sense, there are some limitations on the conditions under which a domain-general inhibitory control mechanism supports language switching. However, there are a few studies (Bobb & Wodniecka, 2013; Festman & Schwieter, 2015; Koch, Gade, Schuch, & Philipp, 2010) suggesting that switch costs alone may not be a reliable index of inhibition in bilingual speech production. Code-switching, a growing area of study in linguistic and socio-linguistic, is primordial to many bilingual communities and has been studied in its different subcategories (alternations, insertions, dense code-switching) (Green & Wei, 2014). Cognitive control processes are assumed to be greater in bilinguals because both languages are active (Costa & Santesteban, 2004, among others). More or less activation might be related to the use of the speaker's languages, such as the community context (the "behavioral ecology of bilingual speakers," Green, 2011), and/or to their level of proficiency in the L2 (Green; Schwieter & Sunderman, 2011). A higher level of proficiency is assumed to be an essential characteristic that allows a bilingual to codeswitch.

It has been argued whether L2 proficiency modulates cognitive control (Costa & Santesteban, 2004). Videsott, Della Rosa, Wiater, Franceschini, and Abutalebi (2012) showed that L2 proficiency level in multilingual children played a crucial role in the development and enhancement of the alerting component of the attentional system. However, as Hulstijn (2012) points out, the construct of L2 proficiency is complex and findings generally do not reveal what exactly it is about L2 proficiency that may influence cognitive control. Schwieter and Sunderman's (2008, 2009, 2011) work along with their Selection by Proficiency Model identified lexical robustness as an important aspect within this complex construct. According to Costa, Santesteban, and Ivanova (2006), lexical robustness is related to the familiarity and frequency of words in each language and leads to greater automaticity of lexical retrieval. It represents an area of global proficiency which taps into the size and strength of the lexicon by considering the greater automaticity of word retrieval due to the familiarity with and frequency of its access.

Schwieter and Sunderman (2008) measured the L2 lexical robustness of a group of English language learners of Spanish and found that their performance in a picture-naming task with language switches was dependent on their L2 lexical robustness. The results supported the notion that inhibitory control may be called upon when

L2 lexical robustness is weak but that the cognitive processes which facilitate speech production for learners with higher L2 lexical robustness may involve language-specific selective mechanisms. Building on the ICM, Schwieter and Sunderman put forth the Selection by Proficiency Model (see Figure 2). In a subsequent review by Schwieter and Ferreira (2013), the researchers state that during language selection and lexical access, L2 lexical robustness determines which cognitive abilities are necessary and functional. When the L2 lexical robustness is weak, language learners are not able to access the conceptual store directly and need to consult the L1, relying on inhibitory control (IC). As L2 lexical robustness increases, stronger L2 conceptual links are established and the ability to engage a language-specific selection mechanism is developed. Higher-proficient bilinguals seem to be able to rely on higher linguistic cues at the conceptual level and potentially less so on IC. This development from a very weak to a very strong lexical robustness is described in Figure 2. The darker arrows represent stronger links and dashed arrows represent weaker links. In the right portion of the model represents a highly proficient bilingual who is hypothesized to rely on higher-linguistic cues at the conceptual level. In other words, the target language can be established from the first stages of speech production. The left side of the model suggests that, for those less-proficient bilinguals, the target language cannot be determined until the lexical level and IC is called upon to assist lexical selection. In certain situations, however, even proficient bilinguals may need to rely on IC (e.g., proficient bilinguals switching between weaker L3 and L4, Costa et al., 2006).

Hennecke (2013) specifically tested the predictions of the Selection by Proficiency model. In this study, the researcher proposed a corpus analysis of different self-repair mechanisms in codeswitching environments in natural speech data of French-English balanced bilinguals born and raised in a francophone area in Canada. Participants were speakers of the Canadian French variety Franco-Manitoban, which evolved in a different way from other French Canadian varieties, being influenced in a considerate extent from English as a result of sociolinguistic and historical aspects. The corpus contained a large amount of code-switching and consisted of 35,600 tokens extracted from 15 conversations. Twenty speakers between 17 and 30 years old participated in the experiment. English represents only one third of the data, which should be expected as participants identified French as their L1. French and English proficiency was only determined by self-assessment and a sociolinguistic questionnaire and no proficiency test was conducted. The results revealed that only a few speech errors and self-repairs occurred in direct codeswitching environments. Furthermore, an analysis of the places at which codeswitching occurred, along with the different repair mechanisms used, supported the notion that highly-proficient bilinguals establish the language of production before lexical selection. Hennecke argued that speech production for highly-proficient bilinguals may involve a language-specific selective mechanism (refer back to the right portion of Figure 2). Although Hennecke's study

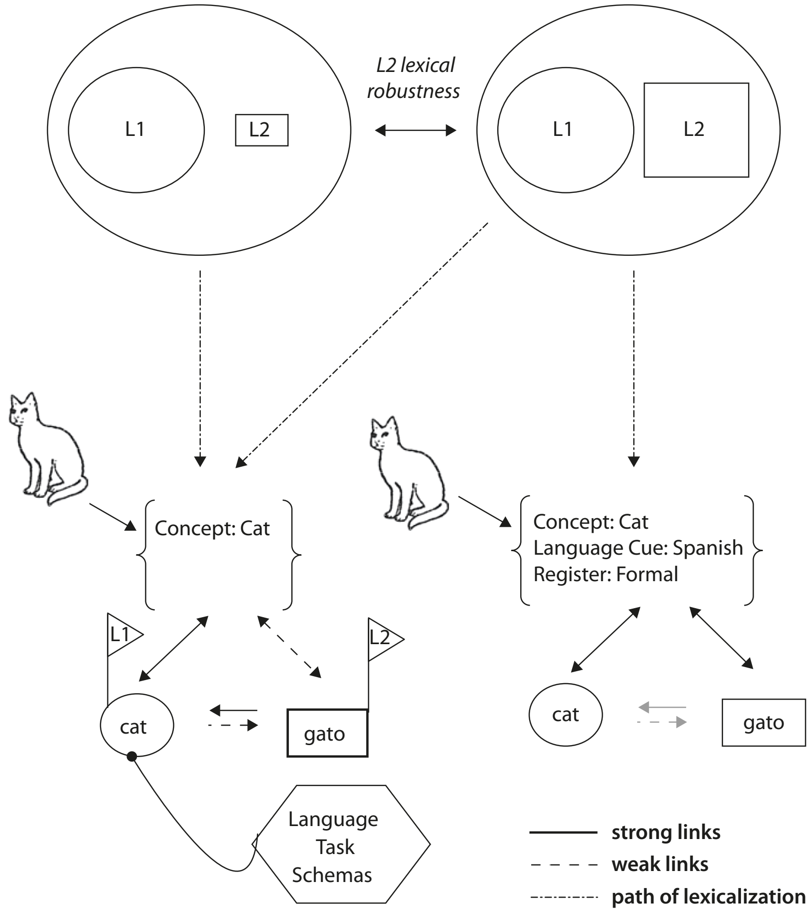

Figure 2. The Selection by Proficiency Model (Schwieter & Sunderman, 2008): An example of a less-proficient (left) and more-proficient English-Spanish bilingual (right) naming a picture of a cat in Spanish (adapted from Schwieter & Ferreira, 2013).

involved voluntary codeswitching, we feel that this work is noteworthy of discussion when looking at cued language switching such as in the present study.

Green and Abutalebi's (2013) Adaptive Control Hypothesis builds on the idea that bilinguals vary in terms of their language use in different community contexts (Green, 2011; Prior & Gollan, 2011). The researchers relate the underlying cognitive and neural control mechanisms to the way in which bilinguals use their languages. The control mechanisms are thought to adapt in accordance with the bilingual experience and the recurrent demands placed on them in interactional situations. These adaptations could be either a change of its parameters or neural efficiency or a change in the way it functions – either alongside or sequential to other cognitive processes. Green and Wei (2014) offer a similar account to speech planning and the cognitive processes that govern codeswitching. Viewing bilingual language production as a competitive account, their cognitive process model of codeswitching argues the importance of understanding "the interactional contexts of the bilingual speaker" (p. 509). Cognitive processes most appropriate to certain situations and types of code switches are "coordinated cooperatively and operate in a coupled or in an open control mode. The former permits alternations and insertions whereas the latter is required for dense codeswitching" (p. 499). In other words, certain situations of multiple language use such as codeswitching entail unique demands on control mechanisms. Each type of linguistic context (e.g., single-language, dual-language, or intensive language switching) will require specific cognitive demands. This could eventually result in varied control adaptations.

3. Present study

A variety of factors may lead to processing differences in cognitive control, including participants' age (Bialystok, Barac, Blaye, & Poulin-Dubois, 2010; Bialystok, Craik, & Freedman, 2007), task difficulty (Bialystok, Craik, & Ryan, 2006), individual differences (Festman, Rodríguez-Fornells, & Münte, 2010; Festman & Schwieter, 2015; Linck et al., 2012), language similarities (Van Heuven, Conklin, Coderre, Guo, & Dijkstra, 2011), language contexts (Green, 2011; Green & Abutalebi, 2013; Kroll & Bialystok, 2013), and the nature and extent of their multilingualism (Linck, Michael, Golonka, Twist, & Schwieter, 2015; Schwieter & Sunderman, 2011). In this study, we will look at the possible effects of cognitive control, lexical robustness, and codeswitching on language switching performance among less- and more-proficient language learners.

Because we also were able to gather information from our participants regarding the frequency of codeswitching in their daily lives, we will also include analyses on this. Given that the L1 has consistently formed part of previous experimental procedures, it is surprising that measures of L1 lexical robustness have not been employed. In the present study, we include lexical robustness measures in the L1 in addition to the L2 and L3.

English (L1) language learners of Spanish (L2) and French (L3) participated in a picture-naming task in which they switched back and forth between their L1 and L2. They also participated in a Simon task. A verbal fluency measure task in all three of their languages was carried out to investigate whether L3 lexical robustness modulates switching between L1 and L2. We compare language switching performance for participants with lower and higher cognitive control; lower and higher L1, L2, and L3 lexical robustness; and lower and higher self-ratings of frequency of codeswitching.[1]

1. It is important to note, however, that *lower* and *higher* refer to a differential level between the experimental groups and we would like to emphasize that *higher L2 lexical robustness,* for example, does not mean *near-native proficiency in the L2*. In fact, because the participants' L2

It is important to point out that the lexical robustness measure validated the participants' self-evaluation of language abilities. This is important given that it could be the case that a participant could declare French as L2 but their lexical robustness in Spanish is stronger. We note that there was a correlation between lexical robustness and self-ratings. Below we present our research questions followed by a description of the participants and experimental procedures.

3.1 Research questions

In this study, we investigate whether L1-L2 switching is affected by cognitive control (Simon effect), lexical robustness, and the frequency of reported codeswitching in daily lives. Previous work (Costa et al., 2006; Schwieter, 2010, 2013; Schwieter & Sunderman, 2008, 2011) has suggested that when a language with low lexical robustness and a language with high lexical robustness are involved in a switching task, asymmetrical switch costs will be observed between the two languages. This was argued to occur because more time is needed to reactivate a language with higher lexical robustness after having been inhibited. We expect to observe this finding in our study as well. In other words, we anticipate larger switch costs for the L1 compared to the L2 given that our participants are significantly weaker in their L2 compared to L1. Furthermore, we hypothesize that cognitive control will influence language switching as reported in Linck et al.'s (2012) trilingual study such that participants with better inhibitory control will exhibit reduced switch costs. We also expect participants who more frequently codeswitch in daily lives to have smaller switch costs.

3.2 Participants

Seventy English language learners of Spanish and French were recruited from the student body at a university in an English-speaking region of Ontario, Canada. These included 38 females and 32 males. Most of the participants were taking language courses as part of their program of study and at least half of them were enrolled in an undergraduate program in which three foreign languages are taken simultaneously. Thus, some of the participants had limited knowledge of a fourth language (e.g., Arabic, German, and Italian, the languages offered in the program). None of the participants reported similar proficiency levels in any of their languages nor living in a non-English speaking environment. They did, however, report learning their L3 (French) from a fairly early age ($M = 7.59$; $SD = 3.71$) as it is part of the required coursework in public schools in Canada. Nonetheless, French was significantly

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and L3 proficiency levels ranged from elementary and intermediate levels, it is very much the case that all participants are by no means *native* or *near-native* in their L2 and L3.

weaker than Spanish given that the participants in the present study were more advanced in their Spanish courses than French. Table 1 presents descriptive statistics for the participants.

Table 1. Participant characteristics

	Mean	SD
Age	19.6	3.8
L1 Age of Acquisition	< 1.0	2.8
L2 Age of Acquisition	15.7	6.3
L3 Age of Acquisition	9.2	3.7
L1 Overall Rating	9.8	0.8
L2 Overall Rating	5.5	2.1
L3 Overall Rating	3.6	3.2
L1 Lexical Robustness Score	116.8	18.2
L2 Lexical Robustness Score	50.4	14.9
L3 Lexical Robustness Score	32.5	25.8
Simon effect	32.0	26.1

Note: L1 = native language (English); L2 = second language (Spanish); and L3 = third language (French). Self-ratings were based on a ten-point scale ranging from 1 (*not fluent*) to 10 (*very fluent*). Lexical robustness scores represent the sum of the number of exemplars produced across the ten categories in the verbal fluency measure (Schwieter & Sunderman, 2011).

3.3 Procedure

The participants were individually tested in a silent room and were shown the instructions for the tasks on a black and white computer screen by reading along with the researchers. They first completed the informed consent form followed by the language questionnaire. The questionnaire inquired about their proficiency in reading, writing, listening, speaking and comfort in level each language (English, Spanish, and French) on a scale from 1 to 10 (1 = not fluent; 10 = very fluent). They were also asked to list all languages of which they some sort of competency, the percent of how often they currently speaking these languages, and how they rate their overall abilities in each. Also, participants rated frequency of codeswitching in their daily lives on a ten-point scale ranging from 1 (never) to 10 (all the time). Following this, the participants completed the Simon task, verbal fluency measure, and picture-naming task, the procedures of which are described below. After completing each task, participants could take short breaks to diminish fatigue. The entire session for each participant lasted approximately two hours.

3.3.1 *Simon task*

The Simon task has been used in a number of bilingual studies (e.g., Bialystok et al., 2004; Bialystok et al., 2005; Linck et al., 2012) as a measure of cognitive control. Bialystok and her colleagues explain that this task is "based on stimulus–response compatibility and assesses the extent to which the prepotent association to irrelevant spatial information affects participants' response to task relevant nonspatial information" (2004, p. 291). According to Hommel (2011), the Simon task assesses the ability to deal with and resolve response conflict. In the present study, red and blue boxes were presented in one of three places of a computer screen: central, left of center, or right of center. Participants responded with a left or right button press based on the colour of the box while ignoring its location. On congruent trials, the locations of the stimulus and the correct response match (e.g., a box on the left requires a left button press). On incongruent trials, the stimulus and response locations were mismatched so that the stimulus appeared on the opposite side of the screen from the location of the correct response (e.g., a box appearing on the left requires a right button press). Neutral trials in which the stimulus was presented at the center of the screen were also included but excluded from the analyses. The Simon task has consistently shown that incongruent trials cause longer response latencies compared to congruent trials because of the mismatch between the stimulus and response locations (Simon & Rudell, 1967). In this sense, we aim to measure one's ability to inhibit the strong tendency to respond based on the location of the box instead of the colour. In the present study, participants were shown a randomized series of red and blue boxes one at a time, on a computer screen. Boxes varied in colour (red or blue) and location (left, centered, or right fixation). Participants were told to press one of two buttons based on the colour and ignore the location. Further specifics about the task design can be found in Linck et al. (2012).

3.3.2 *Verbal fluency measure*

All participants completed a verbal fluency measure adapted from Gollan, Montoya, and Werner (2002) and Schwieter & Sunderman (2008, 2009, 2011). In this task, participants were individually presented with five semantic and five letter categories, and for each category they were instructed to produce as many exemplars as possible within thirty seconds. The semantic categories were: sports, fruits, clothes, vegetables, colours; and the letter categories included words beginning with: m, a, s, r, and g. Categories were blocked by language to avoid language switching. Instructions were given in English at all times. In order to avoid (or at least diminish) priming, the verbal fluency tasks in each language were not administered sequentially, but rather were evenly distributed throughout the experimental session. All answers were recorded and transcribed but only participants' correct answers were considered for RT analyses. The total number of category exemplars produced was taken as an indicator of lexical robustness which we define as an important piece of global language proficiency which represents the familiarity and frequency of lexical items along with the automaticity of their retrieval (Costa et al., 2006; Schwieter & Sunderman, 2008, 2009, 2011). The participants' verbal fluency performance revealed significant differences between all three of their languages: L1 and L2, $t(69) = 26.75$, $p < .0001$; L2 and L3, $t(69) = 5.07$, $p < .0001$; and L1 and L3, $t(69) = 24.61$, $p < .0001$.

Given that verbal fluency is correlated with proficiency, we asked participants in the language questionnaire to rate their L1, L2, and L3 abilities on a 1–10 scale. Once again, significant differences between all three of their languages were reported: for the L1 and L2, $t(69) = 14.79$, $p < .0001$; L2 and L3, $t(69) = 3.77$, $p < .001$; and L1 and L3, $t(69) = 16.29$, $p < .0001$. From the verbal fluency measure and the self-ratings, we can be fairly certain that the participants indeed had significant differences in language dominance between all three of their languages.

3.3.3 *Picture-naming task*

Following previous studies by Costa and Santesteban (2004) and Schwieter and Sunderman (2008), the picture-naming task contained 20 line drawings from the Snodgrass and Vanderwart (1980) standardized picture list. These included pictures of an apple, bear, bed, book, car, cat, chair, dog, donkey, eye, heart, house, leaf, lips, nose, pencil, sun, table, watch, and window. Forty-eight randomly sequenced lists of 5–14 pictures were created. Each list did not repeat a picture and included anywhere from 0–4 switch trials. We define switch trials as pictures whose immediate proceeding trial was named in a different language. A nonswitch trial was a picture which was named in the same language as its proceeding trial. The total number of trials named included 480 pictures where 70% were nonswitch trials and 30% were switch trials (336 and 144 trials, respectively). A colour code was used as in previous studies to cue participants of the language of production for each picture presented. Participants were asked to name pictures in English (L1) if they appeared in a blue box or in Spanish (L2) if they appeared in a yellow box. Of the 480 pictures, half were named in English and half were named in Spanish and each of the 20 pictures appeared 24 times during the entire experiment.

Participants completed 5 practice lists of pictures before beginning the 48 experimental lists. The experimental procedure of each list of pictures (both practice and experimental) adhered to the following sequence: (1) a black fixation point (+) was presented in the centre of the screen on the white background for 500 ms; (2) the first picture of the list appeared in either a blue or yellow box for 2000 ms or until the participant responded into a microphone; (3) a black fixation point (+) was presented; (4) the next picture was shown (either a switch or nonswitch trial) and the cycle was repeated until the end of the list. RTs were measured by the computer and accuracy was coded by the researcher as correct or incorrect on a master key. The participants had the option of taking a short break after every 8 lists (approximately every 5 minutes) to avoid fatigue.

3.3.4 *Data analyses*

Participants were asked to carry out the tasks as quickly and accurately as possible, but because accuracy is sometimes sacrificed at the expense of speed increase (Glickman, Gray, & Morales, 2005), we opted to report only accurate answers. In our analyses, we report only response latencies of correct responses. For the picture-naming task, a response was deemed correct when a picture was correctly named in the right language and incorrect in all other cases. Incorrect responses, for example, included naming the picture in the wrong language, stuttering, microphone malfunction, etc. To better standardize the data, RTs faster than 300 ms and slower than 2000 ms were considered as outliers and were removed from the analyses. These excluded data primarily were instances in which the microphone may not have registered the response. The amount of excluded data equalled 1.8% of the data. We also considered RTs that were 2.5 SDs above or below a participant's mean RT for each condition to be outliers. These were also excluded from the analyses and represented 2.1% of the data.

Five separate analyses of variance were conducted by grouping the participants as "less" or "more" according to their (1) cognitive control score; (2) L1 lexical robustness; (3) L2 lexical robustness; (4) L3 lexical robustness; or (5) frequency of codeswitching.[2] The grouping in each of the ANOVAs was based on a simple median split of the factor in question. This resulted in two groups of 35 participants in each analysis. A 2 × 2 × 2 ANOVA was carried out using participant means as random factors with trial type (nonswitch or switch) and response language (L1 or L2) as within-group factors and the five factors above (less and more) as between-group factors.

4.0 Results

4.1 Analyses of cognitive control

We first compare language switching performance between language learners with less and more cognitive control. From the ANOVA, there was a main effect for trial type, $F(1, 68) = 156.37$, MSE = 274,021, $p < .0001$, suggesting that switch trials (939 ms) were slower than nonswitch trials (875 ms). There were also trends towards significance for a main effect for response language, $F(1, 68) = 2.90$, MSE = 20,163, $p = .09$, such that pictures named in the L2 (916 ms) were marginally slower than those named in the L1

2. We chose to use analyses of variance in our design in accordance with previous studies that have used these exact experimental procedures (Costa & Santesteban, 2004; Schwieter & Sunderman, 2011). Future work may wish to consider multivariate approaches which may reveal a fuller range of cognitive consequences of multilingualism. The reader should refer to Bobb, Wodniecka, & Kroll, 2013 and Kroll & Bialystok, 2013 for further discussion).

(898 ms). There was a significant interaction for trial type *response language, $F(1, 68) = 53.56$, MSE = 93,165, $p < .0001$, such that L1 switch costs (101 ms) were significantly greater than L2 switch costs (27 ms).

Although it is unconventional to report findings of $p < .10$, we did note an interesting finding in the data. There were trends towards a significant interaction for cognitive control *trial type, $F(1, 68) = 2.97$, MSE = 5,200, $p < .09$, implying that language learners with more cognitive control (i.e., lower Simon effects) had marginally lower switch costs (55 ms) than learners with less cognitive control (72 ms) (see Table 2). Importantly, this finding was not sensitive to the response language as evidenced by the lack of significant three-way interaction for trial type *response language *cognitive control ($p > .05$).

Table 2. Effects (in ms) of cognitive control on trial type

	Less cognitive control (i.e., higher Simon effect)	**More cognitive control (i.e., lower Simon effect)**
Switch	882	868
Nonswitch	954	923
Switch cost	72	55

4.2 Analyses of lexical robustness

We compared language switching performance between learners with less and more L1, L2, and L3 lexical robustness. Below we present the results of these analyses. Not surprising, given that the data from the same sample is used in these analyses below, many of the main effects and interactions were found.

4.2.1 *L1 lexical robustness*

There was a main effect for trial type, $F(1, 68) = 146.89$, MSE = 262,009, $p < .0001$, suggesting that switch trials (930 ms) were slower than nonswitch trials (867 ms). We also found a main effect for response language, $F(1, 68) = 4.14$, MSE = 27,168, $p < .05$, such that pictures named in the L2 (909 ms) were slower than those named in the L1 (889 ms). Finally, there was a significant interaction for trial type *response language, $F(1, 68) = 51.15$, MSE = 89,260, $p < .0001$. This implied that L1 switch costs (99 ms) were significantly greater than L2 switch costs (26 ms).

There was also a significant interaction for response language *L1 lexical robustness, $F(1, 68) = 5.18$, MSE = 34,058, $p < .03$, suggesting that whereas learners with lower L1 lexical robustness named pictures at similar speeds in the L1 (958 ms) and L2 (956 ms), learners with higher L1 lexical robustness named pictures faster in both the L1 (819 ms) and L2 (862 ms).

Table 3. Effects (in ms) of L1 lexical robustness on trial type

	Lower L1 lexical robustness	**Higher L1 lexical robustness**
L1	958	819
L2	956	862

4.2.2 *L2 lexical robustness*

There was a main effect for trial type, $F(1, 68) = 148.91$, MSE = 272,675, $p < .0001$, showing that switch trials (938 ms) were slower than nonswitch trials (874 ms). We also found a significant interaction for response language * trial type, $F(1, 68) = 54.61$, MSE = 82,916, $p < .0001$. This implied that L1 switch costs (99 ms) were significantly greater than L2 switch costs (29 ms).

There was a significant interaction for response language *L2 lexical robustness, $F(1, 68) = 3.99$, MSE = 26,644, $p < .05$. A comparison of means showed that learners with less L2 lexical robustness named pictures in their L2 (935 ms) significantly slower than in their L1 (900 ms) while learners with more L2 lexical robustness named pictures at similar speeds in both L2 (892 ms) and L1 (897 ms). Finally, there was an important significant three-way interaction for response language *trial type *L2 lexical robustness, $F(1, 68) = 10.05$, MSE = 15,260, $p < .01$. This interaction implied that the magnitude of the switch costs were dependent on the level of L2 lexical robustness such that higher levels of L2 lexical robustness resulted in smaller differences between L1 and L2 switch costs (40 ms) compared to lower L2 lexical robustness (100 ms) (see Table 4). In line with Schwieter and Sunderman (2008), this finding suggests that as L2 lexical robustness increases, so does the symmetry between L1 and L2 switch costs.

Table 4. Effects (in ms) of L2 lexical robustness on language switching performance.

	Lower L2 lexical robustness		**Higher L2 lexical robustness**	
	L1	**L2**	**L1**	**L2**
Switch	957	942	939	914
Nonswitch	843	928	855	870
Switch cost	114	14	84	44
Magnitude of asymmetry	100		40	

4.2.3 *L3 lexical robustness*

There was a main effect for trial type, $F(1, 68) = 149.93$, MSE = 264,589, $p < .0001$, showing that switch trials (935 ms) were slower than nonswitch trials (872 ms). We also found trends towards a significant main effect for response language,

$F(1, 68) = 2.98$, MSE = 20,988, $p < .09$, such that pictures named in the L2 (912 ms) were marginally slower than those named in the L1 (894 ms). Finally, there was a significant interaction for trial type * response language, $F(1, 68) = 52.35$, MSE = 91,585, $p < .0001$. This implied that L1 switch costs (99 ms) were significantly greater than L2 switch costs (26 ms). There were no significant interactions with L3 lexical robustness. At least for the purpose of the present study, the lexical robustness of the weakest language which is not involved in the switching task, does not appear to modulate switching between two other languages. It will be important for future work to address whether this is because of the L3's relative weakness or because of its exclusion from the experimental design.

4.3 Analyses of frequency of codeswitching

Bobb and Wodniecka (2013) argue that research must not only take into account proficiency level, but also participants' experience with language switching (see also Green, 2011). Previous work has shown that experience with language switching in daily life may lead to reduced switch costs (Christoffels, Firk, & Schiller, 2007; Prior & Gollan, 2011). Similar findings have also been reported for simultaneous interpreters whose frequent language switching on a daily basis influenced control processes (Ibáñez, Macizo, & Bajo, 2010; Yudes, Macizo, & Bajo, 2011). In the present study, the language questionnaire elicited participant ratings on how frequently they codeswitch in their daily lives on a ten-point scale ranging from 1 (never) to 10 (all the time). A median split (5.95) divided the participants into two groups: less and more frequent code switchers. From an ANOVA, the results showed that more frequent code switchers were significantly slower overall (976 ms) in the language switching task compared to less frequent code switchers (880 ms), $F(1, 68) = 22.24$, MSE = 635,037, $p < .0001$. Unlike Ibáñez et al.'s and Yudes et al.'s studies, the participants in the present study who reported more frequently codeswitching did not have reduced switch costs. In fact, these participants support the opposite (see Table 5): compared to the participants who reported less frequently codeswitching, those who

Table 5. Effects (in ms) of frequency of codeswitching on language switching performance

	Less frequent code switchers		**More frequent code switchers**	
	L1	**L2**	**L1**	**L2**
Switch	902	913	1046	991
Nonswitch	810	896	916	950
Switch cost	92	17	130	41
Magnitude of asymmetry	75		89	

more often codeswitch had larger switch costs in the L1, $t(68) = 3.15$, $p < .01$; and in the L2, $t(68) = 1.85$, $p < .06$. The magnitude of the asymmetrical switch costs between the L1 and L2 was not affected by the reported frequency of codeswitching. Unfortunately, these estimates were the only data related to the frequency of codeswitching in the daily lives of the participants and future work may wish to consider incorporating several measures of this variable.

Although these effects did not depend on response language or trial type, it is worth speculating as to why language learners who claim to frequently codeswitch were slower in a switching task. It is possible that they are more sensitive to language switching in general given that it seems to be a much more frequent practice for these learners. On the other hand, the participants in the present study were significantly less proficient than the professional translators and interpreters in Ibáñez et al. (2010) and Yudes et al. (2011). Nonetheless, this finding demonstrates the effects of language experience and individual differences on language switching and potentially the control processes underlying multilingual speech production. Festman and Münte (2012) investigated the relationship between language switch costs and four cognitive control tests. Participants were divided into two groups, depending on their ability to remain in the instructed target language. Results showed that the group that rarely switched unintentionally showed a faster and better performance on cognitive control tests. Future work should tease apart the *multilingual experience* by looking at factors such as codeswitching and interpreting (Dong & Xie, 2014) or the extent to which their languages form part of certain social and professional situations (Green & Abutalebi, 2013).

5.0 Discussion

In the present study, we examined the effects of cognitive control, lexical robustness, and frequency of codeswitching on performance of a L1-L2 switching task. Several findings were consistent with previous work. Regarding cognitive control, as operationalized by the participants' Simon effect, the results showed that participants with higher cognitive control had marginally lower switch costs compared to learners with less cognitive control. This finding (marginally) supports Linck et al. (2012) in which better inhibitory control predicted smaller switch costs when the language switching involves the L1. It also validates Festman and Münte's (2012) claim in the sense that better cognitive control was related to a better performance.

We were also interested in whether lexical robustness would show modulating effects on control processes as was reported in Schwieter and Sunderman (2008). The present study similarly found that naming pictures in the L2 was significantly slower for learners with less L2 lexical robustness compared to learners with more L2 lexical robustness. The important three-way interaction for trial type * response language * L2 lexical robustness that was reported in Schwieter and Sunderman was also significant in the present study, demonstrating the sensitivity of control processes to the size and strength of the L2 lexicon. Although the magnitude of L1 switch costs and L2 switch costs was significantly different for all participants, this difference was significantly less marked among learners with more L2 lexical robustness. This supports the notion that learners with higher L2 lexical robustness are on the path to closing the gap between switch costs in their L1 and L2 (Schwieter & Sunderman). Future work will need to further test whether control processes are sensitive to lexical robustness or whether learners with more L2 lexical robustness (but perhaps not those with less lexical robustness) are able to adapt their control processes (Green & Abutalebi, 2013) to the demands of the task. Is it possible that learners with more L2 lexical robustness conceptualize and plan their speech differently than learners with less L2 lexical robustness and perhaps show less (empirical) evidence (Schwieter & Sunderman, 2008)? Are asymmetrical switch costs truly indicative of reliance on inhibitory control mechanisms during multilingual speech production (Bobb & Wodniecka, 2013)?

The size and strength of the L1 lexicon is an individual difference among participants which adds another layer of complexity to the nature of multilingualism. From our analyses, we found that learners with more L1 lexical robustness were faster to name pictures in both the L1 and L2 compared to learners with less L1 lexical robustness. Furthermore, while participants with less L1 lexical robustness named pictures in L1 and L2 at similar speeds, learners with more L1 lexical robustness named pictures significantly faster in the L1 than in the L2. If bilinguals come to know and use both of their languages in unique ways that could have the potential to shape the control processes that underpin their speech, we argue that future work should incorporate L1 measures into its experimental design. Taken with more robust and comprehensive measures of participants' non-native languages, analyses of the L1 could hold fruitful results and explanatory power.

In terms of whether or not codeswitching as part of daily lives affected language switching, surprising results emerged. Unlike frequent code switchers who have shown reduced switch costs in previous work (e.g., Christoffels et al., 2007; Ibáñez et al., 2010; Prior & Gollan, 2011; Yudes et al., 2011), our participants, although admittedly much less proficient, had larger switch costs in both the L1 and L2. We would like to caution the fact that even the most proficient participants in the L2 were significantly less experienced bilinguals than the professional translators and interpreters in previous work. It is very likely that even though participants may have rated their frequency of codeswitching very high on the ten-point scale, their experience with codeswitching in their daily lives is no doubt vastly different than that of the highly proficient bilinguals. In addition to incorporating both highly-proficient bilinguals and less-proficient language learners in future work, researchers should attempt to better replicate codeswitching in an experimental setting. Also, "real world codeswitching" is done without hesitation, cueing, pauses, or corrections, during the natural language production, and it is "neither random interference from one language to the other nor a manifestation of disfluency." (Valdés-Kroff, Dussias, Gerfen, Perrotti, & Bajo, in print). According to Valdés-Kroff et al., actual code-switching is an inherently discourse-based phenomenon, and lexical switch studies have investigated cost trigged by a language change that might be more related to switch costs in non-linguistic domains.

On a methodological level, in the last couple of years, research has begun to incorporate other indices of inhibitory control rather than exclusively relying on language switch costs (see Bobb & Wodniecka, 2013 for a review). Some of these innovative tasks include competitor priming (Wodniecka et al., under review), blocked naming (Misra, Guo, Bobb, & Kroll, 2012), and long-lag priming paradigms (Verdonschot, Middelburg, Lensink, & Schiller, 2012). Kroll and Bice (2016) argue that "some aspects of inhibitory control appear to be local and tied to specific patterns of lexical activation whereas others are more global and sustained and associated with the control of the language itself" (p. 251). Festman and Schwieter (2015) review behavioural methodologies (e.g., picture naming, digit naming, the verbal fluency measure, phrasal production, reading aloud, self-paced reading, and categorization of animacy) that have been used to measure language control in production and comprehension. Echoing these suggestions, we argue that future work employing picture and digit naming would highly benefit by incorporating both mixed-language and single-language blocks. We posit that this may help to establish a baseline for proficiency and performance abilities for multilingual participants. It is certainly possible that previous inconclusive findings can be clarified by avoiding methods that limit themselves to mixed-language blocks without a guiding baseline of language switching performance.

The results from the present study point to similar implications from previous work. Individual differences can account for language learners' diverse multilingual background. The notion of a *multilingual experience* needs to be fully explained and delineated and should incorporate analyses of the L1 in addition to other factors that paint a diverse, yet comprehensive, linguistic background. Social factors play a large role in these multilingual experiences. For instance, Morton and Harper (2007) showed no difference in performance on a Simon task between monolingual and bilingual children but they did report a significant correlation with socioeconomic status. Calvo (2011) further delineated socioeconomic status by examining multiple factors of language ability, memory, attention, and cognitive control among monolingual and bilingual children. Their results suggested that bilingualism and socioeconomic status affected performance in differential ways: the main effects of socioeconomic status were revealed in language ability and attention while the main effects of bilingualism were found in executive functioning. Dong and Xie (2014) investigated how L2 proficiency and language interpreting experience contribute to cognitive control differences among young adult bilinguals. Their study demonstrated that bilinguals' language use ecology – namely their experience as interpreters – significantly contributes to mental set shifting enhancement in cognitive control. These results are in line with Green and Wei's (2014) theories and should be considered in future studies.

6. Conclusion

In this chapter, we have looked at the effects of individual differences on the production of words while switching back and forth between two languages. We were specifically interested in whether non-linguistic cognitive control, lexical robustness, and reported frequency of codeswitching in daily life would affect language switching performance. The results discussed above demonstrate the complicated nature of how multiple languages are controlled in one mind. While it appears as though cognitive control (as indexed by the Simon effect) and lexical robustness (as indexed by verbal fluency scores) affect language switching performance in different ways, we also found preliminary support for counterintuitive effects related to the frequency of codeswitching in the daily lives of the language learners. Future studies will need to untangle the difficulty in operationalizing *multilingualism* while considering complicated issues such as what it means to participants to "codeswitch in their daily lives." Given our participants' low L2 proficiency, we question the true extent of their frequent codeswitching when such switching is greatly restricted by lack of L2 vocabulary, grammatical competence, fluency, among other things. The multilingual experience is a dynamic procedure that consists of several dimensions, perhaps far from being categorical (Luk & Bialystok, 2013). A fine-grain level of analysis and operationalization of such experience must explain and capture the reconfiguration of cognitive control processes. Future studies should consider viewing multilingualism as a dynamic procedure that consists of several dimensions which interface to depict the multilingual experience.

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