Second language learners' processing of inflected words:

Behavioral and ERP evidence for storage and decomposition

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Abstract

This study reports the results of two behavioral and two event-related brain potential (ERP) experiments examining the processing of inflected words in advanced second language (L2) learners with Russian as their native language (L1) who learnt German as an L2 after childhood. Two different subsystems of German inflection were studied, participial inflection and noun plurals. For participial forms, L2 learners were found to widely generalize the *-t* suffixation rule in a nonce-word elicitation task, and in the ERP experiment they showed an anterior negativity followed by a P600 – both results resembling previous findings from native speakers of German on the same materials. For plural formation, the L2 learners displayed different preference patterns for regular and irregular forms in an off-line plural judgment task. Regular and irregular plural forms also differed clearly with regard to their brain responses. Whereas *-s* plural regularizations produced a P600 component, irregularizations elicited an N400. In contrast to native speakers of German, however, the L2 learners did not show an anterior negativity for *-s* plural regularizations.

Taken together, the results show clear dissociations between regular and irregular inflection for both morphological subsystems. We argue that the two processing routes posited by dual-mechanism models of inflection (lexical storage and morphological decomposition) are also employed by L2 learners, even though the decomposition route appears to be more limited in the L2 learners than in the native controls.

INTRODUCTION

Previous research indicates that inflectional morphology is an area of specific difficulty for adult L2 learners. It has been found that L2 learners use inflectional morphemes in an unsystematic fashion (Meisel 1991) with reduced morphological paradigms involving fewer distinctions than in the target language (Klein 1986). This even holds for relatively simple inflectional systems such as the regular subject-verb agreement paradigm of German (Clahsen 1988; Köpcke 1987) and for both verb inflection and nominal inflection (Parodi et al. in press). Some researchers (Haznedar & Schwartz 1997, Prévost & White 2000) speculate that the adult L2 learners' difficulties with inflectional morphology might be due to processing reasons, such that morphologically complex word forms, even those that form part of the L2 grammar, cannot be consistently accessed or retrieved from the lexicon. However, the details of L2 morphological processing have not been studied by these researchers. An interesting hypothesis as to how L2 processing might differ from L1 processing has been advanced by Ullman (2001). He argues that processing one's native language involves two different brain memory systems, a lexical store of memorized inflected words which depends upon declarative memory and is rooted in temporal lobe structures, and a mental grammar which includes combinatorial rules and is rooted in frontal brain structures. Given these assumptions, Ullman (2001) claims that L2 processing and representation is largely dependent upon the lexical memory system and invokes grammatical computation to a much lesser extent than L1 processing. For morphological processing, this means that L2 learners mainly rely on full-form storage of inflected words, while morphological decomposition is underused or even absent in L2 processing of inflected words. According to this account, L2 learners rely on just one of the two processing mechanisms that are employed in L1 processing, and this might perhaps be the reason for why inflectional morphology is hard for L2 learners.

Unfortunately, however, there is very little empirical evidence for these claims. There are a few studies on L2 processing of past-tense forms, but the results are inconclusive (see below), and the details of how adult L2 learners process inflected words remain largely unknown.

The present study represents a first step into examining on-line morphological processing in adult L2 learners using event-related brain potentials (ERPs). ERPs consist of a series of positive and negative voltage changes in the ongoing electroencephalogram that are recorded from the intact human scalp while the participant is performing some task, such as reading or listening to a sentence or a word (see e.g. Kutas & Van Petten 1994, Osterhout 1997). Precisely time-locked to the stimulus presentation ERPs possess time resolution in the millisecond range and provide a continuous recording, which make them particularly useful for the investigation of the temporal organization of linguistic processing. Moreover, ERPs provide for a rich source of data, including information about a waveform's polarity, amplitude, latency, and topographical distribution. In addition to two ERP experiments, one on nominal and one on verbal inflection, we will report the results of two behavioral experiments on the same phenomena, to determine the L2 learners' performance in an off-line task.

MORPHOLOGICAL PROCESSING IN A NATIVE LANGUAGE (L1) [1]

Experimental studies using a range of different psycholinguistic methods and techniques have led to a number of consistent and replicable results, e.g. frequency effects for irregularly inflected word forms in lexical decision tasks, stem-priming effects for regularly inflected word forms in different kinds of priming experiments, anterior negativities for incorrectly inflected word forms in ERP violation studies and modulated N400 effects in ERP priming studies; see Clahsen (1999), Marslen-Wilson & Tyler (1998)

and Pinker (1999), for review. The theoretical interpretation of these and other results on morphological processing in adult native speakers has been the subject of a controversy between associative single-mechanism models and a family of dual-mechanism models of inflection. The former claim that all inflected words are stored and processed within a single associative system in which morphologically complex words are processed like simple words, through associatively linked orthographic, phonological and semantic codes (see e.g. Bybee 1995, Rumelhart & McClelland 1986, Sereno & Jongman 1997, among others). Dual-mechanism models, by contrast, hold that morphologically complex word forms can be processed both assocatively, i.e. through stored full-form representations and by rules that decompose or parse inflected word forms into morphological constituents (Chialant & Caramazza 1995, Clahsen 1999, Frauenfelder & Schreuder 1992, Laudanna & Burani 1985, 1995, Pinker 1999, Schreuder & Baayen 1995, among others). A detailed review of this controversy and of previous psycholinguistic studies on inflectional morphology is beyond the scope of the present article (see e.g. Pinker 1999, Clahsen 1999). It is, however,important to provide a brief summary of previous *ERP studies on morphological processing*.

Previous ERP studies have led to the identification of different components involved in lexical-semantic and morpho-syntactic processing. It was found that lexical-semantic violations, e.g. a semantically inappropriate sentence-final word, elicited an increased amplitude of the N400 component, i.e. a negativity at central electrode sites (specifically Cz) with a maximum at approximately 400ms after stimulus onset (for a recent review see Kutas & Schmitt 2003). By contrast, morpho-syntactic violations have been found to elicit anterior negativities (sometimes larger over the left than over the right hemisphere, see Osterhout (1997: 497)), and/or a parietal positivity with a peak latency of about 600ms (P600); see Brown, Hagoort, & Kutas (1999) and Friederici (2002) for review. While the

exact functional properties of these two components are still controversial, it is safe to say that morpho-syntactic violations reliably elicit similar brain responses across different languages.

Replicable ERP effects have also been found in studies of inflectional morphology, in German (Penke et al. 1997, Weyerts et al. 1997, Lück et al. 2001), English (Münte et al. 1999, Newman et al. 1999), Catalan (Rodriguez-Fornells et al. 2001), Italian (Gross et al. 1998), and Spanish (Rodriguez-Fornells et al. 2002). As the present study examines German as a target language, our focus here is on the three German ERP studies. Penke et al. (1997), Weyerts et al. (1997) and Lück et al. (2001) used a morphological violation paradigm in which the brain responses to correctly formed inflected words were compared to brain responses for words that were formed using an incorrect ending. Two types of violation were tested, (i) *regularizations*, formed by adding a regular suffix to a verb or noun that requires an irregular one, e.g. **gelauft* instead of the correct *gelaufen* - 'run-past participle' or **Vases* instead of *Vasen* 'vases', (ii) *incorrect regulars*, in which a verb or noun that takes the regular default suffix appeared with a different incorrect ending, e.g. **getanzen* instead of *getanzt* 'danced participle' or **Waggonen* instead of '*Waggons 'wagons*'. Penke et al. (1997) examined participle formation in three experiments, Weyerts et al. (1997) and Lück et al. (2001) noun plurals. Penke et al. (1997) and Weyerts et al. (1997) presented their stimuli visually, Lück et al. (2001) auditorily.

In all these experiments, an anterior negativity between 300 and 800ms was found for regularizations (which was larger over the left than over the right hemisphere). Moreover, Lück et al. found a centro-parietally distributed positivity (P600) in the 800-1200ms time window for regularizations. For incorrect regulars, both the visual and the auditory studies on plurals elicited a central N400-like negativity compared to their correct counterparts, an effect that was not seen in Penke et al.'s visual experiments on participles. These

results were interpreted as supporting a dual-mechanism account of morphological processing. From this perspective, regularizations are violations of the default rule, i.e. misapplications of the participle *-t* or the plural *-s* rules to (irregular) verbs or nouns that would normally block the rules, to produce illegal stem+affix combinations such as **gelauf-t* and **Vase-s*. The anterior negativity (which may be followed by a P600) found under these conditions has been shown to be a marker for syntactic, rule-based mechanisms, and can therefore be interpreted as reflecting decomposition processes involved in morpho-syntactic structure building. By contrast, irregular inflection is not rule-based but thought to be based on full-form storage. Misapplications of irregular inflection do not involve rule-violations, but rather seem to produce unexpected or anomalous words as suggested by the central N400 effect for (plural) irregularizations[2].

These results indicate that native speakers of German respond differently to violations of regular and irregular inflectional processes. Regularizations elicited signals that are typical of morpho-syntactic rule violations, whereas irregularizations produced waveforms that are typical of the reaction to anomalous words. These differences correspond to the distinction between rule-based and storage-based inflection.

MORPHOLOGICAL PROCESSING IN A SECOND LANGUAGE

In contrast to the rich experimental literature on L1 morphological processing, very little is known about how adults process inflected words in an L2. There are three previous studies that employed the speeded production task originally developed by Prasada et al. (1990) to determine differences between regular and irregular inflection in the on-line production of inflected words in an L2 (Beck 1997, Lalleman et al. 1997, Brovetto & Ullman 2001). In the speeded production task, participants are asked to produce as quickly and accurately as possible a corresponding inflected form for a given verb stem. Accuracy

rates and production latencies are measured, the latter of which provide the crucial on-line measure. The critical items are matched on (verb) stem frequencies, but differ with respect to word-form frequencies, i.e. the frequencies of their past-tense forms. The rationale is that if an inflected word form is stored in the mental lexicon, then the retrieval should be faster for high-frequency word-forms than for low-frequency ones, and this contrast should be reflected in different production latencies. This seems to be a sensible assumption given that memory traces get stronger with additional exposure, so that high-frequency items should be more readily accessed than low-frequency ones. Birdsong & Flege (2000) also examined frequency effects for regulars and irregulars in an L2, but they employed a speeded grammaticality judgment task for correct and incorrect inflected word forms. All of the above-mentioned studies tested adult native speaker controls and adult L2 learners.

The findings from these studies on L2 learners are inconsistent and partly surprising. Whereas the native speaker controls showed a consistent response-time advantage for high-frequency irregulars (but not for regulars) in all experiments, most studies failed to replicate this effect for the L2 learners. Beck (1997:105) found no response-time difference between high and low-frequency irregulars for the L2 learners. Lalleman et al. (1997: 13) found an advantage for both high-frequency irregulars and regulars. Birdsong & Flege (2000) obtained a significant frequency-by-regularity interaction for the L2 learners, but only with respect to the accuracy data. In the on-line data, there were no significant differences between high and low-frequency irregulars. Only Brovetto & Ullman (2001) obtained the same significant frequency effect for irregulars in L2 learners as in native controls. The results from the L2 learners on regulars were even more inconclusive. In some experiments (Birdsong & Flege 2000; Beck 1997, Experiment 6), low and high-frequency regulars did not yield significantly different response times, in

others (Lalleman et al. 1997, Brovetto & Ullman 2001), low-frequency regulars produced longer latencies than high-frequency ones, and still in others (Beck 1997, Experiment 4), a significant anti-frequency effect was found with shorter production latencies for low-frequency regulars than for high-frequency ones. Given the inconsistencies across and even within studies, any general conclusions would appear to be premature. Clearly, more research on L2 morphological processing is needed.

THE PRESENT STUDY

As the available behavioral studies have not been able to provide a clear picture of morphological processing in an L2, we made use of ERPs to further investigate how L2 learners process inflected words on-line. Recall that ERPs possess time resolution in the millisecond range and thus provide an excellent on-line measure of language processing in real time.

To examine L2 morphological processing, we investigated German participial inflection and noun plurals in advanced L2 learners of German with Russian as L1. In addition to two main ERP experiments, the L2 participants underwent two off-line tasks (acceptability judgment, elicited production) to examine the generalization patterns of the inflectional systems tested in the two main experiments. The ERP data allow us to address the question of whether adult L2 learners *process* inflected words differently from native speakers. Specifically, we ask whether advanced L2 learners of German show the same ERP violation effects as native speakers of German. We will also assess the possibility that the mechanisms used for L1 processing of inflected words are not or only partially available for L2 processing.

PARTICIPANTS

Eighteen advanced learners of German with Russian as L1 were tested (mean age 25 years, range 20 – 33 years; 5 males). They had lived in Germany for an average of 4.5 years (range 0.5 – 12 years) and had their first exposure to German at age 17 (range 8 – 29 years). All participants were right-handed. They had no known hearing deficits and were paid for their participation. When the experiments took place, all learners were living and working in the Leipzig area. All the participants reported using German on a daily basis for interaction with native and non-native speakers, i.e., all participants use German in their work environment, and all of them have German friends or partners, and they communicate with them in German. To obtain a general measure of their proficiency, they were asked to rate their German language proficiency on a 6-point scale (6 = very good; 1 = hardly any knowledge); this yielded an average score of 5.0 suggesting that their knowledge of German is at an advanced level.

All the L2 learners participated in an elicited participle production task (Experiment 1), a plural acceptability judgment task (Experiment 3), and in the two ERP experiments, one on participles (Experiment 2) and one on plurals (Experiment 4). Experiment 4 was conducted in the same session as Experiment 3. The two ERP experiments were separated by at least one week, and the order in which the experiments were administered was counterbalanced across participants.

In the following, we will first provide a brief description on how participles are formed in German and in the L2 learners' native language (Russian). We then present the two experiments on participles.

PARTICIPLE FORMATION IN GERMAN AND RUSSIAN

(Past) participle formation in German involves two endings, *-n* appears on all participle forms of so-called strong (= irregular) verbs, and *-t* appears on participle forms of all other verbs. Irregular verbs undergo (phonologically unpredictable) stem changes in the preterit and at times also in the participle, e.g. *laufen* (infinitive) – *gelaufen* (participle) – *lief* (preterit) 'to walk' – 'walked' – 'walked'. There are about 160 simplex verbs that fall into the strong (= irregular) class. Regular (= weak) verbs do not exhibit any stem changes in the past participle or the preterit, e.g. *tanzen* – *getanzt* – *tanzte* 'to dance' – 'danced' – 'danced'. In addition, traditional grammars identify a small class of 13 verbs of so-called mixed inflection which take the (regular) participle ending *-t* but also show a stem change in the preterit and in the participle, e.g. *denken* – *gedacht* – *dachte* 'to think' – 'thought' – 'thought'. As illustrated in the examples, many German participles are prefixed with *ge-*. This prefixation is prosodically determined depending on the stress pattern of the verbal stems: *ge-* occurs when the verbal stem is stressed on the first syllable. Since German verbal stems are often stressed on the first syllable, the (unstressed) *ge-* prefix is highly frequent. Note, furthermore, that the choice of the prefix is irrelevant for the morphological distinction between regular and irregular inflection, as it occurs in both regular (*-t*) and irregular (*-n*) participles.

According to its linguistic properties, the participle suffix *-t* behaves like the English past tense suffix *-ed*: *-t* suffixation on regular verbs does not involve any stem alternations and is applied under default circumstances in the sense of Marcus et al. (1995), i.e. to words for which lexical entries are not readily available, e.g. low-frequency verbs (*schroten* 'to crush (grain)' - *geschrotet*), verbs derived from adjectives or nouns (*sauber* (adj.) 'clean' – *säubern* (verb) 'to clean' – *gesäubert*), onomatopoeia (*brummen* 'to buzz' - *gebrummt*), and nonce words (*flauden* – '*geflaudet*'). In contrast, *-n* suffixation co-occurs with

phonologically unpredictable stem changes and *-n* participle formation does not generalize to nonce words which do not rhyme with existing strong verbs (Clahsen 1997). Hence, *-n* participle forms behave like English irregular past-tense forms.

The *Russian* (Past Passive) participle endings are the same as those in German, *-t* and *-n*, and as in German, the *-t* suffix shows default behavior in that it is not sensitive to particular phonological or other conditions. By contrast, the *-n* participle form appears on stems that end in /a/ or /aj/, and *-en* appears on stems ending with a final non-sonorant consonant other than /j/ or a stem-final front vowel. All other verb stems select *-t* (see Beard 1995: 140f.). Thus, selection of *-n* participle formation in Russian is phonologically determined, by certain segments at the right edge of individual verb stems. In German, however, *-n* participle formation is determined by class membership and only applies to the subclass of strong verbs.

EXPERIMENT 1: ELICITED PRODUCTION OF PARTICIPLES

The purpose of this task was to determine the generalization properties of the two participle endings *-t* and *-n* in L2 German. Specifically, we ask whether the two endings show the same difference in generalizability in L2 learners as in native speakers of German.

Method

We employed an elicitation task with the L2 learners in which participants were presented with a nonce verb in the infinitive and 1st person preterit form (step 1). They were then asked to repeat the preterit form of the nonce verb (step 2), and finally they had to produce the participle form, i.e. an inflectional form of the nonce word which they have not seen before (step 3). An example is shown in (1); see Clahsen (1997) for a more detailed

description. All nonce verbs were presented as part of sentences in written form and in a pseudo-randomized order. Participants were asked to carefully read the sentences and to fill in the blanks in a way which sounded intuitively correct to them. There were 10 sentences each in four experimental conditions: (i) regular ('weak') nonce verbs, (ii) nonce verbs with a mixed inflectional pattern, (iii) irregular ('strong') nonce verbs that rhymed with existing ones, (iv) non-rhyming irregular nonce verbs. The preterit forms provided an unambiguous cue as to whether a nonce verb was regular (in which case the preterit form had a *-te* suffix and no stem changes), 'mixed' (preterit forms with *-te* and vowel changes) or irregular (preterit forms with vowel changes and no *-te*).

(1) *Step 1: presentation of nonce verb in infinitive and 1st person preterit*

'Eines Tages kam mein Freund Peter zu mir und fragte mich, ob ich seinen Zatt teiden kann. Es war kein Problem für mich, und ich tied seinen Zatt.'

(One day, my friend Peter came to me and asked me whether I can teiden (=infinitive) his Zatt . That was no problem for me, and I tied (= 1st preterit) his Zatt. (Note that *Zatt* is a nonword as well.))

Step 2: repetition of preterit form

'Es war nicht das erste Mal, daß ich einen Zatt __'

(It was not the first time that I _____ a Zatt.)

Step 3: production of participle form

'Peter sagte: Danke, daß du meinen Zatt ___ hast.'

(Peter said: 'Thank you that you have ____ my Zatt.)

Results and discussion

One participant had to be excluded from the analysis because of a high error rate of more than 90% in step 2. All other participants carried out step 2 virtually perfectly. There were three trials (0.4 %) in which an error occurred in step 2, and these were excluded from any further analysis. Table 1 shows the mean rates of expected participle suffixation on the basis of the preterit forms which the L2 learners supplied in step 2; recall that from the preterit forms they used in step 2, we can infer whether they have recognized the nonce verb as either strong, weak or mixed.

//INSERT TABLE 1 ABOUT HERE//

Weak and mixed verbs elicited the suffix *-t* in more than 90% of the trials. By contrast, the rates for *-n* participle suffixation were considerably lower, 68% for rhymes and 53% for non-rhymes. Instead, the L2 learners made use of *-t* participle suffixation, not only for mixed and weak verbs, but also for nonce verbs for which they themselves produced strong preterit forms in step 2. By contrast, the *-n* participle ending was hardly ever applied to items that were treated as weak or mixed verbs in step 2. A repeated-measures ANOVA with Suffix (*-t* vs. *-n*) as predicted by Class (weak, strong, mixed) as dependent variable revealed a significant main effect ($F(3, 48) = 17.47$, $p < .001$). Pairwise comparisons between the four conditions in Table 1 (with an adjusted α-level of .008) revealed significant differences for all comparisons (except for 'weak' vs. 'mixed verbs'). These results are similar to those reported in Clahsen (1997) for native speakers of German with the same experimental task. It was found that only 31% of the items that the L1 German speakers reproduced in the strong preterit form in step 2 had the expected *-n*

suffix on the participle, but that 97% of the weak verbs and 98% of the mixed verbs were suffixed with *-t* in the participle, a clearly significant difference.

Taken together, these results indicate different generalization properties of *-t* and *-n* participle formation in both the German native speakers and the L2 learners: *-t* generalizes widely to all kinds of nonce verbs while extensions of *-n* participle formation are narrowly restricted to novel strong verbs, particularly to those that sound similar to existing ones. These differences suggest that *-t* participle formation is rule-based, only constrained by general principles and hence may apply to any kind of verb, whereas strong participles are probably stored together with the *-n*, and hence the similarity-based extensions to nonce verbs found in this experiment. The present findings suggest that this also holds for the group of L2 learners under study.

EXPERIMENT 2: ERPs TO CORRECT AND INCORRECT PARTICIPLES

To examine on-line morphological processing of participles in L2 learners, we made use of the ERP violation paradigm. In native speakers of German regularizations, i.e. incorrect participles with a regular *-t* suffixed to a strong verb (**gelauft* vs. *gelaufen* - 'run-past participle') elicited an anterior negativity between 250 and 500 ms relative to the correctly inflected forms (Penke et al. 1997), whereas incorrect regulars (**getanzen* vs. *getanzt*) did not produce a measurable effect. Here we ask whether L2 learners show the same or different ERP effects to incorrectly inflected participles.

Method and materials

We adopted the design and materials of the 'sentence' experiment from Penke et al. (1997) with one modification. To simplify the experiment, we restricted ourselves to testing participle forms of existing verbs and did not include the additional nonce verb

condition from Penke et al. (1997). In our version, the experiment had a 2x2 design: participle forms were suffixed with *-t* (= regular) or with *-n* (= irregular) and were correct or incorrect. Two types of violations were tested: *regularizations*, a regular *-t* suffixed to a verb that requires an irregular form (**gelauft* vs. *gelaufen* - 'run-past participle') and *incorrect regulars*, a regular ('weak') verb incorrectly suffixed with *-n* (**getanzen* vs. *getanzt* 'danced participle'). Note also that all the strong verbs tested were of the so-called 'A-B-A' –class which have stem changes in the preterit, but not in their participle forms. Hence, the participle forms we tested only differed in terms of their endings, *-t* vs. *-n*. There were 50 regular and 50 irregular participles, which were matched for frequency. These critical participles were embedded in simple declarative sentences which all consisted of six words. The participle was the final word of the sentence; see Penke et al. (1997) for further details.

Sentences were distributed in two blocks such that a correct and an incorrect version of a given participle occurred in different lists. The two blocks were pseudo-randomized with the general constraints that no more than three consecutive trials (a) consisted of either regular or irregular participles and (b) contained either correct or incorrect participles. Three different combinations of presentation order of the two blocks were created. Three more presentation lists were generated by reversing the order of the original lists. Each of these six lists was presented with a probe verification task (see below) which required a button press either with the left or with the right hand, thus yielding a total number of twelve different lists. None of the lists was presented more than twice.

Procedure

Participants were tested in a soundproof booth. Sentences were presented on a computer screen word by word in yellow letters on a blue background. The words were presented

for 700 ms with no blank interval in between[3]. The stimulus onset asynchrony was as in Penke et al. with a 2300 ms interval between two stimulus sentences. The words subtended 0.75° of visual angle in height and a maximum of 4.85° in width. After 10 sentences a 'probe sentence' was presented in red letters. Half of these probe sentences were exact repetitions of one of the 10 sentences shown before and the other half differed with regard to the content words of any of the previous sentences[4]. True and incorrect probes were equally distributed across the four experimental conditions. Participants received a written instruction in which they were asked to carefully read each sentence and to indicate via a push button response whether a probe sentence was or was not a repetition of one of the previous 10 sentences. Furthermore, they were asked to minimize eye and body movements during the presentation of the sentences. The experiment was subdivided in four blocks of 55 sentences each.

Subsequent to the EEG session a list of all critical verbs was read out to the participants in their infinitive form and they were asked to generate the participle forms. This provided additional information as to whether the experimental items including their correct participle forms are familiar to the L2 learners.

ERP recording

The EEG was recorded from 25 scalp sites (Sharbrough et al. 1991) by means of AgAgCl electrodes attached to an elastic cap: FP1/2, F7/8, F3/4, FT7/8, FC3/4, T7/8, C3/4, CP5/6, P7/8, P3/4, O1/2, FZ, CZ, PZ. Recordings were referenced to the left mastoid. In order to control for eye movement artifacts, the horizontal electro-oculogram (EOG) was monitored from electrodes at the outer canthus of each eye and the vertical EOG from two electrodes located above and below the participant's right eye. Electrode impedances were kept below 5 kOhm. EEG and EOG channels were recorded continuously with a band pass

from DC to 40 Hz with a digitization rate of 250 Hz. ERPs were filtered off-line with 8 Hz low pass for the plots, but all statistical analyses were computed on non-filtered data.

ERPs on the critical participle forms were recorded for 1200ms separately for each participant, electrode and condition. All ERP averages were aligned to a 200 ms baseline before the onset of the critical word. Trials with ocular or amplifier saturation artifacts were excluded from the averages. The average percentage of rejected trials was 16%.

All statistical analyses were performed on the mean ERP amplitudes. On the basis of visual inspection and previous studies we chose three different time windows: 250-600ms for the anterior negativity, 600-1000ms for the late positivity, and 450-600ms for possible N400 effects. Repeated measure ANOVAs were performed on all lateral electrodes with three within-subject variables: Condition (correct versus incorrect), Hemisphere (left versus right) and Site (anterior versus central versus posterior). The variables Hemisphere and Site were completely crossed, yielding 6 regions of interest with three electrodes each: left anterior (F7, FT7, FC3), right anterior (F8, FT8, FC4), left central (T7, C3, CP5), right central (T8, C4, CP6), left posterior (P7, P3, O1), right posterior (P8, P4, O2). The Greenhouse-Geisser correction was applied whenever effects with more than one degree of freedom in the numerator were evaluated. Below, we report uncorrected degrees of freedom and corrected probabilities.

Results

Two sets of behavioral data were gathered in this experiment from the L2 learners, (i) elicited production of participle forms for the critical experimental items after the EEG session, (ii) probe verification. Performance on both tasks was very good (>95% correct responses in the elicitation and >96% correct responses in the probe verification task)

indicating that the participants actually read the stimuli in order to make the required distinction and that they were familiar with the critical verbs and their participle forms.

The ERP data of the L2 learners show a regular/irregular distinction. *Regularizations* (i.e. the regular *-t* suffixed to a strong verb such as *laufen* 'run') elicited an anterior negativity between 250 and 600ms as well as a small parietal positivity between 600 and 1000 ms compared to their correct counterparts (see Figure 1). By contrast, *incorrect regulars* (i.e. *-n* suffixed to a weak verb such as *tanzen* 'dance') yielded a centrally distributed negativity between 450 and 600ms relative to the correct participle forms (see Figure 2).

//INSERT FIGURES 1 AND 2 ABOUT HERE//

With respect to the regularization condition (see Figure 1), statistical analyses for the lateral electrodes in the early time window (250-600 ms) revealed a significant interaction of the factors Condition and Site ($F(2,34) = 8.75$, $p < .01$). Subsequent analyses showed that there was a reliable effect of Condition for the anterior ($F(1,17) = 5.71$, $p < .05$), but not for the central ($F < 1$) and posterior electrode positions ($F(1,17) = 2.53$, $p < .13$). For the midline positions there were no significant effects involving the factor Condition. Analyses in the late time window (600-1000 ms) for the lateral electrode positions revealed a reliable main effect of Condition ($F(1,17) = 4.95$, $p < .05$) as well as a significant interaction of Condition and Site ($F(2,34) = 4.85$, $p < .05$) reflecting the fact that there was a reliable positivity over central ($F(1,17) = 4.45$, $p = .05$) and posterior ($F(1,17) = 7.53$, $p < .05$), but not over anterior sites ($F < 1$). Analyses for midline positions demonstrated a main effect for Condition ($F(1,17) = 4.47$, $p < .05$) which interacted with Electrode ($F(2,32) = 3.74$, $p < .06$). A significant positivity for regularizations was only observed for Pz, and not for the other central electrode sites Cz

and Fz ($F(1,17) = 7.11$, $p < .02$; Cz: $F(1,17) = 1.86$, $p < .19$; Fz: $F < 1$)). These statistical analyses confirm the observed anterior negativity between 250 and 600ms plus a later parietal positivity for regularized participle forms.

With respect to the irregularization condition (see Figure 2), statistical analyses comprising the time window of 450-600ms revealed a marginally significant main effect of Condition for the midline electrodes ($F(1,17) = 3.57$, $p < .08$) which indicates a strong tendency towards a centrally distributed negativity for incorrect regulars.

Discussion

The most important finding from the ERP experiment is that the two types of morphological violation (incorrect regulars, regularizations) elicited clearly different brain responses in the L2 learners: *incorrect regulars* elicited an N400, and *incorrect irregulars* a biphasic ERP pattern with an anterior negativity followed by a P600.

The anterior negativity was found in the same time range as in native speakers of German (see Penke et al. 1997). Whereas this effect had its maximum at left anterior sites in the L1 speakers, it was observed bilaterally in our Russian L2 group. Note, however, that topographic variations of anterior negativities in this time range have been observed in a number of ERP studies with adult native speakers; see e.g. Rodriguez-Fornells et al. (2001) for Catalan, Gross et al. (1998) for Italian, and Weyerts et al. (2002) for German, who found either bilateral negativities or even effects at right anterior sites. Both in terms of its timing and its distribution the anterior negativity we found for the L2 learners falls within the range of variation that has been observed in studies with native speakers and can therefore be taken to be an instance of a 'morpho-syntactic negativity', an ERP waveform that is clearly different from the centroparietal N400 which has been found to be associated with lexical-semantic processing. For inflectional morphology, anterior

negativities for regularizations have been interpreted as reflecting violations of rule-based morphological processing (Penke et al. 1997, Weyerts et al. 1997, Rodriguez-Fornells et al. 2001). Given that the anterior negativity observed for regularizations in the L2 learners represents the same functional process, we conclude that L2 learners are indeed employing regular rules of inflection in on-line morphological processing.

Regularizations also elicited a small parietal positive-going wave in the L2 learners with a latency of 600 to 1000ms poststimulus, a waveform that can be identified as a P600. While this effect was not seen in Penke et al.'s (1997) study of native speakers of German, a biphasic ERP pattern with an early anterior negativity followed by a P600 has been reported in a number of sentence processing studies (see e.g. Friederici 1999, 2002 for review) as well as in studies examining morphological violations in Catalan (Rodriguez-Fornells et al. 2001) and German (Lück et al. 2001). The P600 has been interpreted to reflect reanalysis, repair or integration processes at the sentential level (Friederici et al. 2002; Osterhout & Holcomb, 1992; Kaan et al. 2000), and it has been argued to indicate controlled rather than automatized processing (Hahne & Friederici 1999; Friederici 2002). Given that the P600 reflects sentence-level processes, the P600 we obtained suggests that in L2 learners, regularization errors do not only affect early word-internal morphological processing (as indicated by the anterior negativity discussed above), but also later sentence-based processes. In other words, with respect to the *-t* regularization two distinct processes could be identified, a relatively early process of automatic morphological decomposition and a later process which integrates the participle with the rest of the sentence[5].

Taken together, our results show that not only in native speakers but also in advanced L2 learners, the brain responds differently to violations of regular and irregular inflectional processes. Regularizations, i.e. misapplications of the *-t* participle rule, elicited brain

signals that are known to be associated with morpho-syntactic rule violations, whereas irregularizations, i.e. misapplications of irregular patterns, did not produce such effects. This suggests that adults make use of rule-based morphological decomposition for processing inflected words, not only in their native language, but also in an L2.

In the next section, we will report results from two experiments examining a different morphological system, German noun plurals, in the same group of L2 learners. Before presenting the experiments on noun plurals, we will first provide a brief description of the German plural system, in addition to some remarks on how noun plurals are formed in the learners' L1 (Russian).

NOUN PLURALS IN GERMAN AND RUSSIAN

German has a zero plural form and four overt plural suffixes (*-e*, *-er*, *-(e)n*, *-s*), some of which can co-occur with an altered (umlauted) stem vowel. The use of the different plural allomorphs with specific nouns is arbitrary to varying degrees, and for most of them there are preferred tendencies of plural formation interacting with the gender system and the phonological form of the singular form (see Marcus et al. 1995 for further discussion). In the main ERP experiment on noun plurals, we compared *-s* and *-n* plurals; the following remarks, therefore, focus on these two forms.

What is common to *-s* and *–n* plurals is that in contrast to the other plural forms they do not involve any stem changes ('umlaut'). In other respects, however, they are very different from each other. First, among the five German plural allomorphs *-n* is the most common with a type frequency of 48% and a token frequency of 45% in the CELEX lexical database (Sonnenstuhl & Huth 2002), whereas *-s* is the most uncommon plural form (type frequency: 4%; token frequency: 1.8%). Second, the form that acts most clearly as the regular default is the plural *-s,* despite its low frequency (see Marcus et al

1995). The *-s* plural is not restricted to a specific phonological environment and occurs on both vowel-final and consonant-final stems, on masculine, feminine, and neuter nouns. The affix *-s* also serves as the appropriate plural marking whenever a lexical entry is not readily available, i.e. it generalizes to novel, unusual-sounding words and to rootless and headless nouns derived from other categories. None of these properties holds for *-n* plurals. Instead, there are particular morpho-phonological properties of nominal stems that favour *-n* plurals. First, *-n* applies mostly to feminine nouns (83% of *-n* plurals). Second, there is a tendency for *-n* plurals to have a stem-final schwa (37% of *-n* plurals). Note, however, the large number of exceptions, 17% of *-n* plurals apply to masculine or neuter nouns, and 63% do not have stem-final schwas, which make it difficult to formulate an *-n* plural formation rule based on either of these properties. There is only one fully predictable pattern without exceptions: feminine nouns with stem-final schwa take *-n* plurals. Consequently, this subclass of *-n* plurals has been argued to be rule-based (see e.g. Wunderlich 1999, Wiese 1999, Dressler 1999).

Russian makes use of a range of case-number morphemes and three declensional patterns for nouns including subdeclensions. Moreover, case-plural morphemes are largely vocalic and often stressed. Timberlake (1993) distinguishes between declension Ia, basically for masculine nouns, declension Ib which is almost exclusively neuter, declension II composed primarily of feminines, and declension III characterized by the syncretic ending *-i* in genitive, dative and locative, with further subdeclensions. Classes Ia, II, and IIIa prefer the nominative plural *-i*, while classes Ib and IIIb have a preference for the nominative plural *-a*. The preferred genitive plural is *–ov/-ev* in class Ia, *-ej* in class IIIa, and *-∅* in the remaining classes. In addition, there is stem allomorphy in the plural for recognizable groups of nouns along with deviations from the preferred plural endings. Nationality terms, for example, use an otherwise unique nominative plural ending *-e*,

borrowings as well as a substantial number of nouns have the nominative plural *-á* implying end stress throughout the plural, e.g. *inspéktor – inspektorá*. Clearly, noun plural formation in Russian is very different from German.

EXPERIMENT 3: ACCEPTABILITY JUDGMENT OF NOUN PLURALS

The purpose of this task was to determine the generalization properties of the different noun plural forms of German in L2 learners. Specifically, we ask whether the plural *-s* (despite its low frequency) acts as default plural in our group of Russian L2 learners of German in the same way as it does in native speakers of German.

Method

We employed the paper-and-pencil judgment task from Marcus et al. (1995) in which participants are asked to judge the acceptability of plural forms of nonce nouns. The experimental items were 12 monosyllabic nonce nouns that rhymed with existing German nouns that take irregular plural forms, e.g. *Pund* on analogy with *Hund* - *Hunde* 'dog - dogs', and 12 non-rhymes. Each item was first presented in a context sentence in its singular form, followed by 8 test sentences each containing one of the plural forms of German. Participants were asked to rate each sentence on a 5-point scale (1 = ′perfectly natural′, 5 = ′very unnatural′) for acceptability. The critical nonce items were introduced with masculine or feminine gender, and the regular *-s* plural form appeared either as the first or the final item within the 8-items list of plural forms. These factors were counterbalanced across participants yielding four different experimental versions. The experimental sentences were presented in a pseudo-randomized order such that there were no more than three rhyme or non-rhyme items in direct succession. Written instructions

were provided emphasizing that there were no correct or incorrect answers and that participants should rely on their intuition; see Marcus et al. (1995) for further details.

In the analysis, each rating was subtracted from 6, so that the higher the score the more natural a given plural form. Following Marcus et al., we took the highest rated irregular for comparison with the ratings of the regular *-s* plural. A two-way ANOVA with Regularity (*-s* plurals vs. irregular plurals) and Rhyme (rhyming vs. non-rhyming nouns) as within-subjects factors was conducted on the mean rating scores.

Results and discussion

The L2 learners' mean ratings for the plural forms of rhyming and non-rhyming nonce nouns are shown in Table 2.

//INSERT TABLE 2 ABOUT HERE//

Analyses of variance revealed a significant main effect of Regularity ($F(1, 17) = 13{,}60$, $p<.05$) reflecting the fact that ratings for irregular plurals were overall higher than for the *-s* plural. There was no effect of Rhyme ($F <1$), but rather a significant interaction of Rhyme and Regularity ($F(1,17) = 5.58$, $p<.05$), indicating that irregular plural forms were judged as better for nouns that rhymed with existing (irregular) nouns than for non-rhymes, whereas *-s* plural forms were judged as better in the Non-Rhyme condition than in the Rhyme condition.

Table 2 shows that the differences between conditions were smaller in size in the L2 learners than in the German native speakers, which could be due to differences in sample size or to the fact that the L2 learners have not yet completely mastered the German plural system, an issue to which we come back below. Crucially, however, the L2 learners' preference patterns for regulars and irregulars are parallel to those reported by Marcus et al. (1995) for native speakers of German. Marcus et al. (1995) found that native German

speakers judged irregular plurals as overall better than *-s* plurals. More importantly, the L1 speakers showed the same Rhyme-by-Regularity interaction that was found for the L2 learners, with *-s* plurals receiving higher ratings for non-rhymes than for rhymes, and the reverse pattern for irregulars. Thus extensions of irregular plural formation are sensitive to similarity, whereas *-s* plurals are applied elsewhere, even to nouns that are dissimilar to any existing German word. This contrast seems to hold not only for native speakers of German, but also for the group of L2 learners under study.

EXPERIMENT 4: ERPs TO CORRECT AND INCORRECT NOUN PLURALS

To examine on-line morphological processing of German noun plurals in L2 learners, we performed an ERP violation experiment with the same group of advanced Russian learners of German that underwent experiments 1 to 3. Recall that in previous experiments with native speakers of German (Weyerts et al. 1997, Lück et al. 2001), regularizations were found to elicit an anterior negativity (which was followed by a P600 in Lück et al.'s auditory ERP study), whereas incorrect regulars produced an N400. Here we ask whether L2 learners show the same or different ERP effects to incorrectly inflected plural forms.

Method and materials

We adopted the design and materials of the auditory ERP violation experiment from Lück et al. (2001). The critical items were matched for the same frequency and morpho-phonological criteria as detailed in Weyerts et al. (1997). There were 48 critical nouns forming their plural with *-(e)n*. Half of these were masculine and half were feminine. All feminine nouns consisted of two syllables and ended in a schwa. Recall that *-n* plurals on feminine nouns with a stem-final schwa are sometimes regarded as rule-based, and were therefore examined separately from *-n* plurals of masculine nouns which are clearly

irregular. Another 48 critical nouns were examined that require *-s* plurals, none of which had a stem-final vowel. Since most of these items are loan words, these will be referred to as the 'loan word condition'. In addition, 24 surnames served as critical items in the 'proper name condition', all of which require *-s* plurals in German.

Each noun was presented twice, in its correct plural form and with an incorrect plural form. Two types of violation were tested: *default regularizations*, a regular *-s* suffixed to a noun that requires an *-n* plural form (**Vases* vs. *Vasen* - 'vases') and *incorrect regulars*, a noun that requires the regular *-s* plural incorrectly suffixed with *-n* (**Waggonen* vs. *Waggons* 'wagons'). The critical words were embedded in sentences and always appeared in direct object position followed by an adverbial or a prepositional phrase; examples are shown in (2):

(2) a. Nouns requiring *-n* plurals (masculines):
Die Orchester einer Oper brauchen gute *Dirigenten/*Dirigents* für ihre Aufführungen (The opera orchestras require good conductors for their performances.)

b. Nouns requiring *-n* plurals (feminines with stem-final schwa):
Frank schenkt seiner Mutter *zwei Vasen/*Vases* zum Geburtstag (Frank gives his mother two vases for her birthday.)

c. Nouns requiring *-s* plurals (loan words):
Der Kran belädt die grossen Waggons/*Waggonen im Hafen. (The crane loads the big wagons in the harbour.)

d. Nouns requiring *-s* plurals (proper (sur)names):
Das Grillfest am Wochenende wird von den *Lindners/*Lindnern* organisiert (The weekend barbecue will be organized by the Lindners (= the Lindner family.)

Two different experimental sentences were constructed for each noun, and each of these 240 sentences was presented twice, once with the correct and once with the incorrect

plural form of the critical noun. In this way, we made sure that the critical contrast between correct and incorrect plural forms was not affected by different kinds of sentence contexts (see also Besson & Kutas 1993). The different experimental sentences were counterbalanced across subgroups of participants, and each participant received 480 sentences. The order of presentation was pseudo-randomized such that no more than three consecutive items belonged to the same condition, no more than three consecutive trials contained either correct or incorrect plural forms, and repetitions of the same noun were separated by at least 27 intervening sentences.

Sentences were spoken by a trained female speaker of German and recorded onto digital audiotape. They were digitized at a sampling rate of 44 kHz, and stored as separate files for presentation during the experiment.

Procedure

Participants were seated in a comfortable chair in a soundproof booth 130cm in front of a computer monitor. Sentences were presented via loudspeaker while a fixation signal appeared on the screen. Trials were separated by an inter-trial-interval of 2500ms. After eight sentences, participants listened to a warning tone followed by a 'probe sentence' while a question mark appeared on the screen, and participants were instructed to give a push-button response indicating whether this sentence had been presented as one of the previous eight trials. Half of these probe sentences were exact repetitions of one of the eight sentences shown before and the other half differed with regard to the content words of any of the previous sentences. Participants were given a visual feedback on their responses. They were asked to minimize eye and body movements during the presentation of the sentences. After every 48 sentences, participants were given a short break.

The procedures for ERP recording and data analysis were as described for Experiment 2 In the present experiment, ERPs on the critical nouns were computed for 1500ms separately for each participant, electrode and condition. Trials with ocular or amplifier saturation artifacts were excluded from the averages, with an average of 18% rejected trials.

Subsequent to the EEG session all critical nouns were read out to the participants in their singular form and they were asked to generate the corresponding plural forms. This provided additional information as to whether the experimental items including their correct plural forms are familiar to the L2 learners.

Results

Two sets of behavioral data were gathered in this experiment from the L2 learners, (i) elicited production of plural forms for the critical experimental items after the EEG session, (ii) probe verification. Performance on both tasks was good (>86% correct responses in the elicitation and >91% correct responses in the probe verification task) indicating that the participants carefully listened to the stimuli in order to perform the verification task and that they were familiar with most of the critical nouns and their plural forms. It should be noted, however, that performance on these two tasks was worse than in the corresponding tasks for participles (see Experiment 2).

Visual inspection of the ERP data of the L2 learners reveals a clear contrast between *-s* plural regularizations and incorrect regulars. Regularizations of both masculine and feminine nouns elicited a late positivity between approximately 850 and 1250ms (see Figure 3 and 4). By contrast, misapplications of *-n* plurals to loan words yielded a centrally distributed negativity between 300 and 800ms relative to the correct plural forms (see Figure 5). Finally in the proper name condition, correct and incorrect versions are

seen to only differ slightly at parietal scalp sites, with incorrect items yielding a more negative waveform than the correct ones (see Figure 6).

//INSERT Figures 3-6 ABOUT HERE//

The factorial design and the electrodes within each region entered into the repeated measure ANOVA were parallel to Experiment 2. With respect to the masculine condition (see Figure 3), statistical analyses for the 850 – 1250ms time window revealed a marginally significant main effect of Condition ($F(1,17) = 3.37$, $p < .10$) and a reliable Condition-by-Hemisphere interaction ($F(1,17) = 4.55$, $p < .05$). Subsequent analyses showed that regularized plurals of masculine nouns produced a significantly more positive waveform over the right hemisphere than the correct plural forms (left: $F(1,17) = 2.13$, $p < .17$; right: $F(1,17) = 4.37$, $p = .05$). Analyses on midline positions revealed a reliable main effect of Condition ($F(1,17) = 4.76$, $p < .05$). To test for a possible anterior negativity which had been observed in native speakers, an additional analysis was conducted on the data in Figure 3 for the time interval of 300 – 550ms, which did, however, not reveal any significant effects for the factor Condition.

Regarding the feminine condition (Figure 4), analyses for the time window 850 – 1250ms revealed a significant Condition-by-Site interaction ($F(2,34) = 4.07$, $p <.05$) as well as a reliable three-way interaction of Condition, Hemisphere and Site ($F(2,34) = 5.22$, $p <.05$). Regularized feminine nouns elicited significantly more positive waveforms than their correct counterparts over posterior electrode sites (left central: $F(1,17) = 3.61$, $p <.10$; left posterior: $F(1,17) = 5.22$, $p < .05$; right posterior: $F(1,17) = 5.03$, $p <.05$). For midline positions there was a significant Condition-by-Electrode interaction ($F(2,34) = 4.11$, $p < .05$). Subsequent analyses showed a significant effect of Condition at Pz ($F(1,17) = 4.41$, $p = .05$). Again, as for the masculine condition, an additional analysis for the time window

of 300 – 550ms did not reveal any reliable effects of Condition; hence there were no signs of an anterior negativity.

These statistical analyses confirm that in our L2 participants, *-s* plural regularizations of both masculine and feminine nouns that require *-n* plurals in German are associated with a broadly distributed long-lasting positivity, parallel to what was found for native speakers of German (Lück et al. 2001). By contrast, the additional anterior negativity that these two conditions elicited in L1 speakers was not seen in the L2 learners, either for masculines or for feminines.

Concerning incorrect regulars, i.e. *-n* plurals of (loan) words that require *-s* plurals in German (see Figure 5), analyses in the 300 – 800ms time window revealed a highly significant main effect of Condition for lateral ($F(1,17) = 9.41$, $p < .01$) and midline electrodes ($F(1,17) = 8.29$, $p < .01$) which did not interact with any topographical variables. This confirms the centrally distributed negativity for incorrect regulars seen in Figure 5.

With respect to the proper name condition visual inspection of Figure 6 suggested a more negative waveform between 500 – 900ms as well as between 900 – 1500ms over posterior positions. ANOVAs for the 500 – 900ms time window revealed a marginally significant interaction of Condition and Site ($F(2,34) = 3.03$, $p < .10$) for lateral electrodes and a significant interaction of Condition and Electrode ($F(2,34) = 3.90$, $p < .05$) for midline electrodes. Subsequent analyses showed a reliable effect of Condition in the posterior region ($F(1,17) = 5.82$, $p < .05$) and at Pz ($F(1,17) = 5.88$, $p < .05$). For the later time window (900 - 1500ms), there was a marginally significant interaction of Condition and Site ($F(2,34) = 4.16$, $p < .06$). However, when analyses were calculated for each Site separately only the posterior region revealed a marginally significant effect of Condition ($F(1,17) = 3.13$, $p < .10$). There was also a significant interaction of Condition and

Electrode for the midline positions ($F(2,34) = 5.72$, $p < .05$) which gave rise to a reliable Condition effect at Pz ($F(1,17) = 4.49$, $p < .05$).

Discussion

The results of this experiment show that the two kinds of morphological violation we tested, regularizations and incorrect regulars, elicited clearly different brain responses in advanced adult L2 learners. Regularizations, i.e. *-s* plurals appearing on masculine or feminine nouns that require *-n* plurals in German, elicited a late positivity, an ERP component that in terms of its timing and distribution can be identified as a P600. Incorrect regulars, on the other hand, yielded an N400-like waveform, i.e. a centrally distributed negativity between 300 and 800ms. This effect was stronger in the loan word condition than for proper names, and in the proper name condition it occurred relatively late (after 500ms) and had a more parietal distribution. Crucially, however, the negativity found for incorrect regulars, of both loan words and proper names, represents a clearly different ERP component from the late positivity (P600) that was seen for *-s* plural regularizations of both feminine and masculine nouns.

The central negativity for incorrect regulars has also been found for native speakers of German in both the visual and the auditory ERP studies (Weyerts et al. 1997, Lück et al. 2001) and has been argued to reflect the processing of an unexpected or anomalous word. Indeed, from a linguistic perspective misapplications of *-n* plurals to nouns that take *-s* plurals in German produce items that are similar to pseudo-words, e.g. **Waggonen* 'wagons', whereas correct regulars (*Waggon-s*) are existing (morphologically complex) words. The central negativity we found for incorrect regulars in both the L2 learners and the German native speakers corresponds to this difference, and it resembles the N400

effect seen in many previous studies for anomalous or unexpected words, e.g. for pronounceable pseudo-words (Rugg 1987).

We interpret the late positivity (P600) as resulting from the L2 learners' recognition of a morpho-syntactic rule violation. Hence, it occurs with misapplications of the *-s* pluralization rule, but not with misapplications of irregular patterns. This effect was also seen in Lück et al.'s (2001) study of native speakers of German. Note, however, that an additional left anterior negativity was found to precede the P600 in the L1 speakers, suggesting that in native speakers of German, regularization errors affect both early word-internal processing as well as later sentence-based processes. It is conceivable that an *-s* plural regularization error is initially subject to (possibly automatic) processes of morphological parsing by which the inflected word is decomposed into its constituent morphemes; the anterior negativity could reflect the morphological rule violation detected at this level. At a later stage of processing, the regularized plural form has to be integrated with the rest of the sentence, and the P600 effect that Lück et al. found for L1 German speakers suggests that regularization errors cause additional processing at this level, perhaps because participants try to repair or reanalyze the regularized plural form before integrating it with the rest of the sentence. Given this account of the biphasic ERP pattern in native speakers, our present findings indicate that the L2 learners do not employ early processes of word-internal morphological decomposition to parse a plural regularization error, hence the lack of an anterior negativity, but employ repair and integration processes at a later stage of processing, as indicated by the P600.

GENERAL DISCUSSION

The most salient and consistent result of the present study is that advanced adult L2 learners respond differently to violations of regular and irregular inflection during on-line

morphological processing. For misapplications of regular rules of inflection, they showed ERP effects that have independently been argued to tap morpho-syntactic processing, namely an anterior negativity and/or a P600, whereas for misapplications of irregular inflection, they showed an ERP effect (the N400) that has been claimed to be characteristic of lexical processing. Even more strikingly, this contrast in the L2 learners' brain responses to morphological violations was found for two rather different inflectional systems, participle formation and noun plurals, which differ both in terms of their structural properties and vocabulary distribution (see e.g. Marcus et al. 1995).

The current set of ERP results is consistent with the fundamental distinction made in dual-mechanism models of inflection between full-form storage of lexical entries for irregulars versus rule-based morphological decomposition for regulars; see e.g. Pinker (1999) and Clahsen (1999). From the perspective of a dual-mechanism model of inflection, a *-t* participle affix appearing on an irregular verb or an *-s* plural incorrectly affixed to an existing noun produces stem+affix combinations that represent misapplications of a default rule to a verb or a noun that would normally block the rule. By contrast, irregular participles and noun plurals are said to be stored in memory together with their inflectional endings. Hence, misapplications of irregular patterns do not involve violations of (default) rules. The brain responses seen in L2 learners for the two kinds of morphological violation, i.e. 'morpho-syntactic' ERP components for rule violations and a lexical N400 for misapplications of irregular patterns, are compatible with this distinction and suggest that the two processing routes posited by dual-mechanism models of inflection (lexical storage and morphological decomposition) are also accessible and employed by L2 learners.

Comparing the ERP effects in the L2 learners with those of native speakers in the same experiments reveals not only similarities, but also an interesting difference. While N400

and P600 effects were seen in both the L1 and the L2 speakers, anterior negativities in the native speakers were more focal and more consistent across experiments than in the L2 learners. In native speakers of German, a (left) anterior negativity was found in three different experiments on participles (Penke et al. 1997) and in both the visual and the auditory ERP studies on noun plurals (Weyerts et al. 1997, Lück et al. 2001). In the L2 learners, a relatively broad anterior negativity was found for participles, but not for noun plurals. The anterior negativity observed in ERP violation studies of inflection in native speakers has been argued to reflect early automatic processes of word-internal morphological decomposition. If this is correct, then our present findings might mean that L2 learners are less consistent in employing these processes than native speakers. For *participles*, the anterior negativity suggests that L2 learners decomposed the regularized form and recognized the rule violation at an early stage of word-internal processing. For *plurals*, however, the P600 without an anterior negativity suggests that it is only at the later (possibly sentence-level) stage that the L2 learners process regularization errors like native speakers of German.

Linguistic differences between participle and noun plural formation are likely to be responsible for the fact that the L2 learners showed an anterior negativity for *-t* participle but not for *-s* plural regularizations. Note first that the German noun plural system is rather unusual in that it has a default rule (the plural *-s*) which has an extremely low frequency, which means that more than 95% of the German nouns form their plurals according to one of the various irregular patterns. With respect to participle formation, the frequency distribution and the similarity patterns are more common in that irregular verbs are clearly less frequent than regular ones. Moreover, the plural system is linguistically more diverse in that it comprises five different endings while participle formation only involves the choice between *-t* and *-n*. Finally, in relation to our group of Russian learners of German,

it should be noted that both languages share the two participle endings *-t* and *-n*, while noun plural marking in Russian involves affixes and other morpho-phonological changes that are very different from those of German. All these factors may make it easier for (Russian) L2 learners to acquire German participle formation in native-like ways than to learn the noun plural system of German.

There are indeed indications in the behavioral data of Experiments 2 and 4 that noun plural formation in the learners' L2 is less stable than that of participles. Elicited production on the critical items used in the two ERP experiments yielded considerably worse correctness scores for plurals than for participles. Recall that 14% of the elicited plural forms in Experiment 4 were incorrect, while there were hardly any errors for participles, indicating that the L2 learners were less confident in plural than in participle formation. The differences found in the L2 learners' ERP patterns for plurals and participles fit in with these observations. It seems that in our L2 participants plural formation is less stable than participle formation and that this has repercussions for processing, with the L2 learners relying less on early word-internal decomposition when processing plurals than participles. Thus, the L2 learners are not only more confident in forming participles than noun plurals, their processing of participles is also more automatized and native-like than that of plurals.

A comparison with other ERP studies on L2 processing

Previous ERP studies investigating *lexical-semantic processing* in L2 learners and bilinguals obtained N400 effects for semantic anomalies (Ardal et al. 1990, Weber-Fox & Neville 1996, Hahne 2001, Hahne & Friederici 2001) and pronounceable non-words (McLaughlin 1999) in the non-native speakers which were similar to those found in studies with L1 speakers, even though it appeared that in adults who acquired the L2 after

childhood, the N400 had a delayed peak latency compared to native speakers (see Weber-Fox & Neville 1996, Hahne 2001, Hahne & Friederici 2001).

Previous ERP studies of *morpho-syntactic processing* in non-native speakers demonstrated P600 effects for phrase-structure violations (Hahne 2001, Weber-Fox & Neville 1996) and violations of subject-verb agreement and gender concord (Sabourin 2003). Again, there were indications in all these studies that the ERP effect was delayed in adult L2 learners with a later onset and/or longer duration than in native speakers. Moreover, the learners' proficiency in the L2 seems to affect the ERP findings. Hahne (2001) found a P600 effect for a group of highly proficient Russian learners of German, but when Hahne & Friederici (2001) administered the same experiment to a group of Japanese L2 learners with a lower proficiency in German, there were no significant differences between the correct sentences and the phrase-structure violations in any relevant time window. Likewise, Friederici et al. (2002) report findings from an artificial grammar experiment in which adult subjects were trained on an artificial language system (BROCANTO) to a level at which they were highly proficient and produced hardly any errors. A subsequent ERP experiment examining syntactic violations in BROCANTO revealed the familiar biphasic ERP pattern known from comparable studies of natural languages in native speakers, i.e. an early negativity followed by a P600. Finally, Sabourin (2003) found a P600 for gender concord violations, but only in the subgroup of German L2 learners of Dutch, who Sabourin independently demonstrated to be more proficient in L2 gender marking than the other subgroups of L2 learners she tested. Taken together, these results suggest that at least in domains in which they are highly proficient, L2 learners can employ the same processing mechanisms as L1 speakers.

Our results support this conclusion. We did not only find N400 and P600 effects in non-native processing in different inflectional domains, but also an anterior negativity for

regularized participles in the same time window as for native speakers. It is true that this component had a left anterior maximum in the L1 speakers and occurred bilaterally in our L2 learners, but topographic variations of anterior negativities in early time windows have also been observed for L1 processing in a number of ERP studies (Rodriguez-Fornells et al. 2001, Gross et al. 1998, Weyerts et al. 2002). The anterior negativity for the L2 learners falls within that range of variation and can therefore be regarded as an instance of a 'morpho-syntactic negativity'. If this interpretation is correct, then our findings show that rule-based morphological processing is indeed employed by adult L2 learners, at least for grammatical phenomena (in our case participle formation) in which they are highly proficient and confident.

CONCLUSION

The results of the present study show regular/irregular contrasts in adult L2 learners' processing of inflected words. In processing grammatical rule violations, the L2 learners evidenced ERP components (an anterior negativity and/or a P600) that have been linked to morpho-syntactic processing, and for misapplications of irregular inflection, they showed an ERP effect (the N400) that has been claimed to be characteristic of lexical processing. These results indicate that the two processing routes posited by dual-mechanism models of inflection (lexical storage and morphological decomposition) are also accessible in second language processing of inflected words, at least by advanced learners and in inflectional domains in which they are highly proficient.

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FOOTNOTES

[1] The literature referred to in this section is concerned with adult processing in 'monolingual mode' (see Grosjean 1997). It is assumed in this literature (though not always made explicit) that what is under study is the language the participants have acquired in childhood. This means that even though they may have acquired a second language (typically in a school setting when they were adults), simultaneous bilinguals (who have learned two languages simultaneously before the age of 5 to 6 years) are normally not included.

[2] Even though participles of nonce verbs elicited an N400 component, participles of existing verbs did not. This is probably due to the fact that incorrect participles of existing regular verbs - even though ungrammatical - are rather similar to the infinitive form of the corresponding verb (compare **ge-tanzen* 'danced' vs. *tanzen* 'to dance'), and hence do not elicit a non-word effect.

[3] Note that this procedure deviates slightly from Penke et al. (1997) where words were shown for 300 ms followed by a blank screen for 400 ms. For the present study, we chose longer presentation times as word recognition processes are likely to be slower in L2 learners than in native speakers.

[4] Note that we created new incorrect probe sentences, as the ones used by Penke et al. (1997) included only very slight modifications of the correct sentences, which we thought were too hard for the L2 learners to detect.

[5] There are a number of reasons as to why the P600 effect was not seen in native speakers of German. From a linguistic perspective, a regularized participle such as **gelauf-t* is a purely morphological (i.e. *word-internal*) violation that should not affect *sentence-level* processing; the finding of an anterior negativity without a P600

in native speakers of German corresponds to this distinction. A difficulty for this interpretation, however, is that the Catalan study of Rodriguez-Fornells et al. (2001) also examined purely morphological (stem) violations and found the familiar biphasic ERP pattern with an anterior negativity followed by a P600. Another possibility that may have precluded the identification of a P600 component in the Penke et al. (1997) experiment is that an analysis epoch of only 900ms poststimulus was used (whereas in the present study the recording epoch was 1200ms), so that a late positivity might simply have gone undetected. Note also that even for the L2 learners the observed P600 was relatively small. For native speakers it may even be smaller and hence hard to identify. We will leave the question open as to why the P600 was not seen in the Penke et al. study; see Rodriguez-Fornells et al. (2001) for further discussion.

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Table 1: *Participles of nonce verbs*

Form supplied in step 2	Expected participle ending	Mean rates and (standard deviations) of expected participle endings in step 3 (maximum score = 10)
strong preterit /non-rhymes	*-n*	5.3 (3.5)
strong preterit /rhymes	*-n*	6.8 (2.6)
weak preterit	*-t*	9.4 (1.1)
mixed preterit	*-t*	9.1 (1.1)

Table 2: *Mean ratings and (standard deviations) for plural forms of nonce nouns*

	Rhymes	Non-rhymes
Highest-rated irregular plurals	4.5 (0.35)	4.4 (0.37)
-s plurals	3.5 (0.88)	3.6 (0.91)

Figure 1: Grand average ERPs for incorrect *-t* versus correct *-n* participles

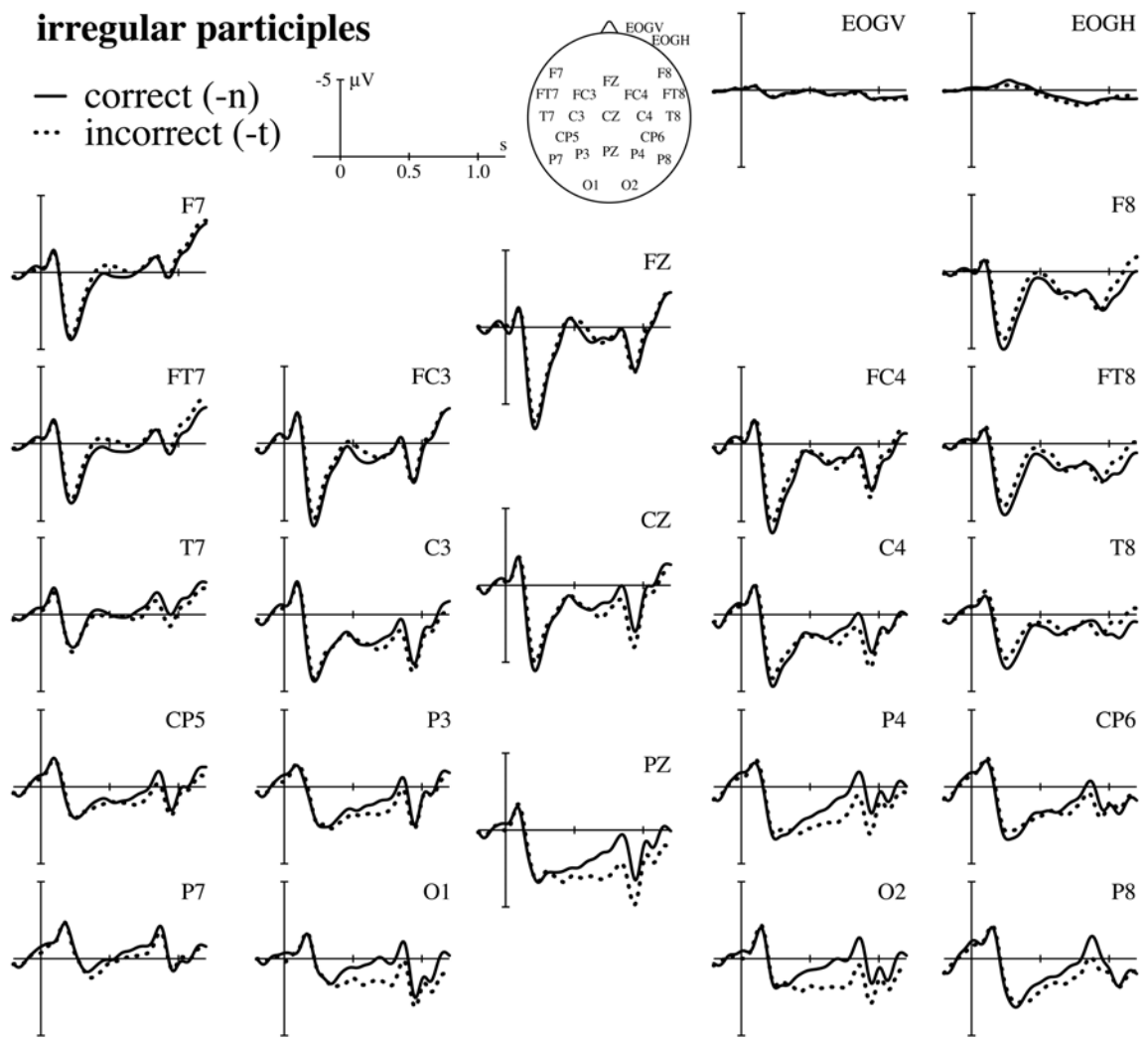

Figure 2: Grand average ERPs for incorrect *-n* versus correct *-t* participles

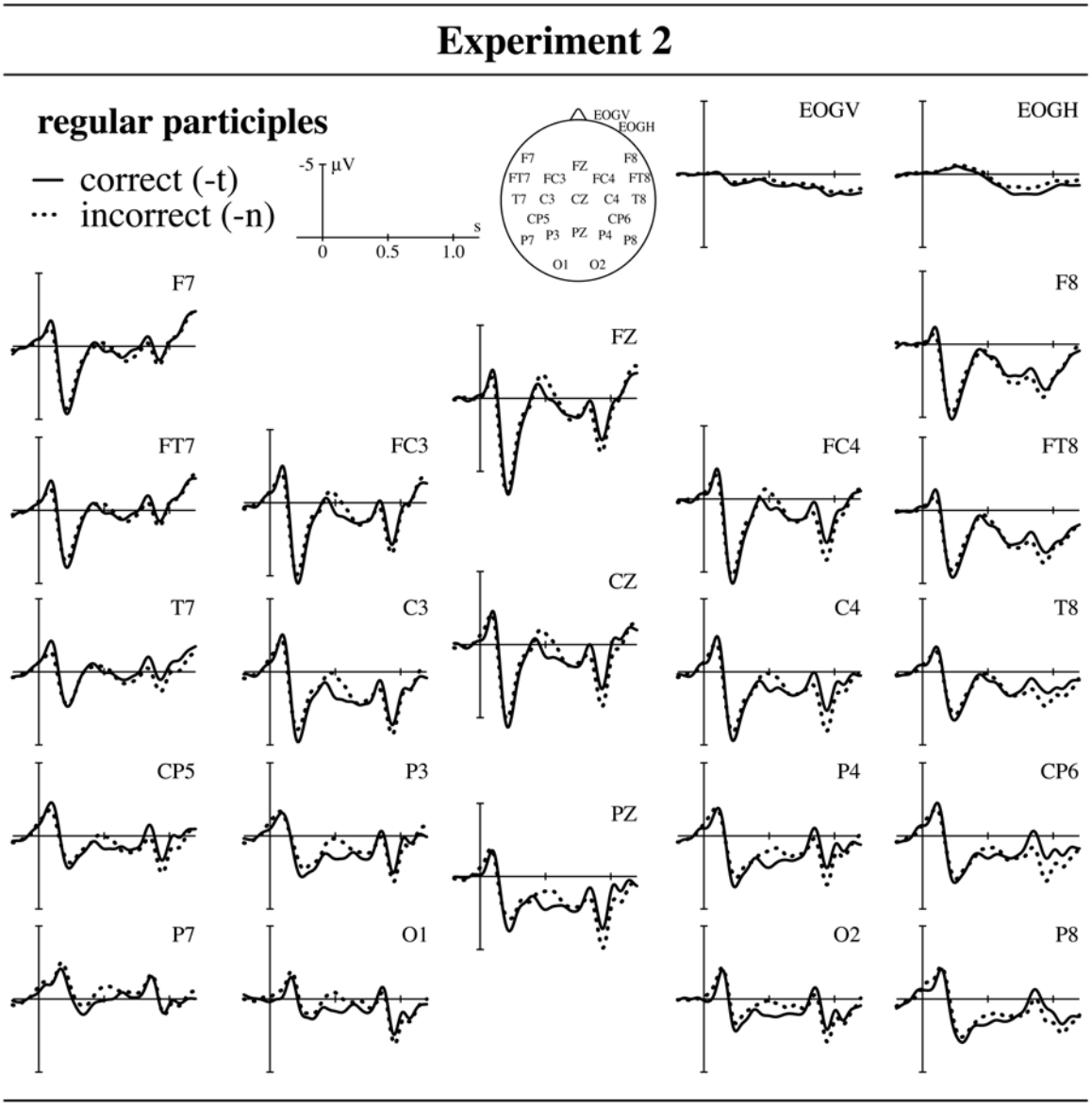

Figure 3: Grand average ERPs for incorrect *–s* versus correct *–n* plurals/ masculine nouns

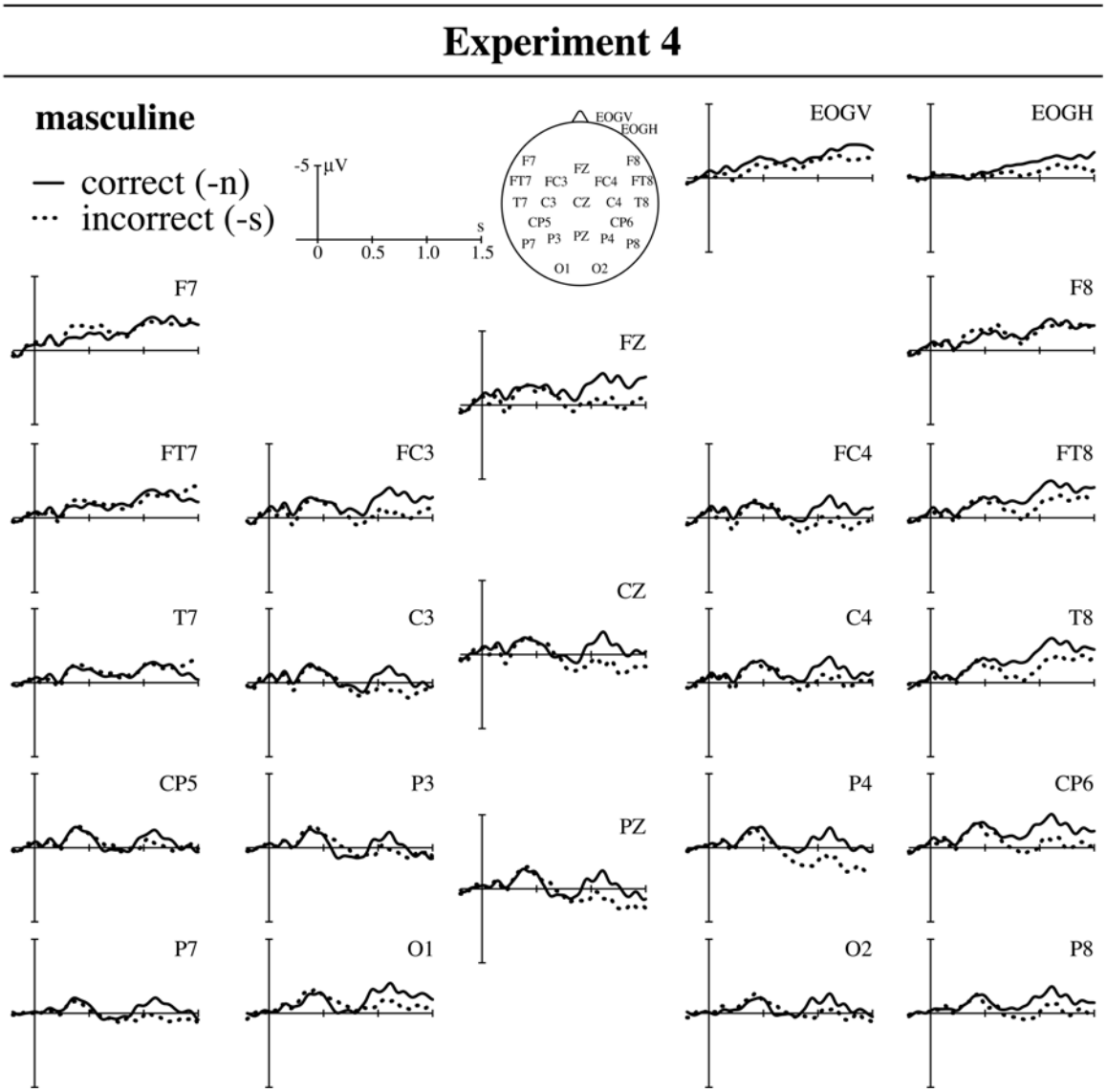

Figure 4: Grand average ERPs for incorrect *–s* versus correct *–n* plurals/ feminine nouns

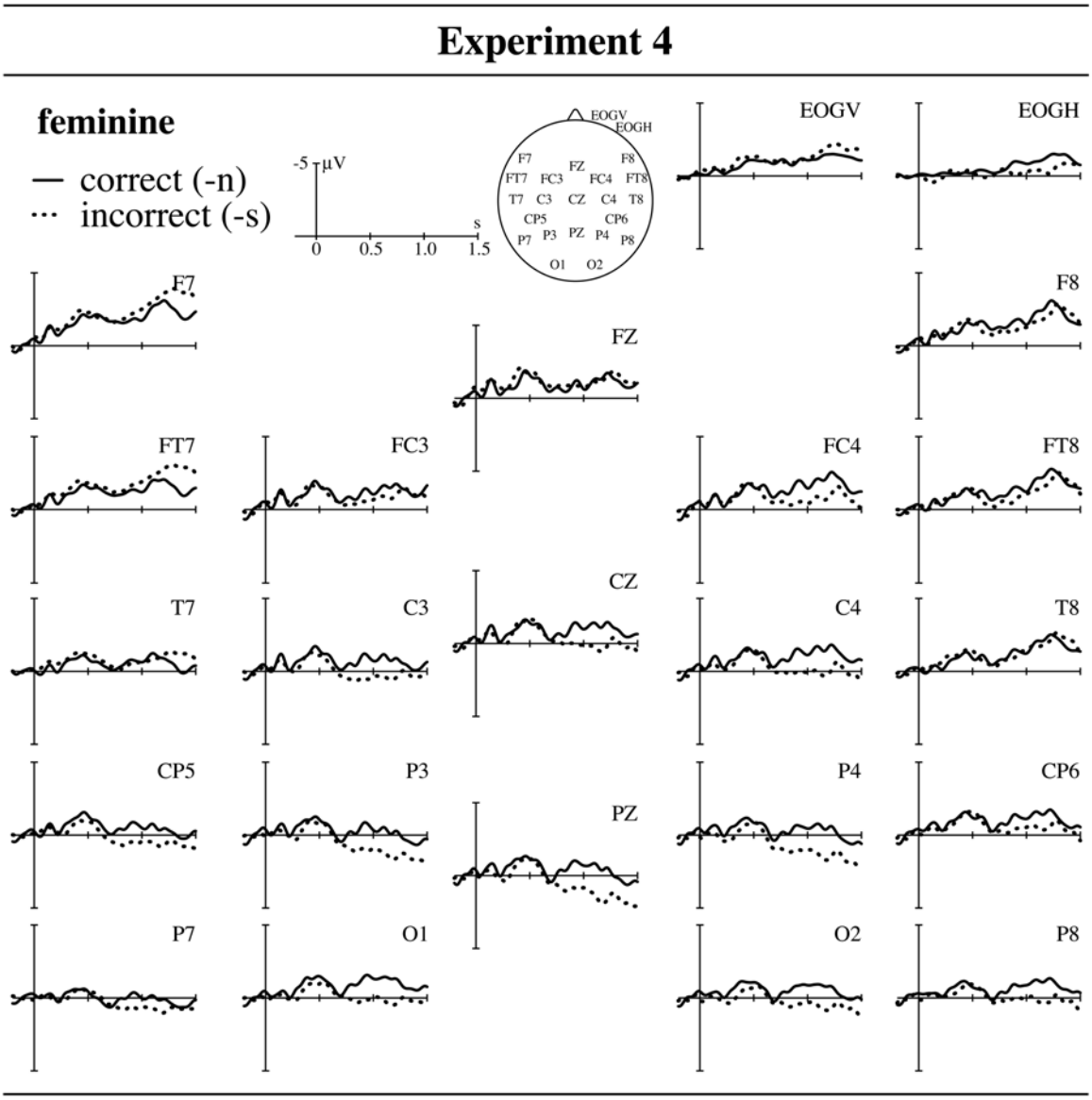

Figure 5: Grand average ERPs for incorrect *–n* versus correct *–s* plurals ('loan words')

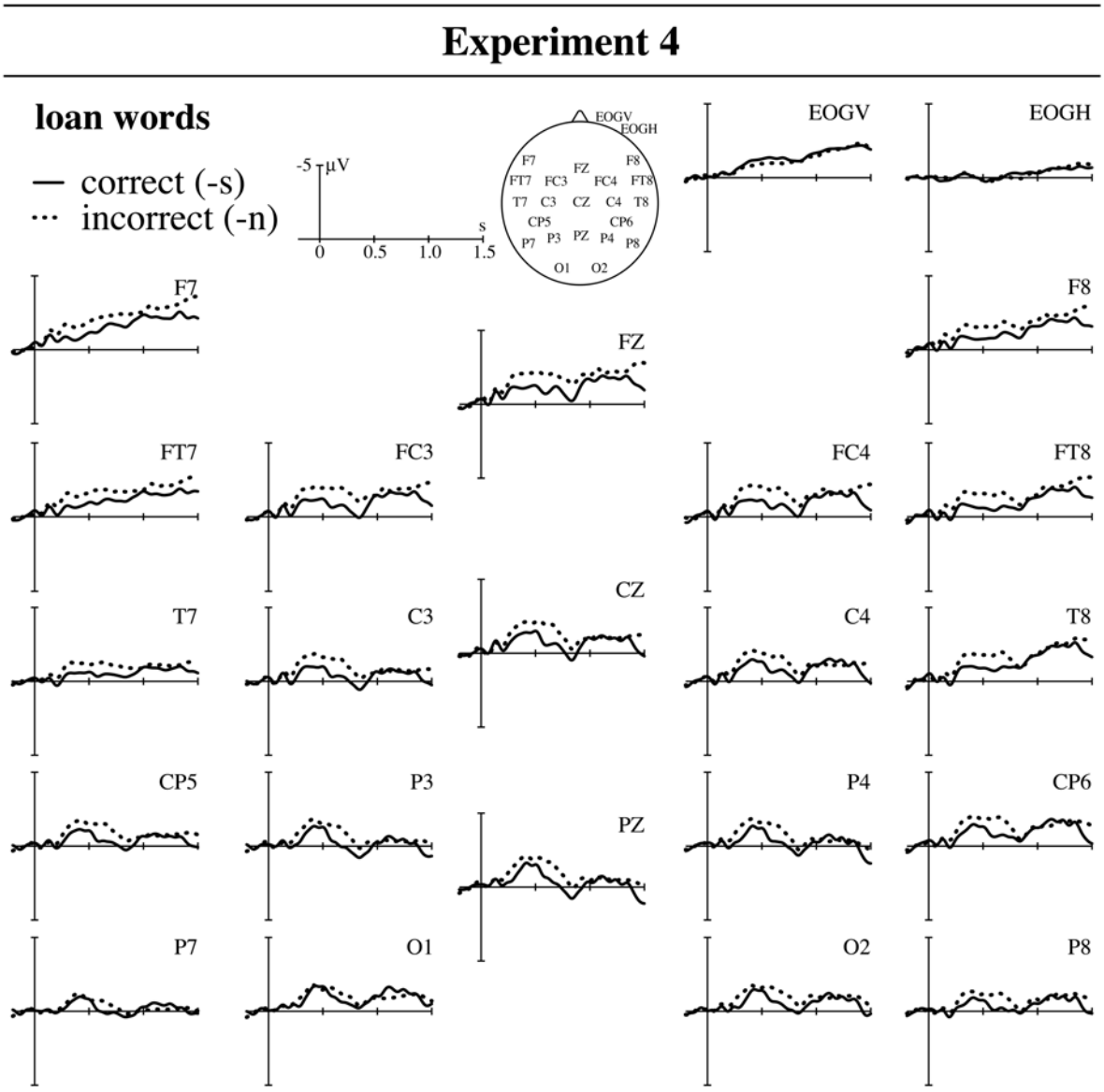

Figure 6: Grand average ERPs for incorrect *–n* versus correct *–s* plurals (proper names)