Brain signatures of L1 attrition - Evidence from event-related potentials

Karsten Steinhauer
McGill University
Major research questions:

1. What happens in the brain when we experience L1 attrition?
   - In particular: Can we find evidence for neuroplasticity that suggests systematic changes in the brain associated with L1 loss?

2. If so, does attrition resemble language acquisition, but ‘in reverse’?
   - E.g., is ‘proficiency’ a good predictor?

3. Are such changes quantitative or qualitative?
   - Why ERPs (event-related brain potentials)?
Why EEG / ERPs??
Electroencephalography / Event-Related Potentials

- Excellent time resolution (1 ms)
- **Continuous online measures** (across entire utterance)
- Distinct multi-dimensional profiles for specific cognitive processes
- Sometimes ERPs reflect changes prior to behavioral measures.

Disadvantages: many trials required, time-consuming (esp. auditory ERPs), relatively poor spatial resolution

Before we turn to attrition: ERPs in L2 ... and in L1
Outline of my talk:

1. ERPs in L1
   - Profiles of lexical and morpho-syntactic processing

2. ERPs and neuroplasticity in L2 acquisition
   - Studies supporting the CPH – and their problems
   - More recent studies avoiding these problems

3. ERP approaches to attrition
   - Studies of morphosyntactic processing
   - An ERP study on ‘confusing words’
   - Summary and Conclusion
EEG → Event-related brain potentials (ERPs)
[lexical semantics]

John ate *broccoli* at dinner.

John ate *democracy* at dinner.
EEG → Event-related brain potentials (ERPs)
[lexical semantics]

John ate broccoli at dinner.

John ate democracy at dinner.

EEG amplifier
EEG → Event-related brain potentials (ERPs) [lexical semantics]

John ate broccoli at dinner.
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EEG $\rightarrow$ Event-related brain potentials (ERPs) [lexical semantics]

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[EEG amplifier]

[e.g., Kutas & Hillyard, 1980; Federmeier & Kutas, 2002]
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The larger N400 reflects effort in lexical-semantic processing

EEG amplifier

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[lexical semantics]

John ate broccoli at dinner.
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EEG amplifier

Vocabulary map of N400 effect

300 – 500 ms

Larger N400 amplitudes (N400 effects) indicate difficulties in processing and integrating word meanings.

[e.g., Kutas & Hillyard, 1980; Federmeier & Kutas, 2002]
L1 profile for **morpho-syntax/grammar:**

**two** brain waves

Correct:  *He hoped to *enjoy* the meal with friends*

Violation:  *He hoped to *meal* the enjoy with friends*

**Early left negativity:**

*automatic* grammar processing → not available in L2ers!

**P600:** reflects more controlled processes of reanalysis and sentence repair.

[e.g., Neville et al., 1991; Friederici, 2002]
ERPs and neuroplasticity in L2 acquisition
Current theories: The “critical period” hypothesis (CPH)

- Why is learning a language late in life more difficult than in childhood?

- **Critical period hypothesis**: Language learning depends on early input before puberty (‘window of opportunity’);
  [Lenneberg (1967), Penfield in Montreal was the first (1950s)]

- In principle, the critical period hypothesis (CPH) is a (neuro-)biological hypothesis! → **brain research**
Current theories: \( L_2 = L_1 \) or \( L_2 \neq L_1 \)?

**Three possibilities** for the relationship between brain mechanisms for early \( L_1 \) and late \( L_2 \) (all under discussion):

1. **Difference hypothesis (CPH)**: \( L_2 \neq L_1 \)  
   - brain maturational constraints responsible for difficulties in late \( L_2 \)  
   - [Penfield, 1957; Lenneberg 1964; Bley-Vroman 1989; deKeyser 2001]

2. **Similarity hypothesis** (same mechanisms; but difficult to explain differences in attainment; \( \rightarrow \) entrenchment, motivation, cultural identity, etc): \( L_2 = L_1 \)  
   - [Hernandez et al., 2005]

3. **Convergence hypothesis**: \( L_2 \rightarrow L_1 \)  
   - \( L_2 \neq L_1 \), then convergence … until \( L_2 = L_1 \) (exception)  
   - [Green 2005; Steinhauer et al., 2009; ~ Osterhout et al., 2010]
Critical periods seem to be domain-specific

3 very influential ERP studies on L2 syntax: Google scholar

1. **Weber-Fox & Neville (1996, vis.)** 760
2. **Friederici & Hahne (2001, aud.)** 369
3. **Hahne (2001, aud.)** 364

→ Critical period for grammar/syntax and likely for phonology (but not lexical semantics)
ERPs in L1 and L2

(Weber-Fox & Neville, 1996; Hahne & Friederici, 2001)
ERPs in L1 and L2

(Weber-Fox & Neville, 1996; Hahne & Friederici, 2001)

No early LAN component → Support for a critical period in L2 grammar
Helen Neville (Bangor, 2009): On critical periods

1. “Native, early-learned languages” are processed primarily in the left hemisphere (e.g., grammar violations elicit left-lateralized negativities, LANs).

2. Because the brain systems underlying grammar depend on experience during a ‘critical period’ in childhood, late language learners cannot use these systems (e.g., thus no LANs).
2 major methodological problems

1. **AoA – proficiency confound:**
   - AoA and L2 proficiency levels were negatively correlated in *Weber-Fox & Neville (1996)* and the two *Hahne / Friederici (2001)* studies.
   - Lower L2 proficiency may also explain the data!
     (see our first BROCANTO study, *Friederici et al., 2002*).

2. **Sentence material was poorly controlled:**
   - Pre-target contexts differed between conditions → ERP baseline problems!
   - [e]LANs may be artefacts!
     [see *Steinhauer & Drury, 2012; Brain & Language*]
Newman et al. (2007, reading)

Yesterday I drank his brandy by the fire

*by brandy the fire
Newman et al. (2007, reading)

Yesterday I drank his brandy by the fire

Yesterday I drank his *by brandy the fire
Newman et al. (2007, reading)

Yesterday I drank his \textcolor{red}{brandy} by the fire

Yesterday I drank his *by brandy the fire
Newman et al. (2007, reading)

Yesterday I drank his brandy by the fire

Yesterday I drank his by brandy the fire
Newman et al. (2007, reading)

Yesterday I drank his brandy by the fire

Yesterday I drank his *by brandy the fire

\textbf{DC offset artifact!} (baseline problem)

- onset of effect in or right after baseline interval
- ‘looking back’ helps understand data
- often ‘cross-over’ of conditions prior to target word

'ELAN' artifact
0-200 ms

LAN/LTN
Illustration of problem: Rossi et al., 2005, 2006

**auditory suffix manipulation:** *sing-t*

<table>
<thead>
<tr>
<th>Experimental items (critical verb is italicized)</th>
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<tr>
<td>Correct sentence</td>
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<td>Category violation</td>
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One might predict: *delayed* ELAN triggered by verb-final *suffix* -t

Finding: **ELAN** 100 ms after *word onset* \(\rightarrow\) *precedes* violation by 300 ms !
\(\rightarrow\) This MUST be an artifact ! [also note *post-onset baseline* !]
→ A new study avoiding …

- … baseline problems (context effects)
- … AoA/proficiency confound

Also: testing for L1 transfer
Balanced design: no baseline problems!

Correct:  
- He hoped to **enjoy** the meal with friends  
- He made the **meal** to enjoy with friends

Violation:  
- He hoped to **meal** the enjoy with friends  
- He made the **enjoy** to meal with friends

---

**Early left negativity:**
Assumed to reflect highly **automatic** grammar processing

→ **CPH:** Should be found only in native speakers, not in late L2 learners
**Balanced design:** no baseline problems!

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**Late parietal P600**
Balanced design: no baseline problems!

Correct: He hoped to enjoy the meal with friends
        He made the meal to enjoy with friends

Violation: He hoped to meal the enjoy with friends
           He made the enjoy to meal with friends

Early left negativity:
Assumed to reflect highly automatic grammar processing
→ CPH: Should be found only in native speakers, not in late L2 learners

- 5μV
T5

+ 5μV

Early left negativity

Late parietal P600

400 - 500 ms

600 - 900 ms
A study avoiding these problems
(Steinhauer, White & Genesee, not yet rejected)

Correct: He hoped to *enjoy* the meal with friends
Violation: He hoped to *meal* the enjoy with friends

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L2 ≠ L1  L2 ≠ L1  L2 = L1  L2 = L1

Critical period or proficiency
???
An L2 study avoiding these problems
(Steinhauer, White & Genesee, not yet rejected)

Correct: He hoped to **enjoy** the meal with friends
Violation: He hoped to **meal** the enjoy with friends

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<td>Left neg par. P600</td>
<td>N400 broad P600</td>
<td>-- frontal P600</td>
<td>left neg par. P600</td>
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L2 Proficiency, not age of L2 acquisition, predicts EEG profile!
Fine-grained ERP effects per group

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<tr>
<th>Time interval onset (ms)</th>
<th>300</th>
<th>400</th>
<th>500</th>
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English L1

HP French

HP Chinese

LP French

LP Chinese
At low L2 proficiency: **Strong delay in P600 shift**
Take home messages: grammar in L2

At *low* L2 proficiency:
- L2 ≠ L1 (no LAN/LTN, later P600 shift)
- Mother tongue makes a difference (French ≠ Chinese)

At *high* L2 proficiency:
- L2 = L1 (many similar findings, but see Meulman et al., 2015)
- Mother tongue does NOT make a difference (French = Chinese)

→ Support for hypothesis 3: *L2 processing converges on L1*
→ Evidence *against* ‘critical period hypothesis’ in L2 syntax
→ Results are *not sufficient to reject CPH* (more subtle paradigms are needed), BUT they do show that previous ERP studies supporting CPH with ‘hard brain data’ were over-interpreted.
ERP effects at very low L2 proficiency: conjugation
(Osterhout, McLaughlin, Pitkänen, Frenck-Mestre & Molinaro, 2006; Tanner, various)

~ 14 hrs of instruction

Session 1

N400

~ 60 hrs

Session 2

Small P600

~ 140 hrs

Session 3

Larger P600

But no LANs, and no effects at all for more difficult structures (e.g., number agreement)!
Take home messages: grammar in L2

Convergence-model by Steinhauer, White & Drury 2009, linking proficiency in L2 morpho-syntax to ERP components:

- Low L2 proficiency → native-like proficiency

Ø / N400 → small P600 → large P600 → (LAN)+P600

native ERP pattern!
(no LAN if absent in L1 !!)

the point here is that L2 learners converge on whatever pattern(s) is/are found in native speakers!

→ See Osterhout et al. (2006) and Tanner et al., (2013, 2014, 2015) for similar ideas
If L2 converges on L1: Does it matter how we learn a second language?
Does it matter *how* we learn a second language?

- **Infants** learn languages implicitly through *immersion*.

- In contrast, **most adults** learn new languages in a *classroom setting*, at least initially. Their textbooks make the L2 grammar rules *explicit*.

- Is it possible that the *type* of L2 exposure influences *how* the brain processes the L2 (and contributes to L1-L2 differences)?
Explicit vs. implicit L2 training in artificial language

Morgan-Short, Steinhauer, Sanz & Ullman, 2012 (JoCN)

Explicit classroom-like rule instruction

Implicit immersion-like training

N = 30 adults
BROCANTO2: practice phase

• 44 practice blocks (22 comprehension / 22 production) using moves on the board game

• Explicit group *initially outperformed* implicit group - but not for long.
BROCANTO2: Behavioral data from ERP study

Grammaticality Judgement (% corr) during EEG Exp. 1 and 2

Low proficiency                  High proficiency

Explicit

Implicit
BROCANTO2 ERP data: Grammar violation

→ Despite comparable behavioral performance the two groups differ in their neural activation:

→ Only the implicit instruction group displayed a ‘native-like’ bi-phasic ERP pattern (early left negativity + parietal P600).
Take-home messages: BROCANTE2

- Implicit SLA in adulthood seems possible (to some extent)
- Explicit instruction had only limited beneficial effect (initially).
- Only the implicit group showed a ‘native-like’ ERP response, which (if replicated) may be relevant to immersion programs.
- Artificial language paradigms are useful !! (contra Osterhout et al.)
- Type of L2 training seems to influence brain mechanisms underlying L2 processing as reflected by ERPs (even in absence of behavioral differences).
Similar findings: ERP effects prior to – or in absence of – performance effects

- McLaughlin et al., (2004): (lexical learning first reflected by N400 in absence of behavioral effects)

- Wu and Thierry (2007, 2008): Chinese learners of English L2 co-activate their L1 phonology and show Chinese phonological priming effects while reading English words (only N400 effects, no performance)

- Steinhauer, Kasparian, et al. (2010): L1-grammar is co-activated as well when reading L2 (post-nominal English color adjectives violating French word order elicit bi-phasic ERP pattern – but ONLY in FRENCH learners, and ONLY if French grammar is violated).

→ Influence of L1 on L2; how about L2 → L1 ??
Summary: Factors in L2 morpho-syntax
(and likely in phonology as well)

- **L2 proficiency** is a better predictor for ERPs than CPH – BUT no one doubts that ‘the younger, the better’ (AoA !)

- **L1 background** shows transfer effects, especially at early stages of L2 acquisition (but still L1 coactivation at later stages)

- **Learning environment** matters (classroom vs immersion)
  - Explicit instruction had only limited beneficial effect (initially).  

- **Other factors contributing to individual variability in L2 success:**
  - Motivation (e.g., Tanner et al. 2014)
  - Usage of L2 (frequency and type)
  - Identification with culture/socialization of L1 vs L2 (part of AoA effects)
  - Individual processing styles (Steinhauer & Nickels, in prep)
  - Individual learning styles (Wong & Morgan-Short, 2013)
  - Executive control (e.g., ability to inhibit irrelevant L1 aspects)
  → ‘Applied Linguistics’ 2014 special issue on age effects in SLA
What has changed since 2001?

Most researchers in the field – and cognitive neuroscientists in particular – are less convinced of a critical period in L2 acquisition.

Even (previous?) proponents of the CPH in L2, such as Monika Schmid, now seem to agree:

Nienke Meulman, Martijn Wieling, Simone A. Sprenger, Laurie A. Stowe, Monika S. Schmid, 'Age effects in L2 grammar processing as revealed by ERPs and how (not) to study them', *PLoS ONE*, December 18th 2015.
What has changed since 2001?

- However …

- … whereas this L2 research suggests that proficiency may be a better predictor than AoA, the two variables are almost always confounded.

- The ultimate evidence would be to show that one’s L2 can be more ‘native-like’ than one’s L1.

→ L1 attrition: the ‘downside’ of neuroplasticity?
ERP approaches to attrition
Language loss (attrition)

**L2 attrition**
- Very few ERP studies; e.g., Osterhout, Tanner et al. (in prep) “Is losing one’s L2 like learning an L2 – but in reverse?” → LAN/P600 – P600 – N400?

**L1 attrition**
- 2 target populations:
  - Adopted children (may lose their L1 entirely, e.g., Pallier et al., 2003; but Pierce, Genesee et al. 2015)
  - Immigrants who are more exposed to their L2 than their L1 (seem to lose their L1, especially vocabulary – but most is anecdotal evidence)
Monika Schmid

She initially studied Jewish immigrants in the US who had left Nazi Germany → huge variability in L1 loss!

Now large-scale international studies of immigrants looking at loss of both vocabulary and grammar (incl. ERPs, with Laurie Stowe and others), including …

Gender agreement: le/*la soleil vs *der/die Sonne [the sun]
- Late L2 learners have problems, attriters don’t → L2-CP/no attrition
- Potential problem: not really grammar but idiosyncratic gender
- → is stored (lexical) knowledge, not rule based (Ullman’s D/P model)
- Excellent: large studies with multiple L1-L2 pairings
L1 attrition in the brain

1. Morpho-syntactic processing
2. Lexical-semantic processing

- PhD thesis project of Dr Kristina Kasparian at McGill
  (analyses still in progress … soon you will see why ….)
Dissertation Research

Neurophysiological Studies of First-Language Attrition
Attrition

- Change in L1 use, due to L2
- L2 proficiency increases and exposure outweighs L1
- **Behavioral/anecdotal reports**: Word-retrieval difficulties and L2-L1 transfer in morphosyntax
- **Mild/no attrition** effects in *adult* migrants
  - Support for maturational limits on neuroplasticity
- **Neurocognitive aspects of attrition unexplored!**
  - *Except* Monika Schmid et al. (in progress) where adult attriters = monolingual controls

Schmid & Köpke, 2007; Schmid, 2011; 2013
Main questions

- L1 processing “native-like”, despite limited use?
- L1 proficiency determines processing patterns?
- Similarities between L1 attriters and L2 learners?
- L2 native-like at high proficiency, despite late AoA?

One of the first neurocognitive studies of L1 attrition in adults
Participants: 4 groups

Attrition group / “Attritors” (n = 24)
- First-generation immigrants
- Predominant English use
- Limited use of Italian
- Unanimously report changes in L1
Age = 36 yrs
AoA-English = 28 yrs
Length of residence (LoR) = 12 yrs
## Participants: 4 groups

### Attrition group / “Attriters” (n = 24)
- First-generation immigrants
- Predominant English use
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- Unanimously report changes in L1

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### Late L2 learners of Italian (n = 20)
- English native-speakers
- Advanced Italian knowledge

<table>
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<tr>
<th>Italian native-speakers (n = 30)</th>
<th>English native-speakers (n = 30)</th>
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<tr>
<td>Age = 30.6 yrs</td>
<td>Age = 30.5 yrs</td>
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Experimental sessions

- **Tested in Italian and English** (2 sessions)
- **Background** questionnaires
- **Proficiency** tasks (also for monolinguals)
  - Written C-test
  - Written Error-detection task
  - Verbal semantic fluency task
  - Verbal “False-friend” translation task (bilinguals)
- **Working memory** and **reading fluency** tasks
- **ERP studies**: **Acceptability judgment** (rating 1-5)
Overview of 6 ERP studies

ITALIAN
- Number agreement
- Confusables
- Word order in relative clauses

ENGLISH
- Word order in relative clauses
- Regular and irregular verbs
- Cognates and homographs in sentences
Overview of 6 ERP studies

ITALIAN
- Number agreement
- Confusables words
  - Study 1
  - Word order in relative clauses
  - Study 2
  - Regular and irregular verbs

ENGLISH
- Word order in relative clauses
- Cognates and homographs in sentences
Overview of 6 ERP studies

ITALIAN

Number agreement
Confusuable words

Study 1
Study 2
STUDY 1

Number Agreement Processing in Italian

Kasparian, K., Vespignani, F., & Steinhauer, K. (in revision)
Study 1: Main premise

- Attriters vs. native-controls in Italy
- Local (subject-verb) and non-local (subject-modifier)

Il lavoratore torna dalla fabbrica sporco di grasso.
The worker$_{sg}$ returns$_{sg}$ from the factory dirty$_{sg}$ with grease.

Based on Molinaro, Vespignani, Zamparelli & Job, 2011
Study 1: Main premise

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*Il lavoratore tornano dalla fabbrica sporco di grasso.*
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_Il lavoratore torna dalla fabbrica sporchi di grasso._
*The worker*$_{sg}$ *returns*$_{sg}$ *from the factory* *dirty*$_{pl}$ *with grease.*

- Examined ERP responses at 2 points (*verb* and *modifier*)
Study 1: Main premise

- Attriters vs. native-controls in Italy
- Local (subject-verb) and non-local (subject-modifier)

Il lavoratore torna dalla fabbrica sporchi di grasso.
The worker returns from the factory dirty with grease.

Q: Attriters still native-like in detection and resolution (“repair”) of agreement errors?
Verb: Native-Controls

- Small LTN (T5)
- Frontal positivity (Fz)
- P600 (Pz)

**Left-temporal negativity**
- 300-500ms

**Frontal positivity**
- 550-650ms

**P600**
- 650-1000ms
- 1000-1200ms
Consistent with previous findings on number agreement (e.g., Barber & Carreiras, 2005; Molinaro et al., 2011; Osterhout & Mobley, 1995)

Early negativities weaker in Italian: Word-order allows subject to follow verb (Angrilli et al., 2002; De Vincenzi et al., 2003; Mancini et al., 2009)

Late P600 indexes sentence-repair (Molinaro, Barber & Carreiras, 2011)
Verb: Attriters

Large, broad N400 at T5

Large, broad N400 at Fz

Less focal and shorter P600 at Pz

300-500ms

550-650ms

650-1000ms

1000-1200ms
**Verb: Attriters**

- **Stronger negativity**: Stronger expectation for subject-verb agreement (influence from English grammar)
- **Shorter P600** suggests less in-depth “repair”  
  (Carreiras, Salillas & Barber, 2004; Hagoort & Brown, 2000; Molinaro et al., 2008)
Modifier: P600 differences

Il lavoratore_{sg} torna_{sg} dalla fabbrica sporchi_{pl} di grasso.
The worker_{sg} returns_{sg} from the factory dirty_{pl} with grease.

- Early P600 (= diagnosis of error):
  Larger in higher proficiency
Modifier: P600 differences

Il lavoratore\textsubscript{sg} torna\textsubscript{sg} dalla fabbrica sporchi\textsubscript{pl} di grasso.
The worker\textsubscript{sg} returns\textsubscript{sg} from the factory dirty\textsubscript{pl} with grease.

- Early P600 (\textit{= diagnosis} of error):
  Larger in higher proficiency

- Late P600 (\textit{= repair} of error):
  Again significant only in Controls
  Larger in Attriters with more frequent L1 use
Only behavioral differences: **slower RTs in Attriters**
- Less efficient in processing
- ERPs more sensitive than acceptability judgment task
- Caution: Rating sentences may not require “repair” for comprehension

First ERP study to show **differences in online grammar processing** in Attriters
STUDY 2

CONFUSABLE VOCABULARY WORDS IN ITALIAN

Kasparian, K., & Steinhauer, K. (Under review)
Study 2: Main premise

- Italian controls vs. Attriters vs. Italian L2 learners
- Nouns that differ in final vowel (+ gender) and meaning (e.g. *cappello* (hat) vs. *cappella* (chapel))

*Il pescatore porta il cappello di lana.*
The fisherman wears the *hat* of wool.  ➔ Correct

*Il pescatore porta la cappella di lana.*
The fisherman wears the *chapel* of wool.  ➔ Swap

*Il pescatore porta la cartella di lana.*
The fisherman wears the *briefcase* of wool.  ➔ Mismatch
Study 2: Main premise

- Italian controls vs. Attriters vs. L2 learners
- Nouns that differ in final vowel (+ gender) and meaning (e.g. cappello (hat) vs. cappella (chapel))

Q: Are L2 learners less likely to detect “Swap” errors (Swap = Correct)?

Are L1-Attriters similar to L2 learners?

ERP patterns predicted by proficiency, regardless of group (i.e., AoA)?
Results: Native-Italian Controls

Mismatch: The fisherman wears the **briefcase** of wool.
Swap: The fisherman wears the **chapel** of wool.
Correct: The fisherman wears the **hat** of wool.
N400 determined by proficiency

HIGH L1 PROFICIENCY ATTRITERS

HIGH L2 PROFICIENCY LATE-LEARNERS

Mismatch
Swap
Correct
N400 determined by proficiency

<table>
<thead>
<tr>
<th>LOWER L1 PROFICIENCY</th>
<th>LOWER L2 PROFICIENCY</th>
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</thead>
<tbody>
<tr>
<td>ATTRITERS</td>
<td>LATE-LEARNERS</td>
</tr>
</tbody>
</table>

Mismatch only

Mismatch only

Mismatch

Swap

Correct
P600 determined by proficiency AND group

- Across all groups: P600 larger with higher proficiency
P600 determined by proficiency AND group

- Across all groups: P600 larger with higher proficiency
- But P600 largest + more broadly distributed in Attriters
  - Enhanced conflict monitoring / double-checking input
  - more explicit “second thoughts” (e.g., Van de Meerendonk, 2009)
Experiential factors in Attriters

- Smaller N400 amplitude in Attriters with:
  - Longer length of residence in L2 environment
  - Less exposure to L1-Italian

→ Less native-like in L1 lexical-semantic processing with longer L2 immersion and reduced L1 exposure
Study 2: Implications

- **Impact of proficiency** on ERP patterns, regardless of L1 / L2
  - In line with longitudinal L2 studies, but in lexical-semantics
    McLaughlin et al., 2009; Osterhout et al., 2006; White, Genesee & Steinhauer, 2012

- **Extending conflict-monitoring theory of P600 to attrition**
  - Enhanced in Attriters (attention, self-consciousness, motivation?)
Study 2: Implications

- Impact of proficiency on ERP patterns, regardless of L1 / L2
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    McLaughlin et al., 2009; Osterhout et al., 2006; White, Genesee & Steinhauer, 2012

- Extending conflict-monitoring theory of P600 to attrition
  - Enhanced in Attriters (attention, self-consciousness, motivation?)

- Attriters may **not show native automatic patterns** for errors involving confusable words
  - Confirms anecdotal reports of “confusing words”
  - Weaker L1 form-meaning links? (Gollan et al., 2005; Jared & Kroll, 2011)
  - Influenced by immersion in L2 and reduction of L1 exposure
Summary and contributions

- **Attrition** in real-time language processing
  - Even in morphosyntax (≠ Schmid)
  - Even in migrants who had lived in exclusively L1-environment
    → Fully-developed L1 modified by L2-experience (plasticity)

- Attrition effects as **increased transfer from L2**, reduced activation of L1 and more conscious monitoring

- Not necessarily mirrored in behavioral tasks

→ **Evidence for ongoing neuroplasticity in L2 and L1**
Summary and contributions

- **Proficiency** is a key factor in L2 and L1
  - Influences ERP patterns
  - Reveals some similarities between L1 attriters and L2 learners

- **BUT proficiency not the whole story**
  - Attriters as *group* differed from native-controls in L1-grammar (Study 1) and lexical-semantics (Study 2)
  - Experiential factors like exposure / immersion influence ERPs
  - Enhanced conflict-monitoring and second-thoughts may be due to other factors (increased attention, motivation, inhibition)

- **Bridges gap** between L1 and L2 processing and attrition
Major research questions:

1. What happens in the brain when we experience L1 attrition?
   - In particular: Can we find evidence for neuroplasticity that suggests systematic changes in the brain associated with L1 loss?

2. If so, does attrition resemble language acquisition, but ‘in reverse’?
   - E.g., is ‘proficiency’ a good predictor?

3. Are such changes quantitative or qualitative?
# Acknowledgements

My collaborators:

<table>
<thead>
<tr>
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THANK YOU!

... and don’t miss Kristina Kasparian’s talk on relative clauses and attrition tomorrow (Wednesday) at 2 pm!
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>‘<em>the</em>masc/<em>the</em>neut <em>garden</em>masc’</td>
</tr>
<tr>
<td>Gender, Det-Adj-N</td>
<td>... *das/*der kranke Bein ...</td>
<td>‘<em>the</em>neut/<em>the</em>masc <em>diseased leg</em>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
(% accuracy on GJT)
RESULTS: EEG data monolinguals vs. attriters (Bergmann et al., submitted)

Significant P600 in both groups no significant differences between populations
RESULTS: EEG data monolinguals vs. gender learners (Meulman et al. 2015)

mid-posterior ROI  correct  violation