Lexical Competition without Phonology: Masked Orthographic Neighbor Priming with Deaf Readers

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Skilled reading is thought to rely on well-specified lexical representations that compete during visual word recognition. The establishment of these lexical representations is assumed to be driven by phonology. To test the role of phonology, we examined the prime lexicality effect (PLE), the index of lexical competition in signing deaf (N=28) and hearing (N=28) adult readers of Hungarian matched in age and education. We found no PLE for deaf readers even when reading skills were controlled for. Surprisingly, the hearing controls also showed reduced PLE; however, the effect was modulated by reading skill. More skilled hearing readers showed PLE, while more skilled deaf readers did not. These results suggest that phonology contributes to lexical competition; however, high-quality lexical representations are not necessarily built through phonology in deaf readers.

Fluent, automatic word recognition requires the reader to select the correct lexical representation from a set of possible candidates. According to the Interactive-Activation model of Reading (IA, McClelland & Rumelhart, 1981) selection of the correct lexical representation during visual word recognition is achieved through lexical competition. Specifically, a word activates its target lexical representation but also similar words, so-called orthographic neighbors (words that differ only in one letter from each other). These orthographic neighbors compete for lexical selection; therefore, they should be suppressed in order for the correct lexical representation to be selected. Lexical selection is achieved by mutual inhibition between the competing lexical representations until the point when the best match suppresses the other competitors.

One popular task to investigate lexical representations in visual word recognition is the masked priming paradigm. In this task, a so-called prime word is presented very briefly (typically for less than 60 ms) and is preceded immediately by a forward mask ("####"). Then a target word is presented to which participants respond in a lexical decision task (is it a word or not). The brief presentation and masking prevents conscious identification of the prime; however, it still influences the processing of the target word. In case of orthographic priming, prime and target words are spelled similarly (e.g. 'rack'– 'race'), and target word is activated through its orthographic representation.

In such a masked priming task, an orthographically related prime (e.g. 'bear') activates the target word and the competitors of the target (e.g. 'pear', 'wear', 'bead'), too. When the target is pre-activated by the prime facilitation (faster reaction times) will occur due to sublexical overlap. Indeed, orthographically related *pseudoword* primes (e.g. 'zear) tend to facilitate target processing (e.g. 'pear) compared to an unrelated control (e.g. 'ribe', Davis & Lupker, 2006; Forster & Veres, 1998). However, the lexical representation of orthographically related *word* primes (‘bear’) may produce both facilitatory priming (faster responses) at the sublexical level and inhibitory priming (slower responses) at the lexical level as the words competitors must be inhibited. Thus, the net of the priming effects is inhibitory. In line with this, several studies showed that an orthographically related word primes interfere with target processing, especially if the target is of lower frequency (Andrews & Hersch, 2010; Andrews & Lo, 2012; Davis & Lupker, 2006; De Moor et al., 2007; Forster & Veres, 1998; Nakayama et. al., 2008; Segui & Grainger, 1990). The phenomenon of differential effectiveness of word versus pseudoword primes is called the prime lexicality effect (PLE).

Fast and efficient selection of the correct lexical representation is supported by well-specified orthographic representations (Ehri, 2005). According to the Lexical Quality Hypothesis (Perfetti & Hart, 2002) a lexical representation has high quality if it is precise and redundant at the same time. A precise lexical representation has a well-specified orthographic representation (spelling), so that the visual pattern of the word quickly activates the lexical representation. Precision is necessary for the reader to distinguish similar words like ‘bear and ‘pear or ‘night’ and ‘knight’. Moreover, when a lexical representation is redundant, orthographic, phonological, and semantic representations become bound together. If these representations are less tightly bound or not precise on their own, word identity is not reliably retrieved form the orthographic input. In a masked priming task, high-quality lexical representations yield faster activation of the prime (‘bear’), which leads quickly to inhibition of similar words resulting in stronger inhibition of orthographic neighbors (e.g. ‘pear’, ‘wear’, ‘bead’) from word primes (Andrews & Lo, 2012). Andrews and Hersch (2010) argue that spelling is the most accurate index of lexical quality, because it requires word-specific and fully specified orthographic knowledge. Indeed, they found that good spelling was associated with stronger inhibitory priming, especially for those whose spelling was relatively better compared to their reading.

Development of these precise, well-specified orthographic representations occurs through item-specific learning. It depends not only on exposure to print in general but on exposure to specific word forms. Acquisition of orthographic representations takes as few as 4 exposures (Share, 1999; Share, 2004) and can occur either through reading aloud or silent reading (De Jong & Share, 2007), but according to orthographic priming studies the fine-tuning of these representations take years (Castles et al., 2007). However, it is still an open question how orthographic representations are tuned.

One possibility is that fine-tuning is achieved through phonological processes. According to the self-teaching hypothesis (Share, 1995) orthographic representations are formed via phonological decoding. Indeed, there is evidence that individual phonological skills are associated with the quality of orthographic representations. Welcome and Trammel (2017) found that phonological decoding skills were related to orthographic priming effects. In fact, weaker phonological skills were associated with facilitatory effects whereas stronger phonological skills were associated with inhibitory effects. This is also in line with the claim of the Lexical Quality Hypothesis (Perfetti & Hart, 2002) stating that precise orthographic and precise phonological representations are needed for well-specified lexical representations, and those representations are tightly bound together. Another possibility is that fine-tuning is achieved through visual-orthographic processes. Pacton and colleagues (2001) demonstrated children could acquire orthographic knowledge through implicit visual statistical learning. However, it is still not known whether purely visual exposure to print is sufficient for the acquisition of well-specified word-specific orthographic representations necessary for lexical competition.

Research on deaf readers provides a unique insight into the processes in question because deafness hinders access to spoken language phonology. Most studies in the past decades examined the phonological processes, and the results pointed to the conclusion that deaf readers do not automatically engage in phonological decoding during reading (Bélanger et al., 2012; Cripps et al., 2005; Fariña et al., 2017; Ormel et al., 2010), and even if they do, their phonological representations are less precise (Sterne & Goswami, 2000). While phonological awareness - the ability to segment and manipulate sublexical elements (sounds) of spoken words - is strongly associated with reading skill in hearing readers (skilled readers: Sprugevica & Høien, 2003; poor readers: Araújo et al., 2010), the association is ambiguous in deaf readers. Some studies found correlation between phonological and reading skills in deaf participants (Domínguez et al., 2014; Dyer et al., 2003), whereas other studies failed to find such relationship (Koo et al., 2008; Kyle & Harris, 2006, 2010; Narr, 2008). Kyle and Harris (2010) in their longitudinal study found that reading skill of deaf children was associated with lip-reading and vocabulary, while phonological awareness was predicted by earlier reading skill suggesting that phonological awareness is rather a consequence than a cause of literacy acquisition (see also Castles & Coltheart, 2004).

Moreover, research investigating phonological recoding (grapheme-phoneme mapping) in deaf readers showed that although they are capable of using some phonological information during reading, the level of phonological recoding is lower compared to their hearing peers (Daigle, Berthiaume, & Demont, 2012; Narr, 2008; Sterne & Goswami, 2000). The ability of phonological recoding is usually measured by the reading pseudo-homophones (e.g. ‘meen’) that have no orthographic representation in the mental lexicon but can be read phonetically as a real word (‘mean’). Research suggest that deaf readers do not use grapheme-phoneme mapping when reading such pseudo-homophones (Bélanger et al., 2012; Fariña et al., 2017; Ormel et al., 2010), and their phonological recoding abilities are not related to reading ability (Bélanger et al., 2012; Gutierrez-Sigut, Vergara-Martínez, & Perea, 2017).

Surprisingly, less is known about the orthographic processes in deaf readers. Research on spelling performance indicates that deaf readers can develop word-specific orthographic knowledge (Hayes et al., 2011; Olson & Caramazza, 2004), and their orthographic awareness seems to be adequately developed, too (Daigle et al., 2009; Miller, 2010). For instance, Miller (2010) presented deaf and hearing children letter strings and participants decided which letter sting could be a real word according to the spelling rules. Although elementary school deaf children showed less orthographic awareness than their hearing controls, the difference disappeared by high school. In addition, good deaf readers consistently showed good orthographic awareness in the study.

For deaf adults, only a handful of studies investigated orthographic priming, which can tap into fast and automatic orthographic processes (Bélanger et al., 2012; Cripps et al., 2005; Gutierrez-Sigut et al., 2019; Perea et al., 2016). Overall, the results indicate that deaf participants exhibit orthographic priming similar to their hearing peers. For instance, Gutierrez-Sigut et al. (2019, Supplementary Material, Appendix C) and Perea et al. (2016) demonstrated that deaf individuals show the canonical repetition priming where the target word is briefly presented as prime (‘table’ – ‘table’) which automatically activates the target lexical representation through its orthographic, phonological, and semantic representations. However, the effect was only present for word targets (e.g. “table” – “TABLE” compared to unrelated control word pairs e.g. “porch” – “TABLE”) but not for pseudoword targets (e.g. “curde” – “CURDE” compared to “gleen” – “CURDE”) which is assumed to index the activation of lexical representation. In addition, Bélanger et al. (2012) found that orthographically related pseudoword neighbor primes (‘zear’) facilitated response to target words (‘bear’) compared to an unrelated pseudoword (‘soid”) for deaf readers. Though these results suggest that masked primes can activate lexical representations and that neighbor primes can activate sublexical orthographic representations, they do not provide insight about the establishment of well-specified orthographic representations in the case of deaf readers.

According to the dual-route model of orthographic processing (Grainger & Ziegler, 2011) written words can be processed along a coarse-grained or a fine-grained route. The two routes mainly differ in the level of precision with which letter order is coded. In the so-called coarse-grained route, only approximate letter position information is computed to provide fast access to semantics. This flexible letter order processing gives rise to the transposed-letter priming effect which is a form of orthographic priming where the prime and target differ in the position of two letters (e.g. ‘caniso’ – ‘casino’). Research suggests that the coarse-grained route works similarly for deaf and hearing readers (Fariña et al., 2017). For instance, Meade and colleagues (2020) showed that the size of transposed-letter priming effect is similar between deaf and hearing individuals indicating that phonological tuning is not required for coarse-grained orthographic processing. In contrast, the fine-grained route provides precise serial position encoding via sublexical phonology and is especially important for the development of precise orthographic information. The pseudo-homophone effect – the priming effect of pseudo-homophone primes (‘meet’) on words (‘meat’) – is considered the hallmark of phonological recoding (Grainger & Ziegler, 2011), and research with deaf individuals showed mixed results so far. Fariña and collagues (2017) did not find evidence for the pseudo-homophone effect in deaf readers; however, Gutierrez-Sigut and collagues (2017) found comparable pseudo-homophone priming effect between the deaf and the hearing participants; nevertheless, the priming effect was not related to the reading ability in the deaf group.

The above findings can be interpreted in the framework of the Qualitative Similarity Hypothesis (Paul et al., 2013) which posits that literacy development of any individuals is similar to that of a typical native literacy learner. This implies that literacy acquisition of deaf children is qualitatively the same but quantitatively may be delayed compared to hearing children. According to a series of research on this topic (Andrews & Wang, 2015), there are mainly similarities in the reading development of deaf and hearing children, although some qualitative differences can be demonstrated, too. Especially effective orthographic-phonological mapping for deaf readers may encompass different mapping units and processes (McQuarrie & Parrila, 2014). Signing deaf children's sublexical representations could be derived from sign language instead of spoken language; thus, skilled deaf readers may map orthography to sign language or fingerspelling. Since fingerspelling is a manual system in which handshapes represent the letter of the alphabet, it maps directly onto print and can serve as an alternative to spoken language phonology (Easterbrooks et al., 2015). In the dual-route model of orthographic processing (Grainger & Ziegler, 2011) this entails that the coarse-grained route works qualitatively similarly for deaf and hearing readers, whereas the fine-grained route which provides mapping via phonology might be different for signing deaf readers. Overall, research indicates that the orthographic processes of deaf readers are similar to that of hearing readers; however, the degree of precision and the role of phonology is not yet fully discovered.

Recently, Meade and colleagues (2019) investigated orthographic precision of deaf readers in a masked neighbor priming paradigm. In their event-related potential (ERP) study, the researchers compared word and pseudoword primes for word targets in a lexical decision task. Deaf readers showed lexical competition from word primes as indicated by slower response times and larger electrophysiological responses. However, though deaf and hearing participants did not differ in the magnitude of these electrophysiological responses, they differed in the distribution of these evoked potentials over the scalp due to less involvement of brain areas responsible for phonological processes.

Similarly, the current study investigated whether precise orthographic representations are available in the absence of well-specified phonological representations. To this end, we examined the prime lexicality effect (PLE) in a masked priming lexical decision task with deaf and hearing readers matched for age and educational level. We directly compared the effectiveness of word versus pseudoword neighbor primes to index lexical competition. As Hungarian orthography is characterized by highly consistent grapheme-phoneme mappings, we tested whether lexical competition effects found in a deep orthography (English) can be replicated in a shallow orthography. We assumed that if phonological processing played a crucial role in the development of high-quality lexical representations (Share, 1995), deaf readers would show reduced or no PLE compared to the hearing control. On the other hand, if orthographic representations develop through visual-orthographic processes (Pacton et al., 2001), no difference in terms of PLE magnitude could be found between the deaf and hearing readers. In addition, to extend the results of Meade and colleagues (2019), we explored how individual differences in reading skills modulate the PLE assuming that better readers show greater PLE.

Method

Participants

Thirty-five deaf participants applied for the experiment via online recruitment. Inclusion criteria was (1) IQ greater than 85 (15th percentile on Raven’s Progressive Matrices, Raven, Raven, & Court, 2003), (2) severe to profound hearing loss (hearing threshold greater than 70 dB[1]), (3) prelingual deafness (onset of hearing loss before age 3), (4) no additional disabilities, neurological, psychiatric, or learning disorders[2]. Two participants were excluded due to low IQ scores, one due to additional disabilities (stroke), two due to hearing threshold lower than 70 dB, and two due to hearing loss after the age of 3. Finally, data of 28 deaf participants (mean age =

44.89 years, SD = 13.89, 11 male, 1 left handed) were included in the analysis. All participants had normal or corrected-to-normal vision. Background data were collected via a questionnaire regarding information about participants' age, gender, education level, years spent in school, hearing status, onset and grade of hearing loss, and language use. All participants but two knew Hungarian Sign Language, 4 of them preferred to use spoken language, 17 sign language, while 7 did not have a language preference. Eight of the participants were native signers. Ten participants completed university (BA/BSc or MA/MSc), 7 participants completed high school, 9 participant completed vocation school, and the remaining 2 completed elementary education. The mean number of years spent in school was 16.32 (SD = 4.97).

Hearing participants were recruited via online platforms, too. Data of 28 hearing participants (mean age = 44.96 years, SD = 14.04, 11 male, 2 left handed) who were matched person-by-person with the deaf participants on age (+/- 3 years), years spent in education (+/- 3 years), and education level (+/- 1 level) were included in the analysis. All hearing participants had normal or corrected-to-normal vision, reported no neurological, psychiatric, or learning disorders and had IQ greater than 85 (15th percentile on Raven). Ten participants completed university (BA/BSc or MA/MSc), 15 participants completed high school, and the remaining 3 completed vocational school. The mean number of years spent in school was 15.21 (SD = 2.64). Deaf and hearing participants did not differ in age (t = -0.02, p = .985) or in the years spent in school (t = 1.04, p = .304). See descriptive statistics for the groups in Table 1.

[Table 1]

Background measures

To measure *non-verbal intelligence*, we used Raven's Standard Progressive Matrices (SPM, Raven et al., 2003) as this 60-item test is regarded as a good estimate of general intelligence. Assessment was carried out by the first author or a research assistant trained by the first author, scoring was always checked by the first author. The mean raw score was 50.43 (SD = 5.57) for the deaf and 53.0 (SD = 4.16) for the hearing participants, the difference was marginally significant (t = -1.96, p = .056).

Semantic fluency was used to assess lexical access and indirectly vocabulary and executive functions. In this task, participants were required to generate as many unique words as possible within a given category (animals and fruits here) in 1 minute (Mészáros et al., 2011). Deaf participants were allowed to produce the items in any modality they were comfortable with (signed, spoken, or both, for previous studies on semantic fluency in deaf individuals see (Marshall et al., 2017; Marshall et al., 2014; Marshall et al., 2012). The assessment was carried out by the first author (for some hearing participants by the research assistant). The task was anonymously video recorded to help the transcription of the answers which was done by the first author. Scoring was double-checked from the transcription by a university student trained by the first author. Semantic fluency score was calculated as the sum of the correct answers given for the two categories. The mean score was 35.68 (SD = 6.96) for the deaf and 44.07 (SD = 7.05) for the hearing participants, the difference was significant between the groups (t = -4.48, p < .001).

A *complex counting span* (Conway et al., 2005; Engle et al., 1999) was administered to measure working memory capacity as this task have been shown to best represent working memory (Gordon et al., 2020). In this task, participants were asked to count a target item (blue circles). Then they were shown the next display and asked to count the items. Participants had to recall the number of the target items from each display in a serial order. Deaf participants were allowed to use their preferred language for the recall (sign/spoken language). The number of displays ranged from two to six in ascending order. The task contained three runs; the average points received in the three runs comprised the working memory score (maximum 6). Due to low linguistic demands, this task is suitable to measure working memory capacity in deaf participants (Davidson et al., 2019; Sawa, 2011). Assessment and scoring was carried out by the first author or a research assistant. The mean score was 3.39 (SD = 0.79) for the deaf and 3.99 (SD = 1.02) for the hearing participants, the difference was not significant between the groups (W = 292.5, p = .102).

An in-house *multiple-choice spelling* test was administered in which participants had to choose the correct spelling from among 2 or 3 options. Altogether 35 items were presented; participants used the mouse to indicate their response. The spelling score was calculated as the total number of correct responses. Since the task does not require acoustic processing or verbal answer, it is suitable for deaf participants. The mean score was 24.31 (SD = 3.34) for the deaf and 22.93 (SD = 3.97) for the hearing participants, the difference was significant between the groups (t = -2.19, p = .033).

To measure reading skills we used an in-house *sentence verification* task in which participants read a list of semantically very simple sentences and indicated with a button press as soon as possible whether the sentence's meaning was true or false. Altogether 40 sentences were presented in a fixed order. Sentence reading score was calculated as the sum of correct responses. Mean score was 37.15 (SD = 2.92) for the deaf and 39.04 (SD = 1.02) for the hearing participants. The groups differed from each other significantly (t = -3.11, p = .004).

The in-house *proofreading task* focused on orthographic knowledge. In this task, participants were presented with a list of 42 sentences and instructed to click with the mouse as fast as possible on the misspelled word in every sentence. The misspellings are of three types: (1) two letter were transposed (TL), (2) one letter was substituted with another letter from the alphabet (SL), (3) two letters were substituted with another letter from the alphabet (SL2). The proofreading score was calculated as the sum of correctly identified misspelled words. As both the sentence verification and the proofreading tasks required the participants to silently read the sentences and indicate their responses with a button or mouse, these tasks are considered to be suitable for deaf participants. Mean score was 40.85 (SD = 1.57) for the deaf and 41.56 (SD = 0.97) for the hearing participants. The groups differed marginally from each other (t = -1.97, p = .055).

Stimuli

Thirty-six words[3] and 36 pseudowords were used as target stimuli. The target words were nouns with 4-6 letter each[4] (mean frequency according to the Hungarian National Corpus (HNC, Váradi, 2002): 14.83/million, SD = 18.72; mean bigram frequency: 13.83, SD = 0.95; mean number of orthographic neighbors (ON): 7.28, SD = 5.81; mean orthographic Levenshtein distance (OLD20): 1.44, SD = 0.29). All word targets had a one letter different word pair, a so-called orthographic neighbor (e.g. bomba-GOMBA, meaning bomb-mushroom). Then, we created a one letter different pseudoword pair by changing the letter that differed in the word-word pair (e.g. fomba-GOMBA). Position of letter substitution was equated among initial, middle, and final letters. Thus, word targets could be preceded by a one letter different word (mean frequency: 63.69/million, SD = 98.63, mean bigram frequency: 14.02, SD = 0.84; ON: 7.92, SD = 6.36; OLD20: 1.39, SD = 0.31)) or a one letter different pseudoword (mean bigram frequency: 13.89, SD = 0.91, range 11.77-15.32, ON: 7.08, SD = 6.44, OLD20: 1.61, SD = 0.3). In case of the word prime – word target pairs, care was taken that the prime had higher relative frequency than the target as this is known to be a factor in inducing inhibition (Davis & Lupker, 2006; Segui & Grainger, 1990).

The pseudoword targets were created from a distinct subset of words with 4-6 letter each by changing one letter (mean bigram frequency: 13.92, SD = 0.55; ON: 5.94, SD = 7.12; OLD20:

1.7, SD = 0.28). Thus, all pseudoword targets had a one letter different word pair (e.g. kenyér-NENYÉR, kenyér meaning bread). Then, we created a one letter different pseudoword pair by changing the letter that differed in the word-word pair (e.g. penyér-NENYÉR). Position of letter substitution was equated among initial, middle, and final letters. Similarly to word targets, pseudoword targets could be preceded by a one letter different word (mean frequency: 66.5/million, SD = 69.73, mean bigram frequency: 14.02, SD = 0.8; ON: 6.44, SD = 4.59; OLD20: 1.43, SD = 0.28) or a one letter different pseudoword (mean bigram frequency: 13.81, SD = 1.01; ON: 5.33, SD = 4.65; OLD20: 1.76, SD = 0.31).

Individual stimulus lists (see Appendix Table A1) were counterbalanced in a way that each target appeared once for each participant and was paired with either its word or pseudoword prime. Order of items for each participant was pseudorandom with the constraint that maximum three items of the same length (4/5/6 letter long), three items of the same lexicality (word/pseudoword), and three items of the same position of letter substitution (initial/middle/final) could follow each other.

Procedure

Informed consent was obtained in written form from all participants at the beginning of the experiment. The experimental procedure was approved by the United Ethical Review Committee for Research in Psychology. For the deaf participants, instructions were provided in written Hungarian and Hungarian Sign Language; for the hearing participants instructions were provided in written and spoken Hungarian. All participants received monetary compensation (~6 Euros) for their participation.

Participants were tested individually in the lab and completed all tests in fixed order. Participants sat at a comfortable distance from a Dell P2213 computer screen with a resolution of

1680x1050 and a refresh rate of 60 Hz. Stimulus presentation and response recording was carried out by Presentation software (version 19.0, Build 12.20.12, Neurobehavioral Systems Inc., Berkeley, California, USA). All stimuli were displayed in black (RGB: 0, 0, 0) Courier New fonts (size: prime 17 pt, mask and target 18 pt) in the centre (x, y = 0, 0) screen. Each trial started with a blank, grey-blue (RGB: 187, 224, 227) screen displayed for 800-1200 ms. Then a forward mask (composed of # characters) was displayed for 500 ms, followed by the prime presented in lower case letters for 50 ms, and the target presented in upper case letters for 2000 ms. The mask, prime, and target stimuli of a given trial were of equal length. Participants were instructed to classify the presented stimuli as words or pseudowords by pressing one or another button on a response box (Cedrus Corporation, RB-540). Response mappings were counterbalanced across participants. The experiment started with 8 practice trials, then trials were presented in two blocks with a brief rest after the 48th trial.

Data analysis

Word and pseudoword targets were analyzed separately. Accuracy data were entered into a generalized linear mixed effect model (Accuracy ~ Group * Prime Lexicality + (1|subj) + (1|item), family = binomial) and analyzed using the glmer function of lme4 (version 1.1-21, Bates, Maechler, Bolker, & Walker, 2015) and afex packages (version 0.25-1, Singman, Bolker, Westfall, Aust, & Ben-Sachar, 2019) in R (version 3.6.1, R Core Team, 2013).

For reaction time (RT) analysis, incorrect responses (in the hearing group 1.98% and 1.98% of the data for word and pseudoword targets, in the deaf group 4.66% and 5.95% of the data for word and pseudoword targets, respectively) and RTs shorter than 200 ms or longer than 2000 ms and RTs +/-2 SD from the participants' individual mean within each condition were excluded from the RT analysis. In the hearing group 0.3% of the word and 1.09% of pseudoword

RT data, in the deaf group 0.6% of the word and 2.38% of the pseudoword RT data were discarded due to extreme RTs. Linear mixed model analysis was conducted on inverse transformed RT data based on visual inspection of the qq-plots and the recommendation of Baayen and Milin (2010). Analysis used the lmer function and treated participants and items as random effects and Prime Lexicality (pw/w) and Group (deaf/hearing) as fixed effect (invRT ~ Prime Lexicality * Group + (1|subj) + (1|item))[5]. For the groups, separate analyses were also run. Table 2 shows mean raw RTs and percent correct.

To assess how differences in reading skills modulate the PLE, we included reading measures into the linear mixed model. Since the Sentence verification and Proofreading measures were correlated (r = 0.64, p = .0005) for the deaf participants, we calculated a composite measure (ZRead) by averaging the standard scores for these measures. Analysis treated participants and items as random effects (invRT ~ Prime Lexicality * Group * ZRead + (1|subj) + (1|item)).

[Table 2]

Results

Accuracy: Analysis of accuracy data showed no effect either for word (Prime Lexicality: z= -0.696, p= .487; Group: z = -1.241, p= .214; Prime Lexicality X Group: z = 0.103, p = .918) or for pseudoword targets (Prime Lexicality: z= -0.417, p=.677; Group: z = -1.795, p = .073, Prime Lexicality X Group: z = 0.031, p = .976).

Reaction times: For word targets, analysis showed no significant effects (Prime Lexicality: t = -0.883, p =.379; Group: t = 0.168, p = .867). The Prime Lexicality X Group interaction also failed to reach significance (t = 0.908, p = .364). Although the hearing group numerically showed larger PLE (see Figure 1), separate analysis for the groups confirmed that

Prime Lexicality was not significant for either the deaf (t = -0.072, p = .943) or the hearing group (t= -1.107, p = .272).

For the pseudoword targets, analysis showed a marginally significant Prime Lexicality effect (t = -1.692, p = .093) indicating that word primes induced slower responses compared to pseudoword primes. This effect was uniform for the groups indicated by the lack of significant interaction between Prime Lexicality and Group (t = -0.642, p = .52). Separate analysis for the groups verified that Prime Lexicality was significant for both the deaf (t = - 2.044, p = .045) and the hearing group (t = -2.075, p = .042).

[Figure 1 here]

Effect of reading skill: To test how differences in reading skills modulate the PLE, we included the composite measure of reading (ZRead) as a covariate to the model. Reading measures were available for 26 deaf and 27 hearing participants. Descriptive statistics for these participants are presented in Table 3.

Accuracy: Analysis of accuracy data showed no effect either for word (Prime Lexicality: z= -0.825, p= .409; Group: z = -0.88, p= .379; Zread: z = 1.167, p= .243, Prime Lexicality X Group: z = 0.3, p = .764, Prime Lexicality X ZRead: z = -0.595, p = .552, Group x ZRead: z = 0.925, p = .355, Prime Lexicality X Group X ZRead: z = 0.284, p = .776) or for pseudoword targets (Prime Lexicality: z= -0.03, p=.976; Group: z = -1.526, p = .127, Zread: z = 1.109, p= .267, Prime Lexicality X Group: z = 0.023, p = .982, Prime Lexicality X ZRead: z = 1.013, p = .311, Group x ZRead: z = 1.058, p = .29, Prime Lexicality X Group X ZRead: z = -0.453, p = .651).

Reaction times: For word targets, analysis showed a three-way interaction between Group X Prime Lexicality X ZRead (t = 2.849, p = .004). Separate analysis for the groups revealed that the deaf group showed a Prime Lexicality X ZRead interaction (t = 2.156, p = .031) indicating that higher scores on the reading skills tasks were associated with less PLE. The hearing group also showed a significant Prime Lexicality X ZRead interaction (t = -2.049, p = .041), but the direction of effect was different; those hearing participants who scored higher on the reading skills tasks showed greater PLE. For pseudoword targets, there was no modulating effect of reading skill revealed by the lack of significant interactions (Prime Lexicality X ZRead: t = 0.525, p = .599, Group X ZRead: t = 0.353, p = .726, Group X Prime Lexicality X ZRead: t = -0.597, p = .55).

[Table 3 here]

Discussion

In the current study, we investigated whether well-specified orthographic representations are available in the absence of well-specified phonological representations as in the case of deaf readers. Our results demonstrate that deaf readers with limited access to phonology show no evidence for PLE. However, the hearing control participants matched on age and education level also did not show PLE. The effect was differently modulated by reading skill for the deaf and the hearing readers; better hearing readers showed PLE; however, better deaf readers did not.

In contrast to the results of Meade et al. (2019) according to which deaf readers clearly show PLE (25 ms) comparable to hearing readers (19 ms), in our study the deaf readers showed almost zero PLE (5 ms) while the hearing readers showed a (non-significant) PLE similar in magnitude (19 ms) to the hearing readers of Meade and colleagues. Contrary to what we expected, hearing participants exhibited reduced competition between lexical representations.

Previous studies (Andrews & Hersch, 2010; Andrews & Lo, 2012; Davis & Lupker, 2006; Forster & Veres, 1998; Nakayama et al., 2008; Segui & Grainger, 1990) investigated mainly university students who represent the high end of the reading skill spectrum and thus are not really representative of the whole population. The results of our diverse hearing sample might suggest that lexical competition is not a universal mechanism possessed by all readers but is only the privilege of good readers. Indeed, our pilot study using the same paradigm and stimulus list with 35 hearing university students showed robust PLE. For word targets, RT data showed a significant main effect of Prime lexicality (t = -2.223, p=.0296, PLE: -32.3 ms) suggesting that word primes induced slower responses compared to pseudoword primes. For pseudoword targets, the effect of Prime lexicality did not reach significance (t=-1.419, p=.16, PLE: -13.4 ms). This argument is in line with the results of Andrews and Hersch (2010). The researchers found that even in highly competent readers there are substantial individual differences in reading and spelling skills and these differences are associated with lexical competition. Similarly, in our hearing control sample, reading skill was associated with the appearance of the PLE. More skilled hearing readers showed PLE, while less skilled hearing readers did not.

Although the hearing readers in our experiment numerically showed a PLE similar in magnitude to the hearing readers of Meade and colleagues, the deaf group in our study showed almost no PLE. It is possible that the deaf participants of Meade et al. (2019) were better readers compared to our deaf participants; however, in our study reading skills modulated the PLE differently for the deaf and the hearing participants. While higher reading scores were associated with larger PLE for the hearing readers, better deaf readers showed a tendency for less PLE. The above results suggest that for the deaf readers, counterintuitively, lexical competition is not necessary for skilled reading.

The above finding alludes to the possibility that while differences between hearing participants are quantitative in nature, deaf readers show qualitatively different orthographic processing. According to the Qualitative Similarity Hypothesis (Paul et al., 2013) reading is similar for deaf and hearing individual, although differences can be detected in reading processes where phonological decoding is required (Andrews & Wang, 2015). Studies that investigate the neurocognitive background of reading in deaf individuals showed mixed results about the nature of differences between deaf and hearing readers.

In an ERP study, Gutierrez-Sigut et al. (2019, see also Perea et al., 2016) compared case-matched and case-mismatched identity primes in a primed lexical decision task. Case effect is thought to disappear for word targets due to top-down feedback from the lexical-semantic level, but deaf readers exhibited case effect both for word and pseudoword targets. Nonetheless, this appeared only at the behavioral level; when measured with ERP, deaf and hearing participants did not differ on how case effect modulated the evoked potentials between 150 and 250 ms, the so-called N250 component which is considered the component of orthographic processing. The authors argued although there is lexical-semantic feedback, for deaf readers it is not strong enough to modulate the reaction times. However, correlational analysis revealed that better deaf readers did show less case effect indicating stronger top-down feedback for them. The above finding suggests that although differences exist in the orthographic processing of deaf and hearing readers, these differences are quantitative in nature. On the contrary, in our case greater effect was found for less skilled deaf readers which hints towards the possibility that skilled reading for deaf participants is different from that of skilled hearing readers.

Indeed, Emmorey and colleagues (2017) argued similarly when examining the role of phonology on orthographic tuning. The researchers studied the N170 ERP component – the evoked potential between 150 and 200 ms after stimulus onset – which is considered to reflect visual specialization for print over symbols. Both deaf and hearing participants showed the N170 effect; however, lateralization was different. The N170 effect is usually left-lateralized in skilled hearing readers due to phonological mapping (Maurer & Mccandliss, 2007); indeed, hearing readers with better reading skills showed smaller effect on the right-hemisphere. Interestingly, for deaf readers better reading skill was associated with larger effect on the right-hemisphere. The authors argued that optimal visual word processing is different for skilled deaf readers than for skilled hearing readers. Along the same line, we could argue that lexical competition in not a characteristic of visual word recognition of deaf readers, and in their case it is not necessary for skilled reading.

In addition, although Meade et al. (2019) found that masked neighbor priming effect was comparable in magnitude between deaf and hearing readers, the topography of the evoked potentials around 400 ms (N400 component associated with lexical-semantic processing) was different. In deaf readers, the effect was stronger over posterior sites; while in hearing readers, the effect was stronger over anterior sites. The authors argued that the anterior distribution signify competition between phonological representations, whereas the posterior distribution is due to competition between orthographic representations. This also hints toward that skilled reading in deaf adults is qualitatively different from skilled reading in hearing adults.

Based on the above findings, we argue that lexical competition emerges partly on the phonological level due to co-activated phonological representations. Indeed, there is some evidence that phonology contributes to orthographic priming (Elsherif et al., 2019; Welcome & Trammel, 2017). Frisson and colleagues (2014) demonstrated that both orthographic and phonological overlap contributes to neighbor priming, and their joint effect produced the greatest priming effect. This would imply that for hearing readers PLE is due to competition between both phonological and orthographic representations. It is possible that our hearing control group varied on phonological skills and this resulted in the reduced PLE. Unfortunately we did not measure phonological skill; therefore, the present study cannot provide evidence for or against this argument. For deaf readers, competition should occur only between the orthographic representations resulting in smaller PLE. This was exactly the case in our study. However, the results of Meade et al. (2019) suggest that competition between orthographic representations alone is enough to produce PLE.

The above discrepancy might be explained in the framework of the dual-route model of orthographic processing (Grainger & Ziegler, 2011). The coarse-grained route which provides fast access to semantics works similarly for deaf and hearing readers as suggested by the results of Fariña et al. (2017) and Meade et al. (2020). However, the fine-grained route which provides precise position encoding and is associated with sublexical phonology does differ between skilled deaf and hearing readers. As phonological access of deaf individuals is restricted, precise letter encoding is probably not achieved through grapheme-phoneme mapping but some other processes as suggested by researches exploring Qualitative Similarity Hypothesis (Andrews & Wang, 2015).

One such possibility is fingerspelling (Easterbrooks et al., 2015; Stone et al., 2015). While American Sign Language (ASL) uses a one-handed fingerspelling which is an integral part of signing frequently used for name signs, loan signs, initialized signs (Padden, 1998), fingerspelling[6] is not widespread in Hungary, it is mainly used for clarifying proper names by spelling the initials accompanied by mouthing (Lancz & Berbeco, 1999). If it is fingerspelling that effectively helps deaf children to establish precise orthographic representations as suggested by Stone et al. (2015), the different degree of fingerspelling use could explain the difference between our results and the result of Meade et al. (2019). It is possible that extensive experience with fingerspelling provided a way for the deaf participants of Meade et al. (2019) to establish orthographic representations strong enough to compensate the absence of the phonological system and produce PLE via orthographic competition alone. Future research should explicitly test the relationship between fingerspelling use and lexical competition in deaf readers.

In addition, we should also consider that many deaf individuals use both sign language and spoken language so that our participants are bilingual with different proficiency in spoken and signed Hungarian. However, their case is special in the sense that sign languages do not have written form while the Hungarian alphabet maps onto the Hungarian spoken language to which they have limited access. Consequently reading for deaf individuals can be regarded as reading in a second language (L2) where the script of the L2 is different from the script of the first language (L1). Nakayama and Lupker (2018) showed that different-script bilingual readers do not engage in lexical competition (see also Qiao & Forster, 2017). Although Japanese readers show PLE when reading in their L1 (Nakayama et al., 2014; Nakayama et al., 2011), bilingual Japanese-English readers do not exhibit PLE when reading in their L2 (Nakayama & Lupker, 2018). The researchers also found that lack of lexical competition in not related to language proficiency.

This is in line with our results that reading proficiency did not resulted in larger PLE for the deaf participants. It is possible that deaf readers co-activate sign language representations during reading (see for evidence Meade et al., 2017; Morford et al., 2011). Then the outcome of a priming task is modulated by the relationship between sign language lexical items; therefore, skilled deaf readers who automatically co-activate sign language representations will show inhibition[7] for form related sign pairs. On the other hand, less skilled deaf readers would use only orthographic information which can lead to smaller PLE effect. Future experiments might compare deaf readers with bilingual (preferably hearing signer) readers to disentangle the effects of sign language usage, orthographic and phonological processes.

Our study shows another surprising result: PLE for the pseudoword targets. Since pseudowords do not have lexical representations, the effect of word and pseudoword primes on pseudoword targets should be indistinguishable from each other. Usually this is the case (Davis & Lupker, 2006; Forster & Veres, 1998); however, Nakayama and colleagues (Nakayama & Lupker, 2018; Nakayama et al., 2014, 2011) found differential effect of prime lexicality on pseudoword targets.

In our study, substantial difference was found between the word and pseudoword primes. This probably does not result from our paradigm, as our unpublished data from hearing university students showed no significant PLE for pseudoword targets. Actually the different groups showed quite different pattern of result for the word and pseudoword targets. PLE was great (-32 ms) for the word targets and small and nonsignificant (-13 ms) for the pseudoword targets in the hearing university sample. In the deaf group, however, PLE was close to zero (-5 ms) for the word targets but greater (-19 ms) for the pseudoword targets. The hearing control group was in between showing a medium but nonsignificant PLE (-18 ms) for the word targets and a bit smaller albeit significant PLE (-15 ms) for the pseudoword targets. PLE for word versus pseudoword targets is most likely the result of different processes used to accept words and reject pseudoword in the lexical decision task (Meade et al., 2019). When rejecting a pseudoword, participants have to suppress the activated word prime (and its co-activated neighbors) in order to correctly respond. The above finding signifies increased difficulty for deaf (and some hearing) participants to reject pseudowords once the word prime is processed and its representation is activated. Future work could directly test under what task demands and circumstances does PLE occur for pseudoword targets.

Limitations and IMPLICATIONS

One limitation of our study is that we did not measure phonological skill of the participants. The control group might had poor phonological skills and this resulted in reduced PLE. Therefore, it is possible that the effect of reading skill in the study is mediated via phonological skills. If PLE is driven by phonology, hearing readers with good phonological skills should exhibit greater effect as suggested by the results of Welcome and Trammel (2017). Moreover, deaf readers with better phonological skills should also exhibit PLE. This would support the Qualitative Similarity Hypothesis (Paul et al., 2013) and imply that limited phonological access is behind the less precise lexical representations in deaf readers, and education should emphasize practices that promote phonological processes. However, if deaf readers do not show PLE regardless of phonological skills, results would support qualitative differences between deaf and hearing readers and alternative literacy instruction should be developed to improve reading skills. Our results cannot provide evidence for or against this case; however, Meade et al. (2019) reported that although deaf participants scored lower on phonological awareness test, they showed similar magnitude of PLE compared to the hearing controls which is against the possible effect of phonological skills.

Second, we did not measure sign language skills. From our results it seems that deaf readers do not engage in lexical competition. However, we cannot exclude the possibility that they engage in lexical competition but competition is between the lexical representations of signs. Examining the relationship between fingerspelling or sign language use and lexical competition could further inform the Qualitative Similarity Hypothesis (Paul et al., 2013). If deaf readers show lexical competition due to competition between co-activated fingerspelling or signs, the Qualitative Similarity Hypothesis could be regarded as modality independent where common reading processes operate on visual phonological elements (sublexical elements of signs, fingerspelling) instead of sound based phonological units. This would also imply that effective reading instruction for signing deaf children should focus on establishing well-specified visual sublexical (sign language or fingerspelling) representations to aid the formation of high-quality lexical representations.

Third, the effect of reading skills on lexical competition should be investigated further. In our sample, better reading skills were associated with greater PLE but only for the hearing readers. However, deaf participants with better reading skills showed no lexical competition. Our results, however, should be interpreted with caution as our experiment used only a restricted set of reading skill measures. Future work should further replicate the effect of reading skill by using more comprehensive and standardized tests of individual differences and possibly incorporate the above discussed phonological and sign language skill measures, as well.

Conclusion

In sum, we found that hearing participants showed PLE only after controlling for reading skills, which highlights the importance of reading skills in the development of high-quality lexical representations. In addition, deaf readers showed no PLE, which suggests that lexical competition does not emerge without access to phonology. Furthermore, reading skill was inversely related to the PLE, better deaf readers showed less effect. Therefore, lexical competition characterizes skilled reading for hearing individuals but probably not for deaf readers.

Notes:

[1] Except for one participant who was profoundly deaf for one ear and had 60 dB hearing threshold on the other.

[2] Hearing threshold, age of hearing loss, and the presence of additional disabilities were assessed through self-report.

[3] A deaf advisor rated a list of words, from which we used only those that were rated as known by the deaf population in general.

[4] In addition, the original stimulus list contained 24 three-letter long word pairs. However, word length is known to be a factor in PLE due to the increased number of neighbors for short words, less degree of orthographic overlap between prime and target (Andrews & Hersch, 2010; Davis & Lupker, 2006) and most studies used 4, 5, 6 letter or even longer words. Therefore, we excluded the 3 letter words from our analysis as their primes are less effective in producing PLE.

[5] Analysis always started with the maximal model: invRT ~ Prime Lexicality * Group + (1+ Prime Lexicality |subj) + (1|item); however, it rarely converged because random-effect variance estimate for Prime Lexicality was nearly zero and correlation was exactly 1. Dropping the random slope or the random intercept until convergence was achieved resulted in different model structure for the different groups (deaf/hearing) or different targets (word/pseudoword). To increase comparability across targets and groups, we consistently used the minimal model. Results of the minimal and maximal models showed the same pattern of results.

[6] In Hungary two manual alphabets are in use: fingerspelling and phono-mimics. The first one is similar to the fingerspelling system of ASL; the second one originates from special education where it is used to help to learn speech sounds.

[7] For sign pairs, whether inhibition or facilitation occurs depends on several factors such as the type of neighbor ('location' vs 'handshape'), extent of overlap between signs, and probably neighbor density. For further information on inhibitory and facilitatory processes in sign languages see e.g. Caselli & Cohen-Goldberg, 2014; Meade et al., 2018)

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Tables

Table 1. Descriptive statistics for the background measures of the deaf and hearing participants comparing the means

	Deaf (n = 28)		Hearing (n = 28)		Statistics
Variable	Mean (SD)	Range	Mean (SD)	Range	p-value
Age	44.89 (13.89)	20-72	44.96 (14.04)	21-71	.985
Years spent in school	16.32 (4.97)	10-27	15.21 (2.64)	12-20	.304
Raven IQ	50.43 (5.57)	36-59	53.0 (4.16)	40-59	.056
Counting span	3.39 (0.79)	2-5	3.99 (1.20)	2.33-6	< .05
Semantic Fluency	35.68 (6.96)	25-52	44.07 (7.05)	29-60	< .001
Spelling*	24.31 (3.34)	18-30	22.93 (3.97)	16-30	.176
Sentence verification*	37.15 (2.92)	26-40	39.04 (1.02)	36-40	< .01
Proofreading*	40.85 (1.57)	37-42	41.56 (0.97)	38-42	.056

Note. SD = standard deviation. *Background measures were missing for two deaf and one hearing participants. If normality assumption was violated, we used the Mann-Whitney signed rank test instead of the T-test.

Table 2. Raw lexical decision reaction times (RTs in milliseconds) means, standard deviations (in parenthesis), and mean accuracy percentages for word and pseudoword targets.

		Target lexicality			
		Deaf (n = 28)		**Hearing (n = 28)**	
Prime lexicality		Word target	Pseudoword target	Word target	Pseudoword target
word	RT	720.184 (184.39)	861.024 (242.29)	725.601 (178.47)	806.108 (177.35)
	Accuracy	95.48% (7.54)	93.75% (14.83)	97.64% (4.08)	97.90% (4.58)
pseudoword	RT	714.703 (183.5)	841.912 (240.85)	707.720 (164.5)	790.771 (196.16)
	Accuracy	96.44% (6.03)	94.25% (10.05)	98.35% (2.66)	98.14% (5.52)
PLE		-5.48	-19.11	-17.88	-15.34

Note. Prime Lexicality effect (PLE) was calculated as the difference of RTs for pseudoword (pw) and word (w) primes (pw-w). Thus, negative values for word targets indicate lexical competition.

Table 3. Descriptive statistics for the background measures of those deaf and hearing participants who completed all reading skills measures

	Deaf (n = 26)		Hearing (n = 27)		Statistics
Variable	Mean (SD)	Range	Mean (SD)	Range	p-value
Age	44.35 (14.27)	20-72	44.48 (14.07)	21-71	.972
Years spent in school	16.35 (5.04)	10-27	15.19 (2.69)	12-20	.305
Raven IQ	50.92 (5.46)	36-59	53.07 (4.22)	40-59	.116
Counting span	3.46 (0.78)	2-5	4.05 (1.18)	2.67-6	.131
Semantic Fluency	35.85 (7.19)	25-52	43.81 (7.05)	29-60	<.001
Spelling	24.31 (3.34)	18-30	22.93 (3.97)	16-30	.176
Sentence verification	37.15 (2.92)	26-40	39.04 (1.02)	36-40	.004
Proofreading	40.85 (1.57)	37-42	41.56 (0.97)	38-42	.055

Note. SD = standard deviation.

Appendix:

Table A1. Target words and pseudowords and the primes used in the experiments. English translation of words are provided in brackets.

Word Target	**Word neighbor**	**Pseudoword neighbor**
BORZ [badger]	bors [pepper]	borv
BÉKA [frog]	béke [peace]	békű
FOLT [stain]	bolt [shop]	rolt
CSÍK [stripe]	csók [kiss]	csák
DOMB [hill]	gomb [button]	pomb
KAPA [hoe]	kaja [food]	kara
KUKA [wastebin]	kupa [cup]	kuma
GYÁR [factory]	nyár [summer]	tyár
ÓLOM [lead]	álom [dream]	ulom
SZÍN [color]	szív [heart]	szís
TÚRÓ [cottage cheese]	túra [trip]	túrú
ÜREG [hollow]	üveg [glass]	üdeg
ILLAT [smell]	állat [animal]	éllat
GOLYÓ [bullet]	folyó [river]	dolyó
GOMBA [mushroom]	bomba [bomb]	fomba
HINTA [swing]	hintó [carriage]	hintű
MAJOM [monkey]	malom [mill]	matom
MÉREG [scale]	méret [size]	méres
SÁSKA [mantis]	táska [bag]	máska

SZENT [saint]	szint [level]	szant
TEREP [terrain]	terem [room]	terej
TORTA [cake]	torna [gymnastics]	torva
VIRÁG [flower]	világ [world]	vikág
VONAT [train]	vonal [line]	vonar
VARÁZS [magic]	garázs [garage]	harázs
DISZKÓ [disco]	disznó [pig]	diszmó
BABONA [superstition]	gabona [grain]	dabona
HALLÁS [hearing]	vallás [religion]	ballás
HENGER [cylinder]	tenger [sea]	fenger
FECSKE [swallow]	kecske [goat]	lecske
SIRÁLY [seagull]	király [king]	pirály
POSTÁS [postman]	portás [doorman]	poktás
SZALMA [straw]	szakma [profession]	szatma
SZÖVET [weave]	szöveg [text]	szöver
TÁNYÉR [plate]	tenyér [palm]	tinyér
UTALÁS [reference]	utazás [travel]	utavás

Pseudoword target	**Word neighbor**	**Pseudoword neighbor**
MÁDA	láda [chest]	váda
FOTŐ	fotó [photo]	fota
NANG	hang [voice]	zang
INYA	anya [mother]	onya
TERT	test [body]	teft

KADU	kapu [gate]	kafu
HÁKÓ	háló [net]	háró
AZTÓ	ajtó [door]	astó
TÁRC	társ [partner]	tárk
MESÜ	mese [tale]	mező
NYÚT	nyúl [rabbit]	nyúh
DUGÉ	dugó [cork]	duga
ÉRANY	arany [gold]	őrany
NÉRÉS	kérés [request]	pérés
CELET	kelet [east]	pelet
TÖTÉL	kötél [rope]	fötél
LASÁS	lakás [apartment]	latás
IRENY	irány [direction]	üröny
MOLOR	motor [engine]	mozor
MINGA	minta [pattern]	minda
BÁNYO	bánya [mine]	bányú
MÁJUT	május [May]	májuv
VERÉN	veréb [sparrow]	verét
HATÁN	határ [border]	hatát
PERMÉK	termék [product]	sermék
NENYÉR	kenyér [bread]	penyér
DARACK	barack [peach]	varack
KARÁZS	darázs [wasp]	narázs

HAMERA	kamera [camera]	tamera
TÖLÉNY	bölény [bison]	rölény
ZÖNÉSZ	zenész [musician]	zinész
GYOLOR	gyomor [stomach]	gyosor
HARÁSZ	halász [fisherman]	hanász
CSAKÁN	csalán [nettle]	csafán
SZIKSA	szikla [cliff]	szikma
KOROVA	korona [crown]	korota