A cognitive view of multilingualism: The role of control processes in modulating the activity of more than one language

Judith F. Kroll¹, Janet van Hell¹², & Teresa Bajo³

¹Department of Psychology, Center for Language Science, Pennsylvania State University, University Park, PA USA
²Radboud University, Nijmegen, The Netherlands
³Department of Psychology, University of Granada, Granada, Spain

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Acknowledgments

Collaborators:

• Teresa Bajo
• Susan Bobb
• Cari Bogulski
• Ingrid Christoffels
• Dorothee Chwilla
• Albert Costa
• Annette De Groot
• Franziska Dietz
• Ton Dijkstra
• Giulia Dussias
• Chip Gerfen
• Tamar Gollan
• David Green

• Taomei Guo
• Jason Gullifer
• Noriko Hoshino
• April Jacobs
• Niels Janssen
• Debra Jared
• Sonja Kotz
• Wido La Heij
• Jared Linck
• Pedro Macizo
• Rhonda McClain
• Erica Michael
• Natasha Miller

• Maya Misra
• Jill Morford
• Juliana Peters
• Pilar Piñar
• Eleonora Rossi
• Rosa Sánchez-Casas
• Mikel Santesteban
• Ana Schwartz
• Bianca Sumutka
• Gretchen Sunderman
• Natasha Tokowicz
• Madelon Van Den Boer
• Janet Van Hell
• Zofia Wodniecka

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More people in the world are bilingual than monolingual.

But until very recently, most research on language and cognition examined only monolingual speakers of a single language and typically speakers of English as the native language.
What have we learned in the past 20 years?

- Both of a bilingual’s languages are active regardless of the intention or requirement to use one language alone.

- The parallel activity of the two languages is hypothesized to produce competition that requires resolution.

- Skilled bilinguals rarely make the error of speaking the wrong language yet they often code switch with other bilinguals in the middle of a sentence, suggesting that they possess an exquisite mechanism of cognitive control.

- A life of resolving cross-language competition appears to confer positive consequences for the mind and the brain.
The bilingual is a mental juggler: Both languages are active regardless of the requirement to use one language alone:

Parallel activation in listening, reading, and speaking
What is the consequence of parallel activity and competition across the bilingual’s two languages?

- The hypothesis is that juggling creates a need to negotiate competition across the two languages so that the use of each language is controlled to enable fluent performance.

- These control processes may include inhibition of the L1 or more dominant language with enduring consequences for native language use.

- Skill in resolving cross-language competition is hypothesized to create expertise that affects cognition and the brain.
Bilingualism may confer specific cognitive benefits to executive function and attention to enable bilinguals to:

- ignore irrelevant information
- resolve conflict among competing alternatives
- minimize the costs associated with task switching
Bilingualism good for the brain, researchers say

The skill helps improve multitasking and prioritizing, and helps ward off early symptoms of Alzheimer's disease, experts say.

"Being bilingual has certain cognitive benefits and boosts the performance of the brain, especially one of the most important areas known as the executive control system," said York University psychology professor Ellen Bialystok at the annual meeting of the American Association for the Advancement of Science being held in Washington, DC.

Bilingualism Is Like A Mental Gymnasium For The Brain

Juggling languages can build better brains
March 20, 2012, 3:16 am

If Bilingual Is Good, Is Trilingual Better?

By HEATHER TIMMONS

Amit Bhargava for The New York Times

School children cycle past advertisements for language coaching institutes in Patna, Bihar.
Talk Outline

1. Review briefly the evidence for parallel activation of the bilingual’s two languages in comprehension and production.

2. Illustrate the evidence for cognitive and neural consequences of bilingualism.

3. Consider what sort of language selection and control mechanisms might create these consequences.

4. Does multilingualism make a difference?

To anticipate our conclusions, we will suggest that given what we know at present, the data look quite similar for bilinguals and multilinguals. The differences that have been observed can, for the most part, be explained in terms of the consequences of proficiency across languages and the context in which the languages are used.
Evidence for the parallel activity of the two languages

Studies of bilingual word recognition exploit the presence of cross-language ambiguity:

**Interlingual cognates:**

hotel (English)- hotel (means hotel in Dutch)

**Interlingual homographs (false friends):**

room (English)- room (means cream in Dutch)

If a bilingual can function as two monolinguals in one, then performance in one language alone should be independent of the reading of the word in the other language.
The phonology of the language not in use modulates the time to read words in each language.

Cognates with identical/similar orthography but similar or different phonology:

<table>
<thead>
<tr>
<th>English</th>
<th>Spanish</th>
<th>Cross-language phonology</th>
</tr>
</thead>
<tbody>
<tr>
<td>piano</td>
<td>piano</td>
<td>Similar [+p]</td>
</tr>
<tr>
<td>base</td>
<td>base</td>
<td>Different [-p]</td>
</tr>
</tbody>
</table>

Schwartz, Kroll, & Diaz (2007): Facilitation for naming cognates in L2 when the phonology converges from L1 to L2: But the same result for reading in the dominant L1.
Can sentence context overcome these effects of language nonselectivity? If the sentence provides a cue to language membership, then no cognate effects should be observed.

<table>
<thead>
<tr>
<th>Type of Sentence</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>High constraint</td>
<td>The composer sat at the bench and began to play the <strong>piano</strong> as the lights dimmed.</td>
</tr>
<tr>
<td>Low constraint</td>
<td>As we walked through the room we noticed there was a large <strong>piano</strong> by the window.</td>
</tr>
</tbody>
</table>

**Result:** When bilinguals read, sentence constraint but *not language per se* eliminates the cognate effect (Schwartz & Kroll, 2006; Van Hell & De Groot, 2008)
Do bilinguals need to even be aware of the other language to see these intrusions of the language not in use? No! Thierry and Wu (2007): Proficient Chinese-English bilinguals access the L1 translation equivalent when performing semantic relatedness judgments in English, their L2

<table>
<thead>
<tr>
<th>Chinese character repetition (implicit factor)</th>
<th>Semantic relatedness (explicit factor)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Semantically related (S+)</td>
</tr>
<tr>
<td>Repetition (R+)</td>
<td>Post–Mail</td>
</tr>
<tr>
<td></td>
<td>You Zheng–You Jian</td>
</tr>
<tr>
<td></td>
<td>邮政– 邮件</td>
</tr>
<tr>
<td></td>
<td>SRE 4.34 (±0.40)</td>
</tr>
<tr>
<td></td>
<td>SRC 4.03 (±0.64)</td>
</tr>
<tr>
<td>No repetition (R−)</td>
<td>Wife–Husband</td>
</tr>
<tr>
<td></td>
<td>Qi Zǐ–Zhang Fu</td>
</tr>
<tr>
<td></td>
<td>妻子– 丈夫</td>
</tr>
<tr>
<td></td>
<td>SRE 4.28 (±0.47)</td>
</tr>
<tr>
<td></td>
<td>SRC 3.93 (±0.65)</td>
</tr>
</tbody>
</table>

The critical manipulation in this study was the presence of a repeated character in the Chinese translation of the English words: The bilinguals didn’t see the Chinese words in the experiment.
Thierry & Wu (2007): ERP evidence on semantic relatedness judgments by Chinese-English bilinguals in English only:

The bilinguals were sensitive to the character repetition suggesting that they were accessing the translation equivalent in L1 to perform the semantic task in L2.
Do the two languages need to both be spoken languages?  No!

The activation of the translation equivalent is not limited to bilinguals for whom the two languages are both spoken languages:

We observe very similar effects for bilinguals for whom one language is spoken and the other is signed.

Instead of repeating Chinese characters, we now have ASL translations of English words that have a “phonological” form relation or not.

Phonologically related in ASL:
- movie
- paper

Phonologically unrelated in ASL:
- lion
- baby
Deaf signers reading English as their L2 were faster to make related judgments and slower to make unrelated judgments when the translation of the two words in ASL had similar phonological form.
Studies of bilingual speech planning also exploit the presence of ambiguity across languages and report evidence for activity of the language not in use, a result that is far more surprising in production than in comprehension.

Simple picture naming in L2: You don’t see the word, only the picture’s names are phonologically similar (Costa, Caramazza, & Sebastián-Gallés, 2000).

Cognate facilitation suggests that the other language is active to the level of the phonology and again we see it in languages that are structurally distinct.

Bilinguals: Catalan-Spanish speakers naming in Spanish (L2)
Monolinguals: Native Spanish speakers naming in Spanish (L1)
What are the cognitive and neural consequences of having continuous cross-language activation?

Bilingualism may confer specific cognitive benefits to executive function and attention to enable bilinguals to:

- ignore irrelevant information
- resolve conflict among competing alternatives
- minimize the costs associated with task switching
An illustration of Bialystok’s recent work on elderly bilinguals:

Bilingualism may offer protection against the normal declines in attentional control associated with aging.

Bialystok et al. (2005): Older bilinguals outperform age-matched monolingual counterparts on the Simon Task and on other non-linguistic measures of inhibitory control.

Bialystok et al. (2007): Bilingualism delays the onset of Alzheimers-type dementia by four years. Language experience may provide protection to the brain.
The Simon Task

Congruent Trials

Incongruent Trials

“Press the button on the left for Red and button on the right for Green”
Hypothesis: The bilingual advantage arises from a life of resolving competition across the two languages.
Does the brain reveal structural consequences of using a second language?

Mechelli et al. (2004): Learning an L2 increases the density of grey matter
Bilingualism: consequences for mind and brain

Ellen Bialystok¹,², Fergus I.M. Craik² and Gigi Luk³

Review

Trends in Cognitive Sciences April 2012, Vol. 16, No. 4

Figure 1. Bilingual influence on brain function and structure. Transparent brains showing the left and right hemispheres. Green voxels depict grey matter regions showing high activation during bilingual language switching in a meta-analysis [90]. Red–yellow voxels indicate regions of higher white matter integrity in bilingual older adults relative to monolinguals [107]. Together, the functional and structural data indicate that neural correlates of bilingualism are observed in the frontal lobes, generally responsible for higher cognition such as executive functions.


Bilingualism Tunes the Anterior Cingulate Cortex for Conflict Monitoring

Jubin Abutalebi¹,², Pasquale Anthony Della Rosa¹, David W. Green³, Mireia Hernandez⁴,⁵, Paola Scifo¹, Roland Keim¹, Stefano F. Cappa¹ and Albert Costa⁴,⁶

Monitoring and controlling 2 language systems is fundamental to language use in bilinguals. Here, we reveal in a combined functional (event-related functional magnetic resonance imaging) and structural neuroimaging (voxel-based morphometry) study that dorsal anterior cingulate cortex (ACC), a structure tightly bound to domain-general executive control functions, is a common locus for language control and resolving nonverbal conflict. We also show an experience-dependent effect in the same region: Bilinguals use this structure more efficiently than monolinguals to monitor non-linguistic cognitive conflicts. They adapted better to conflicting situations showing less ACC activity while outperforming monolinguals. Importantly, for bilinguals, brain activity in the ACC, as well as behavioral measures, also correlated positively with local gray matter volume. These results suggest that early learning and lifelong practice of 2 languages exert a strong impact upon human neocortical development. The bilingual brain adapts better to resolve cognitive conflicts in domain-general cognitive tasks.
Brief Communications

Lifelong Bilingualism Maintains White Matter Integrity in Older Adults

Gigi Luk,1,5 Ellen Bialystok,1,3 Fergus I. M. Craik,1,2 and Cheryl L. Grady1,2,4
1Rotman Research Institute at Baycrest, Toronto, Ontario M6A 2E1, Canada, 2Department of Psychology, University of Toronto, Toronto, Ontario M5S 3G3, Canada, 3Department of Psychology, York University, Toronto, Ontario M3J 1P3, Canada, 4Department of Psychiatry, University of Toronto, Toronto, Ontario M5T 1R8, Canada, and 5Harvard Graduate School of Education, Cambridge, Massachusetts 02138

Previous research has shown that bilingual speakers have higher levels of cognitive control than comparable monolinguals, especially at older ages. The present study investigates a possible neural correlate of this behavioral effect. Given that white matter (WM) integrity decreases with age in adulthood, we tested the hypothesis that bilingualism is associated with maintenance of WM in older people. Using diffusion tensor imaging, we found higher WM integrity in older people who were lifelong bilinguals than in monolinguals. This maintained integrity was measured by fractional anisotropy (FA) and was found in the corpus callosum extending to the superior and inferior longitudinal fasciculi. We also hypothesized that stronger WM connections would be associated with more widely distributed patterns of functional connectivity in bilinguals. We tested this by assessing the resting-state functional connectivity of frontal lobe regions adjacent to WM areas with group differences in FA. Bilinguals showed stronger anterior to posterior functional connectivity compared to monolinguals. These results are the first evidence that maintained WM integrity is related to lifelong naturally occurring experience; the resulting enhanced structural and functional connectivity may provide a neural basis for “brain reserve.”
How does the mental juggling of two languages create these advantages for cognition?

The evidence to date is largely correlational. Bilinguals are advantaged relative to monolinguals on measures of attentional control and executive function.

A number of recent studies have shown a correlation between language control tasks and domain general cognitive tasks, e.g., Prior & Gollan (2011): Good language switchers are good task switchers!

But what aspect of language use is responsible for these benefits to cognition?
Two general alternatives to the answer of how cross-language competition is resolved:

- Bilinguals develop skill in selectively attending to the critical information that signals language status.

- Bilinguals learn to inhibit irrelevant information once it has been activated.

Either of these mechanisms might confer positive cognitive consequences.
The research on crib bilinguals suggests that infants may have enhanced attention skills to exploit the cues that separate their world in two; adult bilinguals do not appear to exploit these cues as easily.

Here we focus on evidence for inhibition once the other language has already become active.
Evidence for inhibition in comprehension: Local and short lived? Martín, Macizo, & Bajo (2009); Macizo, Martín, & Bajo (2010)

Two semantic relatedness judgments in English by Spanish-English bilinguals:

[Diagram showing the method and results of the experiment]
But the spillover inhibitory effect is absent for skilled interpreters/translators! They show the same initial sensitivity to the activation of the homograph as ordinary bilinguals but appear to be able to more quickly inhibit the consequences of that activation.
Induce phonological competition: “plum” vs. “plug”

Then on next trial, indicate the cell containing the grey asterisk by pressing a button.

Bilinguals show no difference between control and competitor trials at the point at which button responses were made. This suggests that bilinguals eliminate inhibition more quickly than monolinguals.
Evidence for inhibition in bilingual speech planning:

Misra, Guo, Bobb, & Kroll (in press): Use ERPs to examine the time course of cross-language activation in bilingual speech planning.
The effect of language blocking in picture naming in the L1 and L2.

Relatively proficient Chinese-English bilinguals but dominant in L1 Chinese.

**Group 1:** Name pictures in L1 then L2  
**Group 2:** Name pictures in L2 then L1

*The pictures were the same for both languages; two blocks per language: L1, L1, L2, L2 or L2, L2, L1, L1*
Blocked Picture Naming: Early indices of inhibition

Inhibitory pattern for L1 and facilitatory pattern for L2:

If it were a matter of recovering from momentary inhibition following naming in L2, then later in the L1 naming blocks we should see this recovery but the pattern persists, suggesting the presence of global inhibition.
Persistence of apparent inhibition of the L1 in the final two blocks of the experiment (Block 3 and Block 4)

Also no repetition priming in the RT data for L1 but this was a between-subjects design so in the next experiment we improved the design to determine whether a similar inhibitory pattern would be observed within bilingual speakers.
Gerfen et al. (in preparation): Effects of language blocking on articulatory duration: Are there late inhibitory effects?

Name pictures in three blocks: L1 Chinese- L2 English- L1 Chinese

<table>
<thead>
<tr>
<th>Name L1</th>
<th>Name L2</th>
<th>Name L1</th>
</tr>
</thead>
</table>

Mean Duration to Speak L1

Articulatory duration is longer in L1 following picture naming in L2. These data are similar to the conditions that produced extended negativity in the ERPs. The effect is present even for identical tokens that should produce repetition priming, suggesting that there is inhibition of the L1 following naming in the L2.
Is there supporting fMRI evidence? Yes. Abutalebi & Green (2007)

Fig. 1. Multiple levels of cognitive control and bilingual language production. The figure schematically illustrates the neural devices responsible for cognitive control (see text for details) as displayed on a BrainVoyager template. Cognitive control emerges from the integration of separable neural systems including the anterior cingulated cortex, the basal ganglia, the inferior parietal lobule and most prominently the prefrontal cortex (for illustration’s sake these areas are represented on the same axial brain slice). Each of these systems is responsible for distinct aspects of cognitive control as outlined in the “callout” boxes of the figure. In the domain of language, cognitive control refers to processes not directly concerned with the representation of language (i.e., lexical items), but rather with the selection and temporal sequencing of such representations. During bilingual word production, cognitive control may be at work in order to achieve the correct selection of the lexical item in the target language and to keep it free from non-target language interferences. This is achieved through the normal interplay of the mentioned neural devices; the left basal-ganglia and the anterior cingulate cortex will modulate activity in the left prefrontal cortex providing a normal modulatory influence on the systems mediating word production (left prefrontal cortex and inferior parietal cortex).
Guo, Liu, Misra, & Kroll (2011): fMRI evidence for global inhibition

Chinese-English bilinguals named pictures in three blocks:

Blocked Chinese (L1) – Blocked English (L2) – Mixed Language
Blocked English (L2) – Blocked Chinese (L1) – Mixed Language

The comparison between **blocked** and **mixed** picture naming performance was defined as local switching, while the comparison between **blocked naming in each language** was defined as global switching. Distinct patterns of neural activation were found for each of these comparisons.
Distinct patterns of neural activation were found for local inhibition as compared to global inhibition in bilingual word production:

The dorsal anterior cingulate cortex (ACC) and the supplementary motor area (SMA) appear to play important roles in local inhibition, while the dorsal left frontal gyrus and parietal cortex appear to be important for global inhibition.
Summary on Inhibitory Mechanisms

- When relatively proficient bilinguals understand and speak words in their L2, there is inhibition that appears to suppress the activity of the stronger L1.

- In comprehension, that inhibition appears to be specific and short lived but can be seen in measures of behavior and also of the earliest stages of brain activity.

- In production, the inhibition seen for the L1 can be seen in the earliest measures of speech planning evident in ERPs, in performance on behavioral tasks, in late acoustic measures of produced speech, and in differential patterns of brain activity in fMRI studies.

- A similar inhibitory pattern of L1 is seen among immersed L2 learners in both comprehension and production.

- Understanding the short and long-term consequences of these changes will be critical for developing a comprehensive account of what it means to be a proficient bilingual but also for what it means to lose access to the native language following extended L2 immersion in healthy adults or for bilingual aphasic patients.

- A critical issue for future research will be to understand how the observed inhibition relates to the presence of bilingual advantages in the realm of executive control: Is there a causal link?
Talk Outline

1. Review briefly the evidence for *parallel activation* of the bilingual’s two languages in comprehension and production

2. Illustrate the evidence for *cognitive and neural consequences* of bilingualism

3. Consider what sort of language selection and control mechanisms might create

4. **Does multilingualism make a difference?**
Does multilingualism make a difference?

For activation in comprehension:
Is there influence of the L3 on the L1? Yes!

Van Hell & Dijkstra (2002): Asked Dutch-English-French trilinguals to perform lexical decision in Dutch, their L1, without any knowledge that English or French was relevant to the experiment. The materials included words that were cognates in Dutch and English and in Dutch and French or controls that were uniquely Dutch.

<table>
<thead>
<tr>
<th>cognates with English</th>
<th>e.g., appel bakker</th>
</tr>
</thead>
<tbody>
<tr>
<td>cognates with French</td>
<td>e.g., tante meubel</td>
</tr>
<tr>
<td>noncognates</td>
<td>e.g., wortel tuin</td>
</tr>
</tbody>
</table>
Van Hell & Dijkstra (2002)
Lexical Decision performance in Dutch
Dutch-English-French Trilinguals:
Cross-language influences on the L1

But it also depends on L3 skill (see Szubko-Sitarek, 2012 for a replication)
Poarch & Van Hell (under review): Is cognate facilitation in production increased when trilinguals name pictures that potentially have three sources of cross-language overlap vs. only two? Yes! Some evidence for stronger cross-language activation in L2 when all three languages converge.
Do we see enhanced facilitation for triple cognates when bilingual and trilingual readers process cognates in sentence context?  **No!**

Van den Boer, Ting, Minnicks, van Hell, Dussias, & Kroll (in preparation): Not for naming cognate words or cognate pictures.

**Naming words**

**Naming pictures**

Sentences were high or low in semantic constraint. **Cognates** are red.
Does multilingualism enhance the protection from Alzheimer’s type symptoms that have been reported for bilinguals? The evidence is mixed.

Bialystok, Craik, & Freedman (2007): Compared hospital records of monolingual and bilingual dementia patients: Monolingual patients were, on average, almost four years younger than bilingual patients at time they were diagnosed.

Gollan et al. (2011): Replicated the bilingual advantage in providing protection against the onset of Alzheimer’s type symptoms but only for those bilinguals with lower levels of education.
There is some recent evidence extending the advantage to multilinguals but cautiously, with some limited evidence for more is better and other studies suggesting that it depends on the context in which the languages are used, in which speaker is immersed, and the nature of their language dominance (e.g., Kavé et al., 2008).

Bialystok et al. (2012) speculate about this:

The first question is the possibility of a cumulative benefit for multiple languages. If managing two languages enhances cognitive control processes, then does further enhancement accrue from the management of three or more languages, as explicitly proposed by Diamond [132]? Research by Chertkow et al. [119] on Alzheimer’s disease and Kavé et al. [123] on normal aging showed better outcomes for multilinguals than for bilinguals, but there may be significant differences between multilinguals and bilinguals that do not exist between bilinguals and monolinguals. As we have suggested, bilinguals are typically not pre-selected for talent or interest but multilinguals may often be individuals with high ability and motivation to learn other languages, factors which may impact as well on cognitive performance.
Conclusions

- Our review of the recent psycholinguistic and neurocognitive evidence on juggling more than one language in the same mind and brain suggests that life experience in using more than one language has profound consequences for both language processing and domain-general aspects of cognitive function and cognitive control.

- There is not a simple answer to the question of whether more is better; it appears to depend on a set of factors that also determine the way in which cognitive control is manifest in bilinguals, including the context and age of acquisition, proficiency and language dominance, and the structural properties across the languages.

- Other recent research suggests that early learning mechanisms are affected by language use (see, e.g., Petitto et al., 2012, on the Perceptual Wedge Hypothesis) and ultimately it may be those learning mechanisms and the plasticity associated with them that are responsible for some of the consequences we have described.
Why multilingualism may really be a good thing after all…

http://www.youtube.com/watch?v=Xtbbo_lHqAs

Thank you!