Contributions of Memory Brain Systems to First and Second Language

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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

  - 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

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

Procedural memory system

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
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

(Please refer to specific studies for detailed information.)

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

(Please refer to specific studies for detailed information.)
Event-Related Potentials (ERPs)

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

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

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

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 al. 1996; Friederici, 2002, 2004)
### Data Suggests That in L1

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

(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

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

Procedural memory system

Language

Grammar

Little or nothing learned and processed here
Declarative/Procedural Theory: High L2 Experience (L1-Like)

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

Procedural memory system
- 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

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

Second Language

Hemodynamic Neuroimaging

Lexical/semantic processing tasks:
- No L1/L2 differences in activation patterns
- 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
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