Grammatical gender and age of onset in bilingualism: an EEG study

Monika S. Schmid¹, Sanne M. Berends², Christopher Bergmann², Susanne Brouwer³, Nienke Meulman², Bregtje Seton², Simone Sprenger² & Laurie A. Stowe²

¹University of Essex, ²University of Groningen, ³Utrecht University
BILINGUALS vs. MONOLINGUALS

Bilinguals differ from monolinguals in that
- they have a larger repertoire => slower
- they have a large amount of similar/competing information => crosslinguistic influence
- cognitive limitations (WM, executive control, in particular under time pressure, distractions, cognitive demands) => more instances of imperfect application/realisation of underlying knowledge (e.g. Prévost & White 2000)

- these effects are uncontroversial
- they affect both attriters and L2ers
ULTIMATE ATTAINMENT IN LATE LEARNERS

some researchers assume that

- language learning is maturationally constrained
- some grammatical features cannot be acquired after puberty (or earlier?), unless preinstantiated by L1
- in such cases, L2 learners have to rely on compensatory (non-grammatical) strategies (e.g. Hawkins & Chan 1997, Hawkins & Hattori 2006)

➤ these effects are highly contested
➤ if they do exist, they affect only L2ers but not attriters
ULTIMATE ATTAINMENT IN ATTRITERS

• the age effect in L1 attrition is underexplored
• there are indications that age plays an important role
  • young attriters (incomplete learners?) are more similar to L2ers
  • older attriters are more similar to (monolingual natives)

➢ what does this tell us about AoA in bilingualism?
IS L1 KNOWLEDGE MORE ‘STABLE’?

if a speaker knows two languages
• language X, which has grammatical feature A
• language Y, which does not have grammatical feature A

what is the impact of the sequence of acquisition?
➢ if X is L1 and Y is L2, is A susceptible to attrition?
➢ if X is L2 and Y is L1, is A blocked by its absence in Y?
➢ what happens if both languages are of type X?
GRAMMATICAL GENDER

• acquired early in (monolingual) first language acquisition
• one of the most persistently problematic grammatical features in SLA
• very little is known about gender in L1 attrition
• gender has often been the focus of the debate on maturational constraints
GRAMMATICAL GENDER IN GERMAN

Every noun has a gender, and there is no sense or system in the distribution; so the gender of each must be learned separately and by heart. There is no other way. To do this one has to have a memory like a memorandum-book. In German, a young lady has no sex, while a turnip has. Think what overwrought reverence that shows for the turnip, and what callous disrespect for the girl.
(Mark Twain, *The Awful German Language*)
GRAMMATICAL GENDER IN GERMAN

• German has a three-way gender system (masc, fem, neut)
• gender is largely opaque
• gender is marked on determiners, adjectives, quantifiers, (anaphoric) pronouns etc.
• gender is acquired early by children (more or less targetlike by age 2–3)
• gender is persistently difficult in L2 acquisition
  ➢ do attriters and L2ers process gender similarly?
GRAMMATICAL GENDER IN DUTCH

• Dutch has a two-way gender system (com, neut)
• gender is largely opaque
• gender is minimally marked on determiners, adjectives, quantifiers, (anaphoric) pronouns etc.
• gender is acquired later by children than in German (targetlike by age 6)
• gender is persistently difficult in L2 acquisition

➢ do attriters and L2ers process gender similarly?
PROCESSING OF GERMAN/DUTCH GENDER IN L1A AND SLA

• advanced L2 learners of German/Dutch with different linguistic backgrounds:
  ➢ languages which do encode gender (Slavic languages)
  ➢ languages which do not encode gender (Persian, Turkish, Chinese, Hungarian, Estonian, Finnish)
• different age at onset groups:
  ➢ “early” learners (7–16)
  ➢ “late” learners (18+)
• late L1 attriters of German/Dutch in an English language setting
• predominantly monolingual controls
## PARTICIPANTS GERMAN EXPERIMENT

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>L1</th>
<th>L2</th>
<th>Age</th>
<th>AoA</th>
<th>LOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>monolinguals</td>
<td>29</td>
<td>German</td>
<td></td>
<td>38(22–58)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1 attriters</td>
<td>24</td>
<td>German</td>
<td>English</td>
<td>44(29–65)</td>
<td>26(14–47)</td>
<td>16(7–32)</td>
</tr>
<tr>
<td>‘early’ L2ers</td>
<td>26</td>
<td>+gen</td>
<td>German</td>
<td>24(18–33)</td>
<td>11(7–16)</td>
<td>14(7–24)</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>−gen</td>
<td>German</td>
<td>27(20–45)</td>
<td>12(7–16)</td>
<td>15(8–36)</td>
</tr>
<tr>
<td>‘late’ L2ers</td>
<td>40</td>
<td>+gen</td>
<td>German</td>
<td>32(24–53)</td>
<td>22(17–36)</td>
<td>10(4–25)</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>−gen</td>
<td>German</td>
<td>33(24–52)</td>
<td>23(19–37)</td>
<td>11(5–27)</td>
</tr>
</tbody>
</table>
## PARTICIPANTS DUTCH EXPERIMENT

<table>
<thead>
<tr>
<th>Category</th>
<th>n</th>
<th>L1</th>
<th>L2</th>
<th>Age</th>
<th>AoA</th>
<th>LOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>monolinguals</td>
<td>43</td>
<td>Dutch</td>
<td></td>
<td>42 (22–58)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>early attriters</td>
<td>13</td>
<td>Dutch</td>
<td>English</td>
<td>46 (19–63)</td>
<td>9 (5–12)</td>
<td>37 (10–56)</td>
</tr>
<tr>
<td>late attriters</td>
<td>37</td>
<td>Dutch</td>
<td>English</td>
<td>48 (23–67)</td>
<td>27 (17–48)</td>
<td>21 (5–47)</td>
</tr>
<tr>
<td>late L2ers</td>
<td>23</td>
<td>+gen</td>
<td>Dutch</td>
<td>36 (24–62)</td>
<td>22 (13–37)</td>
<td>13 (5–40)</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>−gen</td>
<td>Dutch</td>
<td>39 (23–61)</td>
<td>24 (10–41)</td>
<td>14 (3–37)</td>
</tr>
</tbody>
</table>
Proficiency results: German C–Test

C–Test results

homogenous subsets (Tukey HSD)
Proficiency results: Dutch C-Test

C-Test results

Homogenous subsets (Tukey HSD)
METHOD: EVENT-RELATED POTENTIALS (ERPs)

- EEG records ongoing voltage changes in the brain through electrodes placed on the scalp.
- In ERP measurements, these changes are time-locked to the presentation of a particular stimulus.
- Their temporal resolution allows assessing the time course of operations related to linguistic processing.
- This is achieved by comparing the response to two types of stimulus (e.g., correct sentence and sentence containing a violation).
- Best-known EEG components: N400 (semantic violation), P600 (morphosyntactic violation).
ERP COMPONENTS RELATED TO LANGUAGE PROCESSING

• **N400** (Kutas & Hillyard 1984)
  - negative going deflection
  - located on centro-parietal electrodes
  - ca. 300–500 ms post stimulus
  - modulated by aspects related to semantic processing
  - amplitude related to difficulties in semantic integration

• **P600** (Osterhout and Holcomb, 1992)
  - positive going deflection
  - most pronounced at posterior sites
  - ca. 500–800 ms post stimulus
  - related to syntactic complexity/violations
METHOD (see Schmid et al. 2015, SpringerBriefs)

- **Stimuli**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Example stimulus</th>
<th>English translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender, Det-N</td>
<td>... der/*das Garten ...</td>
<td>‘the\textsubscript{masc}/*the\textsubscript{neut} garden\textsubscript{masc}’</td>
</tr>
<tr>
<td>Gender, Det-Adj-N</td>
<td>... das/*der kranke Bein ...</td>
<td>‘the\textsubscript{neut}/*the\textsubscript{masc} diseased leg\textsubscript{neut}’</td>
</tr>
</tbody>
</table>

- **Procedure**
  - Auditory sentence presentation (n=24 per condition)
  - ERPs measured to target words: P600 indicative of native–like processing
  - followed by grammaticality judgment
RESULTS: Behavioral data – German
(% accuracy on GJT)
RESULTS: Behavioral data – Dutch (% accuracy on GJT)

Determiner-Noun

Determiner-Adjective-Noun
GERMAN EEG: monolinguals vs. attriters (Bergmann et al., 2015)

Significant P600 in both groups, no significant differences between populations.

Graphs showing mid-posterior ROI for correct and violation conditions.
GERMAN EEG: monolinguals vs. +gender learners (Meulman et al. 2015)

mid-posterior ROI  

- correct
- violation
GERMAN EEG: monolinguals vs. gender learners (Meulman et al. in prep.)

mid-posterior ROI  correct  violation
DUTCH EEG: attriters vs. L2ers (work in progress)
BEYOND MEANS–BASED ANALYSES

• traditional analyses of EEG data:
  • sentences are constructed in identical pairs, presentation is counterbalanced:
    • *Vera plant rode rozen in de tuin van haar ouders.*
    • *Vera plant rode rozen in *het tuin van haar ouders.*
    • Vera is planting red roses in the garden of her parents.
  • EEG signal is time–locked to the onset of the word that encodes the violation or its counterpart in grammatical sentence
  • from each trial, a segment of ca. 1.5 sec is extracted, beginning with the marker
  • this signal then consists of ≈ 200 numbers per electrode, each representing a voltage (typical sampling rate: 120 Hz)
  • EEG dataframes are huge, e.g.: 50 participants, 64 electrodes, 80 stimuli = 51,200,000 datapoints
BEYOND MEANS–BASED ANALYSES

- traditional analysis of EEG data:
- take time-window of interest (e.g. 500–900 ms for P600), create average for each trial, electrode and participant
- average these averages for all correct vs. all incorrect stimuli
- take Region of Interest (ROI) on scalp (5–10 electrodes) and average the averages of the averages
- create average of ROI averages per participant
- instead of 1 million datapoints per participant, we now have two: average Hz for correct vs. incorrect stimuli
- advantage: we can run an ANOVA on this
GERMAN EEG: monolinguals vs. attriters (Bergmann et al., 2015)

monolinguals

attriters

mid-posterior ROI

P600 in both groups no significant differences between populations

significant P600 in both groups no significant differences between populations
BEYOND MEANS–BASED ANALYSES

• traditional analysis of EEG data:
• take time–window of interest (e.g. 500–900 ms for P600), create average for each trial, electrode and participant
• average these averages for all correct vs. all incorrect stimuli
• take Region of Interest (ROI) on scalp (5–10 electrodes) and average the averages of the averages
• create average of ROI averages per participant
• instead of 1 million datapoints per participant, we now have two: average Hz for correct vs. incorrect stimuli
• advantage: we can run an ANOVA on this
• disadvantage: huge loss of variability
• obvious potential problem: P600 may occur later in L2 speakers or attriters, voltage changes in time window can cancel each other out (is looks as though there was nothing there)
KARSTEN’S DATA

Time interval onset (ms)  300  400  500  600  700  800  900  1000
N400  LAN/LTN  early P600  late P600

English L1

HP French

HP Chinese

LP French

LP Chinese
ANALYZING ERP DATA

• it would be better to run statistical analyses on the raw signal
• problem #1: takes a lot of computer time (can be solved with better analysis techniques and more computing space)
• problem #2: autocorrelation: the best predictor of the measurement at any given point in time (x) is the measurement preceeding it (x−1)
• this is a problem with all time-series data (e.g. EEG, eyetracking, fMRI etc.)
• problem #3 (similar): traditional statistical methods require all measures to be independent (you cannot have many values from the same participant)
NOVEL METHODS OF DATA ANALYSIS

• linear mixed effects regression methods (lmers)
• generalized additive modeling (GAMs)

• these take into account problems of autocorrelation, the fact that many measurements are from the same participant etc.
• predictors do not have to be dichotomized (‘early’ vs. ‘late’) but can be interval data
• GAMs can model nonlinearities in predictors
AoA IN DUTCH ATTRITION: GAM
(Seton, in progress)
SUMMARY OF EEG STUDY

- there is no difference between natives and late attriters, either on offline GJT or on EEG responses, in either German or Dutch
- early attriters behave similarly to late learners
- some early learners behave similarly to natives and late attriters
- more work needed to fully explore impact of age effect!