The bilingual brain: an introduction to the cognitive neuroscience of bilingualism

Andrea Marini
Universita’ degli Studi di Udine
IRCCS “E. Medea”, Ass.ne “La Nostra Famiglia”
Landesfachhochschule für Gesundheitsberufe, Bozen

andrea.marini@uniud.it
Overview

- What does it mean to be bilingual?
- Effects of bilingualism on linguistic structures
- Effects of bilingualism on cognition
- Neuropsychology of bilingualism
- Neural correlates of bilingual competence
What does it mean to be bilingual?
Bilingualism: a widespread phenomenon

- 6912 official languages in 160 Countries

- More than 50% of the world’s population speaks at least two languages (de Hower, 1998; Tucker, 1998; Grosjean, 1982, 1994)
Bilingualism: a terminological problem
“Strong” interpretation

"In the extreme case of foreign language learning, the speaker becomes so proficient as to be undistinguished from the native speakers round him...In the case where this perfect foreign-language learning is not accompanied by loss of the native language, it results in bilingualism, (the) native-like control of two languages"

(Bloomfield, 1933)
However …

- How can we define abstract notions such as
  - “Balanced” bilingualism
  - “Ideal” bilingualism
  - “Perfect” bilingualism

- Do perfect bilinguals exist?

- We should rule out more than 90% of the world’s population!
Weak interpretations ...

Later on, the focus has been shifted on the modalities of acquisition and levels of proficiency in the languages mastered by an individual.
There are different ways to be bilingual
Age of Acquisition of an L2

- Simultaneous bilinguals
- Early sequential bilinguals
- Late sequential bilinguals
How about proficiency?

- Balanced bilinguals
- Dominant bilinguals

(Peel and Lambert, 1962)
Effect exerted by the L2 on L1

- Additive bilinguals
- Subtractive bilinguals

(Lambert 1974)
An operational definition of bilingual competence

Clinical Neurolinguistics
of Bilingualism
Andrea Marini, Cosimo Urgesi, and Franco Fabbro

Knowledge and use of two or more languages/
dialects independently from the age of acquisition
and the level proficiency
Understanding bilingualism: a multidisciplinary endeavor
Bilingualism: a multidisciplinary endeavour

- Linguistic level
  - Side effects of bilingualism on linguistic structures
  - Code switching/mixing "Pappa, vuoi come here a casa lunchen?"
  - Linguistic interference (e.g., borrowings vs. calchs)
  - Crosslinguistic factors (e.g., positive vs. negative transfer)
  - Interlanguage
Examples of Interlanguages
I.O. 0 months in Italy
Origin: Romania

L’acqua / mama / albero ... / bi- biscuot biscottini / ... bambini

Tempo: 100”
Li Li a few months in Italy
Origin: Cina

“Una bambino è è / lui papà vado a lago / .. prendi pesce / loro anda- andiamo andar andàno andàno casa / papà vuomo mangiar- mangiato pesce / quello bambino ... /pr pr ... ... loro loro va- viado vanno vano la- lago il lago / il lago meno meno pesce in lago”

Tempo: 61”
Florence 2 years in Italy
Origin: Ghana

D) Ti ricordi una cosa di scienze che hai studiato in Gana?

R) abbiamo studiato erba / come è erba / come quando c’è autunno / co come fai abbero / diventa tutto tutto caldo tutto i giorno pecché è autunno / quando c’è estate è diventato caldo / non c’è flesco / non c’è alia per dolmire bene / e ma però in Gana nostro tempo dov- c’è … / c’ha piove / e ha cado / come qui / ma pelò non c’è neve in Gana / a noi non facc facciamo troppo fredo / se no piove che noi facciamo fredo / …

Tempo: 30’
Understanding bilingualism: a multidisciplinary endeavour

- Linguistic level
- Teaching level

- How to teach a new L2 / foreign language?
  - e.g., influence of social contact and interactions on the process of linguistic acquisition
**Foreign-language exposure**

- **Live exposure**
- **Television exposure**

**Mandarin Chinese phonetic discrimination**

- **Live Chinese language intervention**
- **Television and audio-only Chinese language intervention**
- **Monolingually raised infants**

(Kuhl et al., 2003)
American infants (9 months)

Exposed to Spanish native speakers in 12 Spanish sessions

After 12 sessions → amplitude of MMN while hearing Spanish phonemic contrasts (/d/ - /t/) correlates with the children’s eye shifts from the eyes of the Spanish speaker to the toys used in the interaction

(Conboy et al., 2008)
Bilingualism: a multidisciplinary endeavour

- Linguistic level
- Teaching level
- Social level
- Cognitive level
Cognitive level

- Children exposed to one language learn it with apparent ease

- Bilinguals must face additional difficulties
  - Language discrimination
  - Derivation of syntactic rules for different languages
  - Acquisition of different lexicons
Nonetheless ...

- Bilinguals can acquire their languages with no delay (Werker, Byers-Heinlein, 2008; Yip, Matthews, 2007; Pearson et al., 1993; De Hower, 1990)

  - They utter their first words by 12 months
  - They can produce 50 words at the age of 18 months
How can they manage this?

- Hypothesis → the exposure to more than one language triggers the development of new abilities affecting:
  - auditory discrimination
  - learning from mixed inputs
  - generalization abilities
Better skills in auditory discrimination
Subcortical encoding of sound is enhanced in bilinguals and relates to executive function advantages

Jennifer Krizman\textsuperscript{a,b,c}, Viorica Marian\textsuperscript{b,c}, Anthony Shook\textsuperscript{b,c}, Erika Skoe\textsuperscript{a,c}, and Nina Krause\textsuperscript{a,c,d,e,f,1}

- **Type of study** → EEG (auditory brainstem response to complex sounds - cABR) and behavioral

- **Participants** → 48 freshmen (High School, Chicago)
  - 25 Monolinguals (52% fem.)
  - 23 Bilinguals Spanish-English (56.5% fem.)
  - Balanced for age (14 y.o.) and SES
Tasks

- EEG
- Auditory Continuous Performance test
EEG

- Subjects watched a movie while they were wearing a headphone
  - Left ear → free
  - Right ear → receives a series of /da/ (6.300 times)

- Two conditions
  - Quiet → only auditory stimuli (/da/)
  - Multitalker Babble → stimuli presented among other voices talking to each other (4 fem., 2 male)
Bilinguals ➔ Intense brainstem response
Higher response to /da/ (F₀=100Hz)
Better auditory sustained selective attention

![Bar graph showing improved auditory sustained selective attention for bilinguals compared to monolinguals.](image)
Better auditory sustained selective attention correlates with F₀ amplitude in the babble condition

\[ r = 0.442 \]
\[ p = 0.0002 \]
Better skills in learning from mixed inputs and in generalizing rules
Study → Eye-tracking

Subjects → Preverbal infants (12 months): bilinguals vs. monolinguals

Task → Listen to novel trisyllabic sequences while staring at a monitor

Stimuli → Trisyllabic clusters of two kinds: ABA vs. AAB

Note → AAB perceptually easier
Two conditions

- Familiarization to the task
- Experimental condition
Familiarization
Experiment

Note → stimuli are different from the familiarization condition
Results

Conclusions → Advantage for bilinguals in learning new auditory-visual associations
Bridging language and attention: Brain basis of the impact of bilingualism on cognitive control

- Type of study → fMRI

- Participants
  - 19 bilinguals (spanish-catalan)
  - 21 monolingual (spanish)

- Tasks → non verbal switching paradigm
Bridging language and attention: Brain basis of the impact of bilingualism on cognitive control

Fig. 1. Stimuli and task Conditions. Switching and Non-switch conditions: a “switch” event was defined as the condition of changing the set to be used in order to answer the upcoming stimulus in relation to the previous one (shape–color or color–shape trials). Coherently, a “non-switch” event was assumed to happen when the subject answered the upcoming stimulus with the same set as the previous one (shape–shape or color–color).
Bridging language and attention: Brain basis of the impact of bilingualism on cognitive control

Impact of early **second**-language acquisition on the development of first language and verbal short-term and working memory

Andrea Marini\textsuperscript{a,b}, Nadezda Eliseeva\textsuperscript{a} and Franco Fabbro\textsuperscript{b,c}

\textbf{Table 4.} Mean (standard deviations) and ranges of the performance of the two groups of participants on tasks assessing their linguistic comprehension skills in Italian.

<table>
<thead>
<tr>
<th>Linguistic comprehension</th>
<th>Monolingual school</th>
<th>Bilingual school</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lexical comprehension*</td>
<td>15.32 (1.14) – Range: 13–18</td>
<td>14.48 (1.48) – Range: 11–17</td>
</tr>
<tr>
<td>Grammatical comprehension</td>
<td>29.58 (5.33) – Range: 10–37</td>
<td>29.10 (7.73) – Range: 10–37</td>
</tr>
</tbody>
</table>

\textit{Note:} The asterisk (*) shows when the group-related differences were significant after Bonferroni correction for multiple comparisons ($p < .017$).
### Delaying the onset of Alzheimer disease

**Bilingualism as a form of cognitive reserve**

---

**Table**  
Mean value (SD) for descriptors for each language group

<table>
<thead>
<tr>
<th>Language group</th>
<th>No.</th>
<th>Age at onset, y&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Age at first appointment, y&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Duration, y&lt;sup&gt;c&lt;/sup&gt;</th>
<th>MMSE&lt;sup&gt;d&lt;/sup&gt; at first appointment</th>
<th>Years of education</th>
<th>Occupation status&lt;sup&gt;e&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monolingual</td>
<td>109</td>
<td>72.6 (10.0)</td>
<td>76.5 (10.0)</td>
<td>3.8 (2.9)</td>
<td>21.5 (5.7)</td>
<td>12.6 (4.1)</td>
<td>2.8 (1.3)</td>
</tr>
<tr>
<td>Men</td>
<td>49</td>
<td>73.3 (9.4)</td>
<td>77.3 (8.9)</td>
<td>3.9 (2.9)</td>
<td>22.1 (5.7)</td>
<td>13.2 (4.4)</td>
<td>3.2 (1.0)</td>
</tr>
<tr>
<td>Women</td>
<td>60</td>
<td>72.1 (10.4)</td>
<td>75.9 (10.8)</td>
<td>3.7 (2.9)</td>
<td>21.0 (5.7)</td>
<td>12.0 (3.8)</td>
<td>2.5 (1.3)</td>
</tr>
<tr>
<td>Bilingual</td>
<td>102</td>
<td>77.7 (7.9)</td>
<td>80.8 (7.7)</td>
<td>3.1 (1.9)</td>
<td>20.4 (5.6)</td>
<td>10.6 (5.1)</td>
<td>2.5 (1.1)</td>
</tr>
<tr>
<td>Men</td>
<td>42</td>
<td>77.6 (7.8)</td>
<td>80.4 (7.8)</td>
<td>2.8 (1.8)</td>
<td>21.0 (4.8)</td>
<td>11.1 (6.1)</td>
<td>3.0 (0.9)</td>
</tr>
<tr>
<td>Women</td>
<td>60</td>
<td>77.8 (8.1)</td>
<td>81.1 (7.6)</td>
<td>3.3 (1.9)</td>
<td>20.0 (6.0)</td>
<td>10.3 (4.3)</td>
<td>2.2 (1.2)</td>
</tr>
</tbody>
</table>

**Abbreviation:** MMSE = Mini-Mental State Examination.

- **a** Age at which symptoms were first reported by family.
- **b** Age at first visit to clinic.
- **c** Duration of elapsed time between <sup>a</sup> and <sup>b</sup>.
- **d** Scores out of 30.
- **e** Based on 4-point scale developed by Human Resources and Skills Development, Canada, in which higher numbers signify higher status.
Understanding bilingualism: a multidisciplinary endeavour

- Linguistic level
- Teaching level
- Social level
- Cognitive level
- Psycholinguistic level
- Neurolinguistic level
How are represented the languages in a bilingual brain?

- Contributes from Neuropsychology
- Contributes from Cognitive Psychology
- Contributes from Cognitive Neuroscience
Contributes from Neuropsychology

Bilingual aphasic patients have heterogeneous symptoms
Types of linguistic recovery in bilingual patients (Paradis, 1977)

- Parallel recovery (40% - 60% of cases [Paradis, 2001; Fabbro, 1999; Paradis, 1977])

- Differential recovery (~ 18% of cases, [Paradis, 2001])

- Successive recovery (~ 5% of cases)

- Selective recovery (~ 7% of cases) (Paradis, 1977; Fabbro, 1996)

- Mixed recovery (~ 9% of cases)

- Antagonistic recovery (Nilipour e Ashayeri, 1989; Paradis, Goldblum e Abidi, 1982)
Clinical features of linguistic impairments in bilinguals
Pathological switch

Pathological mix

Deficits of translation
- *Inability to translate* (L1 > L2; L2 > L1)
- *Spontaneous translation*
- *Translation without comprehension*
- *Paradoxical translation*
But... what does this mean?

There is a relationship between brain injuries and bilingual processing

1. What neural networks are engaged in our ability to acquire and master one or more languages?

2. Why do bilingual patients loose or regain access to their languages in such different ways?
Contributions of Cognitive Psychology
What are the cognitive factors behind language acquisition and use?
Factors potentially affecting the neurocognitive organization of languages

- Age of Acquisition
- Proficiency
- Motivation
- Level of exposure to a language
- Learning modalities
Contributions of Cognitive neuroscience
Neural underpinnings of language processing in bilingual individuals
Study → TBI (single case description of bilingual patient)

- Subject: Alex (23 y.o., in Italy since 7 y.o.)
  - L1 Romanian
  - L2 Italian
- Proficiency → High in both languages
CT Scan (April 12, 2009)
CT Scan (July 13, 2009)
CT Scan (August 8, 2009)
MRI Scan (2013)
fMRI: Verb generation task

Italian

Romenian

Cluster of activation in the right middle temporal gyrus (MTG; BA 22)
Neural underpinnings of language processing in bilinguals
Early Setting of Grammatical Processing in the Bilingual Brain

Study: fMRI

Subjects: 32 bilinguals (L1 Italian; L2 German)
- 11 EAHP (exposed to L1 and L2 since birth)
- 12 LAHP (L2 > 6 y.o.)
- 9 LALP (L2 > 6 y.o.)

Tasks
- Grammatical judgement
- Semantic judgement

Neuron, Vol. 37, 159–170, January 9, 2003,
Behavioural results
- Proficiency levels in the 2 languages -

- EAHP = LAHP
- LALP < EAHP
- LALP < LAHP
Early bilinguals use for both languages the same areas.

Late Bilinguals for grammatical tasks in L2 use wider areas in Left Inferior Frontal Gyrus and in Left Parietal lobe.
Semantic Judgement

- LAHP = EAHP → No effect of Age of Acquisition
- LAHP vs. LALP → Strong effect of proficiency
Structural plasticity in the bilingual brain

(Mechelli et al., 2004)
Bilingualism: consequences for mind and brain

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

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.

Trends in Cognitive Sciences   April 2012, Vol. 16, No. 4
Conclusions
Thanks for your attention!!!