Contributions of Memory Brain Systems to First and Second Language

Michael T. Ullman

Departments of Neuroscience, Linguistics, Psychology and Neurology

Georgetown University

michael@georgetown.edu

Collaborators and Funders

Georgetown

Claudia Bonin
Harriet Bowden
Claudia Brovetto
Helen Carpenter
Jocelyn Curchack
John Drury
Ivy Estabrooke
Joshua Hartshorne
Sarah Lee
Christopher Maloof
Matthew Moffa
Kara Morgan-Short
Kaori Ozawa
Elizabeth Prado
Cristina Sanz
Matthew Walenski
Robbin Wood

MIT

Suzanne Corkin
Joseph Locascio

Harvard/MGH

John Growdon
Walter Koroshetz
Steven Pinker
Jeremy Schmahmann

Other

Stefano Cappa (Milan, Italy)
Myrna Gopnik (McGill; emeritus)
Greg Hickok (UC Irvine)
Tracy Love (UC San Diego)
Helen Neville (Univ of Oregon)
Aaron Newman (Dalhousie)
Elizabeth Pierpont (U. Wisconsin)
Karsten Steinhauer (McGill)
David Swinney (UC San Diego)
Heather van der Lely (London)

Funding

NIH: R01 MH58189; R01 HD049347; R03 HD050671
NSF: SBR-9905273; BCS-0519133; BCS-0001961
Defense: DAMD-17-93-V-3018/3019/3020, DAMD-17-99-2-9007
McDonnell Foundation
National Alliance for Autism Research
Mabel Flory Trust
Pfizer, Inc.

Learning an L2 is Hard

Late learners do not usually attain native-like levels

***But* some aspects of L2 easier to learn than others**

- **Relatively easy:**
  - learning words
- **Difficult:** not just pronunciation, but also
  - grammar (morphology, syntax)

Nevertheless, evidence suggests that native-like abilities in L2 *can* indeed be attained, even for grammar
(Birdsong, 1999; Doughty and Long, 2003; Ullman, 2001b, 2005)

Some Questions

- Why is L2 learning hard?

- Why might word-learning be easier than grammar?

- What are the neurocognitive underpinnings of L2 learning and processing?

- Do these differ for learning words and grammar?

- Do they differ for achieving low and high proficiency?

- Can we manipulate the biology or cognition of L2 learning to improve L2 proficiency?

A Neurocognitive Approach

1. Consider data, theory, and methods from:
   - Study of L1 (linguistic theory, psycholinguistics)
   - Cognitive neuroscience and related fields (eg, genetics)
   - Second Language Acquisition (SLA)

2. Develop and test L2 hypotheses based on findings and theories from across these fields

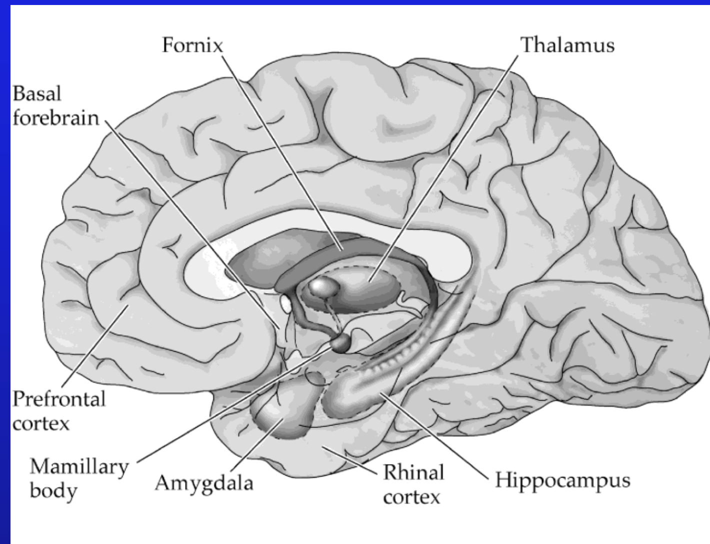
Neurocognitive Theories of L2

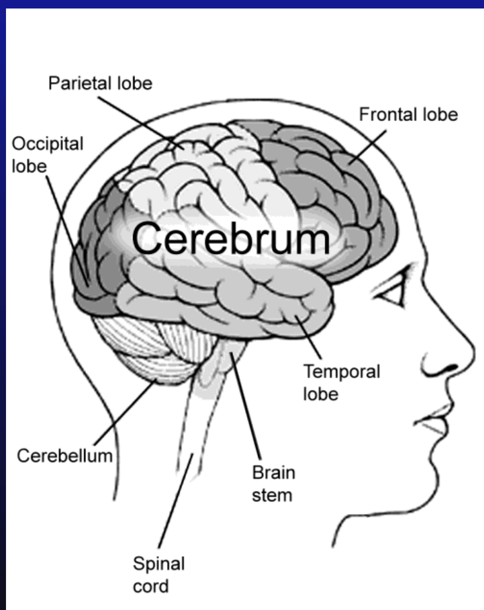
- **Paradis**
- **MacWhinney**
- **Friederici**
- **Ellis**
- **Clahsen**

- **Declarative/Procedural Theory** (Ullman et al., 1997; Ullman, 2001a,2001b, 2004, 2005)
  - **Takes into account data, theory and methods from across disciplines**
  - **Focuses on the dependence of language on well-studied brain systems**

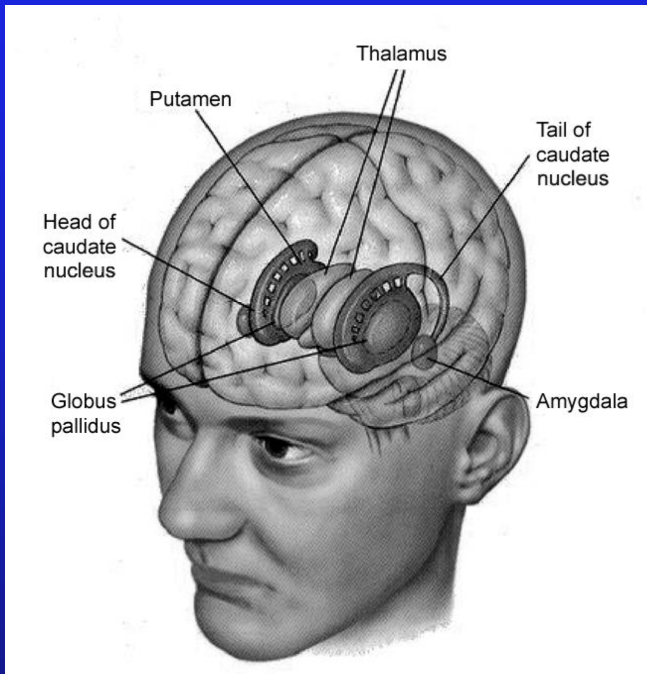
Declarative Memory System

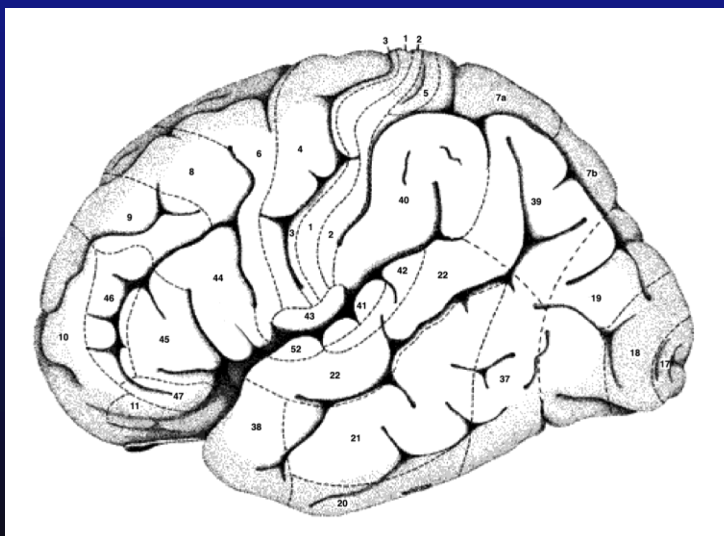
- Learning & processing of facts, events
- Specialized for arbitrary relations
- Explicit and implicit knowledge
- Medial & lateral temporal-lobe; frontal regions (BA 45/BA 47, BA 10)
- Modulated by estrogen, acetylcholine
- Genes: BDNF, possibly others





Procedural Memory System





- Learning & control of cognitive and motor “skills” (e.g., riding a bicycle)
- Specialized for sequences
- Implicit knowledge
- Left frontal (BA 44/premotor)-basal ganglia circuits; superior temporal cortex
- Modulated by dopamine
- Genes: possibly DAT, others

First Language (L1)

Declarative/Procedural Theory

Declarative memory system

Procedural memory system

Lexicon

Memory store: ***(at least)***
all word-specific information:
-simple words (cat)
-irregulars: (dig-dug)
-complements (hit [direct object])

Language

Grammar

Rule-governed hierarchical and
sequential (de-)composition
of complex forms:
-syntax (the cat; NP VP)
-morphology (regulars: walk -ed)

Empirical Evidence

1. **Psycholinguistic**
   - **Frequency effects**
   - **Similarity (neighborhood) effects**
   - **Imageability Effects**
   - **Priming effects**
   - **Working memory effects**

2. **Neurological**
   - **Aphasia (anterior aphasia, posterior aphasia)**
   - **Neurodegenerative disease (AD, PD, HD)**
   - **Developmental disorders (SLI, autism, other)**

3. **Neuroimaging**
   - **Electrophysiological: ERP**
   - **Hemodynamic: fMRI, PET**

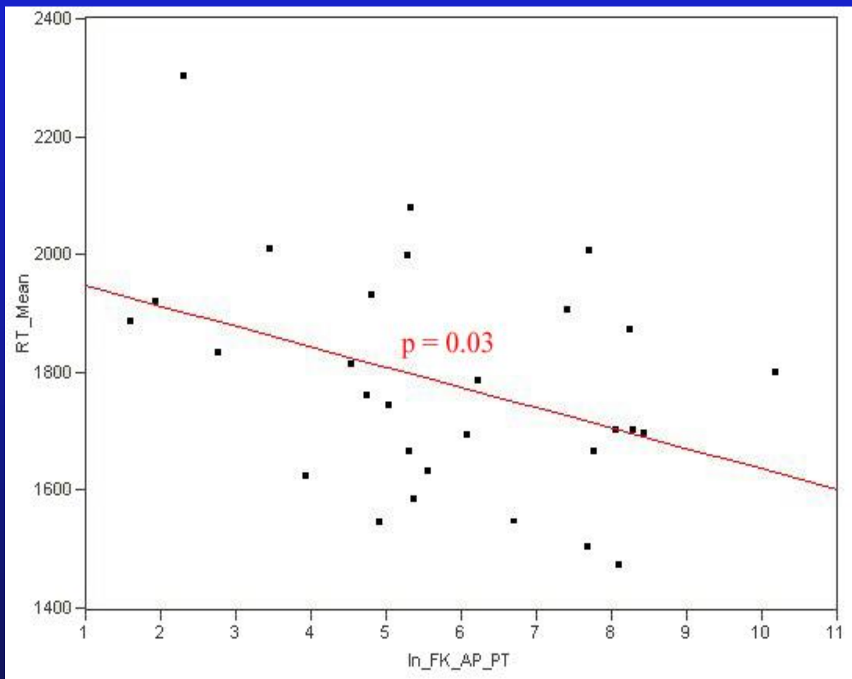
4. **Molecular**

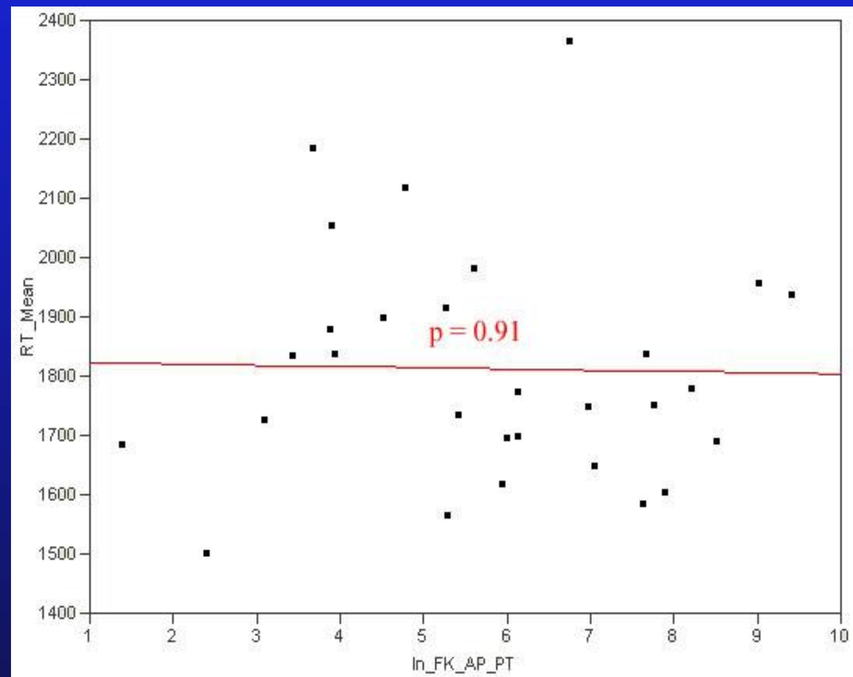
First Language

Psycholinguistic

Frequency effects:

- **Irregulars:** Consistent frequency effects
- **Regulars:** No consistent frequency effects





Evidence Suggests:

- **Irregulars:** Retrieved from memory
- **Regulars:** Can be (de)composed in real time to/from their parts

Neurological: Aphasia

Posterior Aphasia

Lesions: Left temporal regions

Behavior:

- Impaired at content words, conceptual knowledge, irregulars
- No agrammatism, no difficulty with regulars, no motor problems

Anterior Aphasia

Lesions: Left inferior frontal and basal ganglia structures

Behavior:

- Agrammatism, problems with regulars, motor deficits
- Relative sparing of content words, irregulars, conceptual knowledge

Compensation: Storage of complex forms (eg, walked) in lexical memory

(Goodglass, 1993; Alexander, 1997; Ullman, et al., 1997; Ullman, Pancheva, et al., in press)

Neurodegenerative Diseases

Alzheimer's Disease

Degeneration: Temporal > frontal (Broca's/premotor)/basal-ganglia
Behavior:
- Impaired at learning new, using old content words, facts, irregulars
- Sparing of motor & cognitive skills, regulars, maybe syntax

(Arnold et al., '91; Beatty et al., '94; Nebes, '97; Ullman et al., '97; Ullman, '99; Ullman, in press; Walenski et al., under revis.)

Parkinson's Disease

Degeneration: Primarily frontal/basal-ganglia
Behavior:
- Impaired at motor & cognitive skills, syntax, regulars
- Relatively spared: learning new, using old content words, facts, irregulars

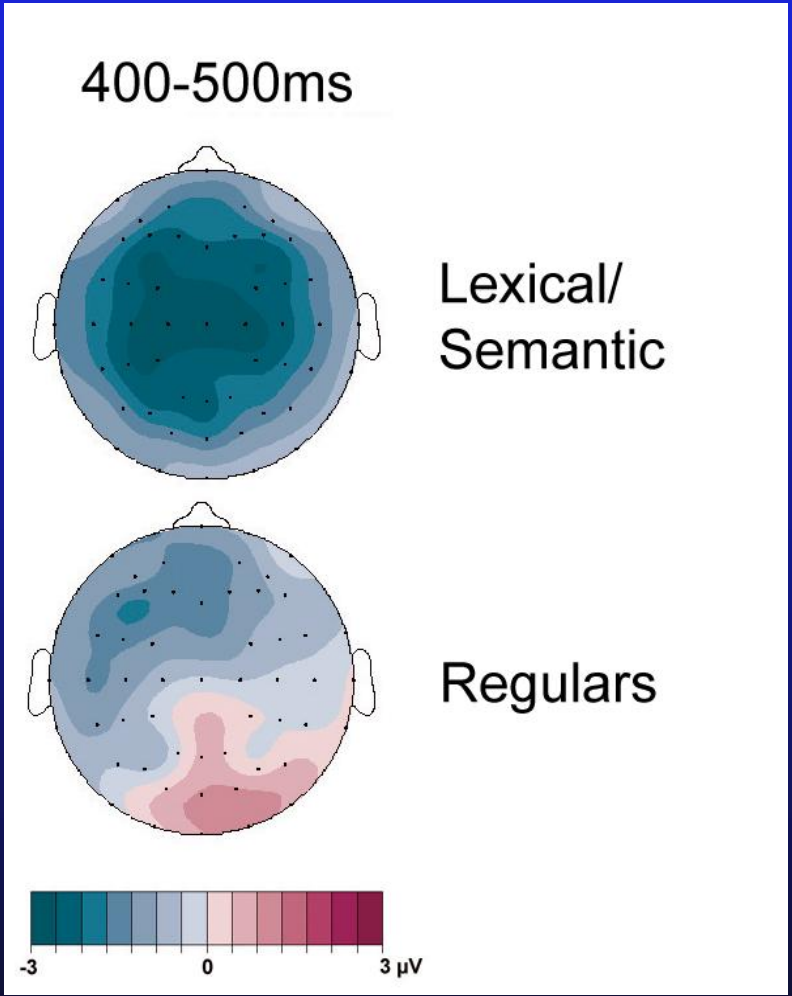
(Dubois et al., '91; Lieberman et al., '92; Young & Penney, '93; Ullman et al., 1997; ; Ullman, 1999; Ullman, in press; Estabrooke & Ullman, in prep.)

Event-Related Potentials (ERPs)

ERPs are the EEGs following stimuli (e.g., words).

<u>Lexical/Semantic</u> processing:
- Central Negativity (N400)
  - Temporal lobe

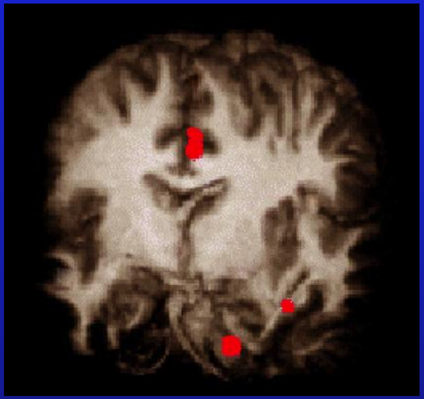
<u>Grammar</u> processing difficulties:
- Left Anterior Negativity (LAN)
  - Left frontal
- Central/posterior positivity (P600)
  - Basal ganglia

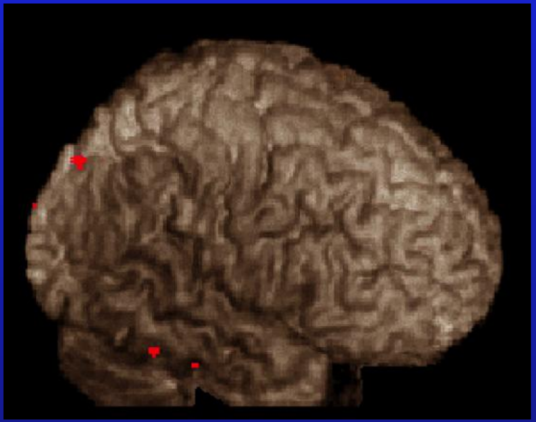


(Friederici et al. 1993, 1996, 1998; Kutas & Hillyard, 1980; Neville et al., 1991; Kotz et al., 2003; Osterhout & Holcomb, 1992)

Hemodynamic Neuroimaging: fMRI, PET

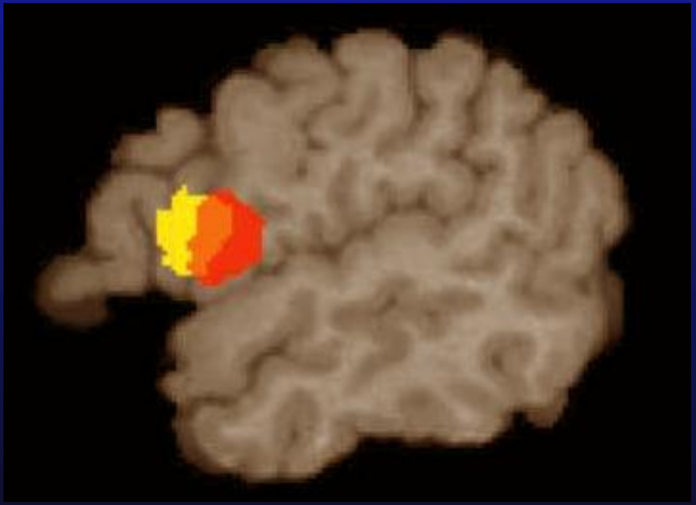
- Measure changes in blood oxygenation/flow in the brain.
- Changes correlate with changes in neural activity.





Lexical processing:

- Temporal lobe regions; BA 45/47 for retrieval



Grammatical processing:

- Broca's (especially BA 44); the basal ganglia; superior/anterior temporal cortex

(Damasio et al., 1996; Embick et al., 2000; Indefrey et al. 1999; Moro et al., 2001; Newman et al., 2001; Ni et al., 2000; Stromswold et a. 1996; Friederici, 2002, 2004)

Data Suggests That in L1

Language	Lexicon	Grammar
Computation	Associative memory	Rule-governed composition
Brain Systems	Declarative Memory	Procedural Memory
Non-Language	Facts, Events	Motor, Cognitive skills
Specialized for	Arbitrary relations	Sequences
Anatomy	Medial & lateral temporal cortex; BA 45/47, BA 10	Left BA 44/premotor-basal ganglia circuits; superior temporal
Molecular	Estrogen; acetylcholine	Dopamine
Genetic	BDNF	DAT?

(for reviews and discussion, see Ullman et al., 1997; Ullman, 2001a, b, 2004, 2005; Ullman & Pierpont 2005)

Late-Learned
Second Language (L2)

Declarative/Procedural Theory: Low L2 Experience

Declarative memory system	Procedural memory system

Language

Lexical/Declarative Memory

- -All word-specific information
- -Stored complex structures (walked)
- -Declarative memory based rules

Grammar

Little or nothing learned and processed here

Declarative/Procedural Theory: High L2 Experience (L1-Like)

Declarative memory system

Procedural memory system

Lexicon

Memory store: (*at least*)
all word-specific information:
-simple words (cat)
-irregulars: (dig-dug)
-complements (hit [direct object])

Language

Grammar

Rule-governed hierarchical and sequential (de-)composition of complex forms:
-syntax (the cat; NP VP)
-morphology (regulars: walk -ed)

Frequency Effects

Lower L2 experience (Brovetto and Ullman, 2001)

- Subjects: L2 Learners of English (mean of 6 years exposure)
- Results: Frequency effects for irregulars *and* regulars
- Suggests: Irregulars and regulars *both* stored

Higher L2 experience (Birdsong and Flege, 2001)

- Subjects: L2 Learners of English (10 to 16 years of exposure)
- Results: Frequency effects for irregulars but *not* regulars (L1-like)
- Suggests: Irregulars stored, *not* regulars (i.e., like in L1)

Neurological: Focal lesions, Alzheimer's & Parkinson's

Temporal-lobe damage (herpes simplex, Alzheimer's)

- L2 worse than L1, including syntax

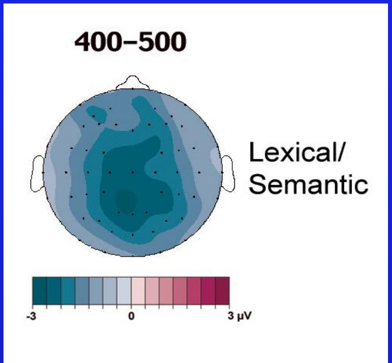
Frontal or basal-ganglia damage (left focal lesions, Parkinson's)

- Grammar: L1 *and* highly-practiced L2 worse than less-practiced L2
- Lexicon: No L1/L2 difference

(Ku, Lachmann, & Nagler, 1996; Fabbro & Paradis, 1995; Ullman, 2001c; Zanini et al, 2004)

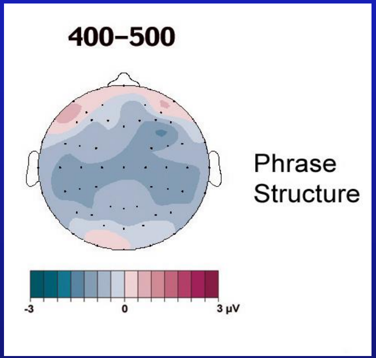
Event-Related Potentials

Lexical/semantic processing

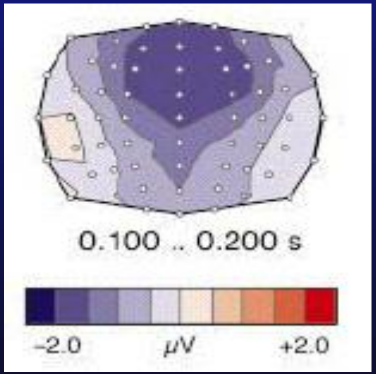


- Low *and* high proficiency L2:
  - N400s present

Grammatical processing



- Lower proficiency L2:
  - No LANs; sometimes N400-like negativities
  - P600s generally present
- Higher proficiency L2:
  - LANs (including in artificial language)
  - P600s



(Webber-Fox and Neville, 1996, 1999; Osterhout & McLaughlin, 2000; Hahne, 2000, 2001; Hahne and Friederici, 2001; Friederici, Steinhauer & Pfeifer, 2002)

Hemodynamic Neuroimaging

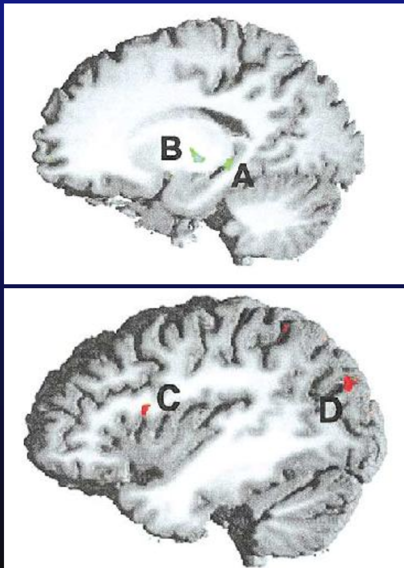
Lexical/semantic processing tasks:

- No L1/L2 differences in activation patterns
  (Chee et al 1999; Illes et al 1999; Klein et al 1999; Pillai et al 2003)
- Minimal L1/L2 differences (likely reflecting articulation, retrieval)
  (Klein et al 1995; Chee et al 2001; De Blesser et al 2003)

Sentence (syntactic) processing tasks:

- Greater activation in declarative memory structures in L2 than L1 – especially in lower proficiency L2 learners
  (Perani et al 1996; Perani et al 1998, Exp 1; Dehaene et al 1997; Opitz & Friederuci, 2002; Wartenburger et al 2003; Exp 1)

- Greater activation in procedural memory structures (left BA 44) in L2 than L1 - but only in higher proficiency L2 learners
  (Wartenburger et al 2003, Exp 2; Ruschemeyer et al 2005; Opitz & Friederuci, 2002)



- Artificial language learning, within-subjects (Opitz and Friederici, 2002)
  - low-proficiency: medial and lateral temporal activation
  - high-proficiency: activation in left BA 44

Overall Summary: L1 and L2

1. **Linguistic representations with arbitrary relations:**
   - *Always* seem to be stored in lexical/declarative memory – in L1 & L2.

2. **Rule-governed complex representations**:
   - **In L1, and in high experience L2:**
     Generally put together by the grammatical/procedural system
   - **In lower experience L2:**
     Depend largely on lexical/declarative memory

Current & Future Directions

- **Individual differences in L2 learning:**
  - sex differences, age, handedness, genotype, etc.

- **Improving L2 learning:**
  - selecting high-aptitude individuals
  - learning-context and pharmacological manipulations