COGNITIVE CONTROL MECHANISMS IN BILINGUALS: IS IT ALL THE SAME?

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INTRODUCTION

There is a great deal of variability across the empirical literature in the bilingual advantage in cognitive control, with some studies finding supporting evidence [1][2][3] and others failing to replicate these results [4][5]. This inconsistency sustains a debate on the robustness of the effect of bilingualism on executive control[4][6].

However, bilinguals are not all cut from the same cloth. There are many individual differences in the bilingual experience that may have an impact on cognitive control. Furthermore, these individual differences may have strong implications for how bilinguals manage their two languages and should therefore be carefully studied.

One important variable to consider is proficiency. As bilinguals become more proficient in their second language, there are more opportunities for both intra and cross-linguistic competition which must then be resolved. Presumably, bilinguals who are highly proficient in their second language must exert more control in order to properly manage their two languages and select one of them for speech production.

Code-switching is another important –albeit complex – factor to consider. It can be elicited proactively (e.g., actively monitoring for relevant languages cues) or reactively (e.g., in response to an interlocutor switching), allowing for a large range of individual variations. Assuming similar levels of proficiency, bilinguals who generally code-switch proactively may be less likely to experience unwanted switches than bilinguals who code-switch more reactively. This may reflect greater control over one's languages.

Cognitive control

- Regulates and coordinates one's cognitive processes in a goal-directed manner [7] (e.g., working memory, shifting between task sets, inhibiting irrelevant information)
- There are two different ways to engage cognitive control resources: proactive control and reactive control [8]
- Flexibility in using these two types of cognitive control based on the current context may afford a behavioural advantage (faster reaction time and/or higher accuracy) compared to using solely one control strategy (i.e., proactive control or reactive control only)

- **Proactive control [8]**
  - Information is actively maintained before the onset of cognitively challenging events. This biases attentional and perceptual systems in accordance with the goal of the task at hand
  - Proactive control deals with interference before it happens
- **Reactive control [8]**
  - Reactive control works as a "late correction" mechanism that is only engaged after interference has been detected.
- **AX-CPT**
  - A modified version of the CPT that is sensitive to dynamic variations in proactive and reactive control because it creates a global prepotent "go" context that must occasionally be overridden
  - Two studies have found that bilinguals were better able to flexibly alter their cognitive control strategies (i.e., proactive vs. reactive) compared to monolinguals who tended to predominantly use a proactive strategy [9] [10]
  - Adding blocks with different proportions of go and no-go trials should challenge the executive system to adapt to new contexts
- **Electroencephalography (EEG) and event-related potentials (ERPs)**
  - EEG is a functional imaging technique that records mass neuronal activity at the level of the cortex via electrodes placed on scalp. It has very high temporal resolution
  - ERPs are extracted from the ongoing EEG signal by averaging stimulus-locked activity across numerous trials
- **N2 component**
  - The N2 is a negative-going component that peaks approximately 200-350 ms after stimulus onset. It is thought to mark conflict detection [11][12]
  - In the AX-CPT, stimuli (i.e., cue and target) give potentially conflicting information (e.g., an A cue followed by a Y target)

METHOD

Participants

- Young right-handed, adult bilinguals (n = 15)
- Age : M = 23.8 years, SD = 4.26 years
- Education: M = 15.47 years, SD = 1.06)
- Participant pool at Concordia University + community.
- English-French or French-English bilinguals
- L1 proficiency: M=4.84/5, SD= .33
- L2 proficiency: M=3.85/5, SD= .75
- Exclusion criteria: functional knowledge of a third language, medical or psychiatric history that could impact cognitive function (self-report)

Procedure

- **Session 1 EEG Recording**: EEG recording during the completion of a modified AX-CPT task (see below)
- **Session 2 Neuropsychological battery:**
  - Collect data on various aspects of participants' cognitive abilities
  - Collect information on code-switching
- **AX-CPT task**
  - Participants presented with a pairs of letters (one at a time)
  - Respond by pressing the "yes" button to X targets only when preceded by an A cue
  - Respond by pressing the "no" button to any other pair of letters
  - **Four types of trial:**
    - AX
    - AY (Y = any letter other than A or X)
    - BX (B = any letter other than A or X)
    - BY

METHODS, CONT.

Figure 1. AX-CPT

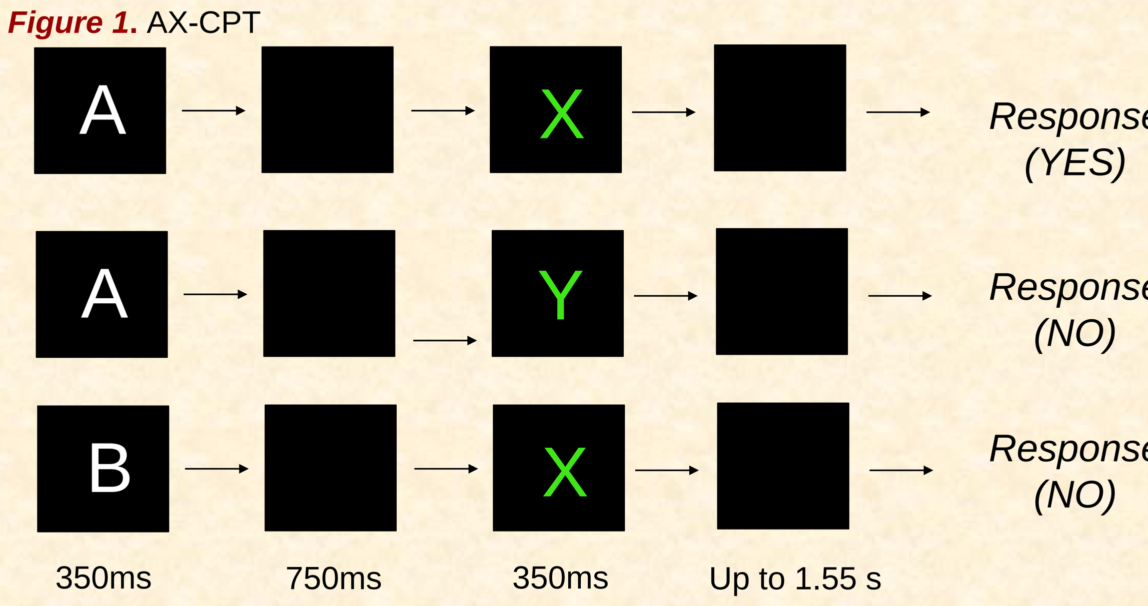


Table 1. Cue-target pairs as a function of block

Block	Trial	% of total trials	Cue information	Target Information
AX-70	AX	70	Go	Go
	AY	10	Go	No-go
	BX	10	No-go	Go
	BY	10	No-go	No-go
AY-70	AX	10	Go	Go
	AY	70	Go	No-go
	BX	10	No-go	Go
	BY	10	No-go	No-go
BX-70	AX	10	Go	Go
	AY	10	Go	No-go
	BX	70	No-go	Go
	BY	10	No-go	No-go

The degree to which participants use proactive control strategies versus reactive control strategies can be indexed by contrasting RT on different trials of interest:

- AX-70: BX – AY → Negative = proactive; positive = reactive
- AY-70: BX – AX → Negative = proactive; positive = reactive

- **EEG Recording Session**
  - EEG recorded continuously
  - Biosemi ActiveTwo system with 64 electrodes
  - Organized in the 10-20 system
  - Bandpass of 0.01-100Hz was used to filter all data, sampling rate 512Hz
- **EEG Processing**
  - Brain Vision Analyzer 2
  - Epochs: -100ms to 900ms for both cue and target stimuli
  - Corrected for eye blinks using ocular correction ICA
  - Data screened for artifacts

Table 2. Questions from code-switching questionnaire and composition of the four factors [13]

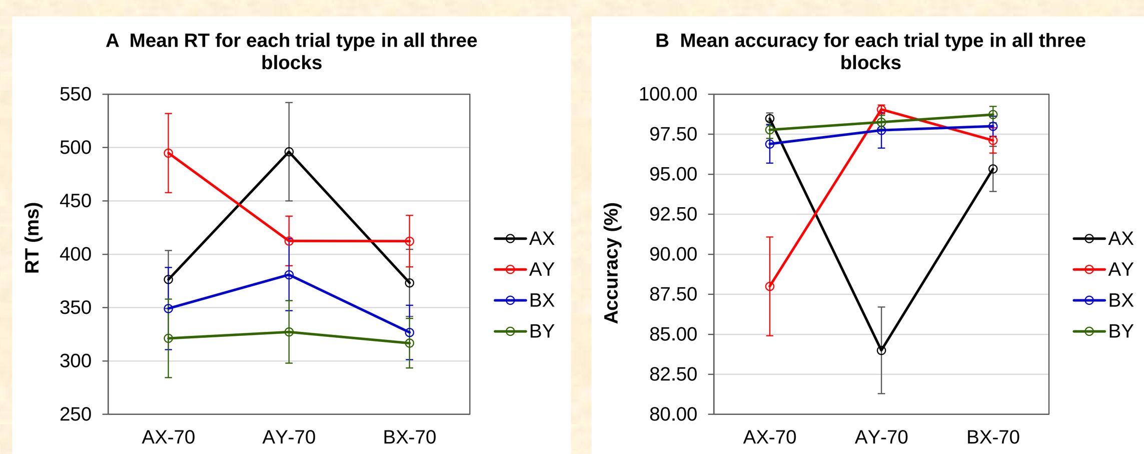
Factor	Question
L2 to L1 Switches	I do not remember or I cannot find some English words when I am speaking in English.
	When I cannot find a word in French, I tend to immediately produce it in English.
	Without meaning to, I sometimes produce the English word faster when I am speaking in French.
L1 to L2 Switches	I do not remember or I cannot find some French words when I am speaking in French.
	When I cannot find a word in English, I tend to immediately produce it in French.
	Without meaning to, I sometimes produce the French word faster when I am speaking in English.
Contextual Switches	I tend to switch languages during a conversation (for example, I switch from English to French or vice versa).
	There are situations in which I always switch between the two languages.
	There are certain topics or issues in which I normally switch between the two languages.
Unwanted Switches	When I switch languages, I do it on purpose.
	It is difficult for me to control the language switches I introduce during a conversation (e.g., from French to English).
	I do not realize when I switch the language of a conversation (e.g., from English to French) or when I mix the two languages; I often realize only if I am informed of the switch by another person.

RESULTS

Behavioral results

- Repeated measures 3 (Block) X 4 (Trial) ANOVA
- **RT (Figure 2 A):**
  - Main effect of Block (F (2, 28) = 3.492, p = .044, η2 = .05)
  - Main effect of Trial (F (1.76, 24.57) = 27.217, p < 0.01, η2 = .3)
  - Block * Trial interaction (F (6, 84) = 10.454, p < 0.01, η2 = .13)
- **Accuracy (Figure 2 B):**
  - Main effect of Block (F (1.26, 17.70) = 4.286, p = .045, η2 = .03)
  - Main effect of Trial (F (2.38, 33.27) = 10.411, p < 0.01, η2 = .12)
  - Block * Trial interaction (F (2.41, 33.73) = 10.454, p < 0.01, η2 = .34)

Figure 2. Mean RT and accuracy for each trial type in all three blocks



ERP results: N2

- Repeated measures 3 (Block) X 4 (Trial) X 5 (Electrode) ANOVA

Latency (Figure 3 A):

- No main effect of Electrode (F (1.95, 27.32) = 1.213, p = .312, η2 = .002)
- Block * Trial interaction (F (3.57, 50) = 2.9, p = .034, η2 = .26)

Amplitude (Figure 3 B):

- Main effect of Electrode (F (1.61, 22.51) = 4.8, p = .024, η2 = .02)
  - Fronto-central distribution
- Block * Trial interaction (F (3.30, 46.14) = 9.3, p < .001, η2 = .13)

RESULTS, CONT.

Figure 3. Mean N2 amplitude and latency at electrode FCz

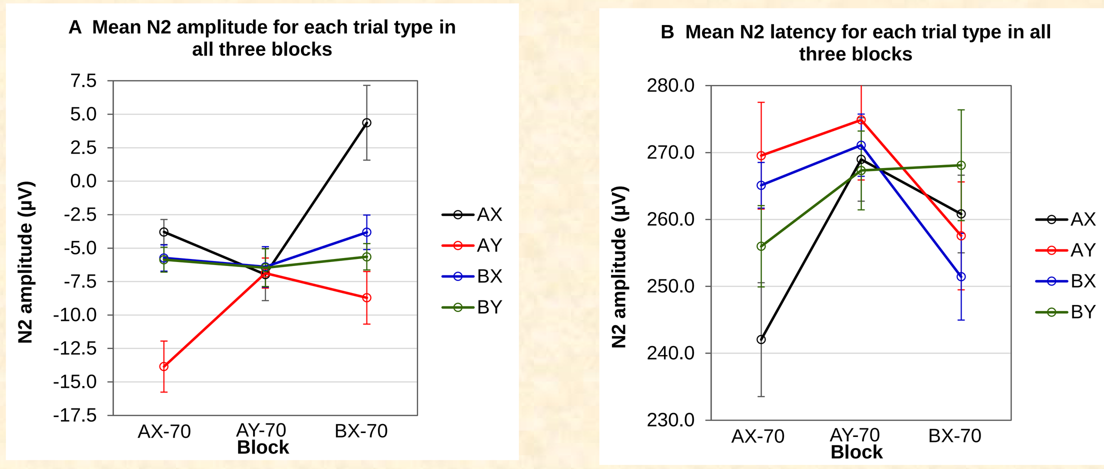
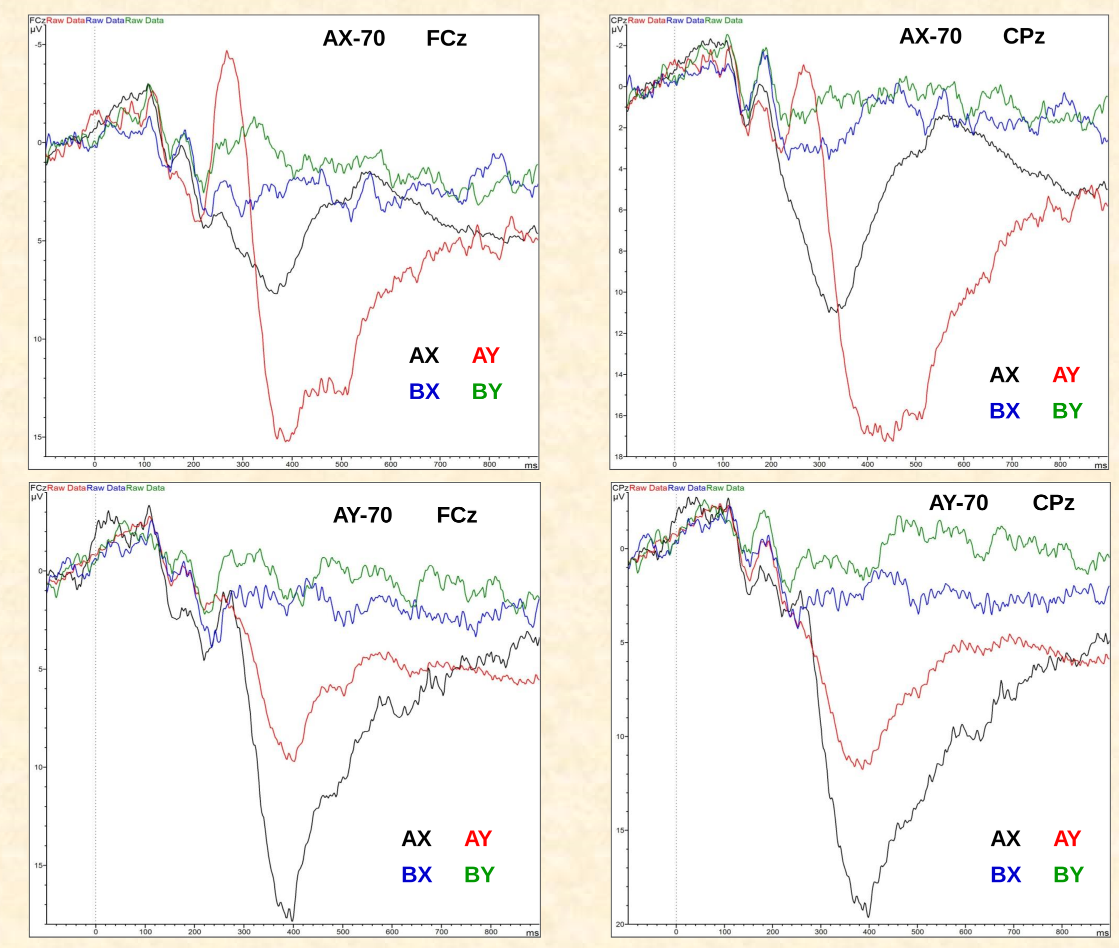


Figure 4. Average waveforms at FCz and CPz locked to the onset of the target letter

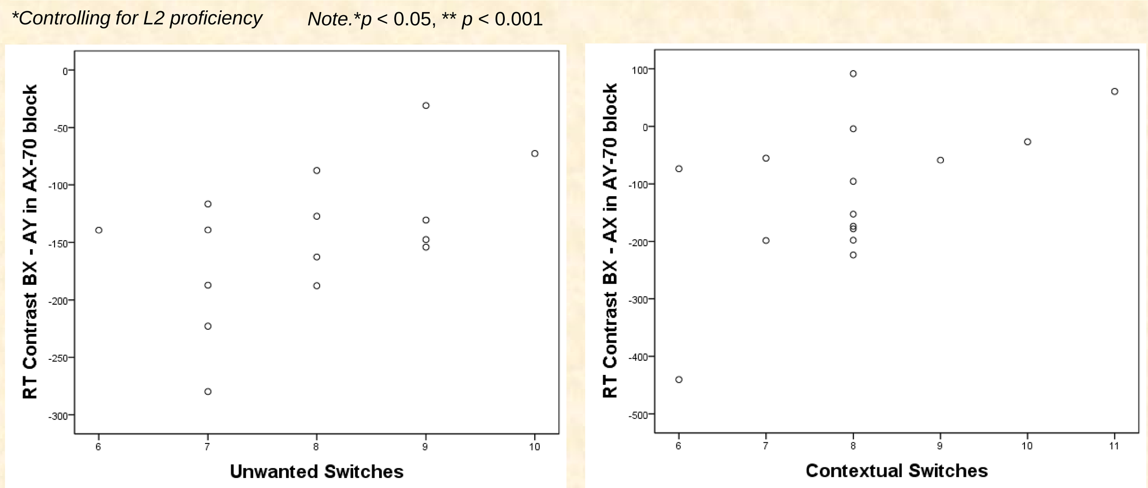


All of the following contrasts were normalized by subtracting the RT for BY trials in the appropriate block to control for individual differences in speed.

Code-switching* and cognitive control strategy

Measure	L2 to L1 switches	L1 to L2 switches	Contextual switches	Unwanted switches
RT Contrast BX - AY trials in AX-70	-0.322	0.022	0.366	.504*
RT Contrast BX - AX trials in AY-70	-0.427	0.121	0.585*	0.142

**Controlling for L2 proficiency*   *Note.*p* < 0.05, ** *p* < 0.001

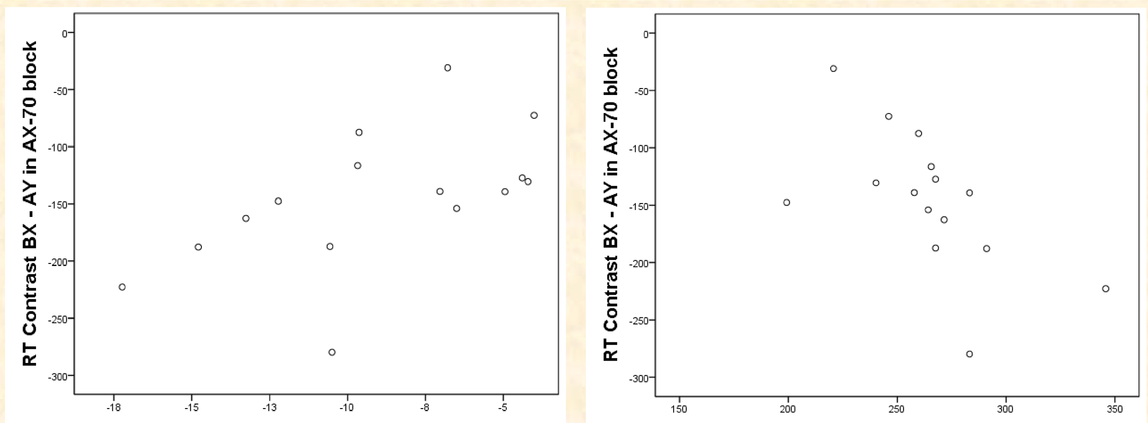


N2 amplitude at midline electrodes and cognitive control strategy

	AX				AY			
Measure	Fz	FCz	Cz	CPz	Fz	FCz	Cz	CPz
RT Contrast BX - AY in AX-70	-0.200	-0.056	-0.460	-0.280	0.378	0.438	0.501	.564*

N2 latency at midline electrodes and cognitive control strategy

	AX				AY			
Measure	Fz	FCz	Cz	CPz	Fz	FCz	Cz	CPz
RT Contrast BX - AY in AX-70	0.269	0.268	0.289	0.250	-0.330	-0.289	-0.282	-.603**



DISCUSSION

Participants generally relied on a proactive strategy as evidenced by faster RTs on BX trials compared to AY trials in the AX-70 block and by faster RTs on BX trials compared AX trials in the AY-70 block. No predominant strategy could be identified for the BX-70 block.

When controlling for L2 proficiency, the frequency of Unwanted Switches vs Contextual Switches was associated with greater use of proactive control strategies, albeit in different blocks. Greater use of proactive strategies (indexed by BX < AY RT) in the AX-70 block (i.e., global yes context) was positively correlated with Unwanted Switches. In contrast, greater use of proactive strategies (indexed by BX < AX RT) in the AY-70 block (global no context) positively correlated with contextual switches.

Finally, participants who made greater use of proactive strategies showed faster (i.e., shorter latency of N2) and more sensitive (i.e., higher amplitude of N2) conflict detection in the AX-70 (global yes response) condition. This is consistent with the idea that proactive strategies involve the active maintenance of task-relevant information. In other words, actively maintaining the cue during the interval before the onset of the target allows for faster detection of cue-target conflict. Furthermore, the higher N2 amplitude may reflect greater salience of conflict for individuals who are maintaining cue information during the ISI.

Overall, the results of the present study support the idea that there are individual differences in the relative use of proactive and reactive mechanisms in bilinguals, even on a task that biases participants to adopt a proactive strategy. Furthermore, these differences were related to aspects of code-switching which is an important source of interindividual variability among bilinguals.

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