ERP evidence for implicit L2 word stress knowledge in listeners of a fixed-stress language

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Abstract

Languages with contrastive stress, such as English or German, distinguish some words only via the stress status of their syllables, such as “CONtent” and “conTENT” (capitals indicate a stressed syllable). Listeners with a fixed-stress native language, such as Hungarian, have difficulties in explicitly discriminating variation of the stress position in a second language (L2). However, Event-Related Potentials (ERPs) indicate that Hungarian listeners implicitly notice variation from their native fixed-stress pattern. Here we used ERPs to investigate Hungarian listeners’ implicit L2 processing. In a cross-modal word fragment priming experiment, we presented spoken stressed and unstressed German word onsets (primes) followed by printed versions of initially stressed and initially unstressed German words (targets). ERPs reflected stress priming exerted by both prime types. This indicates that Hungarian listeners implicitly linked German words with the stress status of the primes. Thus, the formerly described explicit stress discrimination difficulty associated with a fixed-stress native language does not generalize to implicit aspects of L2 word stress processing.

Keywords: ERPs; L2 learning; lexical stress; stress “deafness”; word onset priming

1. Introduction

In many languages, a single syllable of a multisyllabic word or phrase is acoustically more salient (i.e., stressed) compared to the other syllable (or the other syllables) of that word or phrase. The stressed syllable typically is longer and louder and shows characteristic pitch and formant frequencies (Sluijter & van Heuven, 1996; Sluijter, van Heuven, & Pacilly, 1997). However, languages differ in the actual phonetic realization of stress: For example, in Hungarian, stress is realized mainly by changes of f0 (pitch) and intensity (Fónagy, 1958) with syllable duration playing a minor role (White & Mády, 2008), while in German, all three acoustic cues are crucially involved (Jessen, Marasek, Schneider, & Classen, 1995). Across languages that use stressed syllables, more or less restrictive rules govern their position within words or phrases. In fixed-stress languages, a single restrictive rule determines stress assignment. Hungarian and Finish, for example, mandatorily assign stress to the initial syllable of a word, while French assigns stress to the final syllable of a phrase. In other languages, such as English and German, rules govern stress assignment for many but not for all words. Stress can even become contrastive in those languages, differentiating, for example, the English words “CONtent” vs. “conTENT" or the German words “AUGust” (male name) vs. “auGUST” (name of the month August; here and in the following examples capital letters indicate a stressed syllable). In the present study, we investigate listeners with a fixed-stress native language (L1, Hungarian) processing a second language with more variable stress (L2, German).

Listeners with a fixed-stress L1 implicitly detect deviation from the mandatory stress pattern of their native language. This was attested by Event-Related Potentials (ERPs) recorded for correctly and incorrectly stressed words: Across several studies, spoken strings deviating from the mandatory stress position elicited different ERPs than strings following the mandatory stress position in Hungarian listeners (Honbolygó & Csépe, 2013; Honbolygó, Csépe, & Ragó, 2004), in Polish listeners (Domahs, Genc, Knaus, Wiese, & Kabak, 2013; Domahs, Knaus, Orzechowska, & Wiese, 2012), and in French listeners (Astésano, Besson, & Alter, 2004; Magne et al., 2007; Schön, Magne, & Besson, 2004). Furthermore, incorrect stress hampered word recognition in listeners with a fixed-stress L1. Finish listeners detected the word “HYmy” [smile] faster in “pyHYmy” than in “PYhymy (Vroomen, Tuomainen, & de Gelder, 1998). The latter finding might imply that Finish listeners store the mandatory word-initial stress position together with each word and have difficulties in accessing a word with incorrect stress. This would be in accordance with the characteristic ERP responses for stress deviation obtained for native listeners from other fixed-stress languages (see above). In addition, or alternatively, as Vroomen et al. (1998) argue, Finish listeners might selectively exploit stressed syllables (which obligatorily are word onsets in their L1) for lexical search. According to this interpretation, Finish listeners would take every stressed syllable to access a new word.

Across two studies, listeners with a fixed-stress L1 (French) were restricted in their ability to use syllable stress for explicit word identification in an L2 with variable word stress: In a study by Tremblay (2008), French learners of English heard either a stressed English word onset, such as “MYS-“, or an unstressed English word onset, such as “mis-“. Their ability to complete those word onsets correctly (“MYStery” and “misTAKE”, respectively), was only slightly above chance level. In a study by Dupoux, Sebastian-Galles, Navarrete, and Peperkamp (2008), French leaners of Spanish had difficulties in distinguishing correctly stressed Spanish words, such as “ROpa” [clothing], from incorrectly stressed versions, such as “roPA”. Also in that study, accuracy rates were only slightly above chance level. Together, both studies suggested that listeners with fixed-stressed L1 do not store different stress patterns of L2 words or that they cannot exploit their implicit knowledge about syllable stress for explicit judgements on the stress pattern of L2 words.

Stress discrimination difficulties that listeners with a fixed-stress L1 showed for L2 words found a parallel in stress discrimination difficulties for meaningless strings. In one type of respective tasks, participants listened to sequences of nonsense words differing only in the position of the stressed syllable, such as “BOpelo – boPElo – BOpelo”. Participants judged which strings had the same stress pattern, for example by determining whether the third nonsense word was equal to the first nonsense word or to the second nonsense word. Listeners with an L1 that allows stress variation (Dutch, German, Japanese, and Spanish), performed better in those explicit stress discrimination tasks than listeners with a fixed-stress L1 (Finish, French, Hungarian, and Polish, see Dupoux, Pallier, Sebastian, & Mehler, 1997; Dupoux et al., 2008; Honbolygó, Kóbor, & Csépe, in press; Rahmani, Rietveld, & Gussenhoven, 2015). Superior performance of listeners with an L1 that allows the stress position to vary (compared to listeners with a fixed-stress L1) were also obtained for sequence recall tasks, in which nonsense words varying only in stress had to be recalled (Dupoux, Peperkamp, & Sebastian-Galles, 2001; Peperkamp, Vendelin, & Dupoux, 2010). Together, these findings are captured by the stress “deafness” hypothesis, which holds that the processing of varying stress positions poses a problem for listeners with a fixed-stress L1 (Dupoux et al., 2001).

In contrast to previous work investigating explicit L2 word identification and stress discrimination, the present study focuses on the implicit aspects of L2 word recognition, namely, on phonologically mediated mechanisms of lexical access. Since the first conceptualization of parallel processing in the Cohort model of spoken word recognition (Marslen-Wilson & Welsh, 1978), empirical findings indicated that listeners implicitly handle multiple lexical hypotheses simultaneously. As soon as the unfolding speech stream provides some information about word identity, listeners not only consider all word completions that are fully overlapping with the temporary input but also canditates that are only partially overlapping (for a review, see Weber & Scharenborg, 2012). The first connectionist model of speech recognition (TRACE, see McClelland & Elman, 1986) added the assumption that simulteanously considered candidates compete for recognition. Models of spoken word recognition resolve this competition either via lateral inhibition (as in TRACE), via mechanisms that select the candidate that fits the input best (as in revised versions of the Cohort model: Marslen-Wilson, 1990; Marslen-Wilson & Warren, 1994), or via selection mechanisms that consider the evidence from the signal and the probability of a given word (as in instances of the neighboorhood acitvation model [NAM]: Luce, 1986; Luce & Pisoni, 1998). Together, parallel consideration of lexical hypotheses and competition processes are considered to be universal, i.e., those implict ascpects of processing are also involved when L2 words are recognized (for review, see Weber & Broersma, 2012).

Word onset priming allows identifying neurocognitive correlates of phonologically mediated mechanims of lexical access. In cross-modal versions of this paradigm, participants listen to spoken word onsets and make lexical decisions to immediately following printed words (or pseudowords). ERPs for phonologically overlapping target words (e.g., “Ano - Anorak” [anorak]), start to differ from ERPs for unrelated targets (e.g., “Idi – Anorak”), around 300 ms after target word onset (Friedrich, 2005; Friedrich, Felder, Lahiri, & Eulitz, 2013; Friedrich, Kotz, Friederici, & Alter, 2004; Friedrich, Lahiri, & Eulitz, 2008). ERP difference waves (related-unrelated) substantiated left-anterior positive amplitudes that led to the label “P350” effect. In addition, enhanced posterior central negativity for phonologically unrelated targets (between 400 and 600 ms) shows parallels with the phonological N400 effect (Praamstra, Meyer, & Levelt, 1994) and with the phonological mapping negativity (Connolly & Phillips, 1994; Steinhauer & Connolly, 2009). We related the P350 and the N400-like negativity to the systems’ consideration of lexical hypotheses and respective predictions about upcoming words (e.g., Friedrich et al., 2013).

ERPs reflect slightly different aspects of word onset priming than lexical decision latencies recorded in word onset priming. P350 and central negativity effects consistently reflected that candidate words with some overlap with the input (e.g., “Ana - Anorak”) modulate target word processing ((Friedrich, 2005; Friedrich et al., 2013; Friedrich et al., 2008). Following a gradual pattern, ERP amplitudes elicited by partially overlapping target words were in-between ERP amplitudes for completely overlapping target words and unrelated target words. This gradual pattern was even found when lexical decision latencies for partially overlapping target words did not differ from those for unrelated words (Friedrich et al., 2008) or when lexical decision latencies for partially overlapping words were slower than those for unrelated words (Friedrich et al., 2013). We concluded that lexical decision latencies are more prone to competition effects or selection strategies than ERP effects are (for further discussion, see Friedrich et al., 2013). Together our results substantiate models assuming several mechanisms considering different aspects during lexical access (e.g., revised version of the Cohort model or NAM, Luce, 1986; Luce & Pisoni, 1998; Marslen-Wilson, 1990; Marslen-Wilson & Warren, 1994). Mechanisms that focus on bottom-up evidence in favor of a lexical hypothesis (as reflected in the ERPs) are separable from mechanisms that, in addition, consider evidence against a given hypothesis (as reflected in lexical decision latencies).

Although not considered in classical models of speech recognition, syllable stress appears to constrain the evidence in favor of or against a given candidate word. This was attested, for example, by eye-tracking data obtained from Dutch, English, and Italian listeners (Jesse, Poellmann, & Kong, 2015; Reinisch, Jesse, & McQueen, 2010; Sulpizio & McQueen, 2012). Participants listened to words with similar phonemic but different stress onset (e.g., “MUsic” and “muSEum”) in their respective L1. Across these three studies, listeners directed their eye gazes more frequently to printed versions of the stress-matching candidate than to the stress-mismatching candidate well before the offset of the spoken target word. Syllable stress also modulated behavioral responses in word onset priming. Dutch, English, German, Italian, and Spanish listeners responded faster to targets in prime-target pairs with stress overlap, such as “MUs - MUsic”, than to targets that differed in their onsets from the stress status of their preceding primes, such as “MUs - muSEUM” (e.g., Cooper, Cutler, & Wales, 2002; Soto-Faraco, Sebastián-Gallés, & Cutler, 2001; Spinelli, Segui, & Radeau, 2001; Tagliapietra & Tabossi, 2005; van Donselaar, Koster, & Cutler, 2005).

ERPs recorded in word onset priming revealed independent processing of phoneme-relevant information and syllable stress in native listeners (Friedrich, Kotz, Friederici, & Alter, 2004). In the design of that study, phoneme overlap and stress overlap within prime-target-pairs varied independently (for illustration, see Table 1). Phoneme overlap elicited left-anterior ERP positivity (compared to phoneme mismatch), while stress overlap elicited enhanced bilateral-posterior ERP positivity (compared to stress mismatch) in the time window of the P350 effect, respectively. ERP phoneme priming and ERP stress priming did not interact (for separate stress and phoneme priming in a unimodal auditory paradigm, see Schild, Becker, & Friedrich, 2014a; Schild & Friedrich, 2018). These previous findings imply that native listeners of German, a language that allows some variation of the stress position, process phonemes and stress at separate paths of recognition. Furthermore, they consider stress already at very early phases of phonologically mediated lexical access, which are reflected in the ERPs in particular in the time window of the P350.

In the present study, we used auditory-visual word onset priming to investigate the implicit use of syllable stress in L2 learners with a fixed-stress L1 (Hungarian learners of German). As in our previous work, we fully crossed phoneme overlap/mismatch and stress overlap/mismatch in our design. Prime-target pairs varied across four conditions: (i) overlap in stress and in phonemes (“MAN-MANdel” [almond]); (ii) overlap in stress, but not in phonemes (“DOK-MANdel”); (iii) overlap in phonemes but not in stress (“man-MANdel”); or (iv) overlap neither in phonemes nor in stress (“dok-MANdel”, see also Table 1). We focus on the gap between Hungarian listeners’ implicit sensitivity to their native stress pattern, which implies that they are able to extract and use stress when processing their L1 (Honbolygó & Csépe, 2013; Honbolygó, Csépe, & Ragó, 2004); and their diminished explicit stress processing ability (stress “deafness”) in an L2 (Honbolygó et al., in press; Peperkamp et al., 2010). That is, we followed the question whether a processing deficit that native listeners with fixed-stress L1 show for varying stress patterns in explicit tasks generalizes to the implicit phonologically mediated lexical access mechanisms for an L2 with stress variation.

Table 1. The experimental design with examples of prime-target pairs in the different conditions for both types of primes, respectively.

		Phoneme Priming	
		Phoneme Overlap	*Phoneme Mismatch*
Stress Priming	**Stressed Primes**		
	Stress Overlap	MAN – MANdel	DOK – MANdel
		DOK – DOKtor	MAN – DOKtor
	Stress Mismatch	MAN – manDAT	DOK – manDAT
		DOK – dokTRIN	MAN – dokTRIN
	Unstressed Primes		
	Stress Overlap	man – manDAT	dok – manDAT
		dok – dokTRIN	man – dokTRIN
	Stress Mismatch	man – MANdel	dok – MANdel
		dok – DOKtor	man – DOKtor

Note. For illustration purpose only, capital letters indicate stressed primes and stressed syllables in the spoken words that the written targets are representing, whereas lower case letters indicate unstressed primes and unstressed syllables in the spoken words that the written targets are representing. In the experiment, targets were presented in capital letters (MANDEL [almond], DOKTOR [doctor], MANDAT [mandate] or DOKTRIN [doctrine]) in four different conditions (marked in *italics*).

As Hungarian words mandatorily start with a stressed syllable, native listeners might handle stressed syllables as word onsets (Vroomen et al., 1998). This processing bias might also guide them in processing an L2. That is, Hungarian listeners might exploit stressed syllables to initiate lexical access mechanisms even in an L2 with variable stress. We follow this possibility by separately testing priming effects exerted by stressed and unstressed prime syllables (see Table 1). If stressed primes (e.g., “MAN”) facilitate lexical access, they might either facilitate the processing of all target words, or they might selectively facilitate processing of target words that overlap in their speech sounds with the primes (“MANDEL” or “MANDAT”). That is, responses might be generally faster and ERP amplitudes reduced for targets following stressed primes (compared to targets followings unstressed primes), or phoneme priming might be selectively enhanced for target words following stressed primes.

Above signaling word onsets, stress does not provide valuable information for word identification in Hungarian. Nevertheless, recent ERP findings show that native listeners of fixed-stress languages (including Hungarian listeners) are able to extract stress information from speech and to match this information with a representation of the native mandatory stress pattern (Astésano et al., 2004; Domahs et al., 2013; Domahs et al., 2012; Honbolygó & Csépe, 2013; Honbolygó et al., 2004; Magne et al., 2007; Schön et al., 2004). From that perspective, difficulties in processing stress patterns other than the native one might emerge. With the present design, we could test whether native Hungarian listeners store different stress patterns together with individual German words. If so, we should find stress priming effects for both types of primes: Stressed primes should facilitate the processing of initially stressed words and, vice versa, unstressed syllables should facilitate the processing of initially unstressed words.

2. Material and methods

2.1 Participants

Thirty-six adult volunteers took part in the experiment. Altogether four of them were excluded: One participant because of excessive artifacts (see section EEG recording and analysis), another one because of technical problems, and two participants due to biased responding to pseudoword targets (they systematically categorized pseudowords as words yielding an error ratio higher than 50% in average). Therefore, thirty-two participants remained in the final sample. Table 2 summarizes the descriptive characteristics of these individuals. All participants were native speakers of Hungarian speaking German as L2. All had normal or corrected-to-normal vision and normal hearing level according to audiometry measurement. Most of the participants were undergraduate students from different universities and language schools in Budapest. All participants lived and were tested in Hungary at the time of their participation in the study, and none of them were enrolled in German language courses. During recruitment, all applicants describing their German language proficiency as intermediate or advanced – based on official language exams – were invited to take part in the experiment. By restricting the sample to those participants who had German language proficiency of at least an intermediate level, we assured that participants could show reasonable performance on the applied lexical decision paradigm (see below). All participants provided written informed consent before enrollment and received payment (3000 HUF, ca.10 Euros) for taking part in the experiment. The study received approval by the Ethical Review Committee for Research in Psychology (EPKEB), Budapest, Hungary. Methods and procedures were in accordance with the Declaration of Helsinki.

Table 2. Descriptive characteristics, language proficiency, and language background of participants (*N* = 32).

Age [years]	
Mean	23.9 (4.1)
Age range	18 – 39
Gender (Male/Female)	13/19
Laterality Quotient [-100 – 100]	79.1 (31.3)
Total score of linguistic test [correct answers; 0 – 100]	71.5 (15.8)
Read aloud task [average rating; 1 – 6]	3.4 (1.0)
Foreign languages spoken	2.6 (0.9)
Started to learn (age) German regularly [years]	10.8 (3.9)
Length of learning German [years]	8.6 (3.6)
Having a native German teacher [yes]	56.3%
Length of residence in a German-speaking country [months]	2.7 (3.7)
Regular usage of German: private life [yes]	31.3%
Regular usage of German: professional / student life [yes]	37.5%
Pronunciation [subjective rating; 1 – 10]	6.4 (1.6)
Vocabulary [subjective rating; 1 – 10]	5.9 (1.7)
Grammar [subjective rating; 1 – 10]	6.8 (1.6)
Importance [subjective rating; 1 – 10]	6.4 (2.7)

Note. Means are provided in the right column, except for Age range, Gender, and variables with frequencies. Values in parentheses denote standard deviation. Laterality Quotient (LQ) was derived from the Edinburgh Handedness Inventory revised version; LQ = -100 means complete left-handedness, LQ = 100 means complete right-handedness. None of the participants was left-handed.

2.2 Materials

We used the same set of stimuli as in a previous unimodal auditory word onset priming study of Schild et al. (2014a). Forty-eight initially stressed and 48 initially unstressed monomorphemic disyllabic German pairs of nouns were selected and *visually* presented as target words (see Appendix). Phonemes of the first syllable and the onset of the second syllable were the same in both words within each pair. For each word, a pseudoword was created following the phonotactic rules of German by changing the last one or two phonemes of the word. Auditory primes were created from spoken words produced by a female native speaker of German by keeping only the first syllable of initially stressed and unstressed words. According to the acoustical measurement, stressed and unstressed prime syllable differed in their intensity, pitch, and duration. Details of the prime stimuli can be found in the study of Schild et al. (2014a).

2.3 Design and procedure

We orthogonally varied phoneme and syllable stress overlap between spoken primes and visual targets. This yielded four different conditions (see Table 1): stress overlap and phoneme overlap between primes and target onsets ("Stress Overlap, Phoneme Overlap" condition), stress overlap without phoneme overlap ("Stress Overlap, Phoneme Mismatch" condition), phoneme overlap without stress overlap ("Stress Mismatch, Phoneme Overlap" condition), neither phoneme nor stress overlap ("Stress Mismatch, Phoneme Mismatch" condition). We presented stressed and unstressed primes. Altogether, eight different conditions resulted.

Participants saw 384 target words and 384 target pseudowords (preceded by a prime syllable respectively) in 4 experimental blocks (altogether 768 trials). Each block consisted of 192 trials comprising all the 48 initially stressed and 48 initially unstressed target words as well as all the 48 initially stressed and 48 initially unstressed target pseudowords in one of the eight conditions. The same target word appeared four times with four different pairings of primes to ensure that the procedure was appropriate for calculating ERPs (i.e., sufficient number of clear EEG epochs could be analyzed). Within each block, the order of trials was randomized. In order to counterbalance the order of blocks, we created 4 different experimental scenarios. We followed a Latin square design in specifying the order of blocks, and these experimental scenarios were counterbalanced across participants.

Each trial consisted of four events. First, a central fixation cross was presented for 500 ms. Then, a syllable prime was delivered via headphones (at approx. 70 dB SPL) for the duration of the given syllable (approx. 220 ms in average, *SD* = 61.3 ms), while the fixation cross remained on the screen to prevent horizontal eye-movement artifacts. Immediately after the offset of the auditory syllable prime, the word or pseudoword target was presented visually in uppercase letters at the center of the screen for 513 ms. Participants were instructed to decide as quickly and accurately as possible whether the visually presented target was an existing word or a pseudoword in German. Half of the participants pressed the right response key with the right index finger to words and the left response key with the left index finger to pseudowords of a Cedrus RB-530 response pad (Cedrus Corporation, San Pedro, CA), while the other half of participants made a reversed response mapping. After target presentation, a blank screen was displayed until the participant gave a behavioral response. The key-press was followed by a 1500 ms delay (the blank screen remained) until the beginning of the next trial. In case of no response occurring, the next trial started after a 3500 ms delay. Instructions were presented orally and visually in Hungarian.

During EEG acquisition, participants were seated in a comfortable chair in an acoustically and electrically shielded, dimly lit room. Before starting the EEG acquisition, handedness was assessed with the Edinburgh Handedness Inventory revised version (Dragovic, 2004a, 2004b; Oldfield, 1971) and participants filled out a screening questionnaire on German language background (see section Other measures). Then, the experimenter conducted an audiometry measurement, which was followed by the EEG data acquisition. After removing the electrode net, the read aloud task was administered; and finally, a linguistic test was filled out (see section Other measures). The entire procedure lasted about 3 hours. The experimental paradigm was written in Presentation software (v. 16.3, Neurobehavioral Systems).

2.4 Other measures

Other measurements were administered to provide a description on individual differences in language proficiency and L2 experience in this sample of L2 learners and to double check our recruitment process (i.e., we invited participants with intermediate or advanced levels of German language proficiency).

2.4.1 Screening questionnaire: The background of second language acquisition

All participants filled out a screening questionnaire, which intended to explore the background and details of their German language knowledge and their knowledge of other foreign languages. We adopted the items used for the same purpose by Dupoux et al. (2008) and Tremblay (2009). Participants specified when they started to learn German; the place, circumstances, and length of German language acquisition; whether they had a native German teacher; whether they had resided in a German-speaking country for longer than 1 month; whether they regularly used German in their professional (student) and / or private life. They evaluated their German competence and assessed the importance of German language in their life. Namely, goodness of Pronunciation, Grammar, Vocabulary, and Importance were rated on ten-point response scales based on the study of Dupoux et al. (2008, pp. 688-689; 1: “Extremely poor” – 10: “Perfect”; 1: “No importance” – 10: “Extremely important”). Moreover, all participants were asked which foreign languages and at which level they spoke. (for details, see Table 2).

2.4.2 Read aloud task

We examined the native-like accent of participants in a read aloud task to evaluate their German pronunciation competence (see Table 2). First, participants were instructed to silently read a short text entitled “Nordwind und Sonne” (The Northwind and the Sun), which is among the standard International Phonetic Alphabet texts (see also Hu et al., 2013). Then, they were asked to read the same text aloud with their best German pronunciation they could. These reading productions were recorded. Following the method proposed by Dupoux et al. (2008), two native German speakers from the University of Hamburg, who were not phoneticians, rated the native-like accent of each recording on a Likert-scale (1 = extremely poor; 6 = perfect). Intra-class correlation (ICC) between the judgments of different raters was calculated to check the inter-rater reliability (consistency) of the method (McGraw & Wong, 1996; Shrout & Fleiss, 1979). The ICC was .77 indicating a good agreement between the raters; therefore, the mean of the two ratings is presented in Table 2.

2.4.3 Linguistic test

Participants filled out a progressive linguistic test consisting of 100 multiple-choice items (Koukidis, 2003). The test, based on the sum of correct answers, determined language proficiency according to the levels of the CEFR (Common European Framework of Reference for Languages: Learning, Teaching, Assessment). Table 2 presents the language proficiency of L2 learners.

2.5 EEG recording and analysis

The continuous EEG activity was recorded using the Electrical Geodesics system (GES 400; Electrical Geodesics, Inc., Eugene, OR) with a 128-channel HydroCel Geodesic Sensor Net. Electrode Cz was used as a reference and a sampling rate of 500 Hz was applied.

EEG data were analyzed using BrainVision Analyzer software (Brain Products GmbH, Munich, Germany). Bad channels were replaced by spline interpolation: 0 – 2 electrodes (mean 0.22) per participant were interpolated. Then, as the first step of pre-processing, EEG data was band-pass filtered offline between 0.3 – 30 Hz (48 dB/oct) and notch filtered at 50

Hz to remove additional electrical noise. Second, we corrected horizontal and vertical eye-movement artifacts and heartbeats with independent component analysis (ICA, Delorme, Sejnowski, & Makeig). Third, EEG data was re-referenced to the average activity of all electrodes. ERPs were computed for *correctly* responded target words in each condition. Epochs extended from -200 to 1000 ms relative to the onset of the written target words, and the mean activity from -200 to 0 ms was used as a prestimulus baseline. To remove artifacts still present in the data after ICA corrections, we used an automatic artifact rejection algorithm implemented in BrainVision Analyzer software. This was based on 4 criteria: The maximum voltage step allowed for an epoch was 50 µV/ms, we rejected those segments where the activity exceeded +/- 100 µV, the lowest activity allowed was 0.5 µV, and the maximum absolute difference allowed between the minimum and maximum voltages in an epoch was 200 µV. A minimum of 15 artifact-free epochs were required in each condition in order for a participant’s data to be included in further analysis. Note that the number of epochs also varied as a function of response accuracy such that only epochs related to correctly responded targets were included in the analysis. The mean number of retained epochs collapsed across all the eight conditions was 30.7 (*SD* = 6.6; range: 15 – 44) for the final sample. Conditions did not differ significantly from one another in the mean number of retained epochs ($F(7, 217) = 0.84$, $p = .503$). The mean percentage of removed epochs was 8.4% (*SD* = 8.6%; range: 0 – 48.3%).

2.6 Data analysis

Mean RTs were calculated from the onset of the visual target words to participants’ responses. Only *correctly* responded target words were included in RT and ERP analysis. Fast responses with RTs lower than 200 ms were eliminated from behavioral and ERP analysis. We did not analyze misses or responses longer than 3500 ms.

RT and error ratio (ratio of incorrect responses) were entered into three-way repeated measures ANOVAs with Stress Priming (Stress Mismatch vs. Stress Overlap), Phoneme Priming (Phoneme Mismatch vs. Phoneme Overlap), and Prime Type (Stressed vs. Unstressed) as within-subjects factors. In all ANOVAs performed on behavioral and physiological measures (see section EEG recording and analysis) partial eta squared (η_p^2) is reported as the measure of effect size. To control for Type I error, we used Tukey HSD tests for pair-wise comparisons in case of significant interactions.

In accordance with previous work (Friedrich, 2005; Friedrich et al., 2013; Friedrich, Kotz, Friederici, & Alter, 2004; Friedrich et al., 2008), we analyzed ERP effects for four regions of interests (ROIs), including anterior left, anterior right, posterior left and posterior right position (see Figure 1). To this end, we applied two additional within-subjects factors encompassing electrode effects: Hemisphere (Left vs. Right electrode sites) and Region (Anterior vs. Posterior electrode sites). Therefore, the full ANOVA design for ERP analysis was Region * Hemisphere * Stress Priming * Phoneme Priming * Prime Type. In the results section, we report significant main effects and interactions only when they include at least one of the factors that were experimentally manipulated, namely Stress Priming, Phoneme Priming, and Prime Type, and when they led to significant pair-wise post-hoc comparisons.

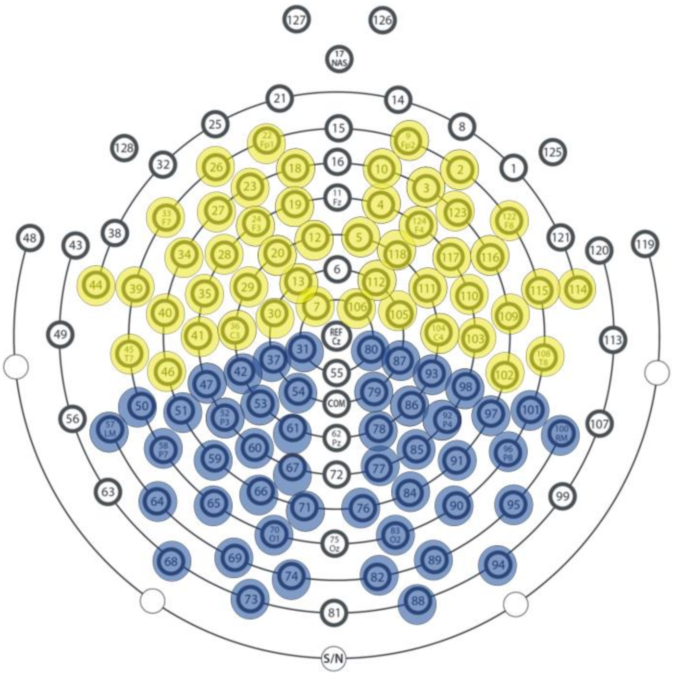

Figure 1. The 128 electrode positions of the HydroCel Geodesic Sensor Net. Yellow shading indicates left and right anterior ROIs, blue shading indicates left and right posterior ROIs used for the statistical analyses of ERP effects.

3. Results

3.1 Behavioral data

Table 3 shows mean RT and error ratio for all conditions. The Stress Priming * Phoneme Priming * Prime Type ANOVA performed on correct mean RT data yielded a main effect of Stress Priming, $F(1, 31) = 5.50$, $p < .05$, $\eta_p^2 = .15$, a main effect of Phoneme Priming, $F(1, 31) = 13.85$, $p < .001$, $\eta_p^2 = .31$, and a main effect of Prime Type, $F(1, 31) = 6.38$, $p < .05$, $\eta_p^2 = .17$. The interaction effect between Stress Priming and Prime Type was also significant, $F(1, 31) = 12.12$, $p < .01$, $\eta_p^2 = .28$ (see Figure 2). RTs for Phoneme Overlap were faster than for Phoneme Mismatch (777 ms vs. 793 ms), indicating a clear phoneme facilitation effect. Pair-wise tests showed that RTs were faster for Stress Overlap than for Stress Mismatch only after stressed primes (759 ms vs. 797 ms, $p < .01$). This Stress Priming effect did not appear after unstressed primes (799 ms vs. 785 ms, $p = .574$). RTs for targets following stressed primes were faster than for targets following unstressed primes only in the Stress Overlap condition (759 ms vs. 799 ms, $p < .01$).

Overall, error percentage for words was 30.3%. The same ANOVA as on RTs conducted on error ratio data revealed a single significant effect. The main effect of Phoneme Priming, $F(1, 31) = 8.49$, $p < .01$, $\eta_p^2 = .22$, showed that participants made less errors in the Phoneme Overlap than in the Phoneme Mismatch condition (29.5% vs. 31.1%). Crucially, there was no significant interaction between the factors Stress Priming and Phoneme Priming either for RT or error ratio (all Fs ≤ 2.22).

Table 3. Mean RT and mean error percentage in the four experimental conditions for both types of primes, respectively. Standard errors of the means are given in parenthesis. Examples of spoken primes and written targets are given in squared brackets.

	Stress Overlap, Phoneme Overlap	Stress Overlap, Phoneme Mismatch	Stress Mismatch, Phoneme Overlap	Stress Mismatch, Phoneme Mismatch
Stressed Primes				
[“MAN”-]	[MANDEL]	[DOKTOR]	[MANDAT]	[DOKTRIN]
RT	740 (24)	777 (25)	791 (28)	803 (29)
Error ratio (%)	28.6 (2.0)	30.6 (2.0)	30.0 (2.5)	31.7 (2.5)
Unstressed Primes				
[“man”-]	[MANDAT]	[DOKTRIN]	[MANDEL]	[DOKTOR]
RT	794 (29)	804 (29)	782 (25)	788 (25)
Error ratio (%)	28.8 (2.2)	31.8 (2.5)	30.1 (1.9)	30.4 (2.2)

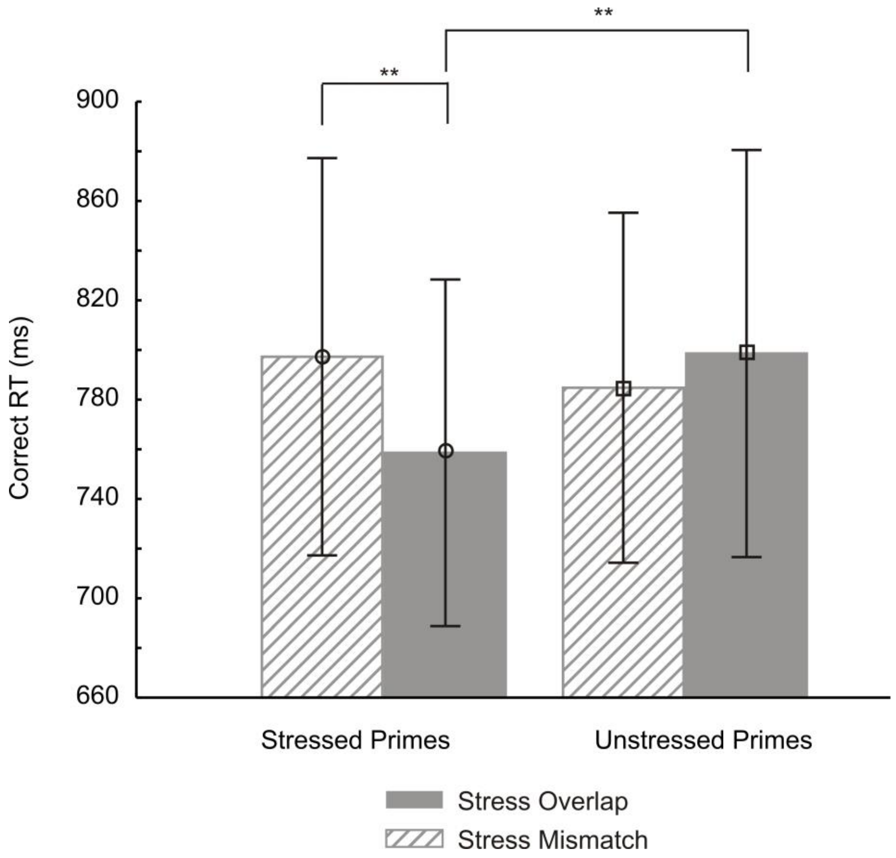

Figure 2. The Stress Priming * Prime Type interaction on mean RTs. Horizontal lines indicate the significant pair-wise comparisons for this interaction. The “Stressed Primes in Stress Overlap” and “Unstressed Primes in Stress Mismatch” conditions represent mean RTs for initially stressed *targets*, while the “Stressed Primes in Stress Mismatch” and “Unstressed Primes in Stress Overlap” conditions represent mean RTs for initially unstressed *targets*. Error bars denote 95% confidence intervals for means.

**p < .01

3.2 ERPs

We first quantified ERP differences by means of successive 50 ms time window analyses starting from target onset (0 ms) until 700 ms after target onset (see Table 4). The effect of Phoneme Priming started already at 250 ms and extended in time. The Stress Priming effect started around 400-450 ms. There were interactions of Phoneme Priming with the factor

Prime Type. Although in a lesser extent than in the case of Phoneme Priming, Stress Priming * Prime Type interactions were also found. According to these results and on the basis of prior cross-modal word onset priming studies (Friedrich, 2005; Friedrich, Kotz, Friederici, & Alter, 2004), we analyzed the 300-400 ms and the 400-600 ms time windows in details in order to quantify P350 and N400 phoneme and stress priming effects, respectively. Figure 3 shows grand average ERPs in the four experimental conditions over each ROI collapsed across the two prime types.

Table 4 attests ERP differences for targets that were following either stressed primes or unstressed primes immediately after the baseline. This suggests that differences are already present at the baseline, i.e., before target word onset. Indeed, those differences are not surprising because there are physical differences between both types of primes. For detailed ERP analysis, we will only consider interactions of the factor Prime Type that include at least one of the two other experimentally varied factors, namely Stress Priming or Phoneme Priming.

Table 4. Results of the 50 ms time window analyses (consecutive ANOVAs) on ERPs from target onset (0 ms) until 700 ms.

Effects	0-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	600-650	650-700
Phoneme Priming						***	***	*				*	*	
Region * Phoneme Priming							*	***	***	***	***	***	***	**
Region * Hemisphere * Phoneme Priming						*	*	**						
Phoneme Priming * Prime Type										*	*		**	**
Region * Hemisphere * Phoneme Priming * Prime Type						**	*	**	**	*	*	**		
Region * Stress Priming											**	*		
Hemisphere * Stress Priming										*	*	**	**	*
Region * Hemisphere * Stress Priming									**	*				
Region * Stress Priming * Prime Type										**	*	*		
Hemisphere * Stress Priming * Prime Type											*	*	*	
Prime Type	***	***	***					**	*	**	***	***	***	***
Region * Prime Type	***	***	***	***	***	***	***	***	***	***	***	***	***	***
Hemisphere * Prime Type											*	*		

Note. An effect was denoted as significant and included in this table if it appeared as significant (*p* < .05) in two or more consecutive time windows according to ANOVAs. Only main effects of *Phoneme Priming*, *Stress Priming*, and *Prime Type*, or interactions including at least one of these factors are included. For the same criteria, see Schild et al. (2014a). Light and dark grey shading indicates the time windows (300-400 ms, 400-600 ms) used for further ERP analysis.

**p* < .05; ***p* < .01; ****p* < .001

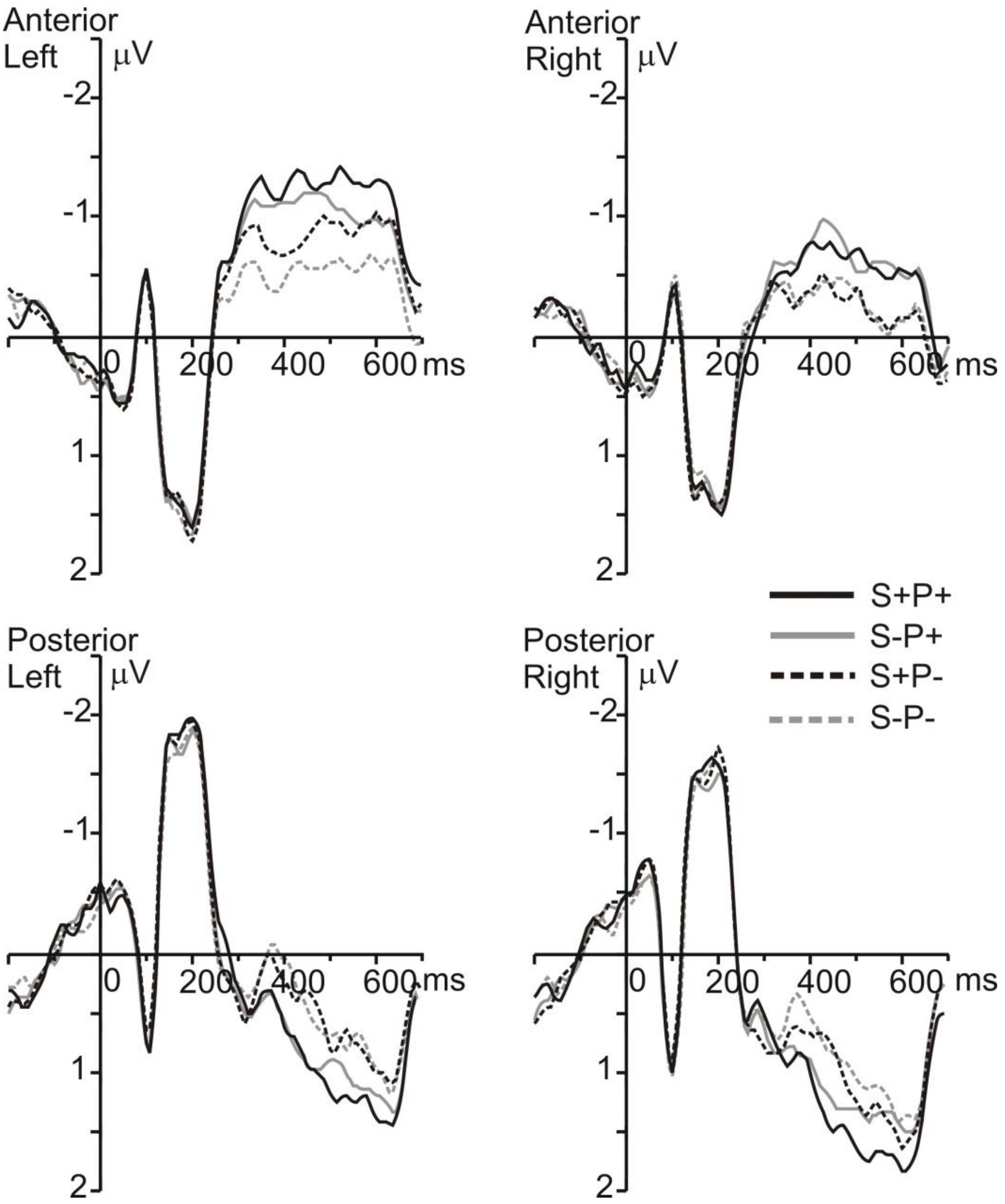

Figure 3. Grand average ERPs for the four basic experimental conditions over the left and right anterior and posterior ROIs. Black coloring indicates conditions that include stress overlap, grey coloring indicates conditions that include stress mismatch. Solid lines indicate conditions that include phoneme overlap. Dashed lines indicate conditions that include phoneme mismatch. The four conditions are abbreviated in the legend as follows. S+P+: Stress Overlap, Phoneme Overlap; S+P–: Stress Overlap, Phoneme Mismatch; S–P+: Stress Mismatch, Phoneme Overlap; S–P–: Stress Mismatch, Phoneme Mismatch.

3.2.1 P350: 300-400 ms

The Region * Hemisphere * Stress Priming * Phoneme Priming * Prime Type ANOVA performed on the mean activity between 300 and 400 ms revealed the significant main effect of Prime Type, $F(1, 31) = 6.70$, $p < .05$, $\eta_p^2 = .18$, and the significant interaction of Region * Prime Type, $F(1, 31) = 53.27$, $p < .001$, $\eta_p^2 = .63$. In addition, there were four significant main effects and interactions including the factor *Phoneme Priming*: (1) Phoneme Priming, $F(1, 31) = 12.34$, $p < .01$, $\eta_p^2 = .28$; (2) Region * Phoneme Priming, $F(1, 31) = 17.22$, $p < .001$, $\eta_p^2 = .36$; (3) Region * Hemisphere * Phoneme Priming, $F(1, 31) = 7.80$, $p < .01$, $\eta_p^2 = .20$; and (4) Region * Hemisphere * Phoneme Priming * Prime Type, $F(1, 31) = 8.52$, $p < .01$, $\eta_p^2 = .22$. Moreover, there was a significant interaction including the factor *Stress Priming*: Region * Hemisphere * Stress Priming, $F(1, 31) = 5.24$, $p < .05$, $\eta_p^2 = .14$.

We followed-up Phoneme Priming effects by separately analyzing them for each ROI and for stressed and unstressed primes, respectively, with pair-wise post-hoc comparisons on the four-way interaction. Over the left anterior ROI, Phoneme Mismatch elicited enhanced positive ERP amplitudes compared to Phoneme Overlap regardless of the stress of the primes (both *p*s < .001). Over the right anterior ROI, enhanced positive ERP amplitudes for Phoneme Mismatch compared to Phoneme Overlap were only evident for targets following unstressed primes ($p < .001$). Considering the posterior electrodes, Phoneme Mismatch elicited more negative ERP amplitudes than Phoneme Overlap only over the left posterior ROI for targets following unstressed primes ($p < .01$). Together, these ERP differences point to a P350 effect for phoneme priming that is comparable with previous work with German L1 listeners (e.g., Friedrich, 2005; Friedrich et al., 2013; Friedrich, Kotz, Friederici, & Alter, 2004; Friedrich et al., 2008). The 50 ms time window analyses revealed that the P350 effect started already 250 ms after target word onset (see Table 4).

We followed-up the Stress Priming effect by separately analyzing it for each ROI, with pair-wise post-hoc comparisons on the three-way interaction. Pair-wise tests showed Stress Mismatch elicited enhanced positive ERP amplitudes compared to Stress Overlap over the left anterior ROI ($p < .001$). In regard to the other ROIs, no significant differences emerged.

3.2.2 N400: 400-600 ms

The Region * Hemisphere * Stress Priming * Phoneme Priming * Prime Type ANOVA performed on the mean activity between 400 and 600 ms revealed the significant main effect of Prime Type, $F(1, 31) = 13.09$, $p < .01$, $\eta_p^2 = .30$, and the significant interactions of Region * Prime Type, $F(1, 31) = 36.88$, $p < .001$, $\eta_p^2 = .54$, and Hemisphere * Prime Type $F(1, 31) = 4.45$, $p < .05$ $\eta_p^2 = .13$. In addition, there were three significant interactions including the factor *Phoneme Priming*: (1) Region * Phoneme Priming, $F(1, 31) = 50.99$, $p < .001$, $\eta_p^2 = .62$; (2) Phoneme Priming * Prime Type, $F(1, 31) = 4.36$, $p < .05$, $\eta_p^2 = .12$; and (3) Region * Hemisphere * Phoneme Priming * Prime Type, $F(1, 31) = 8.04$, $p < .01$, $\eta_p^2 = .21$. Moreover, there were two significant interactions including the factor *Stress Priming*: (1) Hemisphere * Stress Priming, $F(1, 31) = 6.57$, $p < .05$, $\eta_p^2 = .17$, and (2) Region * Hemisphere * Stress Priming, $F(1, 31) = 5.12$, $p < .05$, $\eta_p^2 = .14$.

We followed-up Phoneme Priming effects by separately analyzing them for each ROI and for stressed and unstressed primes, respectively, with pair-wise post-hoc comparisons on the four-way interaction. Over both posterior ROIs, Phoneme Mismatch elicited more negative ERP amplitudes than Phoneme Overlap for targets following both stressed and unstressed primes (all *p*s < .001). Over the left anterior ROI, Phoneme Mismatch elicited enhanced positive ERP amplitudes compared to Phoneme Overlap regardless of the stress of the primes (both *p*s < .001). Over the right anterior ROI, enhanced positive ERP amplitudes for Phoneme Mismatch compared to Phoneme Overlap were only evident for targets following unstressed primes (*p* < .001). Together, these ERP differences point to an N400 effect for phoneme priming that is comparable with previous work with German L1 listeners (e.g., Friedrich, 2005; Friedrich, Kotz, Friederici, & Alter, 2004; Friedrich et al., 2008).

We followed-up Stress Priming effects by separately analyzing them for each ROI, with pair-wise post-hoc comparisons on the three-way interaction. Pair-wise tests showed that Stress Mismatch elicited more negative ERP amplitudes than Stress Overlap over the right posterior ROI (*p* < .001), and the opposite pattern appeared over the left anterior ROI (Stress Mismatch > Stress Overlap, *p* < .001). Crucially, we did not find any interaction effects between ERP phoneme priming and ERP stress priming, neither in the 50 ms time window analyses nor in the specific time windows analyzed (300-400 ms and 400-600 ms).

4. Discussion

We investigated whether a fixed-stress L1 (Hungarian) induces difficulties in implicitly processing stress information in an L2 with variable stress (German). We focused on phonologically mediated mechanisms of lexical access, i.e., listeners' simultaneous consideration of multiple lexical candidates and selection of the most appropriate one. To this end, we used auditory-visual word onset priming in which stress overlap and phoneme overlap between spoken stressed and unstressed word onsets (primes) and written words (targets) varied orthogonally. Crucially, the written words that we used here did not encode the stress position, i.e., the onsets of the printed words were identical at the letter level. Thus, stress priming effects indicate two aspects of processing stress information in an L2; namely, (i) encoding of syllable stress (stressed vs. unstressed primes) and (ii) recalling and matching the stored stress pattern of target words with that of the primes'. We tested native Hungarian listeners who were late learners of German. We found evidence for stress priming in the ERPs

(P350 and N400) and in the lexical decision latencies. Our results show that the formerly described phenomenon of stress “deafness” found for listeners with fixed-stress L1 in explicit tasks (Dupoux et al., 1997; Dupoux et al., 2001; Dupoux et al., 2008; Honbolygó et al., in press) does not reflect a general processing deficit for stress information.

Prime-target stress mismatch was associated with enhanced P350 amplitudes and enhanced N400 amplitudes. The P350 component is thought to reflect the activation of modality independent segmental word form representations; and the phonological N400 has been related to phonological expectancies derived from the activated cohort (Friedrich, 2005; Friedrich, Kotz, Friederici, & Alter, 2004; Friedrich, Kotz, Friederici, & Gunter, 2004; Friedrich, Schild, & Röder, 2009; Scharinger & Felder, 2011; Schild et al., 2014a; Schild, Becker, & Friedrich, 2014b; Schild, Röder, & Friedrich, 2012). According to this interpretation, we conclude that Hungarian listeners used the primes’ stress status for accessing stored prosodic representations of the German target words (P350 effect) and for predicting the stress pattern of the upcoming target words (N400 effect). That is, comparable to native listeners of an L1 with variable stress (Jesse et al., 2015; Reinisch et al., 2010; Sulpizio & McQueen, 2012), native Hungarian listeners with a fixed-stress L1 correctly detected the primes’ stress status and considered matching L2 words as more powerful candidates than mismatching L2 words. This finding expands previous ERP work showing that when processing their fixed-stress L1, listeners extract stress from the speech input and implicitly match this information with the native mandatory stress pattern that L1 words should have (e.g., Honbolygó & Csépe, 2013; Honbolygó et al., 2004). Apparently, Hungarian listeners also extract stress information from L2 input, store stress patterns of L2 words, and match both sources in a priming context.

In the ERPs, we found stress priming effects starting approximately 400 ms after the presentation of target word. This is somewhat later than formerly observed ERP stress priming in German L1 listeners (Friedrich, Kotz, Friederici, & Alter, 2004). The later onset of ERP stress priming in L2 learners compared to native listeners might reflect generally delayed L2 processing. In line with this interpretation, RTs for targets were on average 100 ms slower in L2 learners than in native listeners. At the same time, however, ERP phoneme priming in L2 listeners started at a comparable time window as in previous studies with German natives (e.g., Friedrich, 2005; Friedrich et al., 2013; Friedrich et al., 2008). Thus, further research might follow the hypothesis that implicit use of stress in an L2 is somewhat delayed, at least for listeners with a fixed-stress L1.

Again, our results are evidence for several mechanisms considering different aspects during lexical access: ERPs and lexical decision latencies revealed different priming effects. In the ERPs, we found that stress priming did not interact with the type of prime. That is, stressed primes modulated processing of initially stressed words comparably to unstressed primes modulating processing of initially unstressed words. In contrast to ERPs, lexical decision latencies differed for stressed and unstressed primes: While stressed primes facilitated lexical decisions for initially stressed target words, unstressed primes did not facilitate lexical decisions for initially unstressed target words. Again, ERPs indicate that the processing system considers more lexical candidates than facilitation in the behavioral outcome suggests. Beyond this, the presently obtained dissociation of ERP results, on the one hand, and lexical decision latencies, on the other hand, allows disentangling different aspects of processing syllable stress.

While ERPs reveal that L2 listeners implicitly encode and store syllable stress of initially stressed and initially unstressed L2 words, lexical decisions show that this information is of limited use for them. In their decision responses, Hungarian listeners selectively considered stressed primes for speeding up responses to initially stressed targets, but they ignored unstressed primes. It appears that at a stage of processing associated with the lexical decision response, the system is somewhat restricted to the mandatory stress pattern of the L1. Therewith, the lexical decision latencies are in accord with the assumption that stressed word onsets guide lexical access in listeners with a native language that mandatorily assigns stress to the word initial syllable (Vroomen et al., 1998). Here we refine this assumption by suggesting that this native bias modulates selection of the most plausible candidate among simultaneously considered L2 words. Future research has to reveal whether Hungarian listeners focus on pitch and intensity, because they are used to the informative value of these acoustic cues in their L1 (Fónagy, 1958), or whether they rely on all cues that are relevant in the respective L2 (which would be duration, pitch, and intensity changes in German, e.g., Jessen et al., 1995).

Our procedures might have biased processing strategies towards the L1. Although we restricted our analyses to correct lexical decisions, we could not entirely rule out that in some cases, participants were only guessing about the lexical status of a target word without knowing that word’s meaning. Possibly, L2 listeners are more likely to apply their mandatory L1 stress pattern to such guesses. In addition, participants received the instructions in Hungarian. This could have put them into a Hungarian listening modus and, therewith, could have resulted in a processing bias towards the mandatory Hungarian stress pattern. Obviously, the present behavioral results await replication with procedures that control for both issues. Still, the ERPs found reflected that Hungarian listeners not only linked stressed primes with initially stressed German words, but going beyond their mandatory L1 stress pattern, they also linked unstressed primes with initially unstressed German words. Therewith, ERP stress priming reveals that our Hungarian participants at least knew the correct form of the German target words that we presented (even if they did not know the correct meaning). If we have indeed biased the behavioral outcome towards an L1 strategy and left the ERPs unaffected from this strategy, this would support our conclusion that both measures reflect different aspects of processing.

As indicated in the study of Schild et al. (2014a), with the current set of stimuli, the processing of initially stressed and initially unstressed target words might not be exactly comparable. Caused by the restricted amount of minimal word onset pairs in German, linguistic characteristics such as word frequency could not be matched for the two types of target words. This obviously is a limitation of the present study, as word frequency might be reflected in N400 amplitudes (e.g., Kutas & Federmeier, 2011) and lexical decision latencies (e.g., Grainger, 1990). However, we neither found different N400 effects for initially stressed vs. initially unstressed targets in the former study (see also Schild & Friedrich, 2018), nor in the present study (where such effects should have been reflected in a respective Stress Priming * Prime Type interaction). Nevertheless, in the present study, lexical decision latencies for initially unstressed targets were slower than for initially stressed targets, at least when initially stressed targets were preceded by stressed primes. This behavioral effect, in part, could have originated from initially unstressed words being less frequent in German.

As in our former studies with native German listeners (Friedrich, Kotz, Friederici, & Alter, 2004), ERP stress priming did not interact with ERP phoneme priming and, similarly, behavioral stress priming did not interact with behavioral phoneme priming in the current study with Hungarian learners of German. This reveals that phoneme-free representations of the target words’ stress pattern are involved in ERP and behavioral stress priming effects. Thus, Hungarian listeners are not only storing and using long-term representations of their native initially stressed prosodic word forms, as demonstrated in earlier studies (Honbolygó & Csépe, 2013; Honbolygó et al., 2004; Honbolygó, Kolozsvári, & Csépe, 2017), they are also able to store and use abstract (phoneme-free) prosodic word forms in an L2. Altogether, the behavioral and ERP results strengthen the conceptualization of separate processing paths for word stress and phonemes and point to separate word form representations for both types of information. Apparently, native Hungarian listeners equal native German listeners in this basic cognitive architecture of speech processing.

Here we speculate that stress “deafness” in explicit tasks might relate to redundant interdependency of processing phonemes and syllable stress in a fixed-stress L1. Syllable stress is informative for word identification in languages that allow the stress position to vary. Therefore, listeners with a L1 with variable stress might be used to combine phonemes and syllable stress for word recognition. By contrast, syllable stress is redundant for word identification in fixed-stress languages. Therefore, their listeners might usually not rely on syllable stress for word recognition. This restriction might already appear ontogenetically early during language acquisition: Infants learning a target language with variable stress outperform their peers with a fixed-stress target language in some paradigms. Eight months after birth, infants exposed to an L1 with variable stress (English or German) quickly learned whether strings in a sequence have the same stress pattern (e.g., “daTU”, “saPI”, “kuPO”) or whether strings differ in stress (e.g., “daTU”, “SApi”, “kuPO”, etc., see Abboub, Bijeljac-Babic, Serres, & Nazzi, 2015; Bijeljac-Babic, Serres, Höhle, & Nazzi, 2012; Skoruppa, Cristia, Peperkamp, & Seidl, 2011; Skoruppa et al., 2009). Their monolingual peers with fixed-stress language background (French), either failed in this task (Skoruppa et al., 2009) or needed much longer familiarization phases than their peers learning an L1 with variable stress (Bijeljac-Babic et al., 2012). One might conclude that a fixed-stress language limits the ability to put phonemes and stress together from early on in ontogenetic development.

Appendix

Table A1. The 48 monomorphemic disyllabic German pairs of nouns.

Initial stress	Final stress
Alter [age]	Altar [altar]
Ampel [traffic light]	Ampère [ampere]
Arche [ark]	Archiv [archive]
Armut [poverty]	Armee [army]
Atem [breath]	Atom [atom]
Auge [eye]	August [august]
Balken [bar]	Balkon [balcony]
Basis [base]	Basalt [basalt]
Chronik [chronicle]	Chronist [chronicler]
Datum [date]	Datei [file]
Doktor [doctor]	Doktrin [doctrine]
Extra [extra]	Extrem [extreme]
Ethik [ethics]	Etat [budget]
Fabel [tale]	Fabrik [factory]
Flora [flora]	Florett [floret]
Friese [frisian]	Frisur [hearstyle]
Kanon [canon]	Kanal [canal]
Kanzler [chancellor]	Kanzlei [chambers]
Karte [map]	Kartei [register]
Kosten [costs]	Kostüm [costume]
Konter [counterattack]	Kontrast [contrast]
Konto [account]	Kontrakt [contract]
Magen [stomach]	Magie [magic]
Mandel [almond]	Mandat [mandate]
Mode [fashion]	Modell [model]
Monat [month]	Monarch [monarch]
Motor [engine]	Motiv [motive]
Muse [muse]	Musik [music]
Muskel [muscle]	Muskat [nutmeg]
Note [note]	Notiz [notice]
Orgel [organ]	Organ [organ]
Pappe [board]	Papier [paper]
Parka [parka]	Parkett [parquet]
Party [party]	Partei [party]
Pate [godfather]	Patent [patent]
Perser [persian]	Person [person]
Planung [planning]	Planet [planet]

Poker [poker]	Pokal [cup]
Porto [postage]	Portal [portal]
Probe [rehearsal]	Problem [problem]
Profi [professional]	Profil [profil]
Regel [rule]	Regent [regent]
Solo [solo]	Solist [soloist]
Status [status]	Statut [statute]
Taler [thaler]	Talent [talent]
Torte [cake]	Tortur [ordeal]
Tresen [bar]	Tresor [safe]
Wagen [car]	Waggon [waggon]

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Disclosure of interest

The authors report no conflicts of interest.

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