How Dutch and Turkish-Dutch readers process morphologically complex words: An ERP study

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ABSTRACT

To examine time-course differences between regularly and irregularly inflected, and productively and non-productively derived words, native Dutch speakers and Turkish-Dutch early bilinguals performed a visual lexical decision task combined with electroencephalography (EEG) recordings. Target items were presented in two types of nonword contexts to examine the effects of stimulus list composition and language background. We found similar negative brain responses for regularly and irregularly inflected words, and for productively and non-productively derived words, in the 200–350 ms time window for both participant groups. In the 350–500 ms time window, most negative brain responses were observed for the irregularly inflected verbs. We suggest that the negativities found in the 200–350 ms time window reflect early, form-based processing of complex words. In the 350–500 ms time window, this processing is affected by a discrepancy between orthography and morphology. Different results for the Dutch and Turkish-Dutch speakers in the nonword contexts show that, due to their language background, decomposition is more automatized in Turkish-Dutch speakers. Their processing strategy is thus less affected by the manipulation of stimulus list composition. In contrast, decomposition in our Dutch speakers is less automatized and thus more sensitive to the structure of nonwords.

1. Introduction

According to researchers who argue for morphological decomposition in word reading, a number of processing stages take place before morphologically complex words, such as WORKER or WALKED, are ultimately recognised. Initially, visual decomposition is assumed to take place. Later, licensing and/or recombination of the decomposed parts may occur (Schreuder & Baayen, 1995; Taft & Ardasinski, 2006). It is, however, difficult to distinguish the different processing stages involved in the recognition of the word at hand on the basis of behavioural experimental data. Fortunately, more recently developed research techniques, such as the use of event-related brain potentials (ERPs) or eye-tracking, allow a more refined analysis of the time course of lexical processing. Because ERPs have an excellent temporal resolution, they can shed light on the timing of the various stages involved in the recognition of morphologically complex words.

In line with these points, the general aim of the present study is to test for time-course differences in the processing of regularly and irregularly inflected, and productively and non-productively derived words in both native Dutch speakers and Turkish-Dutch early bilinguals. This was done by studying their performance in a visual lexical decision task in combination with electroencephalography (EEG) recordings. In addition, we manipulated stimulus list composition by presenting the target items in two types

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of nonword contexts. To our knowledge, this study is one of few to use EEG recordings to investigating the morphological processing of complex words in both (Dutch) native speakers and (Turkish-Dutch) early bilinguals.

Before zooming in on our EEG study, we will first discuss available results on morphological processing for the three types of studies that are mostly combined with ERPs: Priming studies, violation studies, and single word studies. As we shall see, there are several ERP components commonly associated with morphological processing: Left Anterior Negativity (LAN), N250, N400, and P600. Each of them will be discussed when it was observed in a study.

1.1. Priming and ERPs

In morphological priming studies, distinct ERP patterns have been reported for *regular* and *irregular* verbs. Primed *regularly inflected* words (e.g., WALKED-WALK) show an attenuation of an N400-type component when compared to similar unprimed words (e.g., WALKED-SEEM). The N400 is a negative waveform, peaking around 400 milliseconds (ms) after stimulus onset (Kutas & Federmeier, 2007). This effect has been found at different time intervals between prime onset and target onset, and for various languages: German (Leminen & Clahsen, 2014; Weyerts, Münte, Smid, & Heinze, 1996), Spanish (Rodriguez-Fornells, Münte, & Clahsen, 2002; Álvarez, Urrutia, Domínguez, & Sánchez-Casas, 2011), and English (Münte, Say, Clahsen, Schiltz, & Kutas, 1999). No or smaller effects have been found for primed *irregularly inflected* words (e.g., SLEPT-SLEEP) (Münte et al., 1999; Rodriguez-Fornells et al., 2002; Weyerts et al., 1996).

Masked priming studies with *derived* words showed attenuations of the N400 for morphologically related pairs (e.g., DARKN-ESS-DARK) and pseudo-morphological pairs (e.g., CORNER-CORN). The reduction of the N400 for these primed pairs was more pronounced than that of non-morphological form pairs (e.g., BROTHEL-BROTH) (Dominguez, de Vega, & Barber, 2004; Lavric, Clapp, & Rastle, 2007; Morris, Frank, Grainger, & Holcomb, 2007; Álvarez et al., 2011). Others have focused on the N250 component (Morris, Grainger, & Holcomb, 2008; Morris, Porter, Grainger, & Holcomb, 2010; Morris et al., 2007). The N250 starts around 175 ms and has a negative peak around 250 ms (Holcomb & Grainger, 2006; Morris & Stockall, 2012). Morris et al. (2008), for example, found similar priming effects for morphologically related and pseudo-morphological pairs in the early stage of the N250. In a later stage, around 250–300 ms, these two conditions showed dissimilarities, while the morphologically related and non-morphological pairs showed similar brain responses. These data support the hypothesis that during an initial stage, visual word recognition involves a morpho-orthographic segmentation of derived items (Morris et al., 2008, 2010, see Morris & Stockall, 2012, for a similar conclusion for regularly and irregularly inflected forms).

The results of the abovementioned studies are in favour of decomposition of *regularly inflected* verbs. Decomposition of the primed word into stem and affix during recognition activates the representations of its constituent morphemes. The stem then works as an effective prime. This is reflected in the attenuation of the N400 effect for primed regular verbs. On the other hand, N400 priming effects for *irregular* verbs are small or not present, and are taken as evidence that irregular verbs have whole-word access (Münte et al., 1999; Rodriguez-Fornells et al., 2002; Weyerts et al., 1996).

N250 priming effects have been found for both *inflected* and *derived* word forms, and point to early (visual) form-based processing of all morphologically complex word forms (Morris & Stockall, 2012; Morris et al., 2008).

1.2. Violation studies and ERPs

In studies that used a violation paradigm, participants read or listened to single words, sentences, or stories comprising inflectional violations, e.g., regularizations as *BRINGED instead of BROUGHT, and irregularizations as *SEPT instead of SEEPED. Again, distinct ERP markers for *regular* and *irregular* inflections were found. *Regularizations* elicited LAN effects, sometimes combined with a P600. The LAN appears as negativity in the 250–500 ms time window, and has a left anterior scalp distribution. The P600 is a positive waveform that has a maximum at centro-parietal scalp locations. It starts between 300 and 500 ms, and has a duration of several hundred milliseconds, with a peak around 600 ms (Kutas & Federmeier, 2007). *Irregularizations* showed an N400 component. These results have been obtained when words were presented visually or auditorily, when violations were presented in sentences, stories or in word lists, and for different languages (German: Hahne, Mueller, & Clahsen, 2006; Lück, Hahne, & Clahsen, 2006; Penke et al., 1997; Weyerts, Penke, Dohrn, Clahsen, & Münte, 1997; Catalan: Rodriguez-Fornells, Clahsen, Lleó, Zaake, & Münte, 2001; Italian: Gross, Say, Kleingers, Clahsen, & Münte, 1998; Finnish: Leinonen, Brattico, Järvenpää, & Krause, 2008; English: Morris & Holcomb, 2005; Newman, Ullman, Pancheva, Waligura, & Neville, 2007).

Fewer ERP studies have investigated the processing of *derived* words using violations. Havas, Rodríguez-Fornells, and Clahsen (2012), Janssen, Wiese, and Schlesewsky (2006), and Leinonen et al. (2008) investigated denominal violations in respectively Spanish, German, and Finnish. All studies found N400 type effects for the violations of derivational morphology. Bölte, Jansma, Zilverstand, and Zwitserlood (2009) created slightly different violations: They compared German derivations that had a correct adjective (FREUNDLICH) with morphological complex pseudowords (*FREUNDHAFT, legal stem-affix combination, semantically interpretable), and complex pseudowords (*FREUNDBAR, illegal stem-affix combination, semantically difficult to interpret). LAN effects were observed for both pseudoword conditions, which differed from the responses to the correct adjectives.

The LAN effects in the violation paradigm studies are taken as evidence that violations of *inflectional* and *derivational* rules are processed as violations of a combinatorial procedure. In the case of *regularizations*, the LAN signals an incorrect combination of a stem that normally blocks regular affixation, with a regular suffix (Gross et al., 1998; Penke et al., 1997; Rodriguez-Fornells et al., 2001). For *derivations*, the LAN indicates a mismatch between incorrectly combined morphemes (Havas et al., 2012). The N400 type effect found for *irregularizations* indicates that these violations are processed according to their full form (Morris & Holcomb, 2005).

1.3. Single word studies and ERPs

Finally, studies focussing on single word recognition by means of ERPs have examined the processing of *inflected* words. Lehtonen et al. (2007), for example, investigated the processing of inflected Finnish nouns compared to matched monomorphemic words. They found an N400 for the inflected, but not for the monomorphemic words. This effect was stronger for low-frequency than for high-frequency words. In a similar study, Leinonen et al. (2009) compared both visually and auditorily presented complex Finnish words with matched monomorphemes. Again, a processing cost was found in both modalities for inflected but not monomorphemic nouns, reflected in an N400. Overall, the effect for *inflected* nouns in both studies appeared in a relatively late time range (400–550 ms), and was believed to stem from a semantic-syntactic stage of processing. In addition to the N400 effect, both Lehtonen et al. (2007) and Leinonen et al. (2009) found an increased positivity for inflected words in the late 600–800 ms time window. The authors argued that this effect was of a post-lexical nature, possibly reflecting larger morphosyntactic processing demands, or a reanalysis of the inflected words.

Single word studies on *suffixed derived* words have found effects as early as 200 ms. Lavric, Elchlepp, and Rastle (2012) compared brain responses to morphological (DARKNESS), pseudo-morphological (CORNER), and non-morphological words (BROTHEL). In the 190–220 ms time window, similar ERPs to morphological and pseudo-morphological words were shown, and these differed from responses to non-morphological words. In the 246–276 ms time window, brain responses were the same for morphological and non-morphological words, but different for pseudo-morphological words. The authors concluded that in an initial stage, decomposition of derived items is based on orthography, so that both morphological and pseudo-morphological items show similar ERP responses. Later, this decomposition is constrained by semantic information, and pseudo-morphological words therefor show a different ERP pattern than morphological and non-morphological words. The results for this single word study are in line with those with masked priming studies on derived words (Morris et al., 2008, 2010). Similar results have been reported for *prefixed derived* words. These items showed the same brain responses as pseudo-prefixed words such as *INTAIN (McKinnon, Allen, & Osterhout, 2003; Palmović & Maričić, 2008), suggesting that both derived prefixed and pseudo-prefixed items are decomposed during recognition.

From the above, we conclude that *regularly inflected, irregularly inflected,* and *derived* word forms show distinct neurobehavioural patterns when it comes to morphological processing. *Regularly inflected* words, depending on the experimental design, show a reduction of the N400 (in masked priming), a LAN (in violations studies), or an N400 (in single words studies). All these components have been related to decomposition, suggesting that regularly inflected words are recognised based on their constituent morphemes. The P600 found for *inflected* words in single word studies possibly reflects larger morphosyntactic processing demands, or a reanalysis of the inflected words.

Irregularly inflected items show no or a small reduction of the N400 in masked priming studies, and an N400 effect in violation studies. These findings have been related to whole-word processing, suggesting that irregularly inflected items have full-form access.

Finally, the N250 found for *regularly inflected, irregularly inflected* and *derived* word forms suggests that recognition of these complex words forms is based on early (visual) form-based processing. For derived items, this early decomposition based on orthography is later constrained by semantic information (in the later N250 time window and in the N400 time window).

1.4. Morphological processing in early bilinguals

Only a limited number of studies have applied ERPs to morphological processing in non-native speakers. In general, two groups of non-native speakers have been involved: Early bilinguals, who acquired their languages before age 7 (De Diego Balaguer, Sebastián-Gallés, Díaz, & Rodríguez-Fornells, 2005; Lehtonen et al., 2012; Rodriguez-Fornells et al., 2001), and late bilinguals, who learned the second language in adulthood (Hahne et al., 2006; Liang & Chen, 2014). These studies make clear that both early and late bilinguals are sensitive to morphological structure in a non-native language. Whether the bilinguals show similar processing patterns as native speakers depends on several factors, such as similarity (of the studied morphological process) across languages (De Diego Balaguer et al., 2005; Hahne et al., 2006), language-specific characteristics of the native language, the amount of exposure to the native and non-native language (Lehtonen et al., 2012), and proficiency in the non-native language (Liang & Chen, 2014). In what follows, we will consider how some of these factors affect morphological processing in early bilinguals, the participant group studied in the current study.

In their studies on morphological processing in early Catalan-Spanish and Spanish-Catalan bilinguals, De Diego Balaguer et al. (2005) and Rodriguez-Fornells et al. (2001), investigated inflectional processes in, respectively, Spanish and Catalan. De Diego Balaguer et al. (2005) used a repetition-priming paradigm to investigate whether the similarity of the morphological systems of two languages affects morphological processing. Catalan and Spanish have a similar suffix for regular verbs, and completely different alternations for irregular verbs. The researchers visually presented both regularly and irregularly inflected Spanish verbs in their experiment. If cross-linguistic similarity does affect processing, then differences should arise in irregular verb but not in regular verb processing. This is indeed what De Diego Balaguer et al. (2005) found: Both the Catalan-Spanish and Spanish-Catalan group showed a reduction of the N400 for related, but not for unrelated regular verbs. For irregular verbs, a different topography of the N400 effect and different ERP patterns between groups were found. The researchers concluded that similarity in morphological systems might benefit morphological processing in the non-native language, when the structure processed is similar in both languages. In contrast, for dissimilar structures interference might appear.

Unfortunately, the study by De Diego Balaguer et al. (2005) did not include a monolingual Spanish speaker group: Early Catalan-Spanish bilinguals were compared to early Spanish-Catalan bilinguals. The last group was referred to as the L1-Spanish group, having "learned Spanish as their primary language and Catalan as their second language", while the first group was called the L2-Spanish

group, having "learned Catalan first" (p. 314). Both groups should be considered early bilinguals, acquiring two languages from an early age, and receiving bilingual Spanish-Catalan education. Whether these two groups show processing (dis)similarities with Spanish monolingual speakers that can be attributed to similar regular verb structures in Catalan and Spanish remains unclear.

Rodriguez-Fornells et al. (2001) used the violation paradigm to investigate Catalan verbs formed by stem formation. Correctly and incorrectly formed past participles were visually presented in short stories. All subjects in this study were "high proficiency bilingual speakers of Catalan and Spanish" (p. 50). Regularizations (e.g., 1st conjugation to 2nd and 3rd conjugation verbs) elicited a LAN similar to that seen for morphological violations in German and Italian (Gross et al., 1998; Penke et al., 1997; Weyerts et al., 1997). Irregularizations (e.g., 3rd conjugation to 1st conjugation verbs) did not show such a LAN effect. The researchers concluded that the LAN is not only sensitive to inflectional rule violations, but "also to violations of stem formation rules" (Rodriguez-Fornells et al., 2001, p. 54). Most importantly, the studies by De Diego Balaguer et al. (2005) and Rodriguez-Fornells et al. (2001) show that early bilinguals are sensitive to (violations of) morphological structure in the non-native language.

Lehtonen et al. (2012) investigated morphological processing in early, high-proficient Finnish-Swedish bilinguals. The researchers applied a visual lexical decision task, and focused on the effects of frequency (high vs. low-frequency words), morphology (inflected vs. monomorphemic Finnish nouns), and lexicality (pseudowords vs. real Finnish words). In all three conditions, larger N400 effects were found for the bilingual group (compared to a native Finnish speaker group tested in Lehtonen et al., 2007). These results were interpreted as follows: Early Finnish-Swedish bilinguals decompose Finnish inflected words in both the high and low frequency range. Native speakers of Finnish, however, show ERP patterns that reflect decomposition of low-frequency items, but full-form access of high-frequency words.

These effects are suggested to stem from differences in target language exposure: Monolinguals have encountered high-frequent inflected Finnish nouns frequently enough to develop full-form representations for these words. Early bilinguals, on the other hand, have had lower amounts of exposure to Finnish complex nouns compared to monolinguals, because they have to "divide their language input between the two languages" (Lehtonen et al., 2012, p. 1370). Therefore, no or fewer full-form representations are developed, and decomposition is used to process both low- and high-frequency Finnish complex nouns.

In the Lehtonen et al. (2012) study, ERP differences between morphologically complex and monomorphemic words were not observed before 450 ms. The authors therefore claim that the effect of decomposition for the inflected nouns is related to a later stage of processing. During this stage, the lexical-semantic representations of the constituents are accessed, and possibly licensing and/or recombination of the morphemes takes place (Lehtonen et al., 2012, 2007; Niemi, Laine, & Tuominen, 1994). Effects of early, visual decomposition of the words, such as found around 200 ms for derived complex items by Lavric et al. (2012), seem to be absent in this study.

Another interesting explanation for the larger N400 effects for bilinguals than for monolinguals is that of language background. The early bilinguals in the Lehtonen et al. (2012) study might have "less automatized language processing mechanisms related to morphological decomposition in particular" (p. 1369). This is related to the other language of the early bilinguals: Swedish. Swedish is a language with a limited morphology. It might be that in Swedish morphological decomposition happens less frequently than in a morphologically rich language such as Finnish. Decomposition is thus less automatized. Similar claims about the importance of language background in non-native morphological processing have been made in behavioural studies (Gor & Cook, 2010; Portin & Laine, 2001; Vannest, Bertram, Järvikivi, & Niemi, 2002).

1.5. The present study

The current study investigated the time course of processing regularly inflected verbs, irregularly inflected verbs, productively derived items, and non-productively derived items in Dutch native speakers, and Turkish-Dutch early bilinguals. In addition, we manipulated stimulus list composition by presenting the target items in two types of nonword contexts.

1.5.1. Morphological properties of Turkish and Dutch

Productive morphology involves rules that are "regularly and actively used in the creation of new words" (Spencer, 1991, p. 49). In this study, we used regular past tense marking in the verbal domain, and in the nominal domain we used *-heid* and *-ing*, affixes that derive nouns from adjectives and verbs respectively. Although subregularities can be identified in the formation of irregular past tenses (usually involving vowel changes), the past tense of new verbs is unlikely to be formed in such a way, so we used these as examples of irregular verbal morphology. For the nominal domain, we used *-te* and *-nis* as non-productive nominalisers. Productive morphology is predicted to trigger decomposition more readily than irregular morphology, and the effect is likely to be bigger for inflectional morphology (here, the verbal domain) than for derivational morphology (Marslen-Wilson, 2007).

Turkish is an agglutinative and therefore morphologically transparent, language known for its elaborate productive morphology on verbs and nouns. As an example, the stem of a verb "can be followed by suffixes expressing, for instance, tense, person, negation, passive reflexivity (one self), reciprocity (each other)" (Aarssen & Backus, 2001, p. 257). Given these morphological characteristics, it has been suggested that Turkish speakers must process morphologically complex words by means of decomposition rather than whole-word retrieval (Frauenfelder & Schreuder, 1992; Hankamer, 1989), and experimental research has confirmed this (see Gürel, 1999, for a visual lexical decision study, Kırkıcı, 2010, for an elicited English past tense production task, and Kırkıcı & Clahsen, 2013, for a priming experiment).

If the language background of the Turkish-Dutch speakers indeed affects how complex words are processed, then the current study expects decomposition to be more automatized and thus take place more quickly in Turkish-Dutch speakers than in Dutch speakers (both groups are equally familiar with English as a third language).

1.5.2. Different types of nonwords

The processing of pseudowords (violations) in the visual domain has been examined in several studies (Bölte et al., 2009; Gross et al., 1998; Hahne et al., 2006; Havas et al., 2012; Janssen et al., 2006; Lehtonen et al., 2007; Leinonen et al., 2008, 2009; Lück et al., 2006; McKinnon et al., 2003; Morris & Holcomb, 2005; Newman et al., 2007; Palmović & Maričić, 2008; Penke et al., 1997; Rodriguez-Fornells et al., 2001; Weyerts et al., 1997). Lehtonen et al. (2007) used different types of pseudowords in their EEG study to investigate the role of the stem in both words and pseudowords during visual recognition. Results showed that the ERP responses to pseudowords with a real stem differ from monomorphemic pseudowords and pseudowords with a fake stem. This suggests that the presence of morphological structure and especially a real word stem in nonwords elicits decomposition of both nonwords and words.

The present study included two types of nonword contexts to test the effect of stimulus list composition on the recognition of morphologically complex Dutch words: A morphologically structured nonword context (nonword context [+]) and a not morphologically structured nonword context (nonword context [−]). In the nonword context [+], words were presented together with nonwords that had a real stem and a real suffix, forming a nonword (e.g., HEARTING). In the nonword context [−], words were presented together with nonwords that had no morphological structure (e.g., SCHIRSAN, for a more detailed explanation, see section 2.2.). Given the results from both behavioural and ERP studies, we expect the nonword context [+] to promote a decomposition strategy, reflected in an N400 type effect for words presented in this context compared to words presented in the nonword context [−]. Furthermore, we expect this difference between nonword contexts to be stronger in Dutch than in Turkish-Dutch speakers. Due to their language background (Turkish), the early Turkish-Dutch bilinguals are expected to have a more automatized decomposition strategy, irrespective of the nonword context. Therefore, the effect of nonword context is expected to be small or not present at all in the Turkish-Dutch group. In contrast, Dutch native speakers are expected to be more sensitive to the nonword context manipulation: They are expected to show a more decomposition based processing strategy in the nonword context [+]. We therefore expect a difference between ERP responses for words presented in the nonword context [−] and nonword context [+].

1.5.3. Predictions

We make the following predictions, formulated now in terms of time course instead of word formation type (as we did above): In the early time window (200–350 ms), we expect to find effects of visual decomposition, reflected in the N250 component. Although we expect visual decomposition to occur for both derived and inflected items, result patterns might differ, because no direct comparison of these two word formation types has as yet been made in this early time window (Lavric et al., 2012; Morris & Stockall, 2012; Morris et al., 2010, 2008). In particular, the ease of visual decomposition might be affected by language background, in which case decomposition would be more automatized in Turkish-Dutch participants. This would result in smaller processing costs compared to the Dutch speakers.

In the 350–500 ms time window, we expect the N400 to reflect morphological decomposition (Janssen et al., 2006; Lehtonen et al., 2012, 2007; Leinonen et al., 2008). Decomposition should especially be visible across nonword contexts: In the nonword context [+], both words and nonwords have a real stem. Because, as suggested by Lehtonen et al. (2007), a real stem is needed to initiate decomposition, there will be stronger decomposition in the nonword context [+] than nonword context [−], which should be reflected in an N400 for words in the nonword context [+] compared to those in the nonword context [−]. Furthermore, if language background indeed affects morphologically processing, processing differences between words in a nonword context [−] and nonword context [+] are expected to be smaller in the Turkish-Dutch speakers compared to the Dutch native speakers. This is because the first are expected to make use of a more automatized decomposition strategy.

In the 500–700 ms time window, we expect to find effects of reanalysis, expressed in a positivity effect in the 500–700 ms time window (Lehtonen et al., 2007; Leinonen et al., 2009). The ease of reanalysis might be affected by the productivity of the suffixes, the word formation type of the complex words, the manipulated nonword context, and by the language background of the participants.

2. Method

2.1. Participants

Twenty-six native speakers of Dutch (19 women, 7 men) and 25 Turkish-Dutch bilinguals (18 women, 7 men) participated in the EEG experiment. All participants were right-handed, had normal or corrected-to-normal vision, and were never diagnosed with any learning or other behavioural disorder. The mean age of the native speakers was 21.9 years (range: 18–27, SD = 2.8), and that of the bilingual participants was 22.2 years (range: 18–26, SD = 2.8). Groups did not differ in age, $t(48.947)$ = −0.30329, p = .763.

All Dutch participants were native speakers of Dutch and, although all of them are at least bilingual in Dutch and English, they did not acquire any language other than Dutch in their early years. However, they should be considered as late bilinguals, because almost all reported to have learned a different language besides Dutch, e.g., English, German, or French, but only after the age of 10. The Turkish-Dutch bilinguals were early bilinguals, and were first exposed to Dutch at the mean age of 0.8 years (range: 0–4, SD = 1.4). They all learned Turkish from birth, and used Turkish on a regular basis.

To determine the speakers' receptive vocabulary of Dutch at the time of testing, a picture selection task (PPVT-III-NL, Dunn, Dunn, & Schlichting, 2005) was administered. Out of four pictures, the participant selects a picture that best corresponds to a given word. The results revealed a mean score of 103.3 (SD = 7.0) for the native speakers, and a score of 86.1 (SD = 17.8) for the bilingual group (with 100 being the mean score for Dutch native speakers).

All participants estimated their language skills (speaking, listening, writing, and reading) in Dutch using a 7-point scale (1 = *no skills*, 4 = *average*, 7 = *excellent*). The Dutch speakers rated their Dutch language skills to be excellent, good, or satisfactory

(M = 6.77, SD = 0.45). The Turkish-Dutch participants rated their Dutch language skills between excellent and average (M = 6.40, SD = 0.70).

In addition, the bilingual participants were asked to estimate their Turkish language skills, and their Turkish language skills compared to those of a native speaker of Turkish, using a 7-point scale (1 = *no skills*, 4 = *average*, 7 = *excellent*). The mean estimate for their Turkish language skills was 5.61, SD = 1.28, and the mean estimate for their Turkish language skills compared to those of a native speaker of Turkish was 4.83, SD = 1.61. When asked about language dominance, 6 bilinguals reported Turkish to be their dominant language, 14 reported Dutch to be their dominant language, and 2 stated that both languages were equally dominant (data are missing for 3 participants due to malfunctioning of the questionnaire software).

2.2. Materials

The stimulus materials included 480 items: 160 complex items, 80 monomorphemes, and 240 nonwords. All complex items and monomorphemes were selected from the SUBTLEX-NL database, a database of Dutch word frequencies based on 44 million words from film and television subtitles (Keuleers, Brysbaert, & New, 2010).

The complex items consisted of words with either productive or non-productive suffixes, divided over two sets. Set 1 included 40 derivational nouns with productive suffixes (20 nouns with the suffix *–ing*, 20 nouns with the suffix *–heid*), and 40 regularly inflected verbs (20 verbs with the plural past tense suffix *–ten*, and 20 verbs with the plural past tense suffix *–den*[1]). Set 2 included 40 derivational nouns with non-productive suffixes (20 nouns with the suffix *–te*, and 20 nouns with the suffix *–nis*), and 40 irregularly inflected verbs (plural past tense, formed by changing the vowel of the stem of the verb). The items of both sets were matched as closely as possible on length in letters, number of syllables, and word frequency. All derived items were nominalizations, with either an adjective or a verb as stem, forming a noun by adding an affix.

The nonwords were also divided over two sets: set A and set B. Set A consisted of 80 nonwords created with the pseudoword generator Wuggy (Keuleers & Brysbaert, 2010). These nonwords did not have an existing stem or an existing affix (hence not morphologically structured nonword context, nonword context [−]), and were matched on letter length of the complex items of set 1 and 2. Set B consisted of 80 nonwords that had an existing stem and an existing suffix, but their combination resulted in a word that does not exist in Dutch (e.g. *duur* + *heid*: 'expensive' plus derivational suffix, *gras* + *ten*: 'grass' plus regular inflection suffix, hence morphologically structured nonword context, nonword context [+]). The nonwords in set B always ended with the same productive affixes as those of the word items in set 1 (20 nonwords with *–ing*, 20 with *–heid*, 20 with *–ten*, and 20 with *–den*).[2]

In addition to the complex items, 80 monomorphemes were selected from the SUBTLEX-NL database. Half of these monomorphemes always appeared in the nonword context [+], and the other half always appeared in the nonword context [−]. The monomorphemes were matched on length in letters, number of syllables, and word frequency with the complex items. For all monomorphemes, nonwords were created that did not have an existing stem or an existing affix. Table 1 displays the properties of the stimuli in the different conditions.

In addition to collecting the SUBTLEX-NL database frequencies, we asked participants to rate the frequency of the word items in the experiment. Participants were asked to indicate how often they used the complex words in their daily language use (including speaking, listening, reading, and writing) using a 7-point scale, 1 indicating never using the word, 4 indicating an average use and 7 indicating the participant used the word very often. There were two lists, each containing half of the word items (120 items per list) from the experiment. Lists were counterbalanced across participants. The mean subjective frequency measure per participant group for each condition can be found in Table 1.

2.3. Procedure

A visual lexical decision task was performed by the participants while their EEG was simultaneously recorded. Before the experiment, participants received a short instruction about the task. They were instructed to decide as quickly and accurately as possible whether a letter string presented on a computer screen was a real Dutch word or not, and examples of a word and a nonword were given. When the presented letter string was a word, participants were asked to press the right button, and when the presented letter string was a nonword, they were asked to press the left button on a button box. The experiment was performed using Presentation software (Neurobehavioral Systems, http://www.neurobs.com), which recorded the participants' reaction time in milliseconds and the correctness of their responses.

Each trial started with a fixation cross in the middle of the screen for 200 ms. A blank screen followed the fixation cross. After 200 ms, a stimulus item was presented at the position of the fixation cross. The stimulus item remained at the screen for 1300 ms, also when a response was given faster. Following the stimulus item, a blinking symbol (#) and a blank screen were presented for 2200 ms and 300 ms, respectively, after which a new trial started. Each trial lasted for 4200 ms. Stimuli were presented in black letters (Arial 28 point) on a monitor with a grey background.

The experiment began with a practice session of 16 items of which 8 were words and 8 were nonwords, where the nonwords corresponded to the type of nonwords used in the actual experiment. The stimuli were presented in four blocks of 120 items, and each

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[1] *–en* denotes the plural part of the verb. Whether *–d* or *–t* is used depends on the final consonant of the verb stem: When the final consonant is voiceless, *–t* is used, otherwise *–d* is used.

[2] No morphologically structured nonwords were created with the suffixes of the complex items in set 2, because we wanted to encourage a decomposition strategy with the nonwords of set B.

Table 1
Properties of the stimuli in the different conditions.

Set	Condition	WL	WS	WF	SF	PF-L1	PF-L2
1	Productive derivation (n = 40) *dreiging, gladheid*	8.93	2.50	1.88	2.39	3.5	4.0
1	Regular inflection (n = 40) *dansten, gooien*	7.53	2.08	1.78	3.19	4.4	4.6
2	Non-productive derivation (n = 40) *stoornis, hoogte*	7.95	2.70	1.88	2.53	3.6	3.8
2	Irregular inflection (n = 40) *smolten*	6.63	2.00	1.70	2.69	4.1	4.0
A	Not morphologically structured nonwords (n = 80) *schirsan*	7.64	–	–	–	–	–
B	Morphologically structured nonwords (n = 80) *huiling, tofheid, grasten, pleinden*	8.29	2.44	–	2.75	–	–
A	Monomorphemes (n = 40) *soldaat*	6.93	2.28	1.84	–	3.5	3.7
B	Monomorphemes (n = 40) *orkest*	6.65	2.35	1.86	–	3.6	3.8
A	Monomorphemes nonwords (n = 40) *warnoei*	6.93	–	–	–	–	–
B	Monomorphemes nonwords (n = 40) *kratoek*	6.65	–	–	–	–	–

Note. Mean value of word length (WL) in letters, mean number of syllables (WS), mean LOG10 word frequency (WF), mean LOG10 stem frequency (SF), and the participants' mean subjective frequency ratings per participant group (PF-L1, Dutch speakers, PF-L2, Turkish-Dutch speakers) on a 7-point scale (1 = *never using the word*, 4 = *average use*, and 7 = *using the word very often*). For each condition, examples are given.

block started with three dummy items. There was a break between each block, which lasted as long as the participant wanted. The first two blocks either contained productive (set 1) or non-productive word items (set 2), and were presented in either a nonword context [−] or nonword context [+] (set A or set B). The third and the fourth block included the opposite sets of the first and second block. If participant 1 was presented first with two blocks combining the items of set 1 and set A, the third and fourth block would consist of the items of set 2 and set B. Four combinations were possible (1A, 1B, 2A, and 2B) and participants saw either 1A and 2B, or 1B and 2A. The order of blocks was counterbalanced across participants, and the presentation of the items in each block was randomized for every participant. The monomorphemes of set A (and their nonword counterparts) were presented together with the nonword context [−], and monomorphemes of set B (and their nonword counterparts) were presented together with the nonword context [+]. The experiment took about 45 min. All communication during the experiment was in Dutch.

After the experiment, a receptive vocabulary test (PPVT-III-NL, Dunn et al., 2005) was administered to measure the participants' receptive vocabulary in Dutch. Furthermore, all participants filled in a questionnaire about their language background before the experiment, and a questionnaire on the subjective frequency of half of the presented complex items after the experiment.

2.4. Electrophysiological recording

The ERPs were recorded from the scalp using Ag/AgCl electrodes mounted in an elastic cap (actiCAP, Brain Products, Munich, Germany). Electrodes were located at 27 standard positions according to the 10–20 system (Fz, F7/F8, F3/F4, FcZ, Fc5/Fc6, Fc1/Fc2, Cz, T7/T8, C3/C4, Cp5/Cp6, Cp1/Cp2, Pz, P7/P8, P3/P4, Oz and O1/O2). Two electrodes (Po9/Po10) were placed at the outer left and right canthi to monitor horizontal eye movements and blinks. Vertical eye movements were monitored using Fp1 above and Fp2 below the left eye. Tp10 was placed on the right mastoid bone. During measurement, all electrodes were referenced to the left mastoid.

All electrode impedances were kept below 10 kΩ. Signals were recorded using a 125 Hz low-pass filter, a time constant of 10s, and a 500 Hz sampling rate. Brain Vision Analyzer (Version 2.1. Brain Products, Munich, Germany) was used to analyse the waveforms.

Afterwards, the EEG signals were re-referenced offline to the activity of the mean of the right and left mastoid. The EOG electrodes were converted into horizontal and vertical bipolar EOG signals. A 30 Hz/12dB low-pass IIR filter was applied, after which the EEG signal was segmented using a window that started 200 ms before, and ended 1300 ms after the target item. Subsequently, baseline correction was applied to the 200 ms pre-critical word interval. Segments were semi-automatically screened for eye-movements, amplifier blocking, drifting and muscle artifacts using a − 75/+75µVolt Amplitude Criterion and a 75µVolt Gradient Criterion. In total, 18.3 per cent segments containing these artifacts were rejected (Dutch native speakers: 15.4 cent, Turkish-Dutch speakers: 21.2 per cent). Artifact-free and correct segments were averaged per participant and per condition. Eight participants were excluded from the analysis because more than 35 per cent of the trials were rejected, leaving 43 participants for subsequent analysis (23 native Dutch speakers, 20 Turkish-Dutch speakers).[3]

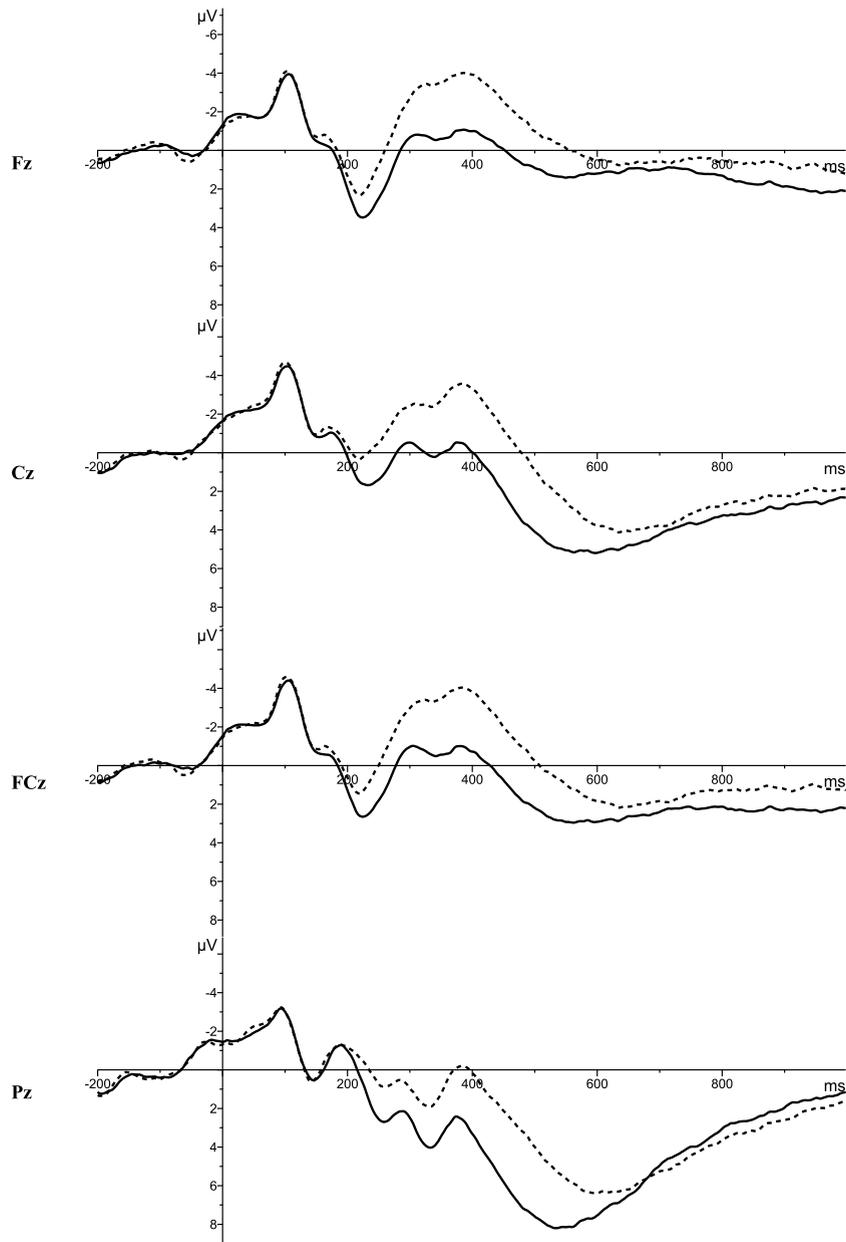[3] This number of excluded participants was due to a technical problem while recording the EEG signal.

Fig. 1. Grand-averaged ERP waveforms on Midline electrodes for the target words (solid lines, N = 43) and the target nonwords (dotted lines, N = 38) for all speakers. Negativity is plotted upward.

2.5. Data analysis

Mean amplitudes were calculated for three selected time windows: 200–350 ms, 350–500 ms and 500–700 ms time window. Time windows were based on earlier research and visual inspection. Mixed linear regression analyses, with mean amplitude measures as dependent variables, subjects as random factor, and Group (Dutch speakers vs. Turkish-Dutch speakers), Productivity (productive vs. non-productive), Word formation type (inflection vs. derivation), and Nonword context (nonword context [−] vs. nonword context [+]) as fixed effects were conducted using R (R Core Team, 2015). For all three time windows, analyses were first performed at 15 electrodes locations (mean activity of Fz, F7/F8, F3/F4, Cz, C3/C4, T7/T8, Pz, P3/P4, P7/P8) and at the Midline electrodes (mean activity of Fz, FcZ, Cz, Pz). We used AIC to determine best fit.

3. Results

3.1. Control analysis: effects of lexicality

Fig. 1 shows the grand-averaged ERP waveforms for the target words and the target nonwords, on the Midline electrodes (Fz, FcZ, Cz, Pz).

A mixed linear regression analysis, with mean amplitude measure of 15 electrodes (Fz, F7/F8, F3/F4, Cz, C3/C4, T7/T8, Pz, P3/P4, P7/P8) as dependent variable, subjects as random factor, and Group (Dutch speakers vs. Turkish-Dutch speakers), and Lexicality (all targets words vs. all target nonwords) as fixed effects, and a similar mixed linear regression analysis, but then with the mean amplitudes of the Midline electrodes (Fz, FcZ, Cz, Pz) were conducted using R. Both analyses showed main effects of Lexicality in all three time windows (200–350 ms $p < .001$, 350–500 ms $p < .001$, and 500–700 ms $p < .001$), reflecting larger negativities for the nonwords than the words.

3.2. Overall and midline analysis

A mixed linear regression analysis, with mean amplitude measure of 15 electrodes (Fz, F7/F8, F3/F4, Cz, C3/C4, T7/T8, Pz, P3/P4, P7/P8) as dependent variable, subjects as random factor, and Group (Dutch speakers vs. Turkish-Dutch speakers), Productivity (productive vs. non-productive), Word formation type (inflection vs. derivation), and Nonword context (nonword context [−] vs. nonword context [+]) as fixed effects was conducted. In all three time windows, a main effect of Word formation was found, reflecting a larger negativity for the inflected than the derived words (200–350 ms $p < .001$, 350–500 ms $p < .001$, and 500–700 ms $p < .05$). In the 350–500 ms time window, a main effect for Nonword context was found ($p < .05$), showing more negativity for words presented in the nonword context [+] than for words presented in the nonword context [−].

A significant interaction between Productivity and Word formation was found in both the 200–350 ms time window ($p < .05$) and the 350–500 ms time window ($p < .01$), reflecting most negative waveforms for non-productive inflected words.

A mixed linear regression analysis, with mean amplitude measure of the Midline electrodes (Fz, FcZ, Cz, Pz) as dependent variable, subjects as random factor, and Group (Dutch speakers vs. Turkish-Dutch speakers), Productivity (productive vs. non-productive), Word formation type (inflection vs. derivation), and Nonword context (nonword context [−] vs. nonword context [+]) as fixed effects showed a main effect of Word formation in the 200–350 ms and the 350–500 ms time window ($p < .001$, $p < .001$), reflecting more negativity for inflected than derived words. In the 350–500 ms time window, a main effect for Nonword context was found ($p < .01$) showing more negativity for words presented in the nonword context [+] than for words presented in the nonword context [−].

A significant interaction between Productivity and Word Formation in the 200–350 ms ($p < .05$) and 350–500 ms ($p < .01$) time windows showed most negative waveforms for non-productively inflected words at midline electrodes. In the 500–700 ms time window, a significant interaction between Productivity and Nonword context was found ($p < .05$), reflecting more positive waveforms to items with productive than non-productive morphology presented in the nonword context [+]. No such difference was present in the nonword context [−]. All effects of the overall and midline analysis can be found in Table 2.

In order to disentangle the previous interactions, we performed follow-up analyses on the different time windows (200–350 ms, 350–500 ms and 500–700 ms) for four regions of interest (Left Anterior, Left Posterior, Right Anterior, Right Posterior), and on the 350–500 ms time window for the N400.

3.3. Five regions of interest

We will first discuss the four quadrants, after which we will specifically look at the N400 electrodes.

To further investigate the significant interaction between Productivity and Word formation in the 200–350 ms and 350–500 ms time windows at the overall and midline analyses, and the significant interaction between Productivity and Nonword context in the

Table 2
Statistically significant results for the Overall and Midline analysis.

Condition	Time-window		
	200–350	350–500	500–700
Word formation	O***	O***	O*
	M***	M***	
Nonword context		O*	
		M**	
Productivity * Word formation	O*	O**	
	M*	M**	
Productivity * Nonword context			M*

Note. Mixed linear regression analysis of Group * Productivity * Word Formation * Nonword context in target words performed at three time windows. Analyses were carried out at Overall (O) electrodes (Fz, F7/F8, F3/F4, Cz, C3/C4, T7/T8, Pz, P3/P4, P7/P8), and Midline (M) electrodes (Fz, FcZ, Cz, Pz). P-values: *$p < .05$, **$p < .01$, ***$p < .001$.

500–700 ms time window at the midline electrodes, we looked at four lateral regions separately (Left Anterior, LA: mean activity of F3, Fc5, Fc1; Left Posterior. LP: mean activity of P3, Cp5, Cp1; Right Anterior, RA: mean activity of F4, Fc6, Fc2; Right Posterior, RP: mean activity P4, Cp6, Cp2). A mixed linear regression analysis, with mean amplitude measures as dependent variables, subjects as random factor, and Group (Dutch speakers vs. Turkish-Dutch speakers), Productivity (productive vs. non-productive), Word formation type (inflection vs. derivation), and Nonword context (nonword context [−] vs. nonword context [+]) as fixed effects were conducted using R.

In the 200–350 ms time window, a main effect for Word formation at all regions was found (LA $p < .001$, RA $p < .001$, LP $p < .001$, RP $p < .001$), reflecting more negative brain responses to inflected than derived words. Furthermore, significant interactions were found between Group and Productivity (LA $p < .05$, RA $p < .05$), and between Productivity and Word Formation (LA $p < .05$, RA $p < .01$) at both Left Anterior (see Fig. 4) and Right Anterior regions of interest in the 200–350 ms time window.

In the 350–500 ms time window, a main effect for Productivity at Left Anterior electrodes ($p < .05$) showed more negative responses to words with non-productive affixes than to word with productive affixes. A main effect for Word formation showed more negative brain responses to inflected than derived words at all four regions of interest (LA $p < .001$, RA $p < .001$, LP $p < .001$, RP $p < .001$). A main effect of Nonword context revealed more negativity to words presented in the nonword context [+] than to words presented in the nonword context [−] at all four regions of interest (LA $p < .01$, RA $p < .01$, LP $p < .01$, RP $p < .05$). A significant interaction between Productivity and Word Formation at all lateral regions (LA $p < .01$, RA $p < .01$, LP $p < .01$, RP $p < .01$) revealed most negative waveforms for non-productively inflected words. At Left Parietal electrodes only, a significant effect between Group and Nonword context in the 350–500 ms time window ($p < .05$) revealed that Dutch participants showed significantly more negative brain responses to words presented in the nonword context [+] than for words presented in the nonword context [−]. No such difference between nonword contexts was present for the Turkish-Dutch speakers.

In the 500–700 ms time window a significant main effect of Word formation was found in the Right Anterior and Right Parietal electrodes (RA $p < .05$, RP $p < .05$), reflecting more negative responses for inflected than derived words. A main effect of Group at Left Parietal electrodes ($p < .05$) showed more positive responses for Dutch than Turkish-Dutch speakers. A significant interaction between Group and Productivity was found for the Left and Right Posterior electrodes (LP $p < .05$, RP $p < .05$), revealing that the Dutch speakers showed more positive responses to words with productive affixes than Turkish-Dutch speakers.

At Left Posterior electrodes, a significant interaction between Productivity and Nonword context was found (LP, $p < .05$), showing more positive responses for non-productive words presented in the nonword context [−] than for non-productive words presented in the nonword context [+]. All statistically significant results for the N400 and the four regions of interest analyses can be found in Table 3.

Finally, we looked at the region known to be associated with a standard N400 effect. A mixed linear regression analysis, with mean amplitude measure of the N400 electrodes (mean activity of F3, Fc5, Fc1, C3, Cp5, Cp1, P3) as dependent variable, subjects as

Table 3
Statistically significant results for the N400 and four regions of interest analysis.

Condition	Time-window		
	200–350	350–500	500–700
Group			LP*
Productivity		LA*	
Word formation	LA***	N***	RA*
	RA***	LA***	RP*
	LP***	RA***	
	RP***	LP***	
		RP***	
Nonword context		N**	
		LA**	
		RA**	
		LP**	
		RP*	
Productivity * Word formation	LA*	N**	
	RA**	LA**	
		RA**	
		LP**	
		RP**	
Productivity * Nonword context			LP*
Group X Productivity	LA*		LP*
	RA*		RP*
Group X Nonword context		N*	
		LP*	

Note. Mixed linear regression analysis of Group * Productivity * Word Formation * Nonword context in target words performed at three time windows. Analyses were carried out at N400 (N), Left Anterior (LA), Right Anterior (RA), Left Posterior (LP), and Right Posterior (RP) locations. Electrodes in analysis N400: F3, Fc5, Fc1, C3, Cp5, Cp1, P3; Left Anterior: F3, Fc5, Fc1; Right Anterior: F4, Fc6, Fc2; Left Posterior: P3, Cp5, Cp1; Right Posterior: P4, Cp6, Cp2. P-values: *$p < .05$, **$p < .01$, ***$p < .001$.

random factor, and Group (Dutch speakers vs. Turkish-Dutch speakers), Productivity (productive vs. non-productive), Word formation type (inflection vs. derivation), and Nonword context (nonword context [−] vs. nonword context [+]) as fixed effects in the 350–500 ms time window was conducted using R. As in the Overall and Midline analyses, main effects for Word formation ($p < .001$, more negativity for inflected than derived words) and Nonword context ($p < .01$, more negativity for words presented in the nonword context [+] than in the nonword context [−]) were found. A significant interaction between Productivity and Word formation ($p < .01$) showed most negative waveforms for non-productively inflected words. In addition, a significant interaction between Group and Nonword context ($p < .05$) revealed that the Dutch speakers showed significantly more negative brain responses to words presented in the nonword context [+] than to words presented in the nonword context [−]. No such difference between nonword contexts was present for the Turkish-Dutch speakers,[4] see Figs. 2 and 3.

4. Discussion

In the present study, Turkish-Dutch and Dutch participants performed a Dutch lexical decision task on morphologically complex and control words that were presented in stimulus lists with nonwords that were either morphologically complex or not. In addition to behavioural data on RTs and accuracies, we collected EEG data. In the associated ERP analysis, we examined three relevant time windows of the EEG one by one. Here we will discuss the contrasts found in our data in the light of (i) the nature of the morphology-related process taking place in these particular windows and (ii) processing differences between the two speaker groups.

Before we go into details, we note that the processing of both the Dutch and Turkish-Dutch speakers showed their sensitivity to word formation and nonword context. Thus, morphological decomposition was found to take place across participant groups. First, a strong main effect of word formation appeared in all time windows (200–350, 350–500, 500–700 ms) and across the whole scalp, with more negative brain responses for complex words with inflectional morphology. This constitutes evidence that all participants responded to whether target items were inflected or derived. This effect already started quite early in processing and persisted across time even up to late time windows. These results are in line with other findings of distinct neurobehavioural patterns for morphological processing of inflected and derived words (Leinonen et al., 2008; Álvarez et al., 2011).

Second, an effect of nonword context appeared in the time window between 350 and 500 ms in regions usually associated with the N400. It indicates that the nonword composition of the stimulus list affects how the target words presented in this list are processed: The nonword context [+]stimulates a processing strategy based on decomposition. A similar effect of the composition of nonwords on the processing strategy by participants was found by Lehtonen et al. (2007). These researchers suggested that including pseudowords with a real stem and suffix in the stimulus set induced a morphological decomposition strategy. Our results are in line with this analysis.

Let us now zoom in the three times windows, starting with the 200–350 ms frame.

4.1. The 200–350 ms time window

Contrasts in this first time window suggest a process of early decomposition based on orthography. At anterior electrodes, both participant groups responded similarly to productively and non-productively derived words, and to regularly and irregularly inflected words forms. The N250 effects that we found for inflectional and productive morphology are in line with earlier results reflecting patterns of early, visual, form-based decomposition (Lavric et al., 2012, 2007; Morris & Stockall, 2012).

4.2. The 350–500 ms time window

Contrasts in this second time window suggest that (i) speakers decompose morphologically complex words, and (ii) Turkish-Dutch speakers respond differently to the nonword manipulation than Dutch speakers, revealing that language background influences processing strategies.

With respect to (i), we observe that from 350 ms onwards a difference arises between responses to irregularly inflected and regularly inflected, and productively derived and non-productively derived words, with irregularly inflected words showing the most negative brain responses. The discrepancy between orthography and morphology is especially present in the irregularly inflected word forms: The past tense form SANG does not contain its root form SING (versus, for example, WALKED-WALK). When orthography does not align with morphology, it is apparently harder to decompose the stem from the complex word form, which is reflected by most negative responses for the irregularly inflected word forms in the 350–500 ms time window. This result supports the view that a recognizable stem must be present to initiate decomposition: Lehtonen et al. (2007), for example, found that only pseudowords with a stem were decomposed. The current study indicates that when a stem was not visually present in the target word, the form-based recognition process initially started in the early 200–350 ms time window, but was obstructed in the later 350–500 ms time window.

With respect to (ii), the effect of nonword context was different for the Dutch and the Turkish-Dutch participant groups. While Turkish-Dutch participants showed no distinct brain responses for words presented in the two nonword contexts, Dutch participants showed an N400-effect for words presented in the nonword context [+] relative to the nonword context [−]. This indicates that a stimulus list with only nonwords that have a real stem has more impact on the processing strategies of Dutch speakers than Turkish-Dutch speakers. This is compatible with the hypothesis that Dutch speakers are more inclined to change their processing preference

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[4] This Group with Nonword context interaction was not present at right hemisphere electrodes (F4, Fc6, Fc2, C4, Cp6, Cp2, P4), $p =$ not significant.
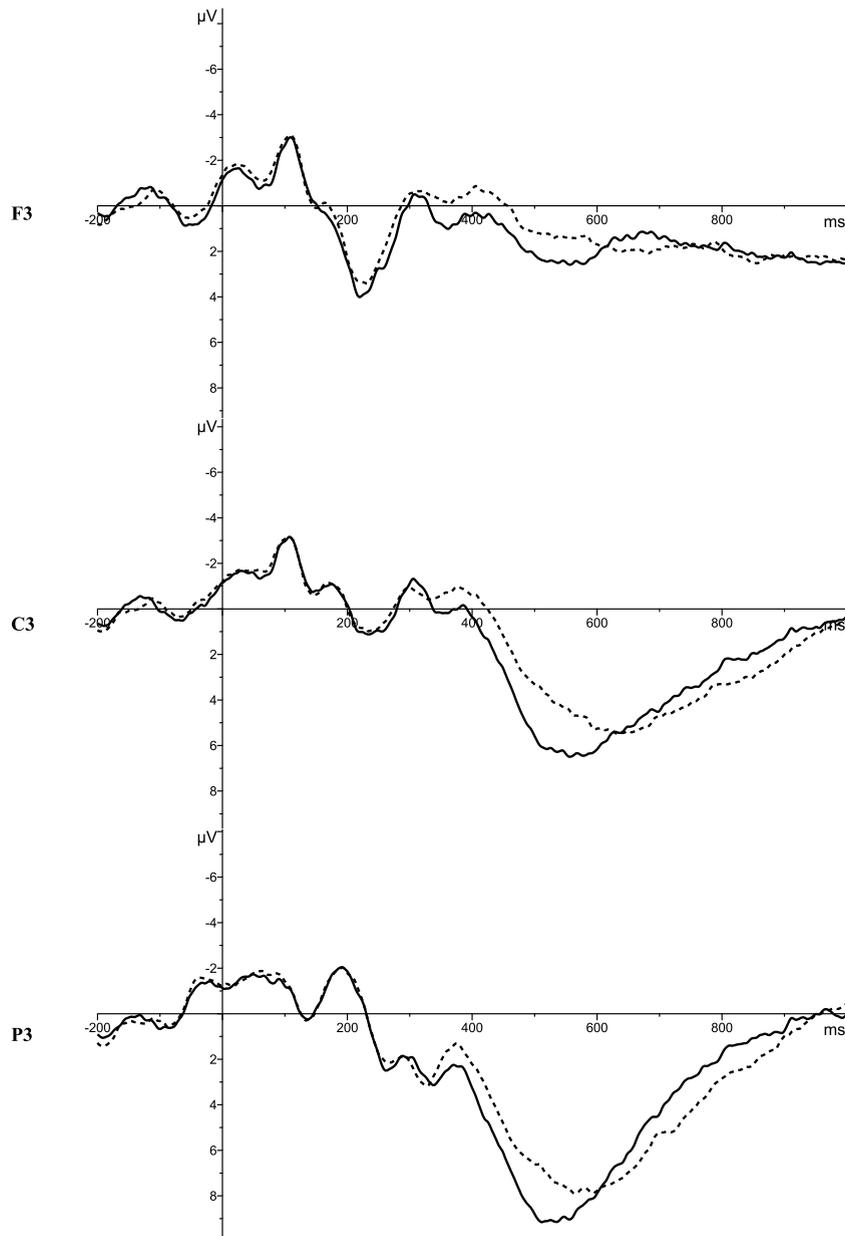
Fig. 2. Grand-averaged ERP waveforms on F3, C3, and P3 for the target words presented in the nonword context [−] (solid lines, N = 23) and the target words presented in the nonword context [+] (dotted lines, N = 23) for Dutch speakers. Negativity is plotted upward.

(from retrieval to decomposition) than the Turkish-Dutch participants do (because they decompose by default).

4.3. The 500–700 ms time window

Contrasts in this third time window suggest that (i) morphologically decomposed words are being reassembled, and (ii) this process is easier for the Turkish-Dutch speakers.

With respect to (i), we observed that more positive responses appeared at Left Parietal electrodes for non-productive items in the nonword context [−] than for non-productive items in the nonword context [+]. In single word studies, positivity effects in the late time window have been thought to reflect larger morphosyntactic processing demands, such as possible reassembly of target items (Lehtonen et al., 2007; Leinonen et al., 2009; Morris & Holcomb, 2005). As concluded earlier, the nonword context [+] initiates a processing strategy based on decomposition in the 350–500 ms time window. As decomposition of the non-productive items presented in the nonword context [+] has already been carried out, reassembly of morphemes in the 500–700 ms time window can proceed faster. This is reflected in a smaller positivity. In contrast, for non-productive words in the nonword context [−]
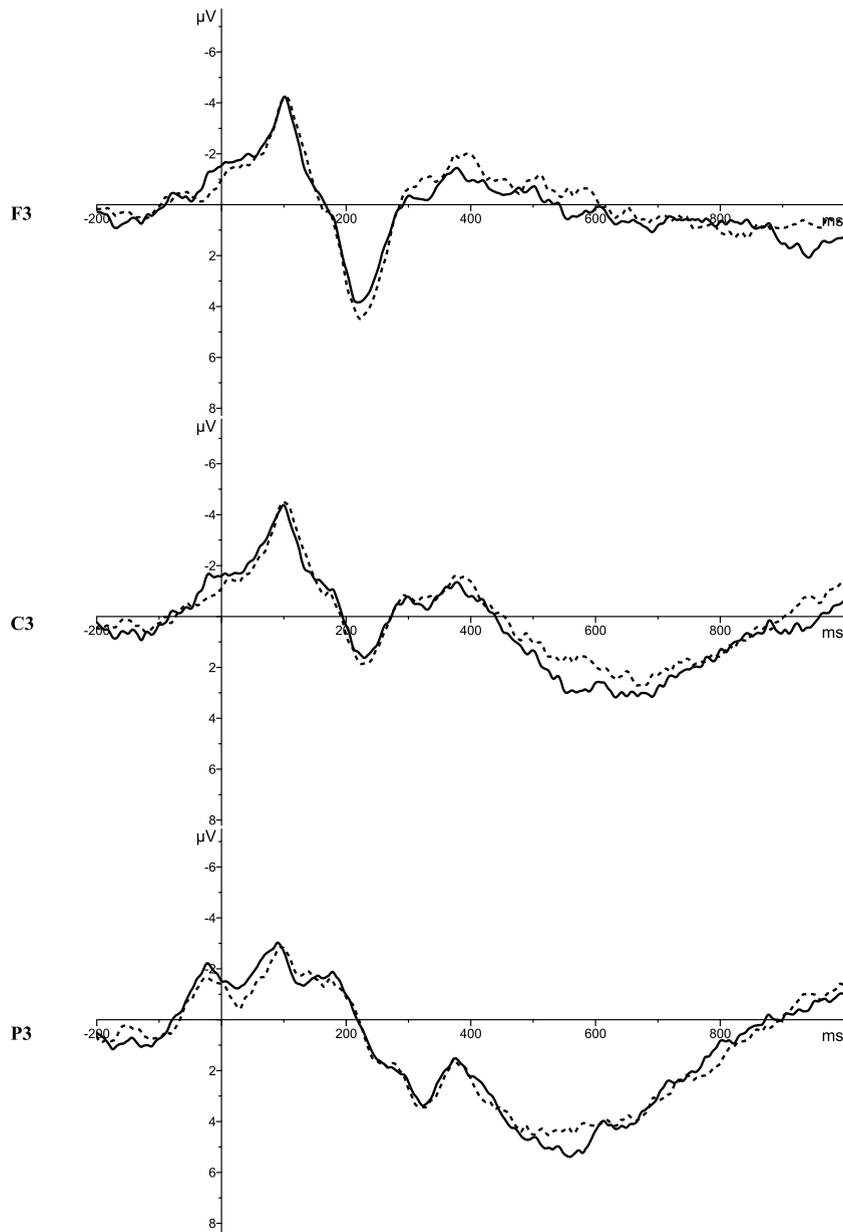
Fig. 3. Grand-averaged ERP waveforms on F3, C3, and P3 for the target words presented in the nonword context [−] (solid lines, N = 20) and the target words presented in the nonword context [+] (dotted lines. N = 20) for Turkish-Dutch early bilinguals. Negativity is plotted upward.

decomposition is less prominent (or more difficult, see results for irregular verbs in 350–500 ms time window), so reassembly of morphemes takes more effort, resulting in the positivity effect in the 500–700 ms time window. This effect has been reported to vary with the complexity of the sentence (Münte, Matzke, & Johannes, 1997), but we argue that it may also vary with the complexity of the nonwords presented together with the target items.

With respect to (ii), the results of our EEG experiment show that the Turkish-Dutch speakers are sensitive to the morphological structure of their non-native language (De Diego Balaguer et al., 2005; Lehtonen et al., 2012; Rodriguez-Fornells et al., 2001). The two participant groups behaved differently in this time window with respect to the manipulation of productivity. Dutch speakers showed a more positive effect than Turkish-Dutch speakers to words with productive affixes at the Left Posterior region. Positivity effects in the late time window have been thought to reflect a possible reanalysis of target items (Lehtonen et al., 2007; Leinonen et al., 2009; Morris & Holcomb, 2005). We interpret this effect as showing the importance of language background in morphological processing by our Turkish-Dutch early bilinguals. If decomposition is easier in Turkish-Dutch speakers due to their Turkish language background, this will also facilitate the reassembly process, visible in the less positive waveform.

To sum up, the Turkish-Dutch speaker group confirms behavioural studies that emphasize the importance of language background
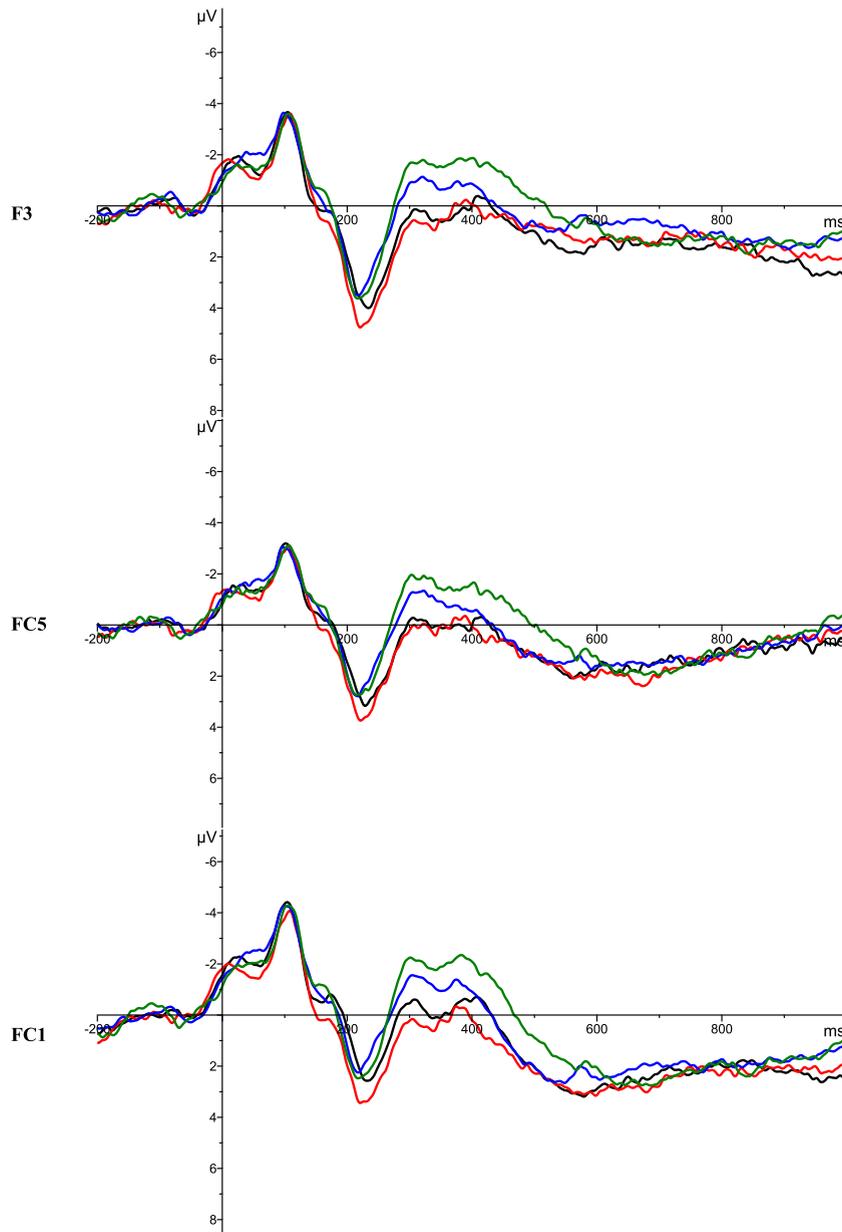
Fig. 4. Grand-averaged ERP waveforms on Left Anterior electrodes for the productively derived (black lines, N = 42), non-productively derived (red lines, N = 42), regularly inflected (blue lines, N = 43), and irregularly inflected (green lines, N = 42) target words for all speakers. Negativity is plotted upward. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

in non-native morphological processing (Gor & Cook, 2010; Portin & Laine, 2001; Vannest et al., 2002), and show the effect of using two languages from an early age. The Turkish language background of our early bilinguals clearly affected their recognition process of Dutch morphologically complex words. For Turkish-Dutch speakers, decomposition proceeds more effortlessly, leading to similar processing results with items presented in the nonword context [−] and nonword context [+].

5. Future research

The different patterns of brain responses we found for inflected and derived items are in line with earlier results (Leinonen et al., 2008; Álvarez et al., 2011). Nevertheless, our findings might also be (partly) affected by the fact that inflected items were always verbs, and the derived items were always nouns. To test this possibility, future EEG research looking into the processing of inflected and derived items, should include both verbs and nouns in both word formation types.

Earlier studies on the morphological processing of complex words did not pay much attention to the composition of nonwords in

the stimulus list. This may have muddled or complicated the comparison of different studies. In the present study, we explicitly considered the effect of nonword context, by choosing two extremes in terms of nonword complexity: nonwords that had both a stem and an affix, or neither of these. This manipulation intended to elicit (and, in fact, did elicit) a decomposition strategy in participants in the nonword context [+]. Future research investigating the effects of nonword context on the processing of morphologically complex words could include more diverse types of nonwords to see in what ways these do affect processing of the accompanying target words (Lehtonen et al., 2007).

Finally, not only are our conclusions about the bilinguals' language background in processing in line with earlier behavioural research (Lehtonen & Laine, 2003; Lehtonen, Niska, Wande, Niemi, & Laine, 2006; Portin, Lehtonen, & Laine, 2007), they also fit well with the known characteristics of Dutch and Turkish. However, we cannot completely exclude that the differences in results for our Dutch and Turkish-Dutch speakers arose because the latter group learned two languages from birth: they are *early* bilinguals. We are therefore currently studying morphological decomposition in a bilingual group comparable to that of the Turkish-Dutch bilinguals, but with a different, less morphologically rich, language background, namely Chinese-Dutch bilinguals. Results for this participant group may help to disentangle the effects of background language and bilingualism on morphological decomposition.

6. General conclusion

With respect to the time course of target recognition in the current study, we propose that negativity results in the earlier time window (200–350 ms) reflect form-based processing. In the 350–500 ms time window, processing is constrained by a discrepancy between orthography and morphology, which is especially visible in the results for the irregularly inflected verbs. The late time window (500–700 ms) reflects reanalysis of the morphologically complex words.

On the basis of this study, we conclude that the general properties of this time course of processing morphologically complex words are similar across participant groups. However, processing takes more or less effort depending on the productivity of the affixes of the presented words, the nonword context in which the complex words are presented, and the language background of participants. With respect to this last point, it seems that decomposition was more automatized in our Turkish-Dutch participants, due to their Turkish language background; as a consequence, their processing strategy was less affected by the manipulation of nonword context. In contrast, for our Dutch speakers, decomposition was less automatized, and therefore more sensitive to the manipulation of nonword structure in the stimulus list.

Acknowledgements

References

Aarssen, J., & Backus, A. (2001). *Colloquial Turkish: The complete course for beginners.* New York/Oxon: Routledge.

Álvarez, C. J., Urrutia, M., Domínguez, A., & Sánchez-Casas, R. (2011). Processing inflectional and derivational morphology: Electrophysiological evidence from Spanish. *Neuroscience Letters, 490*(1), 6–10. http://doi.org/10.1016/j.neulet.2010.12.015.

Bölte, J., Jansma, B. M., Zilverstand, A., & Zwitserlood, P. (2009). Derivational morphology approached with event-related potentials. *The Mental Lexicon, 4*(3), 336–353. http://doi.org/10.1075/ml.4.3.02bol.

De Diego Balaguer, R., Sebastián-Gallés, N., Díaz, B., & Rodríguez-Fornells, A. (2005). Morphological processing in early bilinguals: An ERP study of regular and irregular verb processing. *Cognitive Brain Research, 25*(1), 312–327. http://doi.org/10.1016/j.cogbrainres.2005.06.003.

Dominguez, A., de Vega, M., & Barber, H. (2004). Event-related brain potentials elicited by morphological, homographic, orthographic, and semantic priming. *Journal of Cognitive Neuroscience,* 598–608. Retrieved from http://www.mitpressjournals.org/doi/abs/10.1162/089892904323057326.

Dunn, L. M., Dunn, L. M., & Schlichting, L. (2005). *Peabody picture vocabulary test-III-NL.* Amsterdam: Pearson.

Frauenfelder, U. H., & Schreuder, R. (1992). Constraining psycholinguistic models of morphological processing and representation: The role of productivity. In G. Booij, & J. van Marle (Eds.). *Yearbook of morphology 1991* (pp. 165–183). Dordrecht: Kluwer Academic Publishers.

Gor, K., & Cook, S. (2010). Nonnative processing of verbal Morphology: In search of regularity. *Language Learning, 60*(1), 88–126. http://doi.org/10.1111/j.1467-9922.2009.00552.x.

Gross, M., Say, T., Kleingers, M., Clahsen, H., & Münte T. F. (1998). Human brain potentials to violations in morphologically complex Italian words. *Neuroscience Letters, 241*(2–3), 83–86. http://doi.org/10.1016/S0304-3940(97)00971-3.

Gürel, A. (1999). Decomposition: To what extent? The case of Turkish. *Brain and Language, 68,* 218–224.

Hahne, A., Mueller, J. L., & Clahsen, H. (2006). Morphological processing in a second Language: Behavioral and event-related brain potential evidence for storage and decomposition. *Journal of Cognitive Neuroscience, 18*(1), 121–134.

Hankamer, J. (1989). Morphological parsing and the lexicon. In W. D. Marslen-Wilson (Ed.). *Lexical representation and process* (pp. 392–408). Cambridge, MA: MIT Press.

Havas, V., Rodríguez-Fornells, A., & Clahsen, H. (2012). Brain potentials for derivational morphology: An ERP study of deadjectival nominalizations in Spanish. *Brain and Language, 120*(3), 332–344. http://doi.org/10.1016/j.bandl.2011.10.008.

Holcomb, P., & Grainger, J. (2006). On the time course of visual word recognition: An event-related potential investigation using masked repetition priming. Cognitive Neuroscience. *Journal of, 18*(10), 1631–1643. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6794990.

Janssen, U., Wiese, R., & Schlesewsky, M. (2006). Electrophysiological responses to violations of morphosyntactic and prosodic features in derived German nouns. *Journal of Neurolinguistics, 19*(6), 466–482. http://doi.org/10.1016/j.jneuroling.2006.04.002.

Keuleers, E., & Brysbaert, M. (2010). Wuggy: A multilingual pseudoword generator. *Behavior Research Methods, 42*(3), 627–633. http://doi.org/10.3758/BRM.42.3.627.

Keuleers, E., Brysbaert, M., & New, B. (2010). SUBTLEX-NL: A new measure for Dutch word frequency based on film subtitles. *Behavior Research Methods, 42*(3), 643–650. http://doi.org/10.3758/BRM.42.3.643.

Kutas, M., & Federmeier, K. D. (2007). Event-related brain potential (ERP) studies of sentence processing. In M. G. Gaskell (Ed.). *The oxford handbook of psycholinguistics* (pp. 385–406). Oxford: Oxford University Press. http://doi.org/10.1093/oxfordhb/9780198568971.013.0023.

Kırkıcı, B. (2010). Cognitive processing in second language acquisition. In M. Pütz, & L. Sicola (Vol. Eds.), *Cognitive processing in second language acquisition inside the learner's mind. Vol. 13. Cognitive processing in second language acquisition inside the learner's mind* (pp. 67–84). Amsterdam: John Benjamins Publishing Company.

http://doi.org/10.1075/celcr.13.

Kırkıcı, B., & Clahsen, H. (2013). Inflection and derivation in native and non-native language processing: Masked priming experiments on Turkish. *Bilingualism: Language and Cognition, 16*(4), 776–791. http://doi.org/10.1017/S1366728912000648.

Lavric, A., Clapp, A., & Rastle, K. (2007). ERP evidence of morphological analysis from orthography: A masked priming study. *Journal of Cognitive Neuroscience, 19*(5), 866–877. http://doi.org/10.1162/jocn.2007.19.5.866.

Lavric, A., Elchlepp, H., & Rastle, K. (2012). Tracking hierarchical processing in morphological decomposition with brain potentials. *Journal of Experimental Psychology: Human Perception and Performance, 38*(4), 811–816. http://doi.org/10.1037/a0028960.

Lehtonen, M., Cunillera, T., Rodríguez-Fornells, A., Hultén, A., Tuomainen, J., & Laine, M. (2007). Recognition of morphologically complex words in Finnish: Evidence from event-related potentials. *Brain Research, 1148*, 123–137. http://doi.org/10.1016/j.brainres.2007.02.026.

Lehtonen, M., Hultén, A., Rodríguez-Fornells, A., Cunillera, T., Tuomainen, J., & Laine, M. (2012). Differences in word recognition between early bilinguals and monolinguals: Behavioral and ERP evidence. *Neuropsychologia, 50*(7), 1362–1371. http://doi.org/10.1016/j.neuropsychologia.2012.02.021.

Lehtonen, M., & Laine, M. (2003). How word frequency affects morphological processing in monolinguals and bilinguals. *Bilingualism: Language and Cognition, 6*(3), 213–225. http://doi.org/10.1017/S1366728903001147.

Lehtonen, M., Niska, H., Wande, E., Niemi, J., & Laine, M. (2006). Recognition of inflected words in a morphologically limited Language: Frequency effects in monolinguals and bilinguals. *Journal of Psycholinguistic Research, 35*(2), 121–146. http://doi.org/10.1007/s10936-005-9008-1.

Leinonen, A., Brattico, P., Järvenpää, M., & Krause, C. M. (2008). Event-related potential (ERP) responses to violations of inflectional and derivational rules of Finnish. *Brain Research, 1218*, 181–193. http://doi.org/10.1016/j.brainres.2008.04.049.

Leinonen, A., Grönholm-Nyman, P., Järvenpää, M., Söderholm, C., Lappi, O., Laine, M., et al. (2009). Neurocognitive processing of auditorily and visually presented inflected words and pseudowords: Evidence from a morphologically rich language. *Brain Research, 1275*, 54–66. http://doi.org/10.1016/j.brainres.2009.03.057.

Leminen, A., & Clahsen, H. (2014). Brain potentials to inflected adjectives: Beyond storage and decomposition. *Brain Research, 1543*, 223–234. http://doi.org/10.1016/j.brainres.2013.10.038.

Liang, L., & Chen, B. (2014). Processing morphologically complex words in second-language learners: The effect of proficiency. *Acta Psychologica, 150*, 69–79. http://doi.org/10.1016/j.actpsy.2014.04.009.

Lück, M., Hahne, A., & Clahsen, H. (2006). Brain potentials to morphologically complex words during listening. *Brain Research, 1077*(1), 144–152. http://doi.org/10.1016/j.brainres.2006.01.030.

Marslen-Wilson, W. D. (2007). Morphological processes in language comprehension. In M. G. Gaskell (Ed.). *The oxford handbook of psycholinguistics* (pp. 175–193). Oxford University Press. http://doi.org/10.1093/oxfordhb/9780198568971.013.0011.

McKinnon, R., Allen, M., & Osterhout, L. (2003). Morphological decomposition involving non-productive morphemes: ERP evidence. *NeuroReport, 14*(6), 883–886. http://doi.org/10.1097/00001756-200305060-00022.

Morris, J., Frank, T., Grainger, J., & Holcomb, P. J. (2007). Semantic transparency and masked morphological priming: An ERP investigation. *Psychophysiology, 44*(4), 506–521. http://doi.org/10.1111/j.1469-8986.2007.00538.x.

Morris, J., Grainger, J., & Holcomb, P. J. (2008). An electrophysiological investigation of early effects of masked morphological priming. *Language & Cognitive Processes, 23*(7–8), 1021–1056. http://doi.org/10.1080/01690960802299386.

Morris, J., & Holcomb, P. J. (2005). Event-related potentials to violations of inflectional verb morphology in English. *Cognitive Brain Research, 25*(3), 963–981. http://doi.org/10.1016/j.cogbrainres.2005.09.021.

Morris, J., Porter, J. H., Grainger, J., & Holcomb, P. J. (2010). Effects of lexical status and morphological complexity in masked priming: An ERP study. *Language & Cognitive Processes, 26*, 558–599. http://doi.org/10.1080/01690965.2010.495482.

Morris, J., & Stockall, L. (2012). Early, equivalent ERP masked priming effects for regular and irregular morphology. *Brain and Language, 123*(2), 81–93. http://doi.org/10.1016/j.bandl.2012.07.001.

Münte, T., Matzke, M., & Johannes, S. (1997). Brain activity associated with syntactic incongruencies in words and pseudo-words. *Journal of Cognitive Neuroscience, 9*(3), 318–329. http://doi.org/10.1162/jocn.1997.9.3.318.

Münte, T. F., Say, T., Clahsen, H., Schiltz, K., & Kutas, M. (1999). Decomposition of morphologically complex words in English: Evidence from event-related brain potentials. *Cognitive Brain Research, 7*(3), 241–253. http://doi.org/10.1016/S0926-6410(98)00028-7.

Newman, A. J., Ullman, M. T., Pancheva, R., Waligura, D. L., & Neville, H. J. (2007). An ERP study of regular and irregular English past tense inflection. *NeuroImage, 34*(1), 435–445. http://doi.org/10.1016/j.neuroimage.2006.09.007.

Niemi, J., Laine, M., & Tuominen, J. (1994). Cognitive morphology in Finnish: Foundations of a new model. *Language & Cognitive Processes, 9*(3), 423–446. http://doi.org/10.1080/01690969408402126.

Palmović, M., & Maričić, A. (2008). Mental lexicon and derivational rules. *Collegium Antropologicum, 32*, 177–181. Retrieved from http://hrcak.srce.hr/file/38555.

Penke, M., Weyerts, H., Gross, M., Zander, E., Münte, T., & Clahsen, H. (1997). How the brain processes complex words: An event-related potential study of German verb inflection. *Cognitive Brain Research, 6*, 37–52.

Portin, M., & Laine, M. (2001). Processing cost associated with inflectional morphology in bilingual speakers. *Bilingualism: Language and Cognition, 4*(1), 55–62. http://doi.org/10.1017/S1366728901000128.

Portin, M., Lehtonen, M., & Laine, M. (2007). Processing of inflected nouns in late bilinguals. *Applied PsychoLinguistics, 28*(1), 135–156. http://doi.org/10.1017/S0142716407070075.

Rodriguez-Fornells, A., Clahsen, H., Lleó, C., Zaake, W., & Münte, T. F. (2001). Event-related brain responses to morphological violations in Catalan. *Cognitive Brain Research, 11*(1), 47–58. http://doi.org/10.1016/S0926-6410(00)00063-X.

Rodriguez-Fornells, A., Münte, T. F., & Clahsen, H. (2002). Morphological priming in Spanish verb forms: An ERP repetition priming study. *Journal of Cognitive Neuroscience, 14*(3), 443–454. http://doi.org/10.1162/089892902317361958.

Schreuder, R., & Baayen, R. H. (1995). Modeling morphological processing. In L. B. Feldman (Ed.). *Morphological aspects of language processing* (pp. 131–154). Hillsdale, New Jersey: Erlbaum.

Spencer, A. (1991). *Morphological Theory: An introduction to word structure in generative grammar.* Oxford: Blackwell.

Taft, M., & Ardasinski, S. (2006). Obligatory decomposition in reading prefixed words. *The Mental Lexicon, 1*(2), 183–199. http://doi.org/10.1075/ml.1.2.02taf.

Team, R. C. (2015). *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.r-project.org/.

Vannest, J., Bertram, R., Järvikivi, J., & Niemi, J. (2002). Counterintuitive cross-linguistic Differences: More morphological computation in english than in Finnish. *Journal of Psycholinguistic Research, 31*(2), 83–106. http://doi.org/10.1023/A:1014934915952.

Weyerts, H., Münte, T. F., Smid, H. G. O. M., & Heinze, H.-J. (1996). Mental representations of morphologically complex words: An event-related potential study with adult humans. *Neuroscience Letters, 206*, 125–128 Retrieved from internal-pdf://Weyerts_etal_1996.pdf.

Weyerts, H., Penke, M., Dohrn, U., Clahsen, H., & Münte, T. F. (1997). Brain potentials indicate differences between regular and irregular German plurals. *NeuroReport, 8*(4), 957–962. http://doi.org/10.1097/00001756-199703030-00028.