When *leaf* becomes neuter: event-related potential evidence for grammatical gender transfer in bilingualism

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This study addressed the question as to whether grammatical properties of a first language are transferred to a second language. Dutch–English bilinguals classified Dutch words in white print according to their grammatical gender and colored words (i.e. Dutch common and neuter words, and their English translations) according to their color. Both the classifications were made with the same hand (congruent trials) or different hands (incongruent trials). Performance was more erroneous and the error-elated negativity was enhanced on incongruent compared with congruent trials. This effect was independent of the language in which words were presented. These results provide evidence for the fact that bilinguals may transfer grammatical characteristics of their first language to a second language, even when such characteristics are absent in the grammar of the latter. *NeuroReport* **22:106–110 © 2011 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

NeuroReport 2011, **22**:106–110

Keywords: bilingualism, conflict, error-related negativity, grammatical gender, verbal self-monitoring

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Received 28 September 2010 **accepted** 9 November 2010

Introduction

Errors are part of everyday life and the basis of learning new behavioral skills. Therefore, error processing forms a major part of the research on performance monitoring. An interesting component of the event-related potential for exploring the functional characteristics of the error monitoring system is error-related negativity (ERN; [1,2]). ERN has a frontocentral scalp distribution and peaks at about 80 ms after an overt incorrect response [3,4]. ERN presumably reflects error detection [3], conflict between multiple responses [5], or reinforcement learning [6].

ERN is known to occur immediately after an action error has been committed. Here, we used ERN in a bilingual reading task. Relatively little is known about the influence of one language on another. For instance, Sebastián-Gallés *et al.* [7] showed that Spanish-dominant bilinguals had difficulty in a Catalan auditory lexical decision task rejecting nonwords that were phonologically similar to the existing Catalan (their second language) words and did not show an ERN in their erroneous nonword decisions, whereas Catalan-dominant bilinguals exhibited a clear ERN. This suggests that Spanish-dominant bilinguals were unable to distinguish between experimental words and nonwords, and therefore showed no difference between correct and incorrect responses [7].

This study addressed the possibility of transfer of grammatical properties, such as grammatical gender, from Dutch to English. There is evidence suggesting that the nonresponse language is activated in bilingual situations [8–10], and that native and foreign languages are implemented on similar neural substrates in the brain [11–13]. Therefore, it is possible that bilinguals attribute some grammatical properties of their native language to their second language, even if such properties are absent from the latter. In this study, we used a task that involved reading words. ERN is sensitive to lexical retrieval conflict resulting from the activation of multiple lexical entries [14]. Thus, the central prediction of this study is that if the participants indeed transfer grammatical properties from their first language to their second language, the performance should be more erroneous and ERN should be enhanced on incongruent compared with congruent response trials for both Dutch and English stimuli. This could be interpreted as the grammatical gender being accessed rapidly and automatically and may imply a link between the lexical representations of the languages within the bilingual system.

Methods

Participants

Twenty-one students of Maastricht University in the Netherlands participated in the experiment after signing informed consent. All participants were right-handed native Dutch speakers with good knowledge of English. The participants' proficiency in English was assessed with a nonspeeded lexical decision task [15]. The test consisted of words selected from five different word frequency bins and nonwords. The participants were required to indicate whether they knew the meaning of a visually presented English letter string. The score of the test ranged from 0 to 5000 and is corrected for misattribution of nonwords. The corrected mean score in this

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study was 3930, that is, the participants recognized the existing words and rejected the nonwords correctly in 80% of the trials.

Materials

One hundred and sixty (80 common gender and 80 neuter gender) Dutch words were presented in white print, and 160 (40 common gender and 40 neuter gender) Dutch words and their English translations were presented in color on a black background. White words were presented twice. All colored words were presented once in green and once in blue. Green color was created by setting the red, green, and blue values to 0, 200, and 150. Red, green, and blue values were set to 0, 150, and 200 to create the blue color. Dutch and English words were matched on word length and had a frequency of occurrence between 10 and 200 per million (CEnter for LEXical information [16]). Words with biological gender (e.g. uncle) were excluded from the stimulus list.

Design and procedure

Two practice blocks were administered before the experimental block. During the first practice block, the participants saw white Dutch words and were required to press the left key of a button box for common gender words and the right key for neuter gender words. In the second practice block, the participants saw colored Dutch and English words, once in green and once in blue. Half of the participants were instructed to press the left key for green words and the right key for blue words. The other half of the participants received the reverse color response assignment. None of the words used in the practice blocks occurred in the experimental block. In the experimental block, white and colored words were presented in a random order. None of the colored words were presented as white words. The participants were required to classify white words according to their grammatical gender (common vs. neuter). If words were colored, the classification should be based on the color (green vs. blue). Each trial started with a fixation point in the center of the screen for a duration varying between 500 and 800 ms, followed by a blank screen for 500 ms. Next, the target word was presented that remained in view until a response was given. After the experiment, the participants undertook the English proficiency test and translated the list of English words used in the experimental block into Dutch, including the corresponding definite article.

Apparatus and recordings

The electroencephalographic (EEG) signal was recorded from 29 scalp sites (extended version of the 10/20 system) using tin electrodes mounted on an electrode cap. The EEG signal was sampled at 250 Hz and band-pass-filtered from 0.01 to 30 Hz. An electrode at the left mastoid was used for online referencing of the scalp electrodes. All electrodes were offline re-referenced to the two mastoids. Lateral eye movements were measured using a bipolar montage of two electrodes placed on the right and the left external canthus. Vertical eye movements were measured using a bipolar montage of two electrodes placed above and below the eyes. The impedance level for all the electrodes was kept below 5 kΩ.

Data analysis

Epochs from -300 to $+800$ ms were obtained including a 100 ms preresponse baseline. The EEG signal was corrected for ocular artifacts, using the ocular reduction method implemented in the NeuroScan 4.3.1 software (Compumedics, Melbourne, Australia). To correct for nonocular artifacts, epochs with amplitudes above or below 50 μV were rejected. The amplitude of ERN was derived from each individual's response-locked average waveforms after filtering with a band-pass, zero phase shift filter (frequency range was 1–12 Hz). The mean amplitude analysis was done for the time window from 0 to 100 ms after response onset [17]. The amplitude of ERN was recorded for each condition at electrode sites Fz, FCz, and Cz.

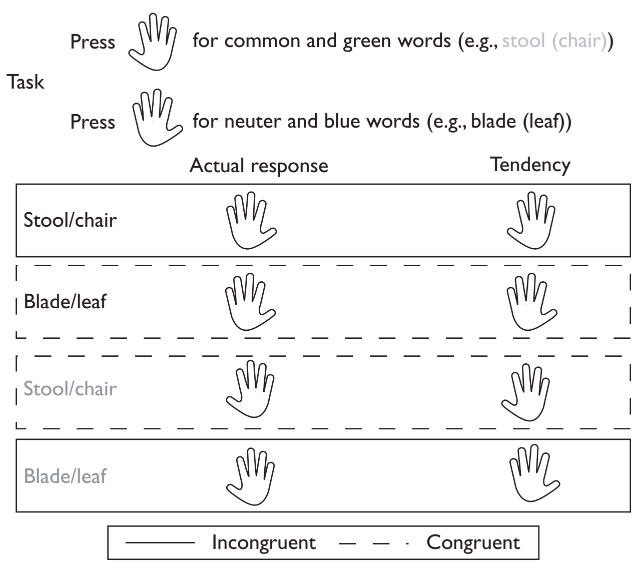
Analyses were done on the colored trials only. The mean reaction times, error rates, and ERN amplitudes from each participant were submitted to the repeated-measures analyses of variance involving planned comparisons with Language (Dutch vs. English) and Conflict (congruent vs. incongruent trials) as independent variables. In incongruent trials, there was a discrepancy between the classification response for grammatical gender and color of the stimulus. For instance, the participants were asked to press the right key for common gender and green words and the left key for neuter gender and blue words. Thus, the neuter-gender green words and the common-gender blue words may lead to increased response conflict because of the mismatch between grammatical gender and color. In congruent trials, however, no such mismatch was present (see Fig. 1).

Results

Behavioral data

The participants correctly translated 95% of the English words used in the experimental block into Dutch using the appropriate determiner. Trials including the English words that the participants did not know were removed from the analysis. Latencies shorter than 300 ms and longer than 1500 ms were also excluded from the analysis. An analysis of variance showed no effect of language or conflict (both Fs < 1), and no interaction between these factors [Dutch congruent: 646 ms, SD = 105; Dutch incongruent: 650 ms, SD = 92; English congruent: 664 ms, SD = 105; English incongruent: 648 ms, SD = 110; $F(1,20) = 3.08$, nonsignificant].

Fig. 1



Schematic representation of the task with an illustration of incongruent and congruent trials for Dutch and English colored words. For colored words, participants were required to make their response based on the color of the presented word (the actual response). The common/neuter-gender decision was required to make in response to white words resulted in a response tendency for colored words. Note that the colors used in the figure are not the actual colors used in the experiment.

An analysis with a proportion of errors as the dependent variable, showed a significant effect of conflict [$F(1,20) = 15.78$, $P < 0.01$], but no effect of language ($F < 1$). The interaction between conflict and language was significant [$F(1,20) = 4.71$, $P < 0.05$]. The participants made more errors in incongruent trials than in congruent trials for both Dutch words [congruent: 2.0%, SD = 1; incongruent: 5.3%, SD = 4; $F(1,20) = 10.85$, $P < 0.01$] and English words [congruent: 2.7%, SD = 1; incongruent: 3.9%; SD = 1; $F(1,20) = 9.75$, $P < 0.01$].

Error-related negativity

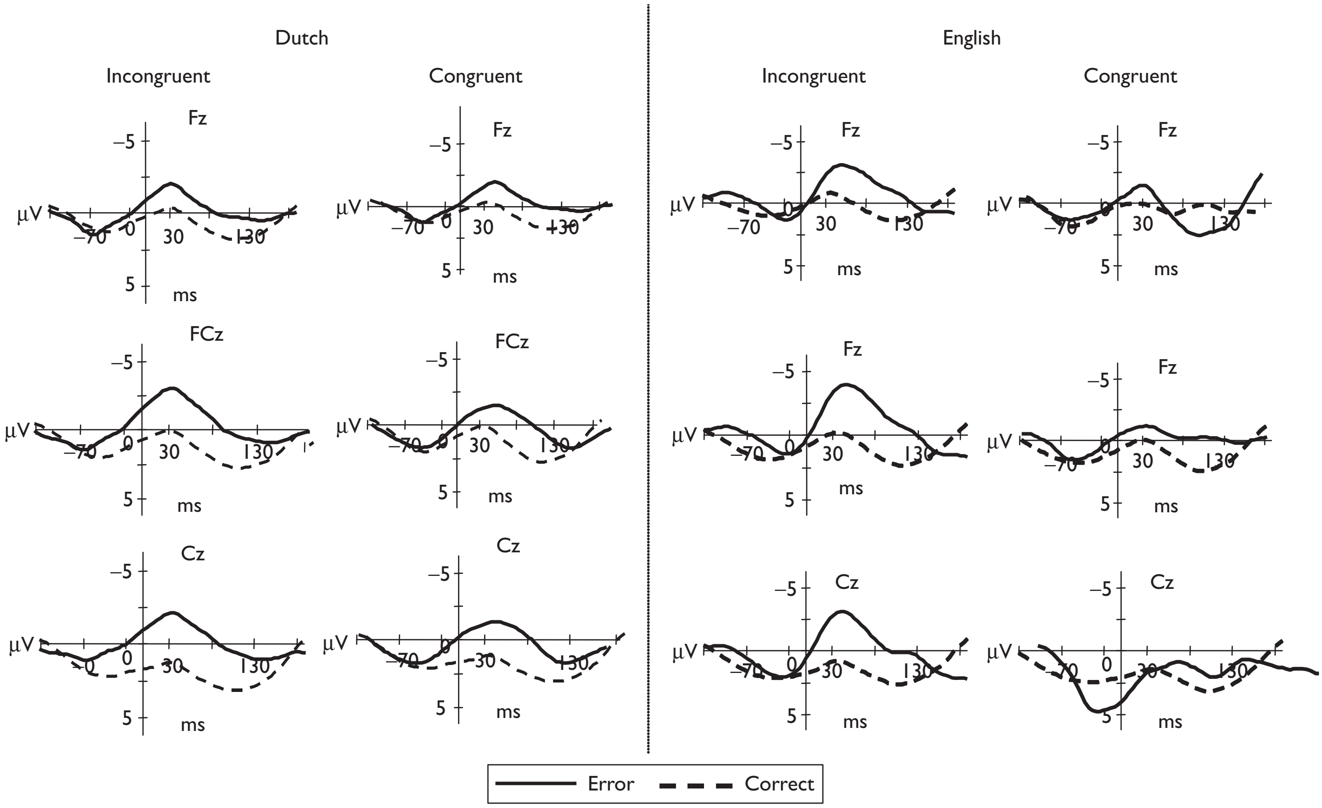
The amplitude of ERN was larger for incongruent trials (2.79 μV, SD = 1.73) than for congruent trials [2.11 μV, SD = 1.76; $F(1,20) = 4.71$, $P < 0.05$]. There was neither an effect of language [$F(1,20) = 1.35$, nonsignificant] nor an interaction between language and conflict ($F < 1$; see Fig. 2).

Discussion

The goal of this study was to investigate whether bilingual speakers transfer grammatical characteristics, such as grammatical gender, from one language to another. We found no difference in reaction times between incongruent and congruent trials. This was not unexpected because the effects of the task used here are most prominent in the error data [18,19]. As expected, we found an enhancement of both error rate and amplitude of ERN in incongruent trials compared with congruent trials for both Dutch and English targets. Note that in critical trials, the participants were instructed to make a nonlinguistic color classification. Therefore, based on the erroneous color decision, there should not be any difference between incongruent and congruent trials, as both types of trials include an incorrect decision about the color of the target word. However, congruent and incongruent trials are different regarding the discrepancy between response mappings for grammatical gender, created by responses to white words and color. Thus, in incongruent trials there was a mismatch between color and gender response mapping, whereas in congruent trials no such discrepancy was present. Presumably, even when carrying out a color classification, the participants not only processed the visual appearance of the word, but also automatically retrieved its grammatical gender. Critically, the participants transferred grammatical gender information from Dutch to English, although the latter does not have grammatical gender in its nominal system. This suggests that grammatical gender can be accessed rapidly and automatically, and that there is a strong link between the lexical representations of the languages within the bilingual language processing system. Thus, there is an interaction between the first and second languages not only at the conceptual and phonological level, but also at the level of grammatical encoding (see [20]). Note that all the participants had good knowledge of English and knew that English does not have grammatical gender.

At first glance, our results disagree with a finding reported by Costa *et al.* [21], who proposed that gender systems of bilinguals are autonomous. The difference between the Costa *et al.* [21] and our findings might lie in the nature of the task. Costa *et al.* [21] asked the participants to name pictures having the same or a different grammatical gender in their first and second language. It is possible that the transfer of grammatical properties, such as gender, from one language to another takes place only under certain circumstances; for example, when speakers are in a gender retrieval mode, which was the case in this study. However, Lemhöfer *et al.* [22] using a picture-naming task showed that German–Dutch bilinguals were influenced by the grammatical gender of their first language when processing gender-marked noun phrases in their second language. In addition, Cantone and Müller [23] reported cases from bilingual language development of children mixing Italian–German determiner-noun phrases such as *una s[ch]metterling* ('a butterfly') in which the head noun *schmetterling* has a masculine gender in German and a feminine gender in Italian (i.e. *farfalla*). The indefinite determiner *una* surfaces in its feminine form, suggesting the influence of the Italian noun's gender on the German noun. The authors argue that bilingual children may represent gender in an integrated way first, and in the course of bilingual language acquisition the two gender systems become autonomous. A similar mechanism may be the case for unbalanced and balanced bilinguals [23]. The degree of autonomy of the gender

Fig. 2



Averaged response-locked event-related potential waveforms for incorrect trials (solid lines) versus correct trials (dashed lines) across conditions (Dutch incongruent, Dutch congruent, English incongruent, and English congruent). Correct and incorrect trials were matched on reaction times and the number of trials.

systems may depend on the degree of performance in a second language [21]. It is possible that the participants in our study were somewhat less proficient than the participants in the study by Costa *et al.* and thus less able to keep the grammatical systems of their two languages apart.

Interestingly, in a recent study, Midgley *et al.* [24] found that in an early stage of English language acquisition, native French speakers showed sensitivity to the French gender during sentence processing in English. We argue that a similar transfer of grammatical gender properties from the first to the second language occurred in this study. Assuming that the participants implicitly attributed grammatical gender to English words, it is possible that at the time of response there was competition between an inappropriate response (e.g. response to grammatical gender) and a correct response (e.g. response to color). It is possible that under the circumstances in which multiple languages are active, the verbal monitor has some difficulty in keeping the languages separated, and therefore suffers more from intrusions from a second language, resulting in less accurate performance. This may particularly be the case for unbalanced bilinguals. As a result, in this study the activation of both English and Dutch words may have resulted in an increased response conflict and thus higher amplitudes of ERN.

One may argue that the response conflict in this study may not have been the result of a transfer of Dutch grammatical gender to English but because of the conflict in response mapping. In our task, the participants were asked to switch between grammatical gender and color classification. At least in some error trials, the participants may have confused instructions leading to a conflict between the intended response (i.e. color classification) and the actual response (i.e. gender classification). However, this account fails to explain why we obtained an effect for English words, as the English words cannot be classified according to grammatical gender. We believe that the conflict in this task resulted from a co-activation of the Dutch and English linguistic systems, and from transferring Dutch grammatical gender characteristics to English grammar.

A point of concern is that because of the nature of the task, both color and gender classification trials were mixed. Mixing these trials might have led to a strategic retrieval of both color and gender information in all trials.

In future studies, the potential strategic effects should be eliminated by systematically manipulating the occurrence of gender and color trials. Further, in this study, Dutch and English words were intermixed. This may have increased the activation of the irrelevant language, and thereby boosted gender transfer from Dutch to English. However, in a recent study, Lemhöfer *et al.* [25] showed a gender-transfer effect from German to Dutch even in a Dutch-exclusive context. Future research will need to determine whether gender transfer between languages can also be observed in a nonmixed-language context even when one language has no gender system. Overall, this study indicates that in situations in which two languages are simultaneously active, some properties (e.g. grammatical gender) of one language can be transferred to the other even when they are absent in the latter.

Acknowledgements

This study was supported by The Netherlands Organisation for Scientific Research grant no. 453-02-006 to Niels O. Schiller. The authors thank Iemke Horemans for her help with this study. Niels O. Schiller's research is supported as a Fellow-in-Residence 2010/11 from the Netherlands Institute for Advanced Study (NIAS) in the Humanities and Social Sciences in Wassenaar, The Netherlands.

References

1 Falkenstein M, Hohnsbein J, Hoorman J, Blanke L. Effects of crossmodal divided attention on late ERP components. II. Error processing in choice reaction tasks. *Electroencephalogr Clin Neurophysiol* 1991; **78**:447–455.
2 Gehring WJ, Goss B, Coles MGH, Meyer DE, Donchin E. A neural system for error detection and compensation. *Psychol Sci* 1993; **4**:385–390.
3 Bernstein PS, Scheffers MK, Coles MGH. 'Where did I go wrong?' A psychophysiological analysis of error detection. *J Exp Psychol Hum Percept Perform* 1995; **21**:1312–1322.
4 Holroyd CB, Yeung N. Alcohol and error processing. *Trends Neurosci* 2003; **26**:402–404.
5 Botvinick MM, Braver TS, Barch DM, Carter CS, Cohen JD. Conflict monitoring and cognitive control. *Psychol Rev* 2001; **108**:624–652.
6 Holroyd CB, Coles MGH. The neural basis of human error processing: reinforcement learning, dopamine and the error-related-negativity. *Psychol Rev* 2002; **109**:679–709.
7 Sebastián-Gallés N, Rodríguez-Fornells A, De Diego-Balaquer R, Díaz B. First- and second-language phonological representation in the mental lexicon. *J Cogn Neurosci* 2006; **18**:1277–1291.
8 Colomé Á. Lexical activation in bilinguals' speech production: language-specific or language independent? *J Mem Lang* 2001; **45**:721–736.
9 Kroll JF, Dijkstra T. The bilingual lexicon. In: Kaplan RB, editor. *Handbook of applied linguistics*. Oxford: Oxford University Press; 2002. pp. 301–324.
10 Rodriguez-Fornells A, Van der Lugt A, Rotte M, Britti B, Heinze HJ, Münte TF. Second language interferes with word production in fluent bilinguals: brain potential and functional imaging evidence. *J Cogn Neurosci* 2005; **17**:422–433.
11 Klein D, Milner B, Zatorre RJ, Meyer E, Evans AC. The neural substrates underlying word generation: a bilingual functional-imaging study. *Proc Natl Acad Sci U S A* 1995; **92**:2899–2903.
12 Klein D, Milner B, Zatorre RJ, Zhao V, Nikelski J. Cerebral organization in bilinguals: a PET study of Chinese-English verb generation. *Neuroreport* 1999; **10**:2841–2846.
13 Perani D, Paulesu E, Sebastián-Gallés N, Dupoux E, Dehaene S, Bettinardi V, *et al.* The bilingual brain: proficiency and age of acquisition of the second language. *Brain* 1998; **121**:1841–1852.
14 Ganushchak LY, Schiller NO. Effects of auditory distractors on verbal self-monitoring. *J Cogn Neurosci* 2008a; **20**:927–940.
15 Meara PM. *X_Lex: the swansea vocabulary levels test. v2.05*. Swansea: Lognostics; 2005.
16 Baayen RH, Piepenbrock R, Gulikers L. *The CELEX lexical database (CD-ROM)*. Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania; 1995.
17 Rodrígues-Fornells A, Kurzbuch AR, Münte TF. Time course of error detection and correction in humans: neurophysiological evidence. *J Neurosci* 2002; **22**:9990–9996.
18 De Houwer J. The extrinsic affective Simon task. *Exp Psychol* 2003; **50**:77–85.
19 Huijding J, De Jong PJ. Specific predictive power of automatic spider-related affective associations for controllable and uncontrollable fear responses toward spiders. *Behav Res Ther* 2006; **44**:161–176.
20 Bordag D, Pechmann T. Factors influencing L2 gender processing. *Biling Lang Cogn* 2007; **10**:299–314.
21 Costa A, Kovacic D, Frank J, Caramazza A. On the autonomy of the grammatical gender systems of the two languages of a bilingual. *Biling Lang Cogn* 2003; **6**:181–200.
22 Lemhöfer K, Spalek K, Schriefers H. Cross-language effects of grammatical gender in bilingual word recognition and production. *J Mem Lang* 2008; **59**:312–330.
23 Cantone KF, Müller N. Un nase or una nase? What gender marking within switched DPs reveals about the architecture of the bilingual language faculty. *Lingua* 2008; **118**:810–826.
24 Midgley KJ, Wicha NYY, Holcomb PJ, Grainger J. Gender agreement transfer during sentence processing in early language learners: an electrophysiological study (abstract). *In Proc annu meet Cogn Neurosci Soc* 2007:170. [abstract]
25 Lemhöfer K, Schriefers H, Hanique I. Native language effects in learning second-language grammatical gender: a training study. *Acta Psychologica* 2010; **135**:150–158.