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Spanish-English Code-Switching and Cognitive Control

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Abstract

Code-switching is the act of alternating between multiple languages within a conversation, common amongst bilingual speakers. The Control Process Model claims that different types of language contexts like code-switching involve different levels of engagement of cognitive control. In studying this phenomenon, prior research has demonstrated that reading code-switched sentences enhanced cognitive control (conflict resolution) on non-verbal trials compared to one-language contexts. The current study investigates how code-switching affects conflict resolution similar to that of the previous study but using more ecologically valid auditory stimuli (speech). Participants are Spanish-English bilinguals in the US who learned both languages before the age of 12. The experiment alternates one-language spoken sentences and Spanish-English sentences. Sentences are interleaved with Flanker trials, congruent (← ← ← ← ← or → → → → →) or incongruent (← ← → ← ← or → → ← → →). Participants respond to the direction of the middle arrow. The prediction made is that both the presence of a code-switch and the type of code-switch modulates the conflict effect. Results show that the presence of a switch and the type of switch matters in modulating cognitive control in bilingual individuals.

Keywords: Code-switching, cognitive control

Introduction

One of the most distinct and unique acts that bilinguals engage in when conversing with one another is the act of code-switching. Code-switching, as defined in this paper, is the simultaneous use of the multiple languages a bilingual knows within a single utterance or conversation. Code-switching is a phenomenon that is nearly universal in communities in which bilingualism is common and almost inevitable. The factors through which code-switching arises are plenty; much previous research has investigated the structural, sociolinguistic, and psychological factors through which code-switches occur. In contrast to previous studies, the current study investigates code-switching and its relationship to non-linguistic cognitive control tasks. In other words, how does code-switching modulate cognitive control?

Code-switching in itself is a multifaceted and varied phenomenon with many distinct types. According to multiple past experiments and studies, one can define two main types of code-switching based on the number and degree of the language switching involved: *dense* code-switching, and *insertional* code-switching (Muysken, 1997). Dense code-switching is defined by frequent switching throughout the utterance and contains multiple words and phrases in both of the bilingual speaker's languages. In insertional code-switching, there is a main language established and spoken throughout the sentence except for a single word, which is switched out into the second language both bilinguals speak.

1. Dense:

El abogado está *grateful for the support* que recibió *from the witness* ayer.

2. Insertional:

El abogado está agradecido por el *support* que recibió del testigo ayer.

3. Unilingual:

El abogado está agradecido por el apoyo que recibió del testigo ayer.

Translation:

The lawyer is grateful for the support that he received from the witness yesterday.

The examples above display the two different types of code-switched sentences along with their corresponding unilingual Spanish and English equivalents. In this dense example (1), there are an equal number of phrases in Spanish and English of similar length and number of words in each. In the insertional example (2), the majority of the sentence is in Spanish with the English word 'support' being inserted inside.

As such, bilingual language processing is an extremely multilayered phenomenon which requires various distinct cognitive control processes than that of monolinguals. When engaging with monolingual speakers, bilingual speakers must focus on a target language for conversation and suppress competing items, representations, and grammar from the non-target language. This therefore contrasts with interlocution with other bilinguals in which both languages are open for use. Frequency and degree of language use is then decided individually depending on personal preference, past experience with the interlocutor, and other situational factors.

The idea then that different levels of code-switching itself can produce an effect on the cognitive control and inhibitory processes is attested in multiple studies. Green and Wei (2014) propose the Control Process Model, which states that different linguistic settings call for various levels of cognitive control. The Adaptation Control Hypothesis suggests that different interactional situations require different demands on the cognitive processing of bilinguals (Han et al., 2022). In other words, the different levels of code-switching presented above might require different levels of cognitive effort between each other as well as compared to unilingual sentences that do not contain any language switching whatsoever.

Adler et al.'s (2020) study is the primary study from which the current study is derived. Adler et al. presented Spanish-English bilinguals with a cross-task conflict paradigm, presenting participants with written code-switched or unilingual sentences immediately followed by a Flanker (arrow) task, congruent (← ← ← ← ← or → → → → →) or incongruent (← ← → ← ← or → → ← → →). The results of this study showed that bilinguals displayed improved performance in subsequent conflict trials by showing reduced reaction times to incongruent Flanker trials when preceded by a code-switched Spanish-English sentence, as code-switching boosted cognitive control which lasted until the Flanker. Another study by Wu and Thierry (2013) found that bilinguals performed better at inhibitory control performance in mixed-language settings in comparison to single-language environments.

The current study is similar to the previous ones in that it investigates the link between code-switching and cognitive control processes. While previous studies have demonstrated that such a link exists and that encountering code-switched sentences does recruit processes that accentuate conflict adaptation, the methods of previous studies have largely used written data as stimuli for their experiments. This presents a major challenge not only to the generalizability of these results but also leaves out the fact that a majority of the time, code-switching most naturally occurs in a spoken context. For this reason, the current study takes Adler et al.'s (2020) approach and reforms it using audio stimuli to replicate bilingual speakers hearing these sentences in real time as if in conversation.

In addition to the different presentation mode (written vs. auditory), we also introduced different degrees of code-switching that are possible in naturalistic environments, as past research has indicated that these different degrees of code-switching (dense vs. insertional) may also show different effects themselves. As such, we utilized both sentences that involved heavy code-switching between languages (dense code-switching), and sentences which involve only a one-word switch (insertional code-switching).

Thus, we had three major predictions. First, participants will exhibit faster reaction times (RT) to congruent Flanker Trials compared to incongruent Flankers, which represents the main conflict effect. Second, RT to incongruent Flankers will be reduced upon hearing a code-switched sentence, showing a smaller conflict effect; moreover, reactions to incongruent Flankers after an insertional switch will be shorter than reactions after a dense switch. Lastly, to add onto the code-switching comparison by examining the difference exhibited from listening to dense code-switches compared to insertional code-switches, Flankers preceded by insertional code-switches will show a smaller conflict effect than Flankers preceded by dense code-switches, as insertional code-switches require more cognitive control to process compared to dense code-switching. Therefore, a three-way interaction between Flanker type, presence of a switch, and type of switch was expected.

Methods

Participants

Thirty-seven adult bilingual Spanish-English speakers (female = 29, male = 6, gender nonconforming or gender variant = 2) were recruited from the University of Florida and Gainesville community; only thirty-six were included in the analysis due to one participant not meeting the threshold for Flanker accuracy criteria (see below). All included participants had learned and became fluent in both Spanish and English before twelve years of age. In addition, these participants had been exposed to Spanish before English or had both languages in their exposure simultaneously (range age of acquisition: Spanish = 0, English = 0-11 years; mean age of acquisition: Spanish = 0 years, English = 3.3 years). The participants came from a variety of Hispanic heritages and cultural backgrounds, including Cuban, Colombian, Peruvian, Argentine, Dominican, Puerto Rican, Venezuelan, Chilean, and Spanish. Participants were students at the University of Florida (range = 18-28 years, M = 20 years). All participants were selected so as to not have any problems concerning their reading, speech, vision, or hearing. Participants were offered monetary compensation of $10 USD per hour in the lab or two credit hours to use for any class that accepts the extra credit.

The participants were assessed on their language background through two different methods. Before the experiment commenced, participants were presented with the MINT (Multilingual Naming Test) sprint created by Garcia and Gollan (2021), a language picture naming test which assesses the lexical proficiency and dominance of the participants in both English and Spanish, and second is the Bilingual Language Profile and code-switching questionnaire in which the participants self-report their proficiency in English and Spanish and the situations in which they use the two; the code-switching questionnaire does the same except concerning the frequency of code-switching use and the situations in which code-switching occurs in daily life (Birdsong, 1989; Olsen, 2023). The language and code-switching questionnaires were presented to the participants after the main task had been completed.

Table 1. Demographic statistics of participants regarding Bilingual Language Profile (BLP), Bilingual Code-Switching Profile (BCSP), MINT sprint testing Spanish dominance, and MINT sprint testing English

Measure	Mean	Standard Deviation
BLP	27.46	47.39
BCSP	62.90	11.01
MINT sprint Spanish	46.74	12.87
MINT sprint English	66.08	8.25

An overview of the participants' scores is given in Table 1. The Bilingual Language Profile (BLP) took the average of all responses and assessed each participant on a scale of -100 to 100, with a negative average showing dominance in Spanish compared to English, and a positive average showing a dominance in English compared to Spanish. The Bilingual Code-Switching Profile informs about the usage and exposure to code-switching in each participant on a scale of 0-100, with a mean score of 0 being not exposed much to code-switching to 100 to heavily exposed to code-switching and used in daily life. The MINT sprint shows the mean of the correct answers (limit of 80) from the current participant pool in both Spanish and English. From the questionnaire and MINT sprint data, it can be concluded that the current pool of participants is on average more dominant in English than in Spanish, could name more objects in English than in Spanish, and are exposed to and do indeed code-switch in their daily life.

Materials and Procedures

The objective of the experiment was to investigate the effect of code-switching and its different levels on non-linguistic tasks that require activation of cognitive control processes. The main task involved participants listening to sentences (purely auditory, no words or captions presented on screen) which were interleaved with Flanker trials to test the effect of code-switched sentences on Flanker trial performance through conflict adaptation.

In the experiment, there were four distinct sentence conditions which included the dense code-switching sentences, insertional code-switching sentences, Spanish unilingual sentences inserted in the dense block, and Spanish unilingual sentences inserted in the insertional block in addition to the two Flanker conditions (congruent and incongruent) following certain sentences, totaling to eight trial types of interest (4 sentence conditions × 2 Flanker conditions = 8 total trial types).

Flanker task

The Flanker task required participants to respond to five-arrow strings that appear in the middle of the screen and indicate whether the middle arrow is facing left or right. Flanker trials were separated into two categories: congruent Flankers and incongruent Flankers. Congruent Flankers, which represent the “no conflict” trial, had all arrows pointing in the same direction (← ← ← ← ←or → → → → →) while incongruent Flankers, the “conflict” trials, displayed the middle arrow facing the opposite direction from the surrounding arrows (← ← → ← ← or → → ← → →) .

Sentences

Each of the eight conditions had twelve items critical to the analysis (one item equaling a single sequence of a sentence followed by a Flanker trial). The syntactic position of the code-switch and the word type of the switches were varied, so as for the participant to not anticipate what type of words could be switches or not. These experimental items were pseudorandomly interleaved with ninety-six Flanker trials and sixty-four filler sentences (forty-eight Spanish unilingual, eight insertional, eight dense) made to distract the participant to prevent participant learning or prediction during the experiment itself. All audio stimuli were recorded by a single bilingual Spanish-English speaker of the Puerto Rican variety. Ninety-six triplets of unilingual, dense code-switched, and insertional code-switched sentences were created and used in this study, and each sentence was normed for plausibility and naturalness through two norming studies, one that had bilinguals rate the Spanish sentences and one rating the code-switched sentences. Every sentence utilized in the experiment as audio stimuli was rated an average 4 or above on a 0-7 Likert scale, with 0 being not plausible and 7 being most plausible and natural.

Filler sentences were followed by a comprehension question to check the participant's attention and responsiveness. Comprehension questions were presented only in Spanish so as to mirror the Spanish unilingual sentences. Each session consists of two blocks: one block that contains the critical dense code-switched sentences intermixed with unilingual Spanish sentences, and another block that contains the critical insertional code-switched sentences intermixed with unilingual Spanish sentences. A series of animal pictures were placed in between and within each experiment block to allow the participants time to rest and continue on to the following block. Participants were assigned one of eight different Latin-squared lists. Before the main task, participants complete a short practice block which contained four unilingual Spanish sentences with examples of the Flanker trials and comprehension questions with the experimenter in the room to ensure that they understood the instructions.

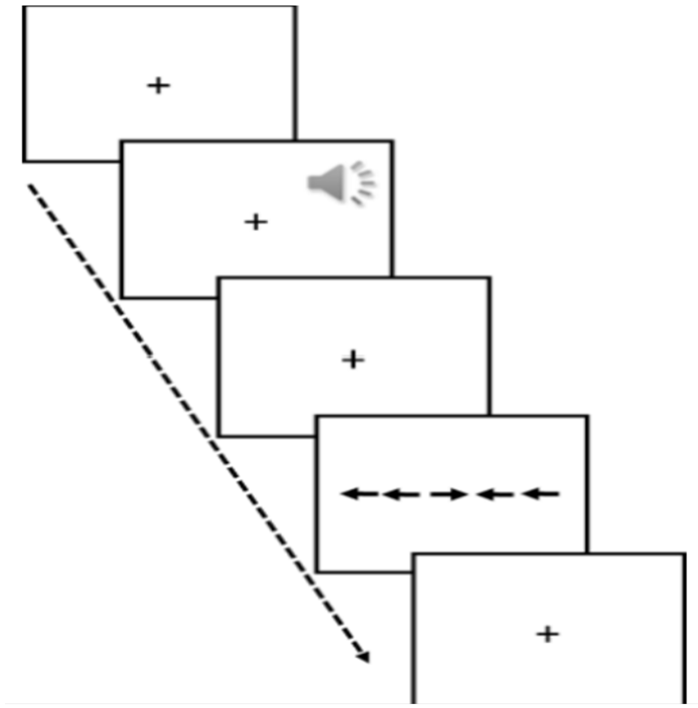

Figure 1. Example trial sequence found throughout the study. The auditory stimulus is presented followed by the Flanker trial with fixation crosses inserted before, after, and between. This represents the critical trials.

Stimuli were administered through Eprime 3.0, and participants used a Chronos box to respond to the stimuli. In the main task, participants only used the outermost buttons on the left and right side of the Chronos box to respond to both the Flanker trials and the comprehension questions. The left button corresponded to a **left** medial arrow in the Flankers and a **Yes** in the comprehension questions, while the right button corresponded to a **right** medial arrow and a **No** in the comprehension questions. The trial structure is illustrated in Figure 1. For every trial, a fixation cross appears for 500 milliseconds, followed by the audio stimuli. Following the audio stimuli, another fixation cross appears for 500 milliseconds, and then either a comprehension question or a Flanker trial is presented, both of which have an unlimited time for the participant to respond.

Results

Data Analysis

Participant inclusion criteria were based on flanker accuracy and language proficiency and background. Participants were excluded if their Flanker trial accuracy fell below 80%. Comprehension question accuracy was also considered in the inclusion-exclusion criteria, from which participants are excluded if the accuracy fell below 80% as well.

For data analysis, both the reaction times (RT) as well as the accuracies to the Flanker task were collected. Analyses were conducted in R (ver. 4.2.2; Ihaka & Gentleman, 2022) using the libraries lme4 (ver. 1.1-31; Bates et al., 2015), lmerTest (ver. 3.1-3; Horthon et al., 2017) and emmeans (ver. 1.8.8; Lenth et al., 2024). A linear mixed effects model (lmer) was conducted on the RTs, and a generalized linear mixed effects model (glmer) was conducted on the accuracy. Trials were excluded from analysis if the RT was under 100 ms and above 2000 ms. Fixed effects were the congruency type of the Flanker trials (congruent vs. incongruent), whether a language switch was involved or not (unilingual vs. code-switched), the switch types found in the blocks (block with insertional switches; block with dense switches), and the interactions between these factors. The formula also included a by-participant random intercept and by-participant random slope for Flanker condition and language type (presence/absence of a switch). A model with a maximum random effect structure was first applied. When this did not converge, random slopes that were associated with the smallest variance were omitted. The final model was the one mentioned above. Coding of the fixed effects was as follows. For type of Flanker trials, congruent was coded as negative (-0.5) and incongruent as positive (+0.5). For language switch, 'No Switch' was coded as negative (-0.5) and 'Switch' as positive (+0.5). Finally, for switch-type, 'Insertional' was coded as negative (-0.5) and 'Dense' was coded as positive (+0.5).

Results

The mean RT based on correct Flanker trials in the Flanker condition across all subjects are given in Figure 2. Overall, participants were faster with congruent Flankers compared to incongruent flankers across all conditions, with congruent Flankers having a mean RT of 537 ms (SD = 192) and incongruent Flankers having a mean RT of 651 ms (SD = 238), demonstrating the main conflict effect [$\beta = 597.157$, SE = 21.011, $t = 28.421$, $p < .001$]. We obtained a main effect of Language Switch; collapsed across Flanker condition and switch type, participants exhibited longer RT on congruent and incongruent Flankers following code-switch conditions (dense and insertional) compared to RT on Flankers preceded by unilingual Spanish counterpart sentences (see Figure 2) [β = 26.407, SE = 5.560, t = 4.749, $p < .001$]. We found a significant three-way interaction between Flanker condition (congruent versus incongruent), switch type (dense versus insertional), and existence of a language switch (unilingual versus code-switch) [β = -68.163, SE = 27.018, t = -2.523, $p < 0.05$]. To further investigate the three-way interaction, we performed a pairwise comparison investigating the difference between the incongruent insertional switch condition and incongruent insertional non-switch condition. Participants exhibited longer mean RTs (M = 669) in the incongruent insertional switch condition compared to the incongruent insertional nonswitch condition (M = 619) which is statistically significant based on the pairwise comparison between the two conditions [β = -73.54, SE = 17.5, t = -4.199, $p < 0.001$]. This is unexpected, as through the original prediction, the RT should be faster after a sentence with a switch than after a nonswitched sentence.

Flanker accuracy was also recorded. However, very few errors were made in Flankers across all subjects, so main effects and interactions could not be assessed.

Figure 2. Graph of the mean reaction times between the two unilingual conditions versus the code-switched conditions. The blue bar represents congruent (con) flankers and the orange bar represents incongruent (inc) flankers. “d_Spanish” and “i_Spanish” refers to the unilingual Spanish sentence conditions measured against the “Dense” code-switching and “Insertional” code-switching conditions, respectively.

Conclusion

Discussion

Our three main predictions for this experiment were as follows: First, participants would exhibit faster reaction times to congruent Flanker Trials compared to incongruent Flankers, which represents the conflict effect. Second, reaction times to incongruent versus congruent Flankers would be reduced upon hearing a code-switched sentence, showing a smaller conflict effect; as such, reactions to incongruent vs. congruent Flankers after a switch will be shorter than reactions after a unilingual Spanish sentence. Lastly, Flankers preceded by insertional code-switches will show a smaller conflict effect than that of Flankers preceded by dense code-switches, as insertional code-switches require more cognitive control to process compared to dense code-switching.

The results suggest a more complicated picture. Our first prediction was borne out; participants exhibited shorter mean reaction times to congruent Flankers than their incongruent counterparts. However, the second prediction that conflict effects would be smaller after a switch than after a non-switch was not borne out. Instead, a main effect of switch was found in that response times were longer after a code-switch than after a unilingual sentence, collapsed over flanker type. This contradicts our predictions and the findings of previous papers which state that code-switching overall will enhance cognitive control processes and reduce reaction times on Flanker trials.

Our third prediction was borne out in the sense that the conflict effect was affected by the type of switch, but in the direction opposite of what was predicted. We predicted that the conflict effect would be smaller after insertional than after dense code-switching. However, the conflict effect was larger in the insertional condition than in the dense condition. In particular, the difference between incongruent insertional no switch versus incongruent insertional switch specifically was significant.

An explanation for what could be going on cognitively as the task is occurring is that as the listener encounters an insertional code-switched sentence, the switch might often come unexpectedly. This might draw attention away from the succeeding Flanker trial, as listeners will then expend more cognitive effort to process the sentence they heard; moreover, they may activate working memory processes in order to remember previous parts of the utterance. This does contradict previous models in code-switching which propose that the consequences of using cognitive control and inhibition processes to properly parse a code-switched sentence will reduce the conflict effect and affect other tasks such as the Flanker task.

Furthermore, the uniqueness of the insertional switch condition may be explained due to the inherent cognitive workings of monitoring and language control. Bilinguals often have to keep track of which language they must use depending on the person with whom they are speaking. Once a language is established and reinforced, it is difficult to switch away from using that language. To relate this back to the unique insertional switch findings, an insertional switch in a sentence breaks the established rule of what language is being spoken in the utterance (an English word disrupting an overarching Spanish sentence), and therefore may require more effort in processing and take attention away from the succeeding Flanker trial (Costa et al., 2009).

Final Words

The current study investigating code-switching presented in this paper is part of a larger project studying Spanish-English code-switching on cognitive control. The findings of the experiment are important to the study of bilingualism and its effects on cognition because it provides a novel look on the topic with a focus on studying a population that heavily employs code-switching in their day-to-day life, emulating a more naturalistic linguistic setting, using similar methods to previous approaches and adjusting it to new environments.

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