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Anomalous Transfer of Syntax between Languages

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Each human language possesses a set of distinctive syntactic rules. Here, we show that balanced Welsh-English bilinguals reading in English unconsciously apply a morphosyntactic rule that only exists in Welsh. The Welsh soft mutation rule determines whether the initial consonant of a noun changes based on the grammatical context (e.g., the feminine noun *cath*—"cat" mutates into *gath* in the phrase *y gath*—"the cat"). Using event-related brain potentials, we establish that English nouns artificially mutated according to the Welsh mutation rule (e.g., "goncert" instead of "concert") require significantly less processing effort than the same nouns implicitly violating Welsh syntax. Crucially, this effect is found whether or not the mutation affects the same initial consonant in English and Welsh, showing that Welsh syntax is applied to English regardless of phonological overlap between the two languages. Overall, these results demonstrate for the first time that abstract syntactic rules transfer anomalously from one language to the other, even when such rules exist only in one language.

Key words: **bilingualism; event-related brain potentials; grammar; language rules**

Introduction

Language syntax is an abstract, rule-based mechanism in which combinatorial operations govern the classification and use of words (Chomsky, 1995). It remains unknown, however, which mechanisms underlie the creation of such linguistic rules, and whether syntactic analysis is performed on the basis of lexical-phonological regularities or whether abstract rules are extracted that can be applied through generalization (Plunkett and Marchman, 1993; Elman, 1998). In the current study, we tested the possibility of implicit syntactic transfer between languages in early adult bilinguals to determine whether the implementation of abstract linguistic rules relies on lexical–phonological associations (Thierry and Wu, 2007; Wu and Thierry, 2010; Wu et al., 2013) or syntactic contingencies (Loebell and Bock, 2003; Hartsuiker et al., 2004; Scheutz and Eberhard, 2004; Thierry and Sanoudaki, 2012). This allowed us to characterize the mechanisms by which syntax can generalize across languages.

We recorded electrophysiological brain responses in Welsh-English bilinguals reading English sentences. All test sentences ended in nonwords created by substituting the initial consonant of the final word with a consonant that produced either a mutated or an aberrant form, according to the Welsh mutation rule (e.g., "p" substituted by "b"-mutated, or "g"-aberrant). Syntactic structure was manipulated such that the Welsh translation of the English sentences required a word-final mutation or not. For example, the soft mutation rule in Welsh imposes a change to the initial consonant of a noun following specific syntactic triggers (Ball and Müller, 1992), which can be nonadjacent to the mutated word, and is defined as a morphosyntactically driven process (Harlow, 1989). This allowed us to distinguish between brain processing of expected and unexpected initial consonants of the final noun, depending on the syntactic context. The phonological mismatch negativity (PMN) is an event-related potential (ERP) index that is sensitive to lexical processing modulated by phonological expectation formed on the basis of the initial letter of a word, and peaks between 250 and 300 ms poststimulus (Connolly and Phillips, 1994; Hagoort and Brown, 2000; Diaz and Swaab, 2007). Assuming that Welsh syntactic rules are active during reading in English, we hypothesized that PMN amplitude would be reduced for mutated word forms, but only in sentences that would elicit a soft mutation if they had been encountered in Welsh.

We also manipulated phonological overlap between English and Welsh, such that in half of the experimental trials, the final word and its mutated form shared their initial consonant with their Welsh translations (Table 1). If syntactic transfer between languages occurs as a result of cross-language lexical associations (Thierry and Wu, 2007; Wu and Thierry, 2010; Wu et al., 2013), we expected a PMN reduction only when the English word and its translation in Welsh shared their initial consonant. However, if syntactic transfer occurs as a result of implementing abstract morphosyntactic rules, the PMN reduction should also be observed when there is no overlap between Welsh and English.

Materials and Methods

Participants. Nineteen Welsh-English bilinguals (5 males, 14 females) were included in the analysis on the basis of good knowledge of the Welsh soft mutation rule, which was assessed via a written sentence completion test (cutoff score, >65%), and self-reported that they were native language Welsh speakers, having learned English from an early age (mean age, 4.9

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years; SD, 2.7 years). Five participants were excluded owing to poor mutation performance or self-report of stronger written and oral abilities in English than in Welsh. A further three participants obtained too few epochs per condition. All participants possessed normal or corrected-to-normal vision. Ethical approval was granted by the School of Psychology, Bangor University Research Ethics Committee, and participants gave written consent.

Stimuli and procedure. In 11% of the cases, the sentence ended in the correct, most expected word (fillers), with nonwords completing the remaining 89% of cases.

In a separate pretest, an additional 26 monolingual participants completed sentences with the first word that came to mind. If the completions matched our experimental sentences, they were given a score of 1, and all other answers were scored 0. Cloze probability was calculated by averaging scores across sentences. In the event that the experimental test word was not the most predictable completion, it was removed from the stimulus list. Thus, cloze probability was calculated for all 160 test sentences. The overall probability was 0.66, with no significant differences among any of the experimental conditions (no phoneme overlap/no mutation context, 0.69; no phoneme overlap/mutation context, 0.67; phoneme overlap/no mutation context, 0.63; phoneme overlap/mutation context, 0.64; $p = 0.816$). Target words were controlled for written frequency, word length, and number of syllables. Participants viewed all 360 sentences, resulting in 40 trials per condition and 40 filler trials in a single session. Sentences were presented in a white 18 point font on a black background. The first clause was presented as continuous text and self-paced, followed by individual word presentation (200 ms with a 500 ms interstimulus interval). Presentation order was pseudorandomized, such that two target words never appeared in immediate succession. A third of all sentences were followed by a comprehension question. Participants responded correctly to comprehension questions with an average accuracy of 94% (SD, 4%; range, 83–98%), and their reading time of the first half of each sentence (mean, 2639 ms; SD, 575 ms) did not differ significantly between conditions (mutation context/mutated word, 2676 ms; mutation context/aberrant word, 2635 ms; no mutation context/mutated word, 2617 ms; no mutation context/aberrant word, 2626 ms; $p = 0.374$).

ERP recording. Electrophysiological data were recorded from 64 Ag/AgCl electrodes according to the extended 10–20 convention and were referenced to the Cz site at a rate of 1 kHz. The electroencephalogram (EEG) activity was filtered on-line with a bandpass filter between 0.1 and 200 Hz, and off-line with a low-pass, zero phase-shift digital filter, which was set at 20 Hz. Observed eye blinks in the EEG were corrected mathematically, and remaining artifacts were removed by manually inspecting the data. Epochs ranging from −100 to 1000 ms after the onset of the target word were extracted from the EEG recordings. Epochs with activity exceeding ±75 μV at any electrode site were automatically discarded. There was a minimum of 30 epochs per condition for every participant. Baseline correction was performed in reference to prestimulus activity, and individual averages were digitally rereferenced to the global average reference.

Results

We analyzed ERP amplitudes over six electrodes where the PMN is known to be maximal (linear derivation of FCZ, FC2, FC4, CZ, C2, and C4; Connolly and Phillips, 1994; Fig. 1) by means of a repeated-measures ANOVA with mutation context (mutation vs no mutation), word form (mutated vs aberrant), and phoneme overlap between languages (overlap vs no overlap) as independent variables.

We found no main effect of mutation context, word form, or phoneme overlap. However, there was a significant mutation context × word form interaction ($F_{(1,18)} = 6.076$, $p = 0.024$). *Post hoc* paired-samples *t* tests revealed that correctly mutated words elicited less negative PMN amplitudes than aberrant words when presented in a mutation context ($t_{(18)} = 3.066$, $p = 0.007$, Bonferroni correction), and this was not the case in no mutation contexts ($t_{(18)} = -0.09$, $p = 0.926$). No other significant interactions were found. In particular, phoneme overlap between English and Welsh did not interact with the mutation context effect ($F_{(1,18)} = 0.349$, $p = 0.562$). Finally, analyses in earlier time windows (N1 and P2) did not show significant differences in amplitude between experimental conditions.

Table 1. Experimental design and stimulus examples

	Correct form	Mutated form	Aberrant form
Phoneme overlap			
Mutation context			
Each book starts with a page listing its	contents	gontents	dontents
"Dechreuir pob llyfr â thudalen yn rhestru ei	gynnwys"		
No mutation context			
The lid was lifted to examine the	contents	gontents	dontents
"Codwyd y caead er mwyn archwilio'r	cynnwys"		
No phoneme overlap			
Mutation context			
As a doctor she saw a lot of	patients	batients	datients
"Fel meddyg, roedd hi'n gweld nifer o	gleifion"		
No mutation context			
At the hospital he would read to the	patients	batients	datients
"Yn yr ysbyty, byddai'n darllen i'r	cleifion"		

The Welsh translation is shown here for information only. Translation accuracy was independently assessed in a group of 15 balanced Welsh-English bilinguals who did not take part in the study. Participants were presented with whole sentences and were asked to translate the second clause of each sentence (including the mutation trigger). Translations were deemed accurate (score, 1) if they satisfied the following two conditions: (1) that the sentence context appropriately elicited a mutation or not; and (2) that the target word was the same as the item included in the experimental items. Translation agreement was very high (average, 89%) and, critically, did not differ significantly between mutation and nonmutation contexts ($p = 0.131$).

Discussion

Here, we questioned whether syntactic rules of one language may transfer to the other language of bilinguals by testing for a covert influence of Welsh mutations applied to English material. We found that English words mutated into nonwords according to Welsh mutation rules are more easily integrated within a sentence context that requires a mutation in Welsh compared with these same nonwords presented in a nonmutation context.

Implicit transfer of Welsh syntactic mutation rules was indexed by a reduction of mean amplitude in the range of the PMN, an ERP modulation known to be sensitive to phonological expectation and phonetic stimulus properties (Connolly and Phillips, 1994; Hagoort and Brown, 2000; Diaz and Swaab, 2007). It is noteworthy that such phonological expectancy effects are also found in reading tasks (Savill and Thierry, 2011; Savill et al., 2011). If predictions normally applying to the Welsh language were also made in relation to English words, we expected reduced PMN amplitude for mutated relative to aberrant word forms, according to the grammatical context.

Importantly, the effect reported here is not merely an artificial process triggered by the use of nonwords in the experiment, because a PMN modulation can only be elicited when participants make predictions regarding the upcoming final word and, in particular, its first phoneme. If the effect was merely triggered by the encounter of a nonword, there is no reason why participants should expect a particular phoneme rather than another, unless they engaged in syntactic processing governed by the rules of the Welsh language. Also we note that filler sentences ended in a correct English completion word, and therefore that participants did not systemically approach the final word as a nonword.

Crucially, this effect was found regardless of phonological overlap between English words and their Welsh translation equivalents. Indeed, language-nonspecific lexical access (Thierry and Wu, 2007, Wu and Thierry, 2010, Wu et al., 2013) fails to account for the results obtained here. If the effect reported here could be accounted for by nonselective lexical access alone, we would expect it to occur only when the initial phonemes of the

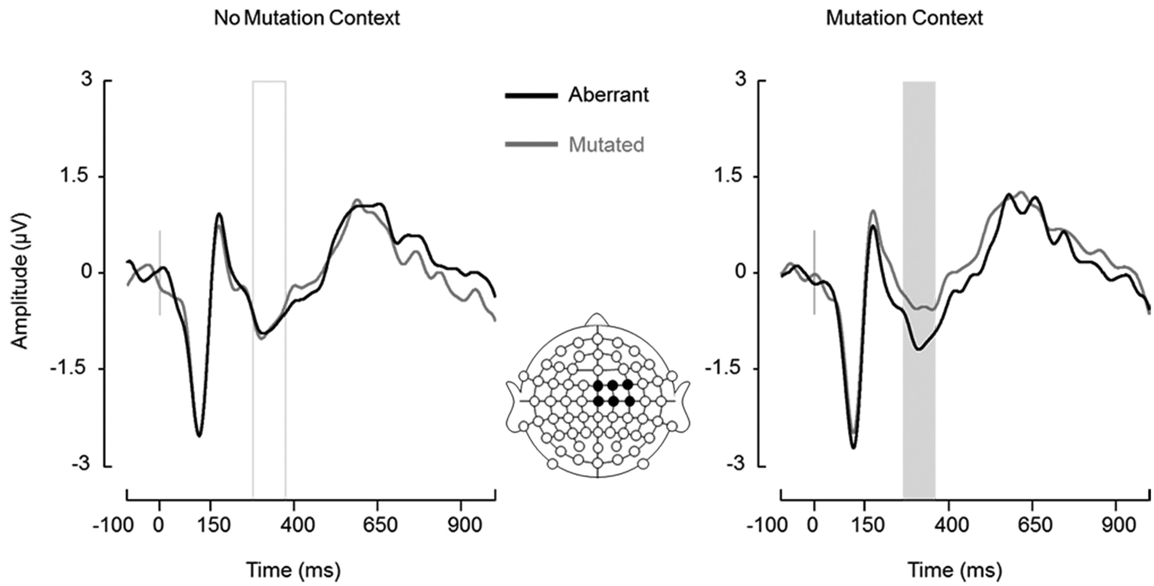

Figure 1. ERPs elicited by mutated and aberrant nonwords collapsed across conditions of phoneme overlap and no phoneme overlap. The plain gray box indicates the window of analysis in which mean ERP amplitude significantly differed between conditions (260–360 ms poststimulus).

word were identical in English and Welsh. The finding that participants appeared to apply the Welsh mutation rule even in the absence of phonological overlap between languages demonstrates that it is based on the implementation of a morphosyntactic rule. Beyond the issue of phonological overlap, the timing of the effect is also incompatible with a lexical mediation account since priming was observed here between 260 and 360 ms, which is considerably earlier than the time period in previous studies of spontaneous access to translation equivalents (Thierry and Wu, 2007). Furthermore, this finding is compatible with results from an electrophysiological study demonstrating word-order transfer in bilinguals (Thierry and Sanoudaki, 2012) and with results from behavioral studies demonstrating cross-linguistic syntactic priming (Hartsuiker et al., 2004).

The use of ERPs in the current study presents an important methodological breakthrough in the investigation of syntactic processing in adult bilinguals, providing unique insights into covert transfer of syntactic rules from one language to another within the same individual (Wu and Thierry, 2013). Our findings therefore provide strong support for theories positing rule-based representation of syntax in proficient adult readers (Opitz and Friederici, 2004; Doeller et al., 2006).

The current study provides the first tangible evidence for spontaneous and anomalous transfer of syntax between languages, even at the level of subtle morphosyntactic changes elicited by a rule alien to English. These data suggest that transfer relies on abstract syntactic representations rather than lexical–phonological associations and lend strong support to theories positing rule-based representation of syntax. Future studies will shed more light on the developmental dynamics of syntactic transfer.

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