Prolonged L2 immersion engenders little change in morphosyntactic processing of bilingual natives

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Published in:
Neuroreport

DOI:
10.1097/WNR.0000000000000469

Prolonged L2 immersion engenders little change in morphosyntactic processing of bilingual natives

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Bilingual and monolingual language processing differ, presumably because of constant parallel activation of both languages in bilinguals. We attempt to isolate the effects of parallel activation in a group of German first-language (L1) attriters, who have grown up as monolingual natives before emigrating to an L2 environment. We hypothesized that prolonged immersion will lead to changes in the processing of morphosyntactic violations. Two types of constructions were presented as stimuli in an event-related potential experiment: (1) verb form combinations (auxiliaries + past participles and modals + infinitives) and (2) determiner–noun combinations marked for grammatical gender. L1 attriters showed the same response to violations of gender agreement as monolingual controls (i.e. a significant P600 effect strongest over posterior electrodes). Incorrect verb form combinations also elicited a significant posterior P600 effect in both groups. In attriters, however, there was an additional posterior N400 effect for this type of violation. Such biphasic patterns have been found before in L1 and L2 speakers of English and might reflect the influence of this language. Generally, we interpret our results as evidence for the stability of the deeply entrenched L1 system, even in the face of L2 interference. ***NeuroReport*** **26:1065–1070**

NeuroReport 2015, **26**:1065–1070

Keywords: electroencephalography, grammatical gender, language attrition, language competition, morphosyntax, multilingualism

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Received 23 April 2015 **accepted** 18 September 2015

Introduction

Bilinguals do not process language the way monolinguals do [1,2], presumably because of constant parallel activation of both languages [3,4]. However, it is difficult to interpret the group differences: apart from the number of languages they speak, monolinguals and bilinguals usually differ on factors such as the amount of linguistic input, age of acquisition, proficiency, etc. It is unclear which processing differences can be attributed to incomplete L2 acquisition and which to the presence of another language. To overcome these problems, we present a comparison of German first-language (L1) attriters and monolinguals. Having grown up in a monolingual setting, attriters had full native L1 input and proficiency before emigration. As adults, they have emigrated to an environment where their L1 is not used and they are immersed in a second language (L2; here English). Using L1 stimuli, we should be able to measure pure effects of bilingual language competition on processing in these speakers. We report the results of an event-related potential (ERP) experiment on two morphosyntactic phenomena: nonfinite verb forms and grammatical gender (GG).

In languages marking GG, nouns are assigned to classes; elements grammatically related to these nouns have to be inflected according to class membership [5]. Violations in GG agreement consistently elicit late positive effects in monolingual L1 speakers (German [6]; Dutch [7]; French [8]).

Although the same effects as in monolinguals are sometimes found in late L2 learners (L1 German/L2 French: [9]; L1 German/L2 Dutch: [10]), sometimes they are not (L1 Romance/L2 Dutch: [10,11]; L1 English/L2 French: [12]). These results may depend either on factors such as L1–L2 similarity, age of acquisition, and proficiency or on the fact that the learners are bilinguals. The processing of verb form combinations (auxiliaries + past participles and modals + infinitives), however, does not differ as much. Incorrect combinations reliably elicit late positive effects in both monolinguals (Dutch: [13]) and late L2 learners (L1 German and L1 Romance/L2 Dutch: [10,11]).

We present the first comparison of ERP data from L1 attriters and monolinguals. The two phenomena that we have selected differ between German and English in specific ways: GG is marked in German, but not in English; thus, no direct competition is expected. However, GG is an unpredictable lexical property of nouns. Many studies have shown that L2 immersion can affect accessibility of the L1 lexicon [14]; thus, GG processing might change for that reason. Verb form combinations are rule rather than item

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based and syntactically similar in German and English. The morphological makeup of the nonfinite forms differs, though, involving a circumfix structure for past participles in German.

We hypothesize that L1 attriters and monolinguals will not differ in the processing of nonfinite verb forms, irrespective of the morphological differences. For gender processing, by contrast, we hypothesize that violations may differ, reflecting the impact of the L2 on access to the mental lexicon of the bilinguals.

Materials and methods

Participants

Fifty-eight native speakers of German participated; five were excluded because of excessive artefacts in the electroencephalographic (EEG) signal. Of the remaining 53 participants, 27 were residents of Germany (= control group speakers) and 26 were residents of the USA or Anglophone Canada (= attriters). All participants were right-handed and reported no neurological, speech or hearing disorders. Written consent was obtained from all participants using forms that were approved by local ethics committees. Participants were debriefed at the end of the study and received a small fee for participation.

Participant characteristics are presented in Table 1. Gender was not controlled across groups. L1 use is an average of self-reports on three settings (home, work, elsewhere). Proficiency was assessed using a cloze test, constructed by Schmid [15], in which participants filled in two texts with a respective share of 37 or 41% incomplete words. Gender assignment was tested by having participants assign the correct gender-marked article to nouns; to remove the effects of guessing, each of the 138 items was repeated three times (in randomized order).

Materials

On the basis of a Dutch ERP experiment [16], 144 German sentences in two structures were created (for examples, see Fig. 1): (1) verb agreement (48 sentences): auxiliaries were combined with past participles and modals with infinitives. Only verbs with a regular inflection were included. For the ungrammatical counterparts, combinations were swapped, pairing auxiliaries with infinitives and modals with past participles. (2) Gender agreement of determiners with nouns (96 sentences): masculine and neuter nouns were combined with determiners that agreed in GG. Determiners and nouns were adjacent in half of the sentences (A), whereas an adjective intervened in the other half (B). Some speakers might process the highly frequent determiner–noun combinations in the adjacent condition (A) as prelearned chunks without actually computing gender agreement (cf. [17]). We have therefore included the nonadjacent condition (B), resulting in less frequent determiner–adjective–noun combinations, in which a chunk-based processing strategy is less likely. For ungrammatical sentences, combinations were swapped, pairing masculine determiners with neuter nouns and vice versa. Only highly frequent nouns and verbs were used [nouns: $\overline{X} = 1.62$ (0.4–2.7); verbs: $\overline{X} = 1.78$ (0.3–2.9) on log lemma frequency per million words in the DeReKo corpus [18]]. The experimental sentences (50% incorrect in each condition) were interspersed with 134 correct filler sentences, which increased the proportion of correct sentences to 74.1%. Feminine gender was avoided because the determiner associated with this gender is identical to the plural determiner that is used for all three genders (die).

The sentences were recorded by a female native speaker of German with a standard accent. The region surrounding the target words was cross-spliced from correct to incorrect sentences and vice versa to avoid potential confounds in the form of prosodic cues. Sentences were presented in four different lists with no repetition of items.

Procedure

The EEG experiment was part of a research project in which participants were tested in two 2 h sessions. The pen-and-paper cloze test was completed during the first session.

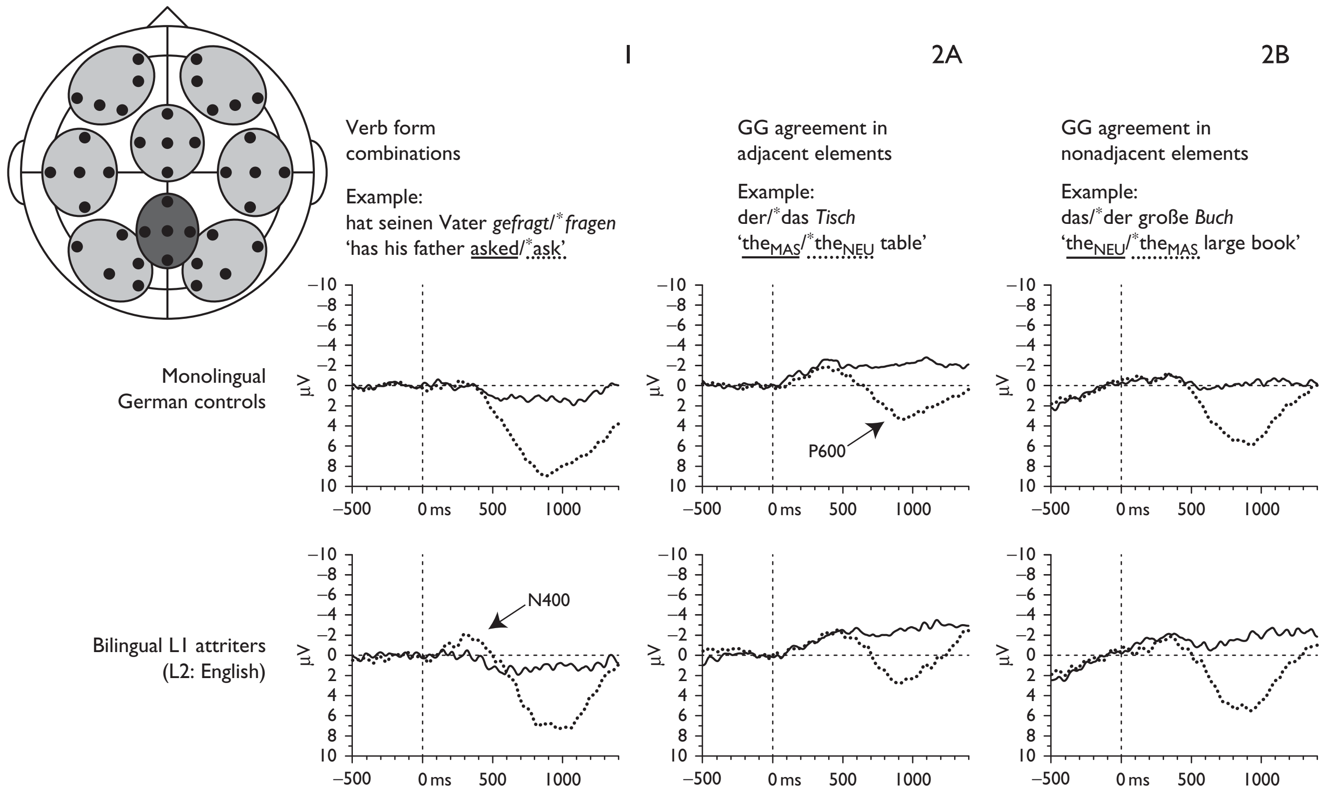
ERPs were recorded during the second session. The recording situation was kept the same across all four testing locations. Participants were tested individually in sound-attenuated chambers. Sentence recordings were presented through loudspeakers using E-Prime [19,20]. After each sentence, participants had to make a binary

Table 1 Participant characteristics

	Control group	Attriter group	Comparison
Male (%)	33.0	8.0	–
Age	40.2 (σ: 11.1; 22–65)	44.4 (σ: 9.0, 29–64)	$W = 427.5$, $P = 0.176$
Age of emigration	–	27.6 (σ: 4.5; 21–39)	–
Length of residence in L2 setting	–	17.2 (σ: 8.1; 6.5–34)	–
L1 use	97.8% (σ: 3.9; 86.7–100)	19.4% (σ: 18.4; 0–76.7)	$W = 0$, $P < 0.001$
Proficiency test[a]	93.2% (σ: 2.7; 86–97.7)	88.6% (σ: 6.9; 72.1–97.7)	$W = 204.5$, $P = 0.008$
Gender assignment[b]	99.9% (σ: 0.3; 99–100)	99.9% (σ: 0.3; 99–100)	$W = 350$, $P = 0.98$

[a]Correct responses. Spelling errors were not counted as incorrect responses.
[b]Correct responses. Nouns that were assigned the correct article two out of three times were counted as correct.

Fig. 1



ERP waveforms of all conditions for both participant groups, taken from the mid-posterior ROI. Waveforms of all ROIs are available as Supplemental digital contents (2–4). Supplemental digital content 2 (*http://links.lww.com/WNR/A357*); Supplemental digital content 3 (*http://links.lww.com/WNR/A358*); Supplemental digital content 4 (*http://links.lww.com/WNR/A359*). ERP, event-related potentials; GG, grammatical gender; ROI, region of interest.

acceptability judgement. Participants were asked to avoid eye and body movements as well as blinking during sentence presentation. The experiment was divided into four blocks with pauses in between. It lasted about 1 h. After the recording, participants completed the pen-and-paper gender assignment task.

EEG recording and analysis

Participants were tested at labs in four cities: Toronto (TO; $n=12$), New York (NY, $n=14$), Mainz (MZ; $n=22$) and Hamburg (HH; $n=5$). (We carried out additional analyses including the factor location. These showed that all effects of interest, reported below, were not influenced by differences in the EEG recording set-up at the different labs.) EEGs were recorded at 500 Hz/22bit (except for TO: 512 Hz, resampled to 500 Hz) from 56 Ag/Ag Cl electrodes in different types of caps [MZ/HH: Easy Cap (Easy Cap GmbH, Wörthsee-Etterschlag, Germany); NY: Neuroscan Quik-Cap (Compumedics, Charlotte, North Carolina, USA); TO: BioSemi (BioSemi B.V., Amsterdam, The Netherlands)]. Eye movements were monitored through additional electrodes, placed at the outer canthi as well as above and below the eyes. Scalp signals were measured against reference electrodes placed at the left mastoid (MZ/TO) or on the nose tip (HH/NY). Impedances were reduced to below 15 kΩ. BrainAmp (MZ/HH), SynAmp 2 (NY) and Biosemi (TO) amplifiers were used.

The data were re-referenced to averaged mastoids and filtered with a band-pass filter of 0.1–40 Hz. The data were segmented and time-locked to the onset of the target word (500 ms before to 1400 ms after stimulus onset). Irrespective of behavioural responses, trials without muscular or ocular artefacts were included in averaged ERPs. Ocular artefacts were corrected. Because of individual channel artefacts, 2.2% of the data had to be rejected in the attriter group and 0.4% in the control group. The data were normalized in a 200 ms baseline period before the onset of the target words. Electrodes were grouped into eight regions of interest (ROIs) with five electrodes each (see Fig. 1).

The amplitudes of the ERP waveforms were analysed in two time windows: 300–500 ms (typical for LAN/N400 effects) and 600–1200 ms (typical for P600 effects). Grand mean analyses of variance (ANOVAs) were calculated separately for each time window and structure. They included the factors group (controls/attriters) and correctness (correct/incorrect). In lateral regions (LA/LC/LP and RA/RC/RP), hemisphere (left/right) and anteriority (frontal/central/posterior) were also included; in medial regions (MC/MP), only anteriority (central/posterior) was included. For violations of the sphericity assumption, the Greenhouse–Geisser correction was applied. Only main effects of or interactions with correctness are reported. Significant higher-level interactions are interpreted rather than main effects or lower-level interactions. False discovery rate correction was applied in follow-up tests to avoid type 1 errors.

Results

Behavioural results

The performance on the acceptability judgement task was at ceiling for both groups (controls: $\overline{X}=98.4\%$, attriters: $\overline{X}=97.4\%$). An ANOVA, carried out on the arcsine transformed proportions of correct responses, showed a marginally significant main effect of group [$F(1,51)=3.37$, $P=0.072$], reflecting the slightly lower accuracy of the L1 attriters. The correctness × structure interaction was significant [$F(2,102)=8.40$, $P=0.001$]. In the verb condition, paired comparisons showed a marginally better performance on ungrammatical sentences [$t(99.2)=-1.7478$, $P=0.084$; correct: $\overline{X}=97.7\%$, incorrect: $\overline{X}=98.7\%$]. In the gender conditions, we find a significantly better performance on grammatical sentences for the adjacent structure (2A) [$t(101.2)=2.9577$, $P=0.004$; correct: $\overline{X}=98.3\%$, incorrect: $\overline{X}=96.4\%$] and no significant differences for the nonadjacent structure (2B) [$t(103.4)=1.541$, $P=0.1264$; mean correct: $\overline{X}=98.4\%$, incorrect: $\overline{X}=97.7\%$].

ERP results: grand mean analyses

Figure 1 shows the grand mean ERP waveforms for controls and attriters, respectively. Detailed results of the omnibus ANOVAs are available as Supplemental digital content 1 (*http://links.lww.com/WNR/A356*). Factors are group (G), correctness (C), anteriority (A) and hemisphere (H).

Verb form combinations

In the 300–500 ms window, we found more negative voltages (i.e. an N400 effect) in attriters for the ungrammatical sentences. This was statistically supported by a significant G × C × A interaction for lateral electrodes. Follow-up analyses showed no significant main effects or interactions in controls. In attriters, by contrast, the C × A interaction was marginally significant [$F(2,50)=4.85$, $P=0.054$], with post-hoc tests showing a posterior effect [frontal/central: both F's <1; posterior: $F(1,25)=8.19$, $P=0.024$]. For midline electrodes, there was a significant G × C × A interaction. In controls, follow-up analyses yielded no significant main effects or interactions. In attriters, there was a significant C × A interaction [$F(1,25)=8.80$, $P=0.014$], again reflecting a posterior effect [central: $F<1$; posterior: $F(1,25)=8.95$, $P=0.012$].

In the 600–1200 ms window, both groups showed more positive voltages (i.e. a P600 effect) for the ungrammatical sentences. This was supported by a significant G × C × A × H interaction for lateral electrodes. Follow-up analyses indicated a significant C × A interaction in the attriters [$F(2,50)=33.97$, $P<0.001$], reflecting an effect with a posterior distribution [frontal: $F<1$; central: $F(1,25)=2.96$, $P=0.146$; posterior: $F(1,25)=26.14$, $P<0.001$]. In controls, there was a significant C × A × H interaction. On frontal electrodes, there was neither a significant effect of C [$F(1,26)=1.66$, $P=0.209$] nor a significant C × H interaction [$F(1,26)=2.50$, $P=0.126$]. On central electrodes, there was a significant C × H interaction [$F(1,26)=17.04$, $P=0.001$], with significant effects of C on both hemispheres [left: $F(1,26)=12.34$, $P=0.002$; right: $F(1,26)=34.26$, $P<0.001$]. On posterior electrodes, there was a significant effect of C [$F(1,26)=65.91$, $P<0.001$]. For midline electrodes, there was a significant C × A interaction, with significant effects of C in both regions [central: $F(1,52)=29.15$, $P<0.001$; posterior: $F(1,52)=85.05$, $P<0.001$].

To sum up, we observed a biphasic N400–P600 pattern over posterior sites in the attriters; visual inspection showed that this was present in the majority of the speakers in this group. The control group speakers showed no effect in the N400 time window, but a P600 effect over central and posterior electrodes.

Gender agreement: adjacent condition

There were no significant main effects or interactions in the 300–500 ms window.

In the 600–1200 ms window, we observed more positive voltages (i.e. a P600 effect) for ungrammatical sentences in both groups. This was confirmed by a significant C × A × H interaction for lateral electrodes. Follow-up analyses showed a significant C × H interaction on frontal electrodes [$F(1,52)=5.49$, $P=0.023$], but effects of C were evident in neither hemisphere [both F's <1.44]. On central electrodes, there was also a significant C × H interaction [$F(1,52)=19.18$, $P<0.001$], reflecting a dextral effect of C [left: $F(1,52)=2.33$, $P=0.133$; right; $F(1,52)=24.43$, $P<0.001$]. On posterior electrodes, the C × H interaction was significant as well [$F(1,52)=8.54$, $P=0.008$] with effects of C in both hemispheres [left: $F(1,52)=59.79$, $P<0.001$: right: $F(1,52)=110.44$, $P<0.001$]. For midline electrodes, the C × A interaction was significant, reflecting an effect of C in both regions [central: $F(1,52)=20.40$, $P<0.001$; posterior: $F(1,52)=93.09$, $P<0.001$].

In summary, we observed no effects in the N400 time window, but a strong P600 effect over posterior and central electrodes in both groups.

Gender agreement: nonadjacent condition

Again, no significant main effects or interactions were found in the 300–500 ms window.

In the 600–1200 ms window, ungrammatical sentences elicited more positive voltages (i.e. a P600 effect) in both groups. This was statistically supported by a significant C×A×H interaction for lateral electrodes. Follow-up analyses showed a significant C×H interaction on frontal electrodes [$F(1,52)=7.08$, $P=0.015$]. However, the effects of C were present in neither hemisphere [left: $F<1$; right: $F(1,52)=2.38$, $P=0.258$]. A significant C×H interaction was also found for central electrodes [$F(1,52)=18.96$, $P<0.001$], with effects of C in both hemispheres [left: $F(1,52)=11.52$, $P=0.001$; right: $F(1,52)=25.76$, $P<0.001$]. For posterior electrodes, there was only a significant effect of C [$F(1,52)=69.15$, $P<0.001$]. For midline electrodes, we found a significant C×A interaction, with follow-up analysis showing effects of C in both regions [central: $F(1,52)=31.84$, $P<0.001$; posterior: $F(1,52)=88.18$, $P<0.001$].

As in the adjacent condition, no effects in the N400 time window were found, but there was a strong P600 effect over central and posterior electrodes for both groups.

Discussion

To isolate the effects of bilingualism on language processing, we compared monolingual speakers of German with L1 attriters of German with L2 English. We analysed ERP data in three structures: (1) agreement in nonfinite verb forms; (2) GG agreement between adjacent (A) and nonadjacent (B) determiners and nouns. In previous studies, violations as in (1) were processed the same across monolingual L1 and bilingual L2, whereas (2A) and (2B) showed some variability in late bilinguals. We hypothesized that attriters would be able to process verb agreement in a native-like way, but that their processing of GG agreement might have changed because of L2 influence on their access to the mental lexicon.

In monolingual controls, violations in all three conditions elicited late positive effects over posterior electrodes (i.e. a P600). These findings are in line with previous research [6–8,13]. In this time window, bilingual attriters showed fully native-like ERP signatures for violations of verb agreement. This established that, as expected, attriters' capability to process regular L1 morphosyntax remained unaltered. Contrary to our hypothesis, attriters were also indistinguishable from controls in the two GG conditions, with no effect of the distance between the agreeing elements. This is a surprising and interesting result because it shows that routines used for processing L1 structures at the interface of the lexicon and morphosyntax remain robust even after prolonged L2 immersion. This suggests that (passive) language processing, as tested in the EEG, is less susceptible to attrition effects than (active) language production, for which the written proficiency test shows a group difference with a slightly lower score in the attriters.

Controls and attriters did, however, differ in the verb condition. For attriters only, violations led to an additional early negative effect over posterior electrodes (i.e. an N400). Biphasic N400–P600 patterns for such constructions have been found before in monolingual natives of Dutch, which is morphologically similar to German, and for English [10,11,16,21]. Dutch natives, unlike Germans, are frequently exposed to and proficient in English. The fact that we observed the biphasic pattern in the L1 attriters, who are immersed in an Anglophone setting, is suggestive of a role of language contact with English in the generation of this additional N400 effect. The fact that attriters process an L1 structure in a way that is similar to the monolingual processing of their L2 (English) is reminiscent of the use of L1 strategies in L2 processing by learners [22]. It cannot be excluded, however, that the group differences are related to the reduced L1 use and proficiency in the attriters, rather than to the transfer of L2 processing strategies.

Conclusion

We have investigated the impact of bilingualism on morphosyntactic processing. On comparing monolingual controls and bilingual L1 attriters, we found that both groups showed late positive effects in response to verb agreement and GG agreement violations. The latter is surprising, given the lexical nature of GG and the vulnerability of the lexicon in L1 attrition. We interpret these results as evidence for the stability of the deeply entrenched L1 system, even in the face of L2 interference.

Acknowledgements

This research was supported by a grant (016.104.602) from the Netherlands Organisation for Scientific Research (NWO) awarded to Monika S. Schmid. The authors thank their colleagues at all four testing locations.

Conflicts of interest

There are no conflicts of interest.

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