Bilingualism transforms language, cognition, and the brain

Judith F. Kroll
Department of Psychology
Center for Language Science
Pennsylvania State University
jfk7@psu.edu

PENNSTATE University Park

CUNY
May 18, 2015

Acknowledgments

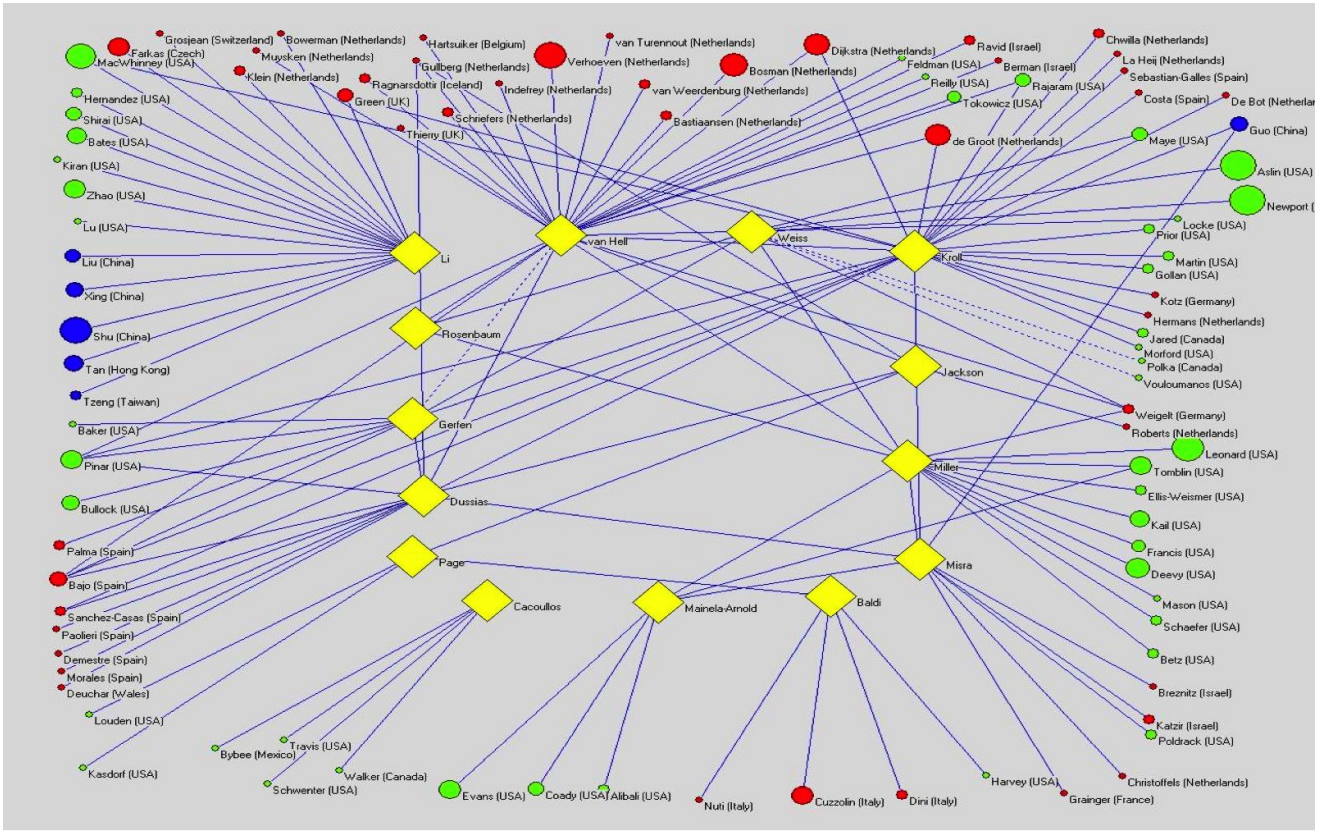
Collaborators:

- Teresa Bajo
- Kinsey Bice
- Susan Bobb
- Cari Bogulski
- Ingrid Christoffels
- Dorothee Chwilla
- Albert Costa
- Annette De Groot
- Franziska Dietz
- Giuli Dussias
- Melinda Fricke
- 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
- Fengyang Ma
- Pedro Macizo
- Mari Cruz Martín
- Rhonda McClain
- Erica Michael
- Natasha Miller
- Maya Misra
- Jill Morford
- Juliana Peters
- Pilar Piñar
- Eleonora Rossi
- Rosa Sánchez-Casas
- Ana Schwartz
- Bianca Sumutka
- Gretchen Sunderman
- Natasha Tokowicz
- Janet Van Hell
- Zofia Wodniecka
- Megan Zirnstein

Research Support:

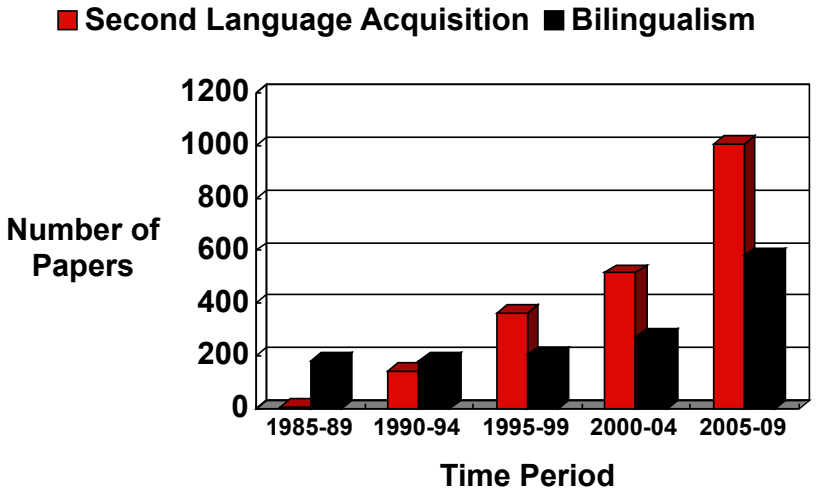
- NIH Grants MH62479 and HD053146; NIH Fellowship F33HD055003
- NSF PIRE Grant, OISE-0968369: *Bilingualism, mind, and brain*
- NSF Grants, BCS-0111734, BCS-0418071, BCS-0955090
- NSF Dissertation Grants to Sunderman, Schwartz, McClain, Hoshino, Bobb, Bogulski, & Gullifer
- Open Project Grant at State Key Laboratory for Cognitive Neuroscience and Learning, Beijing Normal University, China
- John Simon Guggenheim Memorial Foundation Fellowship, 2013-14

The Penn State Center for Language Science International Bilingualism Network



Support from **NSF PIRE (Partnerships for International Research and Education)**: 2010-2015: *Bilingualism, mind, and brain: An interdisciplinary program in cognitive psychology, linguistics, and cognitive neuroscience*

On the 125th anniversary of the journal *Science*, Kennedy and Norman (2005) identified the **biological basis of second language (L2) learning** as one of the top 125 questions to be answered in the next 25 years of research:



Research articles published on **Second Language Acquisition** and **Bilingualism** since 1985 (*Web of Science*)

There has been a virtual explosion of research on bilingualism:

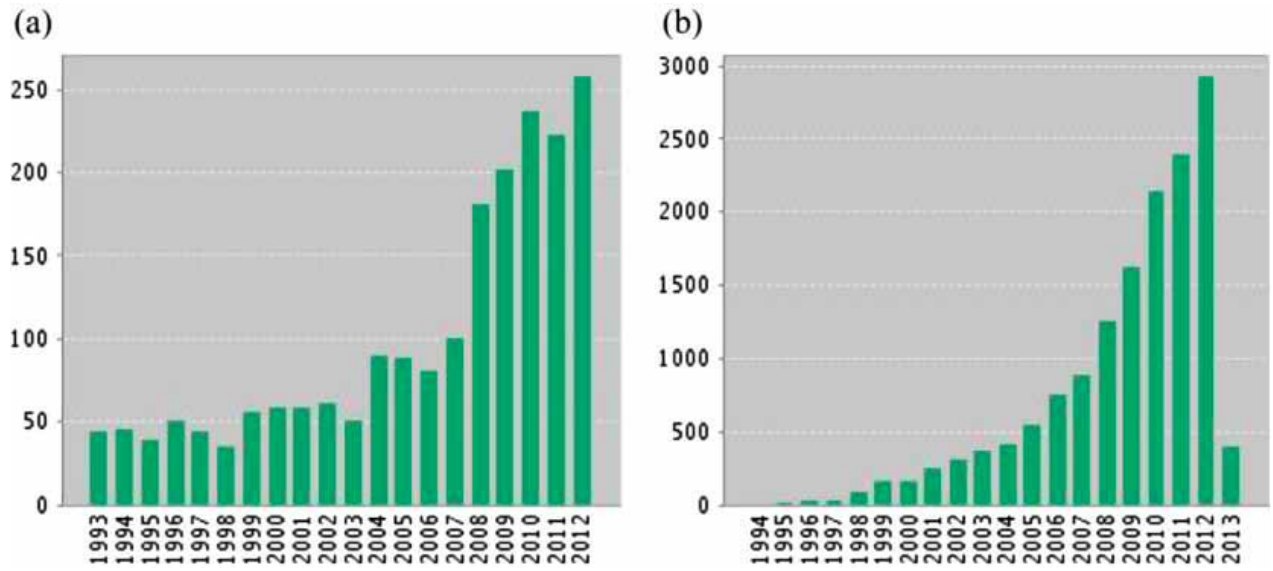
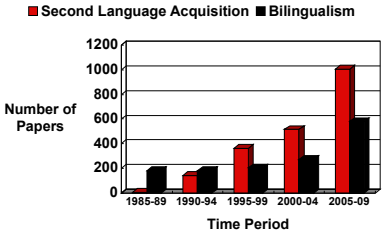


Figure 1. Results of search for topic "bilingualism" on Thompson-Reuters Web of Science for (a) number of papers published and (b) number of citations of those papers for years 1993 to 2012. (From Kroll & Bialystok, 2013, *Journal of Cognitive Psychology*)

What have we learned in the recent upsurge of research?



❖ Recent neuroscience evidence has called into question the presence of hard constraints on L2 learning; proficiency in L2 may often be more important than age of acquisition (e.g., Abutalebi et al., 2005; Steinhauer et al., 2009) and the brain
may outpace behavior in revealing L2 learning.

❖ But there are consequences: proficient bilinguals are not monolingual-like in their native language, suggesting that the native language is open to change and to the influence of the L2 (e.g., Ameel et al., 2009). *Competition across the two languages may reshape the networks that support each language.*

Three discoveries about bilingualism:

1. Both languages are always active and competing.

The two languages are not separate

2. The native language changes in response to learning and using an L2.

Bilingualism has consequences for both languages

1. The consequences of bilingualism are not limited to language but reflect a reorganization of brain networks that hold implications for the ways in which bilinguals negotiate cognitive competition more generally.

Bilingualism has consequences for the mind and the brain

Kroll, Bobb, & Hoshino (2014). Two languages in mind: Bilingualism as a tool to investigate language, cognition, and the brain. *Current Directions in Psychological Science.*

Three discoveries about bilingualism:

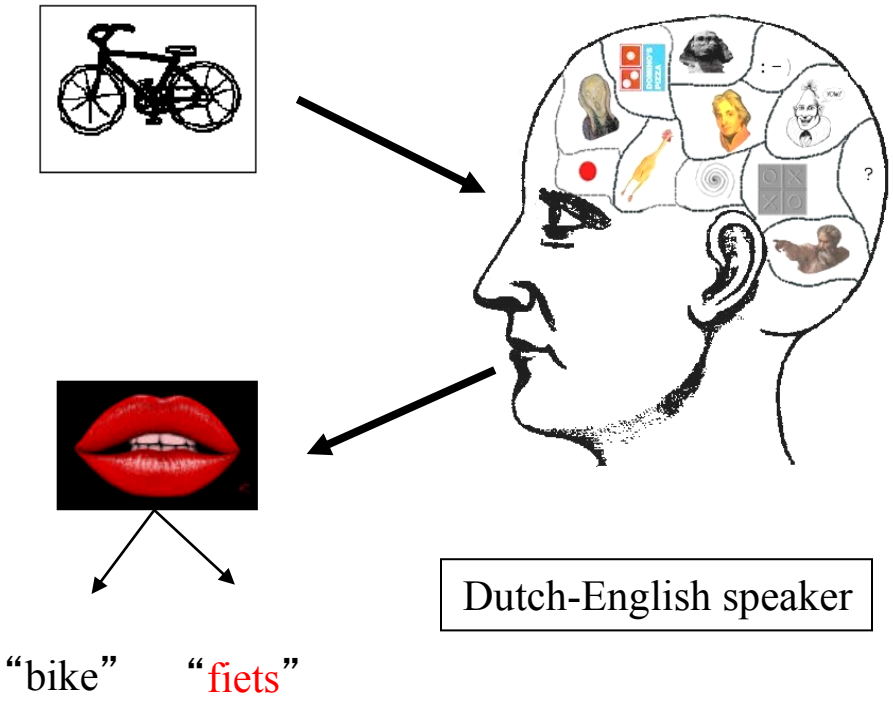
1. Both languages are always active and competing.

2. The native language changes in response to learning and using an L2.

3. The consequences of bilingualism are not limited to language but reflect a reorganization of brain networks that hold implications for the ways in which bilinguals negotiate cognitive competition more generally.

Kroll, Bobb, & Hoshino (2014). Two languages in mind: Bilingualism as a tool to investigate language, cognition, and the brain. *Current Directions in Psychological Science.*

How do the mind and brain accommodate the presence of two languages? The bilingual is a mental juggler: Both languages are active regardless of the requirement to use one language alone:



How does a bilingual select a given language to be used at any moment?

Cross-language interactions are persistent.

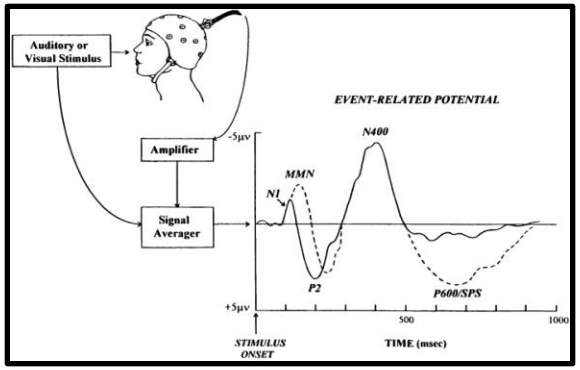
At the **lexical** level, we see them even when bilinguals are processing words in sentence context, even when they are not required to use one of the two languages at all, even when the bilinguals are highly proficient in the L2, and even for language pairings that are highly dissimilar (e.g., Morford et al., 2011).

At the level of the **grammar**, we see them when structures in the two languages converge (e.g., Hartsuiker et al., 2004) and when they conflict (e.g., Dussias & Sagarra, 2007).

At the level of the **phonology**, we see them at the earliest stages of L2 learning (e.g., Chang, 2012; Jacobs et al., in press) and when bilinguals are highly proficient.

But sometimes, these cross-language interactions are seen only in the brain data, not in behavior.

Thierry and Wu (2007): Proficient Chinese-English bilinguals access the L1 translation equivalent when performing semantic relatedness judgments in English, their L2.

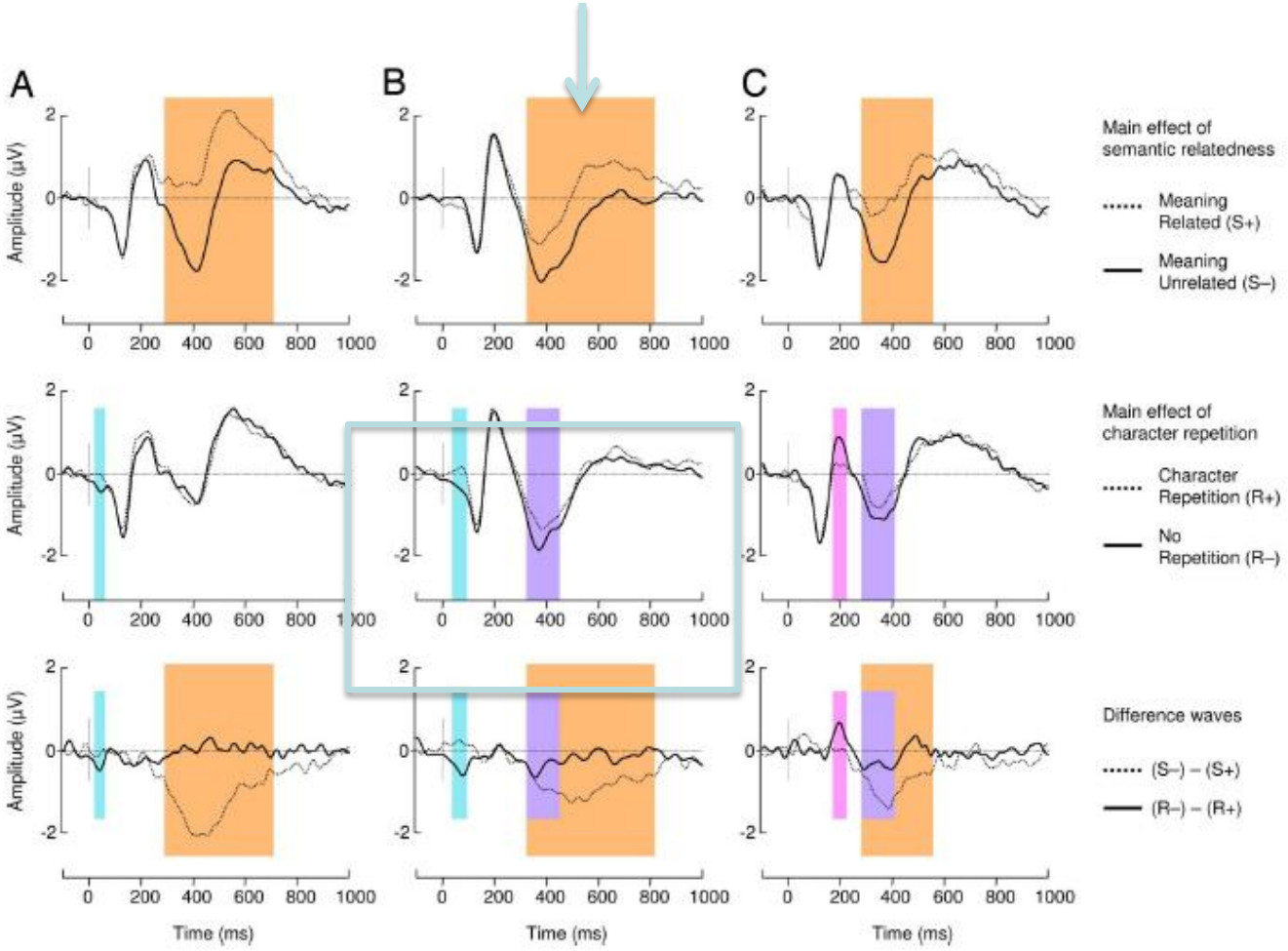


The critical manipulation in this study was the presence of a repeated character in the Chinese translation of the English words: The bilinguals did not see the Chinese words in the experiment.

Table 1. Experimental design and stimulus examples

Chinese character repetition (implicit factor)	Semantic relatedness (explicit factor)	
	Semantically related (S+)	Semantically unrelated (S−)
Repetition (R+)	Post–Mail You Zheng–You Jian 邮政 – 邮件 SRE 4.34 (±0.40) SRC 4.03 (±0.64)	Train–Ham Huo Che–Huo Tui 火车 – 火腿 SRE 1.50 (±0.35) SRC 1.27 (±0.26)
No repetition (R−)	Wife–Husband Qi Zi–Zhang Fu 妻子 – 丈夫 SRE 4.28 (±0.47) SRC 3.93 (±0.65)	Apple–Table Ping Guo–Zhuo Zi 苹果 – 桌子 SRE 1.37 (±0.44) SRC 1.26 (±0.24)

ERP evidence on semantic relatedness judgments by Chinese-English bilinguals



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: *But there was no evidence for the activation of the translation in behavior.*

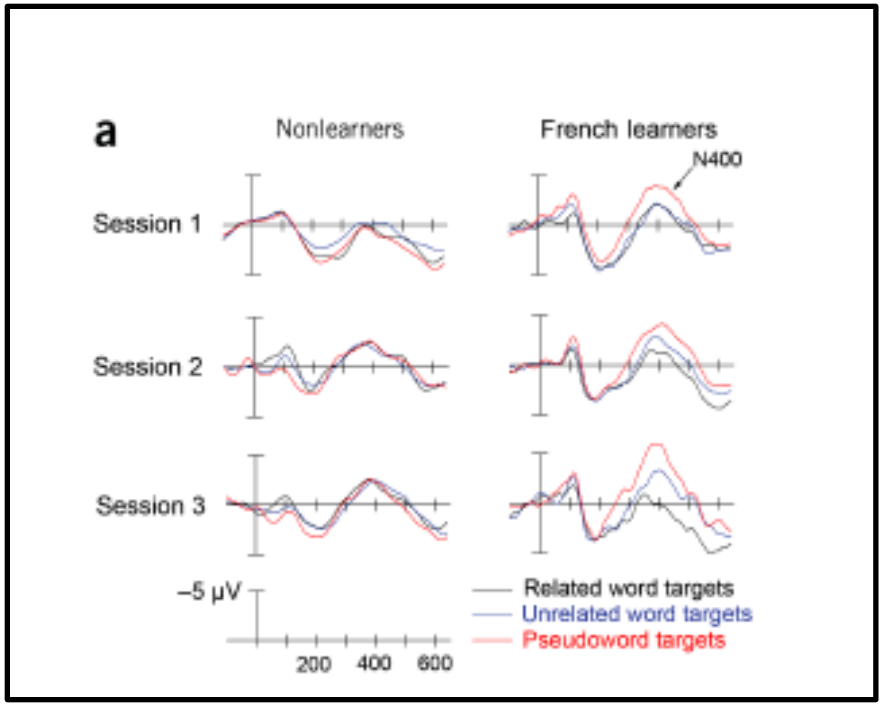
Other evidence that the ERP record may be a more sensitive measure of early stages of L2 learning than behavior: McLaughlin et al. (2004)

NATURE NEUROSCIENCE VOLUME 7 | NUMBER 7 | JULY 2004

Neural correlates of second-language word learning: minimal instruction produces rapid change

Judith McLaughlin, Lee Osterhout & Albert Kim

Adult second-language (L2) learning is often claimed to be slow and laborious compared to native language (L1) acquisition, but little is known about the rate of L2 word learning. Here we report that adult second-language learners' brain activity, as measured by event-related potentials (ERPs), discriminated between L2 words and L2 'pseudowords' (word-like letter strings) after just 14 h of classroom instruction. This occurred even while the learners performed at chance levels when making overt L2 word-nonword judgments, indicating that the early acquisition of some aspects of a new language may be overlooked by current behavioral assessments.



We need converging measures of language processing to fully understand the course and consequence of cross-language activation

Three discoveries about bilingualism:

1. Both languages are always active and competing.

2. The native language changes in response to learning and using an L2.

3. The consequences of bilingualism are not limited to language but reflect a reorganization of brain networks that hold implications for the ways in which bilinguals negotiate cognitive competition more generally.

Kroll, Bobb, & Hoshino (2014). Two languages in mind: Bilingualism as a tool to investigate language, cognition, and the brain. *Current Directions in Psychological Science.*

Illustrate the effects of L2 on L1 in a program of research on bilingual speech planning.

Evidence for inhibition of the L1 to enable speech production in the L2.

We see suppression of the L1 in the earliest measures of brain activity when bilinguals prepare to speak words in either language, in their behavior when they begin to speak, in late acoustic measures of produced speech, and in the fMRI record.

But these effects are not always present in behavior – sometimes we see them and sometimes we don't.

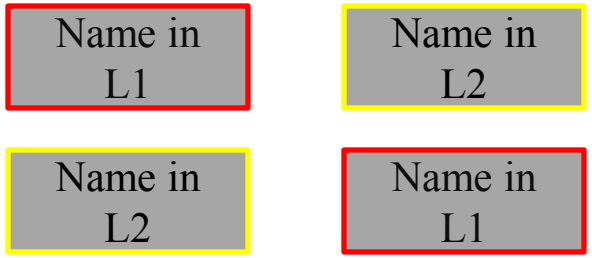
Misra, Guo, Bobb, & Kroll (2012)

Use ERPs to examine the earliest time course of cross-language activation in bilingual speech planning.

The effect of **language blocking** in picture naming in the L1 and L2.

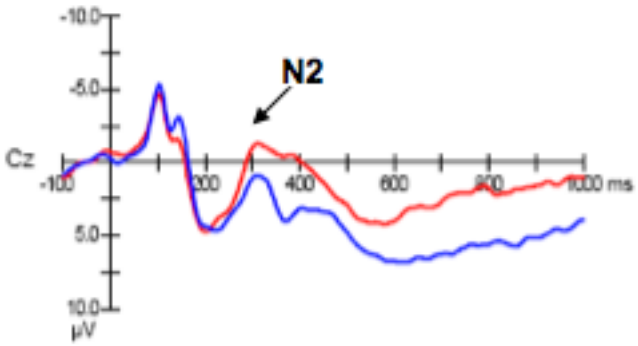
Relatively proficient Chinese-English bilinguals but dominant in L1 Chinese.

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

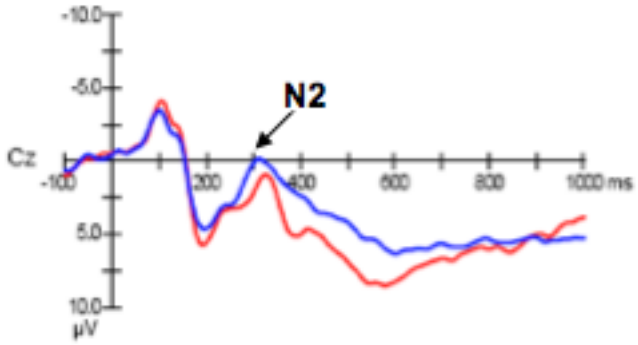


The pictures were the same for both languages; two blocks per language: **L1, L1**, L2, L2 or L2, L2, **L1, L1**

Blocked Picture Naming: Early indices of inhibition



L1



L2

L1 First
L1 Following L2

L2 First
L2 Following L1

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.

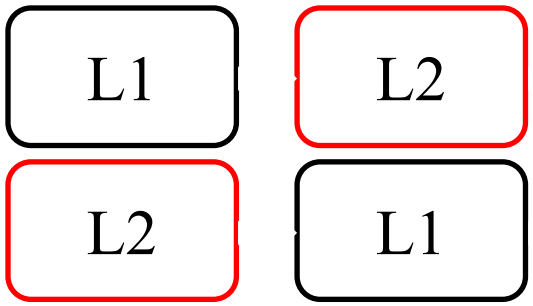
In this study, there was little evidence for inhibition in the behavioral measure.

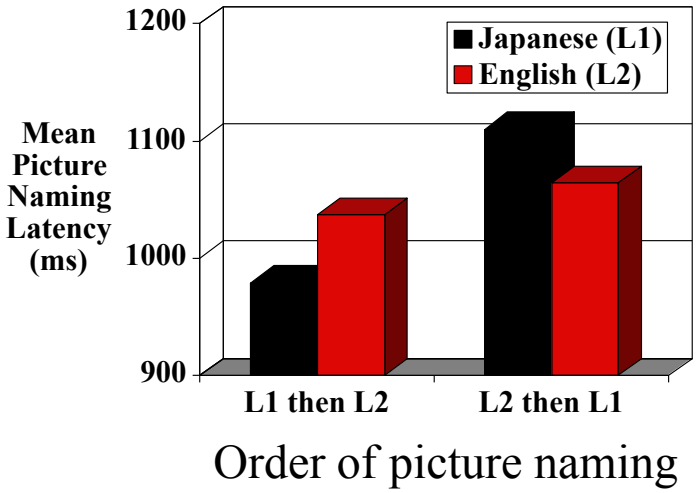
Does behavior also reflect this early inhibitory pattern for the L1?

Moriyasu (2014): examined simple picture naming for Japanese-English bilinguals who were highly proficient in English as the L2 and living in the US but still very dominant in L1 Japanese

Measure	Japanese (L1)	English (L2)
Self rating proficiency (1-7 scale)	**6.5**	4.5
Category fluency (in 30 seconds)	**48.3**	38.6

Moriyasu (2014)





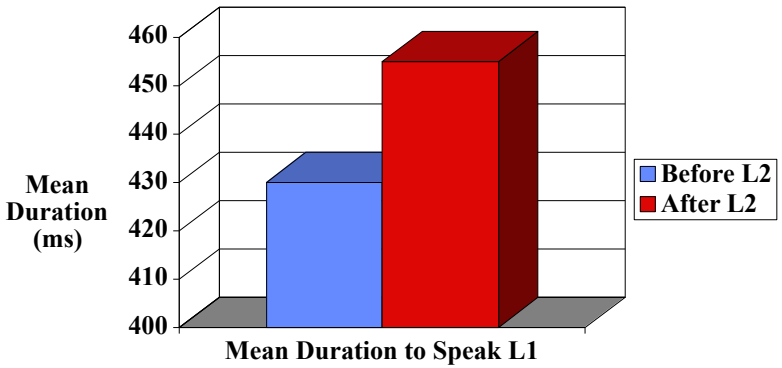
When L1 is named first, we see the expected pattern of faster naming latencies for L1 than L2.

When L1 is named after L2, they are slower to speak Japanese than English! A reversal of their normal language dominance.

Effects of language blocking on articulatory duration: Are there late inhibitory effects?

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

Name L1 Name L2 **Name 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 and longer RTs in the naming. 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.

The evidence that bilingualism has consequences for inhibitory control is now compelling.

But inhibitory control may involve different brain networks that are engaged in specific ways to solve different types of language processing problems. A focus in the recent research has been to examine these effects of bilingualism and language experience on the brain.

Abutalebi & Green (2007): Different loci of cognitive control in the bilingual brain: different components of inhibition?

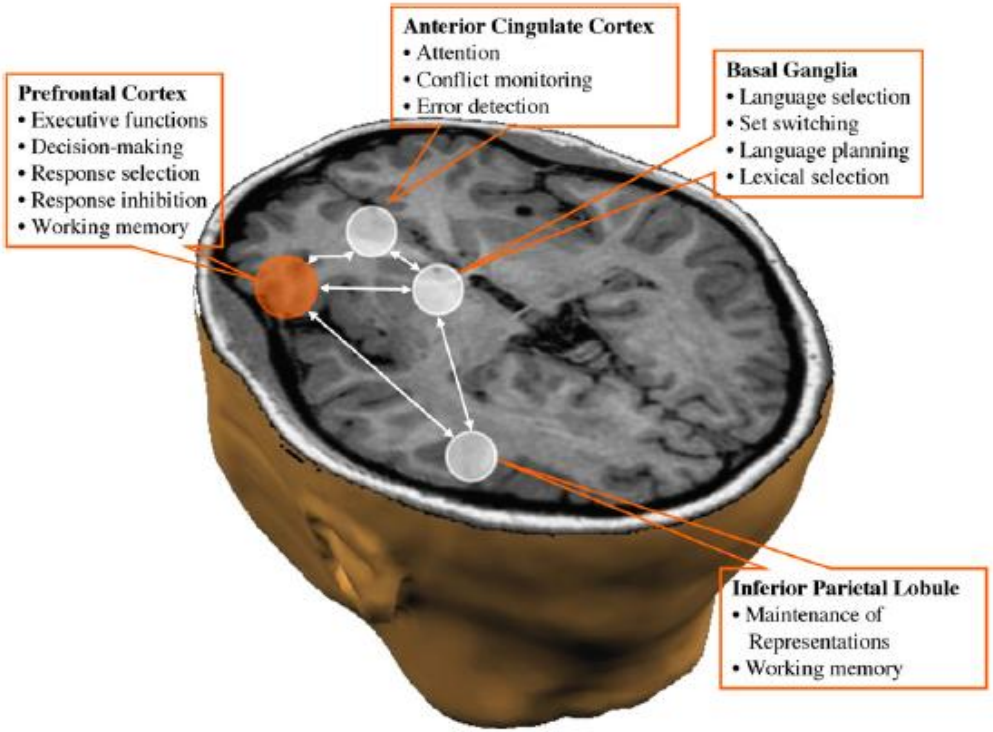
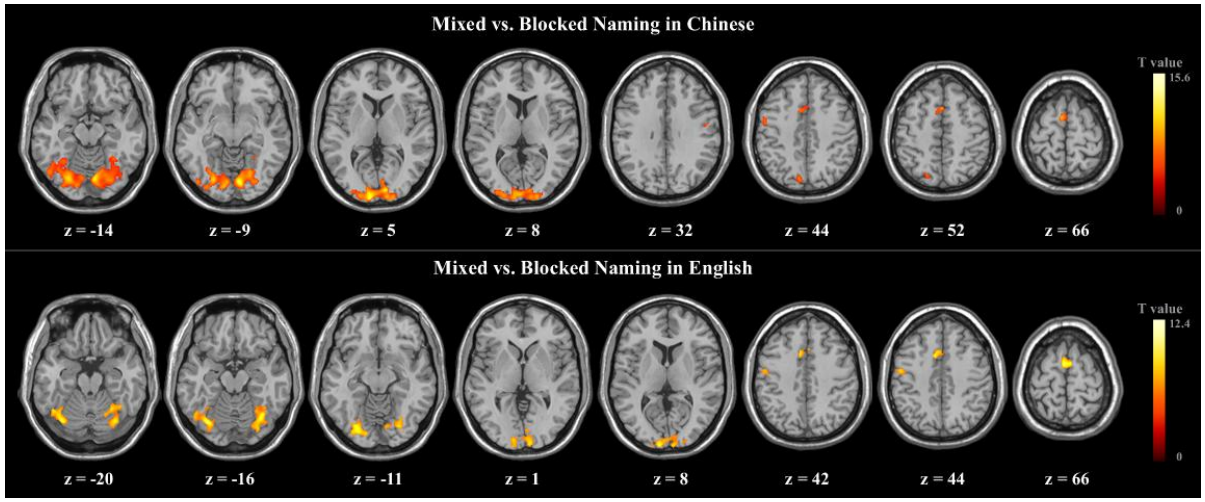


Fig. 1. Multiple levels of cognitive control and bilingual language production. The figure schematically illustrates the neural devices responsible for cognitive control (see text for details) as displayed on a BrainVoyager template. Cognitive control emerges from the integration of separable neural 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 cogntive 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:

Chinese (L1) – English (L2) – Mixed

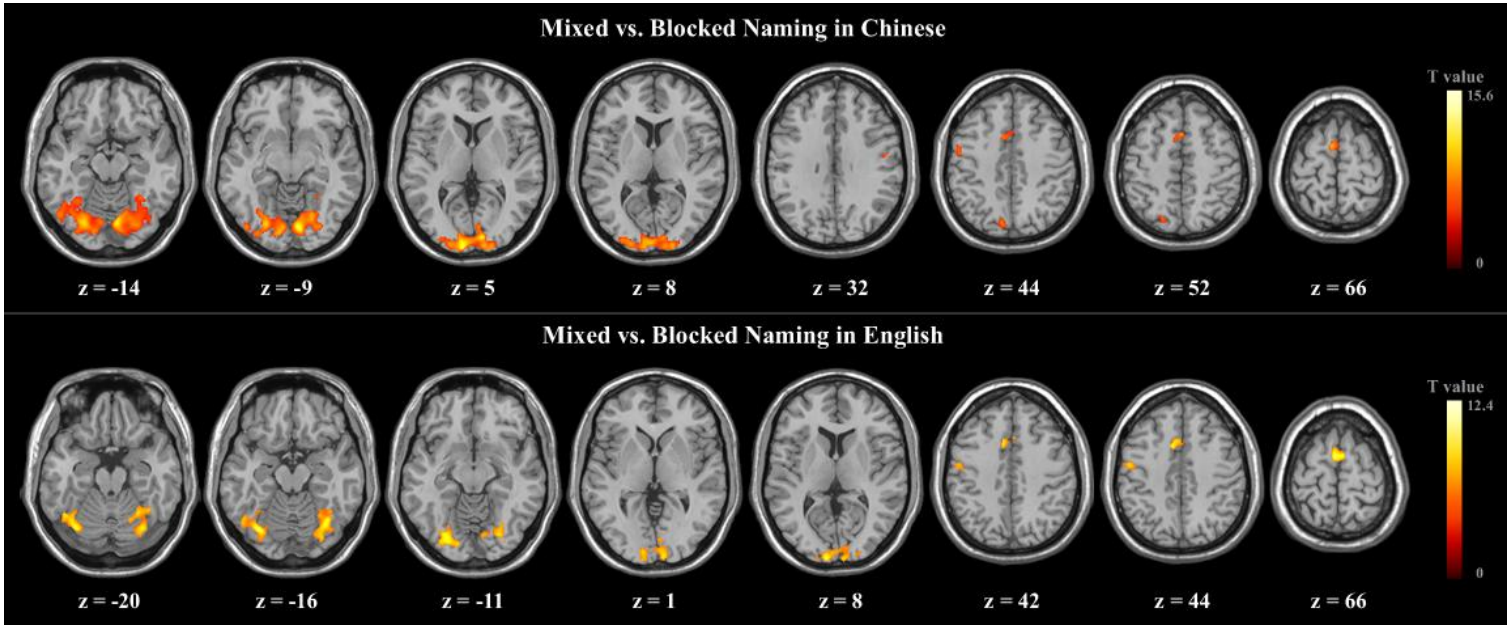
English (L2) – Chinese (L1) – Mixed

Name in L1	Name in L2	Name in L1 or L2
Name in L2	Name in L1	Name in L1 or L2

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.

Guo, Liu, Misra, & Kroll (2011): fMRI evidence



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.

The L2 affects the L1 at the level of the lexicon, the grammar and the phonology. But what are the consequences over time?

Cerebral Cortex
doi:10.1093/cercor/bhr161

Where, When and Why Brain Activation Differs for Bilinguals and Monolinguals during Picture Naming and Reading Aloud

'Ōiwi Parker Jones[1], David W. Green[2], Alice Grogan[3], Christos Pliatsikas[4], Konstantinos Filippopolitis[1], Nilufa Ali[5], Hwee Ling Lee[6], Sue Ramsden[1], Karine Gazarian[1], Susan Prejawa[1], Mohamed L. Seghier[1] and Cathy J. Price[1]

Using functional magnetic resonance imaging, we found that when bilinguals named pictures or read words aloud, in their native or nonnative language, activation was higher relative to monolinguals in 5 left hemisphere regions: dorsal precentral gyrus, pars triangularis, pars opercularis, superior temporal gyrus, and planum temporale. We further demonstrate that these areas are sensitive to increasing demands on speech production in monolinguals. This suggests that the advantage of being bilingual comes at the expense of increased work in brain areas that support monolingual word processing. By comparing the effect of bilingualism across a range of tasks, we argue that activation is higher in bilinguals compared with monolinguals because word retrieval is more demanding; articulation of each word is less rehearsed; and speech output needs careful monitoring to avoid errors when competition for word selection occurs between, as well as within, language.

[And see Palomar-Garcia et al. (2015)]

Grosjean, F. 1989. “Neurolinguists, Beware! The Bilingual Is Not Two Monolinguals in One Person.”

The recent evidence suggests that Grosjean was right!

Three discoveries about bilingualism:

1. Both languages are always active and competing.

2. The native language changes in response to learning and using an L2.

3. The consequences of bilingualism are not limited to language but reflect a reorganization of brain networks that hold implications for the ways in which bilinguals negotiate cognitive competition more generally.

Kroll, Bobb, & Hoshino (2014). Two languages in mind: Bilingualism as a tool to investigate language, cognition, and the brain. *Current Directions in Psychological Science.*

What is the consequence of parallel activity and competition across the bilingual's two languages?

Juggling two languages may tune brain networks that enable control and build cognitive reserve.

Los Angeles Times

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.

Mail&Guardian online

On the tip of the tongue

ALOK JHA Mar 18 2011 16:37

0 comments | Post your comment

"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

And this is the issue that brings us together at this workshop.

- 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.

- Skill in resolving cross-language competition is hypothesized to create expertise that affects not only language but cognition and the brain. Bilinguals become expert jugglers.

  But how? The story can't be this simple.

  - The regulation of the native language may be critical.

Life experience as a bilingual changes the mind and the brain

1. Bilingualism changes the efficiency of the brain networks responsible for resolving competition and conflict in non-linguistic tasks. These changes are sometimes observable in behavior but even when they are not, they may be evident in structural and functional changes in the brain.
2. The consequences of bilingualism are more evident for older bilinguals than for young adult bilinguals. Bilingualism provides protection against cognitive decline.
3. The regulatory processes that are engaged by bilingualism may also be trained outside of language experience, suggesting that they are domain-general mechanisms and may reflect coordination of control mechanisms rather than simple main effects.
4. Some of these control processes can be caught "on the fly" as language processing is ongoing and others are likely to reflect longer term consequences
5. Not all bilingual experience produces the same consequences.

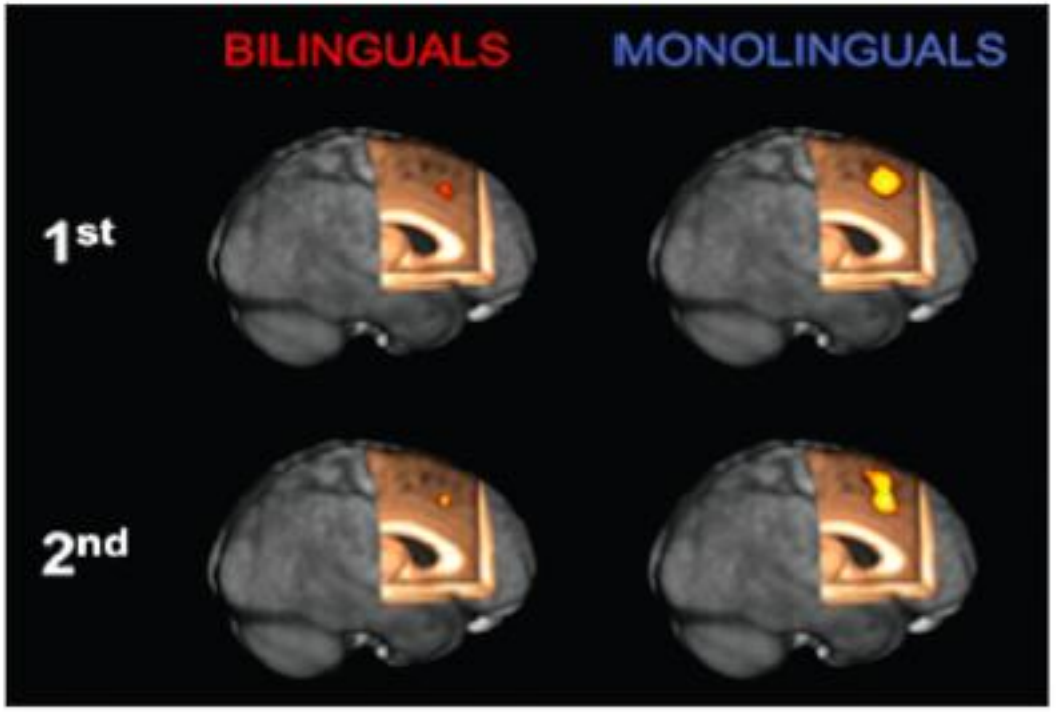
1. Bilingualism changes the efficiency of the brain networks responsible for resolving competition and conflict in non-linguistic tasks.

What is the neural basis of the bilingual effect in resolving conflict?

Cerebral Cortex
doi:10.1093/cercor/bhr287

Bilingualism Tunes the Anterior Cingulate Cortex for Conflict Monitoring

Jubin Abutalebi[1,2], Pasquale Anthony Della Rosa[1], David W. Green[3], Mireia Hernandez[4,5], Paola Scifo[1], Roland Keim[1], Stefano F. Cappa[1] and Albert Costa[4,6]



2. The consequences of bilingualism are more evident for older bilinguals than for young adult bilinguals. Bilingualism provides protection against cognitive decline.

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 non-linguistic measures of inhibitory control.

Alladi et al. (2013); Bialystok et al. (2007) : Bilingualism delays the onset of Alzheimer's type dementia symptoms by four years.

Schweizer et al. (2012): At the point of diagnosis with Alzheimers, bilingual brains are more diseased than monolingual brains.

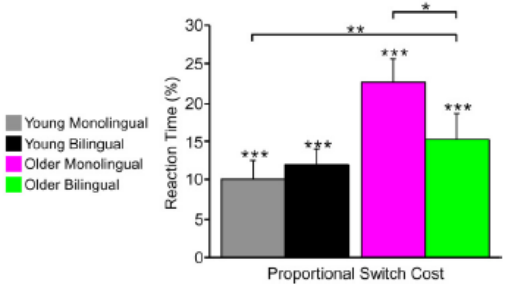
The Journal of Neuroscience, Month ??, 2012 • 32(xx):xxx–xxx • 1

Behavioral/Cognitive

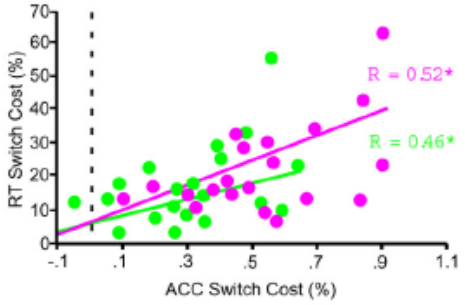
Lifelong Bilingualism Maintains Neural Efficiency for Cognitive Control in Aging

Brian T. Gold,[1,2,3] Chobok Kim,[1,6] Nathan F. Johnson,[1] Richard J. Kryscio,[3,4] and Charles D. Smith[1,2,3,5]

Increased task switching costs with age but older bilinguals fare better than older monolinguals. For young adults, the effect of bilingualism is not as dramatic.



Relationship between neural and behavioral switch costs in older adults. This graph shows an age by group interaction for the ACC, the same region identified in other studies as associated with more efficient conflict resolution for bilinguals.



But again, these are not necessarily simple phenomena:

Contents lists available at SciVerse ScienceDirect

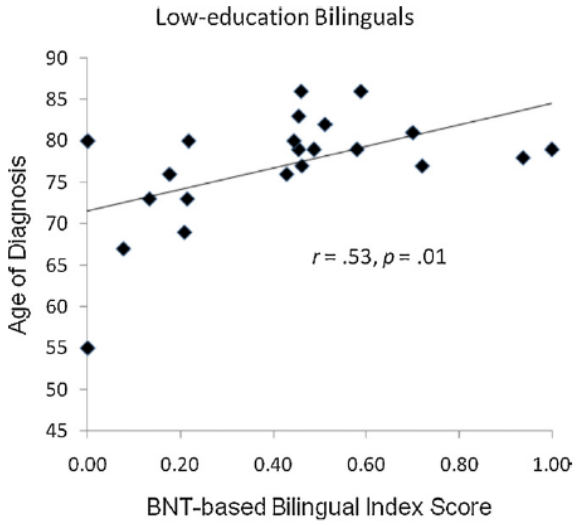
Neuropsychologia

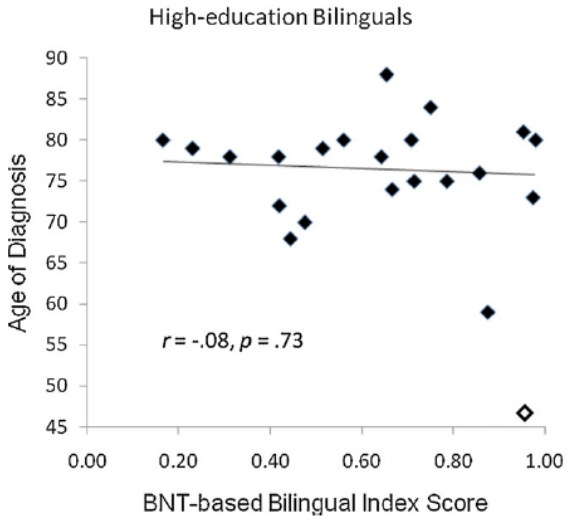
journal homepage: www.elsevier.com/locate/neuropsychologia

Degree of bilingualism predicts age of diagnosis of Alzheimer's disease in low-education but not in highly educated Hispanics

Tamar H. Gollan*, David P. Salmon, Rosa I. Montoya, Douglas R. Galasko

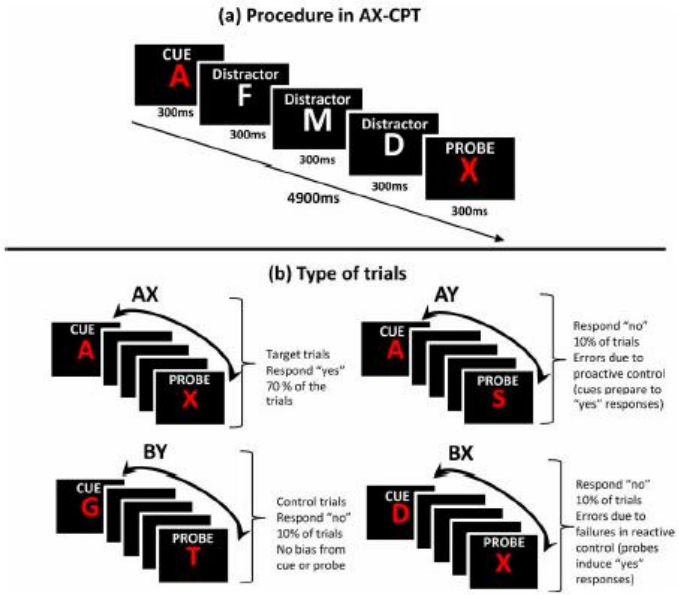
University of California, San Diego, United States





3. The regulatory processes that are engaged by bilingualism may reflect coordination of control mechanisms rather than simple main effects and may trained to extend beyond language experience itself

Studies using the AX-CPT task to dissociate proactive and reactive control processes (e.g., Braver et al., 2002).



Coordination of cognitive control – not necessarily a simple effect

Journal of Cognitive Psychology, 2013
Vol. 25, No. 5, 531–546, http://dx.doi.org/10.1080/20445911.2013.807812

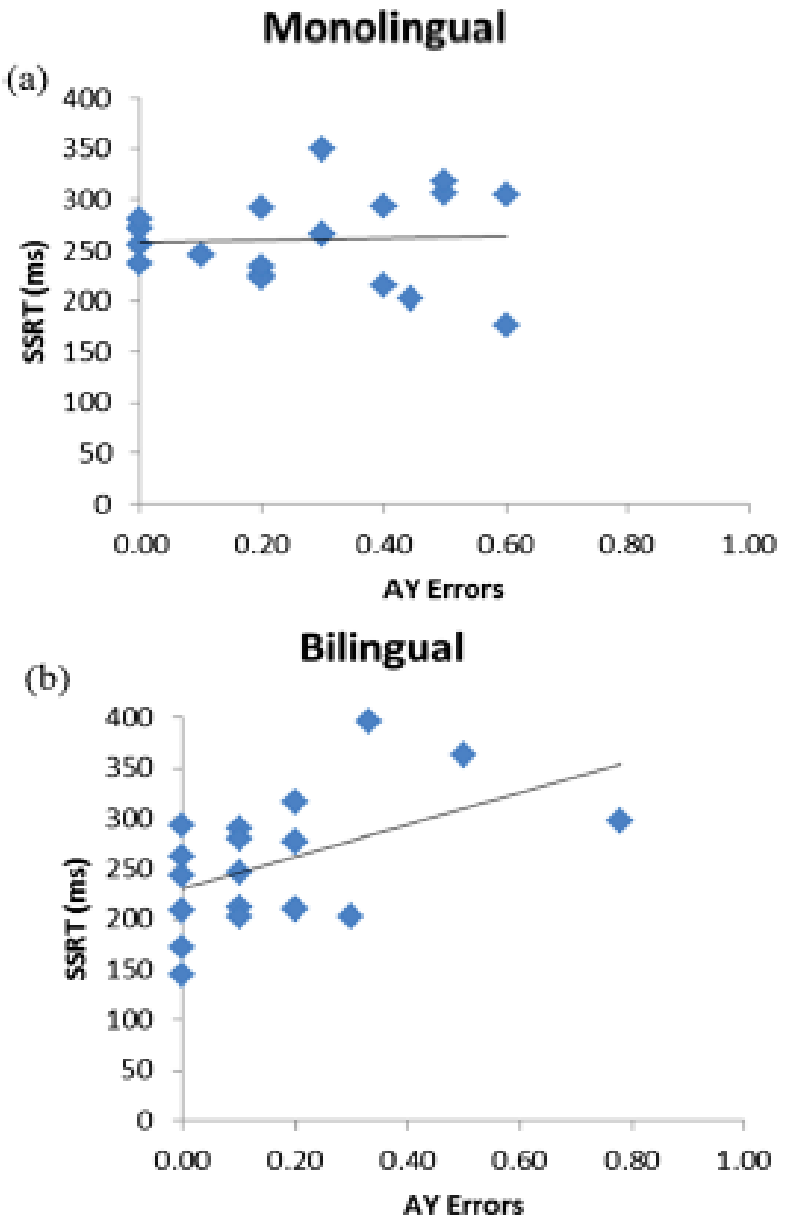
Routledge
Taylor & Francis Group

Dual mechanisms of cognitive control in bilinguals and monolinguals

Julia Morales[1], Carlos J. Gómez-Ariza[2], and M. Teresa Bajo[1]

[1]Research Center for Mind, Brain and Behavior, University of Granada, Granada, Spain
[2]Department of Psychology, University of Jaén, Jaén, Spain

Growing evidence shows that executive functioning benefits from bilingual experience. However, the nature of the mechanisms underlying this advantage remains to be clarified. Whereas some have put forward single process accounts to explain the superior performance of bilinguals relative to monolinguals in executive control tasks, recent findings have been interpreted by considering the dynamic combination of monitoring and inhibitory processes to overcome interference from distractor information. In the present study we explored this idea by comparing monolinguals and highly proficient bilinguals in the AX-CPT. This task requires individuals to adjust proactive (monitoring) and reactive (inhibition) control to achieve efficient performance. We also examined the extent to which a well-known index of inhibitory capacity, the stop-signal reaction time, predicts accuracy in the AX-CPT. Results showed that bilinguals outperformed monolinguals in the experimental condition where higher requirement of proactive-reactive control adjustment was required. Interestingly, the inhibition index predicted errors in this condition only in the sample of bilinguals. These findings suggest that a better understanding of the cognitive benefits of bilingualism may require consideration of how bilinguals adjust different executive control mechanisms to cope with interference.

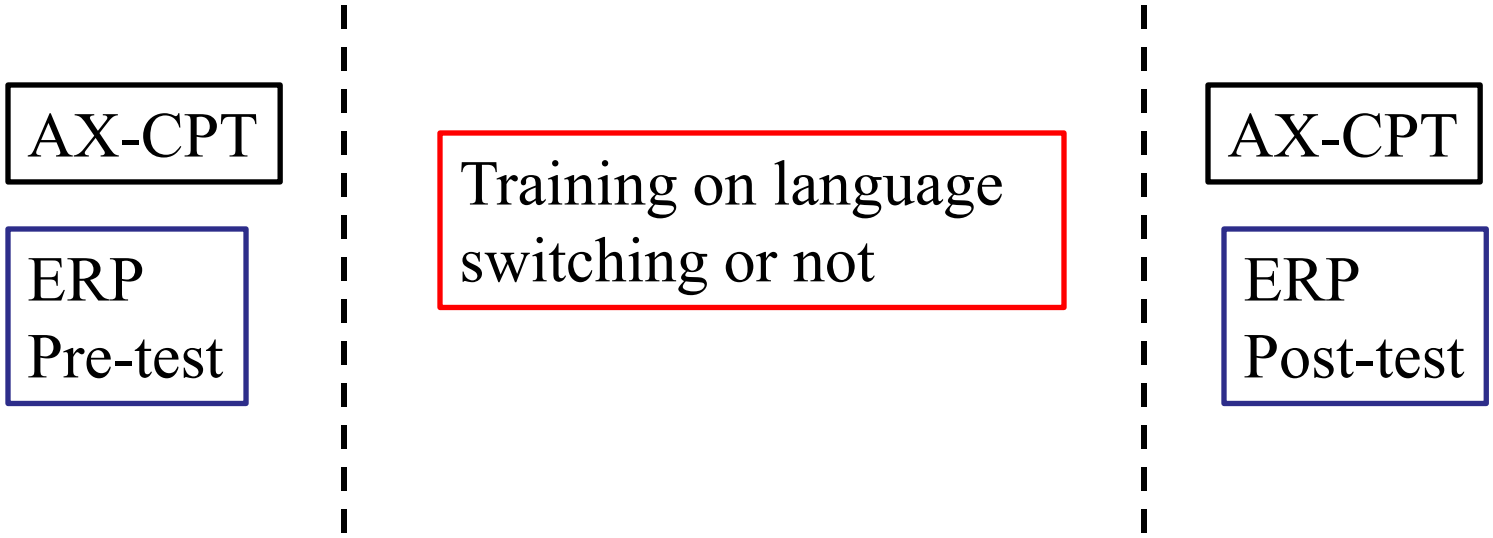


The claim here is that there isn't a simple effect of bilingualism on executive function but that bilingualism modulates the relation between components of EF.

356 NeuroReport 2015, Vol 26 No 6

Improving proactive control with training on language switching in bilinguals

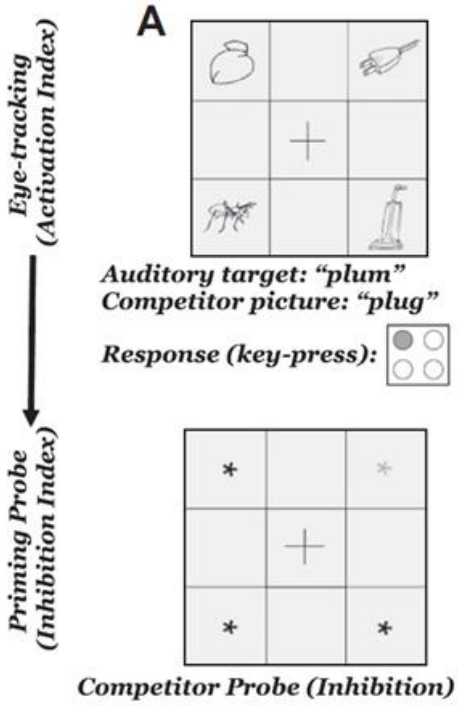
Haoyun Zhang[a], Chunyan Kang[a], Yanjing Wu[c], Fengyang Ma[d] and Taomei Guo[a,b]



Group trained on language switching showed a more proactive control mode in the post-test

4. Some of these control processes can be caught "on the fly" as language processing is ongoing and others are likely to reflect longer term consequences

Blumenfeld & Marian (2011): Visual World Paradigm: track eye movements



Induce phonological competition: "plum" vs. "plug" in the L1 only

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 whereas monolinguals are slower for the competitor position. This suggests that bilinguals eliminate inhibition more quickly than monolinguals.

Behavioral/Cognitive

Fast Modulation of Executive Function by Language Context in Bilinguals

Yan Jing Wu[1] and Guillaume Thierry[1,2]

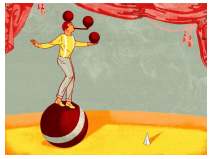
[1]School of Psychology and [2]Economic and Social Research Council Centre for Research on Bilingualism in Theory and Practice, Bangor University, Bangor LL57 2AS, United Kingdom

Mastering two languages has been associated with enhancement in human executive control, but previous studies of this phenomenon have exclusively relied on comparisons between bilingual and monolingual individuals. In the present study, we tested a single group of Welsh–English bilinguals engaged in a nonverbal conflict resolution task and manipulated language context by intermittently presenting words in Welsh, English, or both languages. Surprisingly, participants showed enhanced executive capacity to resolve interference when exposed to a mixed compared with a single language context, even though they ignored the irrelevant contextual words. This result was supported by greater response accuracy and reduced amplitude of the P300, an electrophysiological correlate of cognitive interference. Our findings introduce a new level of plasticity in bilingual executive control dependent on fast changing language context rather than long-term language experience.

5. Not all bilingual experience produces the same consequences.

The use of two languages may impose processing demands that create distinct profiles of bilingual cognition. Different forms of bilingualism may have the consequence of differentially tuning the neural networks that support language use (e.g., Green & Abutalebi, 2013). Some bilinguals code switch frequently and others not at all. Some languages share similar form and others to do not. But in all cases, bilinguals must potentially negotiate a higher level of competition in their everyday use of language than monolinguals.

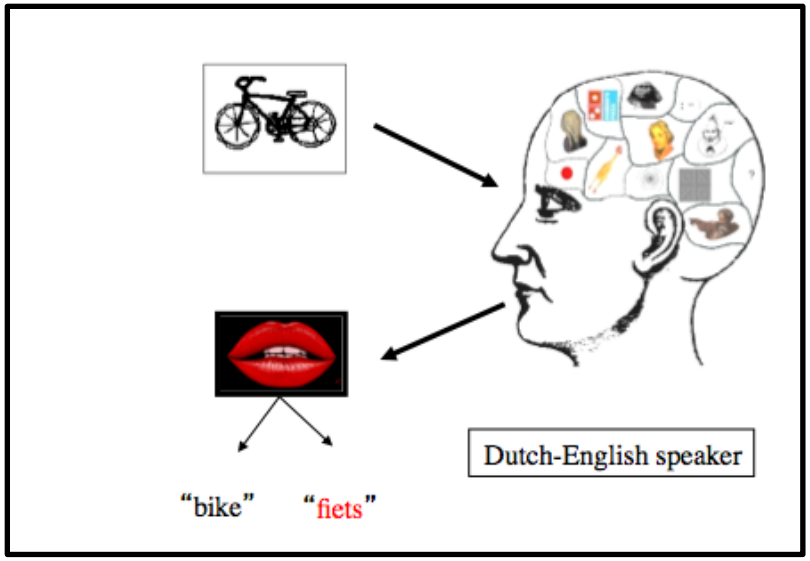
The ability to acquire these regulatory mechanisms and to use them to effectively control the L1 may be a crucial component of successful L2 learning.



Bilinguals use language in many different ways:

- They read and listen to ambiguous words in both languages.
- They select words to speak.
- They resolve syntactic ambiguities within and across languages.
- They code switch from one language to the other.
- They may live in an environment in which everyone is similarly bilingual or where only few are similarly bilingual
- They engage in dialogue with speakers who vary in whether they are monolingual or bilingual.

But some argue that speaking is the critical language processing task. When you speak two languages you must choose between them before you utter a single word and it is that selection mechanism that has been hypothesized that appears most closely related to the observed cognitive consequences of bilingualism.



Bilinguals are continuously selecting the language to speak in even the simplest language production tasks. But some bilinguals don't have to choose: see Emmorey et al. (2008) on bimodal bilinguals.

And the control processes that are engaged during language comprehension and language production may differ:

In spoken production, there appear to be both local and global processes of inhibitory control with some short lived and others extended in time course and scope (e.g., Van Assche et al., 2013) and with support from different neural networks (e.g., Guo et al., 2011)

In comprehension, there may be inhibitory effects that are resolved quickly but that also reveal the consequences of bilingual language experience (e.g., Blumenfeld & Marian, 2011; Martín et al. , 2010).

Why should the cognitive and neural consequences of these language processes be the same?

And there is much that is missing:

The evidence on crib bilinguals whose tuning to the presence of two spoken languages appears to have remarkable effects. If the "bilingual effect" is due only to the consequences of selecting the language to speak, then we might not expect to see differences between bilingual and monolingual-exposed babies because babies do not speak.

Kovacs & Mehler (2009): Bilingually exposed 7 month old babies can exploit a cue to anticipate a switch of attention!

Weikum et al. (2007): Infants as early as 4 months can discriminate languages from different rhythmical classes (English vs. French) by **watching silent talking faces.**

But the amazing result is that not only French-English crib bilinguals can do this but also Catalan-Spanish crib bilinguals who have not been exposed to French and English! (Sebastián-Gallés et al., 2012)

These are different consequences of bilingualism.

Among the goals for the next stage of research, we need:

- An adequate characterization of bilingualism (and multilingualism).
  - How bilingual does a person need to be? Luk & Bialystok (2013): *Bilingualism is not a categorical variable!*
  - What is the role of the context and availability of support or lack of support for bilingualism? Whether a person speaks a majority or minority language? Whether the bilingual is a heritage speaker?
  - Does age of acquisition really matter or only proficiency? And is the answer to that question the same for all the language tasks the bilingual performs?
  - Sufficient attention to variability within monolingual groups: **Not all monolinguals are the same** (see Pakulak & Neville, 2010: even native speakers of a language differ in their proficiency)
- An account of the consequences of bilingualism for new learning, not only for language processing and representation.

The bilingual may be a mental juggler but the science of how experience changes the brain and behavior is only beginning to identify the factors that may be required to provide a comprehensive account of bilingualism and its consequences.

The message is not that things are complicated (they are!) but that research on bilingualism holds enormous promise for revealing fundamental principles about cognition and its neural basis.

We would know none of this if we studied monolinguals only. The implications are not just for our interest and curiosity – they require a revision of the traditional stories about language development, about cognitive control, and about the plasticity associated with language experience.

Thank you!