The use of cognitive control in the comprehension of Spanish-English code-switching

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Introduction

- Code-switching is generally defined as the alternation between languages in bilingual speech (Poplack, 1980)
  - *El niño encontró el book on the floor* [intra-sentential]
  - *Fuimos a la piscina, and we went for a swim* [inter-sentential]
- A bilingual's propensity to code-switch and pattern of code-switching is constrained by proficiency and context
- Code-switching remains understudied; however, experimental evidence on *cued language switching* reveals switch costs in production and comprehension (Meuter & Allport, 1999; Abutalebi et al., 2007)

- It remains an open question whether these switch costs are due to the characteristics of the subjects, the use of external cues to signal switching, or are reflective of code-switching

Questions

- If switching is difficult, is cognitive control recruited to guide the comprehension of code-switches?
  - Cognitive control is used to manage conflicting representations or override prepotent responses in linguistic and domain-general tasks (Novick et al., 2005)
  - Brain regions associated with cognitive control (e.g. LIFG, ACC) have been implicated in bilingual language control and cued language switching (Abutalebi & Green, 2008)
- Does a bilingual's experience with code-switching modulate the difficulty of integrating code-switches?
  - If code-switching use is an experience-based linguistic skill, then bilinguals with more exposure to code-switching should exhibit reduced use of cognitive control

Approach

- Use fMRI with auditory stimuli to investigate involvement of LIFG and ACC in code-switching comprehension
  - Auditory presentation reflects observation that code-switching is primarily a spoken language phenomenon

  Expectancy (Expected, Unexpected) x Switch (No Switch [Span → Span], Switch [Span → Eng]) Design

  Example Stimuli – 164 semantically constrained Spanish sentential frames
  Anoche en el ático encontramos un murciélago del _____
  "Last night in the attic we found a bat hanging from the _____"
  - *techo* [No switch, Expected]
  - *estante* [No switch, Unexpected]
  - *ceiling* [Switch, Expected]
  - *shelf* [Switch, Unexpected]

  - Task: 20 catch trials requiring button press response

- **Stroop Task** to functionally define subject-specific ROIs in LIFG and ACC (e.g. January et al., 2009) : 192 trials in Spanish, blocked by Stroop response-eligibility; responses indicated via button press

  - Response-eligible: *verde* where green is a possible response [motor-response and representational conflict], engages ACC
  - Response-ineligible: *naranja* where orange is not a possible response[representational conflict], engages LIFG (Milham et al., 2001)
- Collect proficiency measures in Spanish and English and language history questionnaire to index individual differences

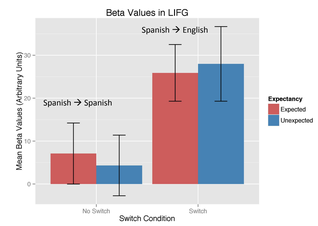
Participants

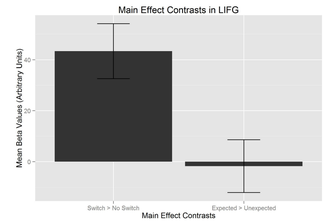
- 24 Spanish (L1) – English (L2) bilinguals

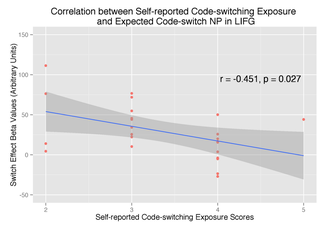
Measure	Spanish	English
BNT	20.92 (4.16)	21.54 (4.05)
Grammar ***	38.42 (4.99)	44.42 (4.81)
AoA ***	0.96 (0.75)	5.77 (3.11)
Speaking	9.42 (0.72)	9.04 (1.23)
Listening	9.79 (0.51)	9.5 (0.83)
Writing	8.67 (1.34)	8.67 (1.2)
Reading	9.04 (1.23)	9.42 (0.72)

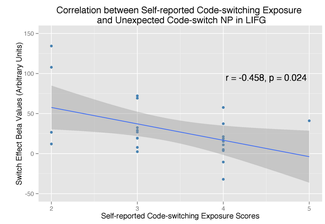
- Bilinguals acquired Spanish as the first language
- Bilinguals are fairly balanced across the two languages, although significant difference on grammar scores

Results within Stroop Conflict Area of LIFG



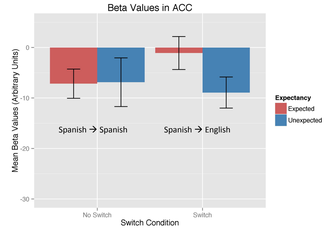


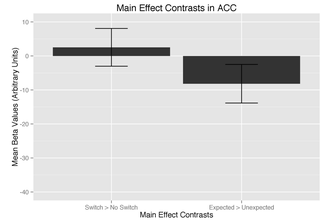




- Main Effect for Switch [F(1,23) = 15.956, p < 0.001]
- Negative correlation with self-reported CS exposure ratings and Switch conditions (r values are p < .03)

Results within Stroop Conflict Area of ACC

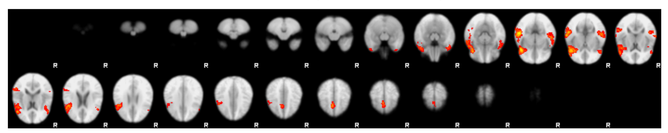




- No effects in ACC

Results—Whole Brain

Switch > No Switch Contrast (Axial Slices)

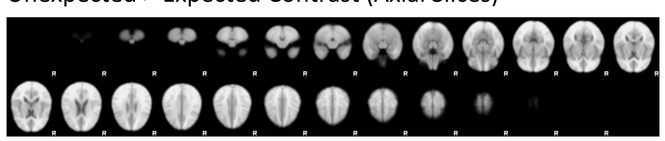
L  R

2.3 8.0

- Clusters thresholded by z > 2.3 with corrected cluster significance threshold of p < 0.05

Cluster	Size (voxels)	X (mm)	Y (mm)	Z (mm)	Central Location
1	1486	-49.6	0.5	5.2	L Superior Temporal Gyrus
2	405	49.4	-15.7	-2.7	R Superior Temporal Gyrus
3	174	-5.3	5.7	52.9	L Superior Frontal Gyrus
4	134	45.3	22.7	12	R Inferior Frontal Gyrus

Unexpected > Expected Contrast (Axial Slices)

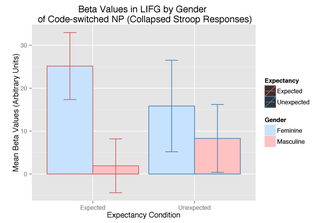
L  R

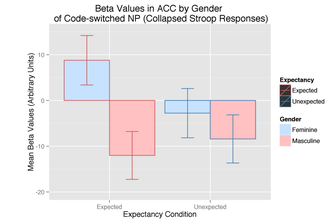
- No clusters pass threshold

2.3 8.0

Exploratory Analysis on Gender of Article

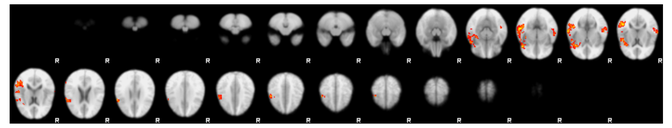
- To the extent that successful integration of code-switching relies upon forming expectations of likelier switch points, *grammatical gender* may be an informative cue
- In contrast with monolingual Spanish use, Spanish-English bilinguals show preferences for using masculine-marked Spanish article with code-switched NPs (Otheguy & Lapidus, 2003)
- If grammatical gender is potentially a cue, then masculine-marked code-switched NPs should require less cognitive control (i.e. less conflict)





- In LIFG and ACC, there is tentative support for a marginal or significant difference between feminine- and masculine-marked Switch Expected trials (fem > masc)
  - LIFG: paired t(23) = 1.83, p = 0.08
  - ACC: paired t(23) = 2.1, p = 0.047
- A similar pattern is found in whole brain analysis

Feminine Switch > Feminine No Switch (Axial Slices)

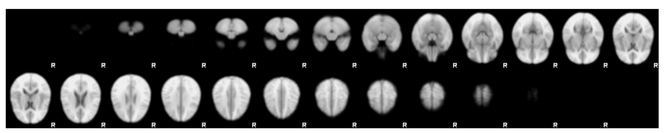
L  R

2.3 3.6

- Clusters thresholded by z > 2.3 with corrected cluster significance threshold of p < 0.05

Cluster	Size (Voxels)	X (mm)	Y (mm)	Z (mm)	Central Location
1	946	-50.3	-13.9	7.7	L Superior Temporal Gyrus
2	135	54	-27	1.8	R Superior Temporal Gyrus

Masculine Switch > Masculine No Switch (Axial Slices)

L  R

- No clusters pass threshold

2.3 8.0

Conclusions

- Bilinguals revealed a robust main effect for code-switches in LIFG but not in ACC
  - The ability to integrate code-switches relies upon attending away from a same language representation to the other language
  - Lack of effect in ACC is in contrast to cued language switching paradigms
- Semantic manipulation showed no reliable effects in co-localized regions or at whole brain
  - Previous neuroimaging studies show effect in LIFG for semantic violations but not expectancy (e.g. Baumgaertner, et al., 2002)
  - Lack of effect differs from behavioral and ERP measures of semantic expectancy
- Individual differences emerge in LIFG based on a bilingual's self-reported exposure to code-switching
  - Indicating experience with code-switching may result in 1) more efficient use of cognitive control when alternating between languages or 2) better ability to form predictions of when a code-switch *may* occur
- This interpretation is supported by tentative differences in masculine-marked v. feminine code-switches in LIFG, ACC, and at whole brain

Acknowledgements
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