Reading and Writing (2020) 33:2073–2095
https://doi.org/10.1007/s11145-020-10036-2

Development of morphological priming effects in reading aloud in the biscriptal Bosnian orthography

Mirela Duranovic[1] · Melanie Gangl[2] · Sabrina Finke[2] · Senka Smajlagic[1] · Karin Landerl[2,3]

Published online: 13 March 2020

Abstract

A substantial body of research has noted morphological priming effects in visual word recognition in deep orthographies, but it is still unclear whether similar effects exist in transparent orthographies. In the present experiment, we investigated the development of morphological decomposition in visual word recognition in the phonologically highly transparentand morphologically rich Bosnian orthography by exploiting the fact that Bosnian is written in two different scripts: Everyday texts are typically presented in Latin, but all children learn and practice reading in Cyrillic script from Grade 3 on. Students in four different age groups (Grades 4, 6, 8, and university students) were asked to read aloud singular target nouns that were preceded by different primes. Three prime types were presented in Latin script: morphologically related (plural) words, morphologically unrelated, but orthographically similar words and unrelated words. We also presented the morphologically related and unrelated primes in Cyrillic, reducing the visual-orthographic overlap between prime and target. In Latin, response times were lower in the orthographic than the unrelated prime conditions and again lower in the morphologically related than the orthographically similar prime condition, irrespective of prime duration (50 and 250 ms). We did not find any evidence for interactions with grade level, suggesting that morphological decomposition is established by Grade 4. Cyrillic primes also induced significant (though smaller) morphological priming effects suggesting that morphemes are units of meaning even during early written word processing.

Keywords Morphology · Masked priming · Transparent orthography · Reading · Semantic processing · Orthographic processing

Mirela Duranovic and Melanie Gangl have contributed equally to this work.

✉ Mirela Duranovic
mirela.duranovic@bih.net.ba

Extended author information available on the last page of the article

Introduction

Competent reading requires fast and automatic recognition of individual words. Research on adults shows that efficient visual word recognition involves rapid decomposition of morphemic constituents (Amenta & Crepaldi, 2012; Rastle, Davis, & New, 2004). For instance, in a seminal study, Taft and Forster (1975) showed that in a lexical decision paradigm, rejecting nonwords consisting of existing prefixes and stems (e.g., *dejuvenate*) is harder than rejecting nonwords consisting of an existing prefix and a nonexisting stem (e.g., *depertoire*). This interference effect indicates that morphological decomposition takes place prior to lexical access as the non-existing stem in *depertoire* renders an additional check of the legitimacy of prefix-stem combination unnecessary.

While morphological processing during visual word recognition has been extensively investigated in adults, developmental mechanisms are as yet largely unclear. Although we know that from about 2 years on children apply inflectional as well as derivational morphology productively in their spoken language (Berko, 1958; Penke, 2012) and can successfully perform morphological awareness tasks at the age of seven (e.g., Kirby et al., 2012), much less is known about how automatic morphological decomposition develops during reading acquisition.

There is evidence that children as young as 7 years read morphologically derived words (e.g., *hilly*) faster and more accurately than matched monomorphemic, "pseudoderived" words (e.g., *silly*, Carlisle & Stone, 2005), indicating that they make implicit use of the morphological structure during word recognition. Similarly, across grades 1 to 8, students are more likely to complete a word fragment (e.g., H M) with a primed word when the prime is morphologically related (e.g., HARMED, HARMFUL), then when the prime is orthographically, but not semantically related (e.g., HARMONY). Morphological effects were equally large for inflected (HARMED) and derived (HARMFUL) words (Deacon, Campbell, Tamminga, & Kirby, 2010; Feldman, Rueckl, DiLiberto, Pastizzo, & Vellutino, 2002; Rabin & Deacon, 2008). Recently, Dawson, Rastle, and Ricketts (2018) replicated the morphological interference effect (Taft & Forster, 1975) in lexical decision among children and adolescents. However, while all age groups (7 years to adults) were less accurate in rejecting pseudomorphemic nonwords (e.g., *earist*) than control nonwords (e.g., *earilt*), only adults and older adolescents (16 to 17 years) also showed higher response times for pseudomorphemic than control nonwords, indicating developmental change.

A central paradigm used in many studies on morphological processing during reading is masked priming. The crucial evidence is that response times to targets (e.g., CAR) are shorter for morphologically related (e.g., *cars*) than for unrelated primes that are similar to targets on either semantic (e.g., *bus*) or orthographic (e.g., *cap*) dimensions (e.g., Beyersmann, Casalis, Ziegler, & Grainger, 2015; Beyersmann, Duñabeitia, Carreiras, Coltheart, & Castles, 2013; Beyersmann, Iakimova, Ziegler, & Cole, 2014; Crepaldi, Rastle, Coltheart, & Nickels, 2010; Diependaele, Sandra, & Grainger, 2005, 2009; Duñabeitia, Perea, & Carreiras, 2008; Longtin & Meunier, 2005). Based on this paradigm, there is a current debate whether the priming effect is form-based or meaning-based. Proponents of the form-based, morpho-orthographic segmentation view claim that initially the morphological decomposition process in visual word recognition is based solely on orthographic information, prior access to meaning. Semantic information is activated only in a later phase of visual word processing (Rastle & Davis, 2008). This hypothesis is based on the finding that against an unrelated baseline, similar priming effects were observed for pseudo-morphologically suffixed words (e.g., *corner—CORN*) and for true morphologically suffixed words, (e.g., *darkness—DARK*). *A number of studies found support for this theory, suggesting* that early morphological processing is semantically blind (Beyersmann, Castles, & Coltheart, 2011; Lavric, Clapp, & Rastle, 2007; Lavric, Elchlepp, & Rastle, 2012; Lázaro, Illera, & Sainz, 2016; Longtin & Meunier, 2005; Longtin, Segui, & Hallé, 2003; McCormick et al., 2008, 2009; Rastle, Davis, & New, 2004).

Contrarily, the second hypothesis suggests that both morpho-orthographic and morpho-semantic information affect the early processing of morphologically complex words. This view mostly rests on studies reporting a larger magnitude of true morphological priming (e.g., *darkness—DARK*) than of pseudo-morphological priming (e.g., *corner-CORN*), indicating semantic contributions during the initial decomposition of words into their morphemic constituents (e.g., Diependaele, Dunabeitia, & Keuleers, 2011; Feldman, Kostić, Gvozdenović, O'Connor, & del Prado Martín, 2012; Feldman, O'Connor, & Moscoso del Prado Martín, 2009; Feldman, Soltano, Pastizzo, & Francis, 2004).

Interestingly, there is evidence for developmental change of the basis of morphological decomposition, but findings are mixed: English children aged 7 to 10 years showed priming for true, but not for pseudosuffixed words, while older children and adults showed similar facilitation in both conditions (Beyersmann et al., 2012). Similarly, German children in Grades 2 to 5 showed target facilitation from real suffixed words (*kleidchen*—KLEID), suffixed nonwords *(kleidtum*—KLEID), and nonsuffixed nonwords *(kleidekt*—KLEID), relative to unrelated control primes (*träumerei*—KLEID). However, in contrast to adults, they did not show differences between suffixed and nonsuffixed conditions (Hasenäcker, Beyersmann, & Schröder, 2016, 2020). These findings suggest that English and German elementary school children may not (yet) make use of morpho-orthographic segmentation. On the other hand, evidence for early morpho-semantic as well as morpho-orthographic priming was reported for French (Quémart, Casalis, & Colé, 2011) and Hebrew (Schiff, Raveh, & Fighel, 2012).

Obviously, this inconsistency may be related to differences between the languages and orthographies investigated. Most studies on morphological processing in children have been obtained for English and French, deep orthographies with complex and often opaque correspondences between graphemes and phonemes. In deep orthographies readers employ larger grain size units (Prior, 2012) and knowledge of morphemes is important for reading acquisition (Verhoeven & Perfetti, 2003), therefore morphological effects are not unexpected. Another language feature that is likely to be relevant is morphological structure. Particularly English morphology is not extensively productive compared to other languages (Meunier & Segui, 2002).

Effects of morphological processing during visual word recognition have also been demonstrated for a range of other languages including German (Hasenäcker et al., 2016), Dutch (Perdijk, Schreuder, Baayen, & Verhoeven, 2012); Brasilian Portuguese (De Oliveira & Reis Justi, 2017), Spanish (Lázaro, Camacho, & Burani, 2013), and Italian (Burani et al., 2002). While these languages vary largely in grapheme-phoneme consistency as well as morphological complexity, each of them has homophonic word spellings which sound the same and can only be differentiated based on morpho-semantic knowledge (e.g., Engl.: to—two—too; German: viel—fiel [engl.: many—fell], Italian: lago—l´ago [engl: lake—nail]. This is not the case for Bosnian, which is one of the few orthographies with a one-to-one relationship between letters and sounds. The high transparency of Bosnian orthography (Duranovic, 2017) may lead to the assumption that morphology does not have a strong influence on reading because reliance on grapheme-phoneme correspondence rules is sufficient (Defior, Martos, & Herrera, 2008). However, Bosnian is a morphologically rich language, particularly with respect to inflectional morphology. Changes in word forms are typically generated by adding monosyllabic suffixes (consisting of a vowel only or a vowel-consonant combination (Lukatela, Mandić, Gligorijević, Kostić, & Savić, 1978). Almost 800 different suffixes are available for word formation (Cedic, 2001). Lukatela et al. (1978) postulated that nouns are not represented in the lexicon with their grammatical cases. Instead, root morphemes for all nouns, as well as the small set of inflectional morphemes, are stored in the lexicon. Appropriate combinations of a root and its inflections are determined by separately stored syntactic rules. We argue that parsing a word into morphemic units would be of great value for languages with such a rich morphology. In a language with a complex morphological system, where every word can have numerous inflectional forms, the representation of each word as a whole unit would be cognitively extremely costly and recognition of words would be impossible if a particular inflectional form is encountered for the first time. Therefore, decomposing a word into its constituent morphemes would be useful (Lehtonen & Bryant, 2005). Thus, the present study aims to investigate whether morphological effects on word reading may be observed in Bosnian language with its highly transparent orthography and rich morphology, and if so, how such effects might change across different levels of age and reading experience.

Another characteristic of reading acquisition in Bosnian language is also particularly interesting in the context of morphological priming effects. Conflicting evidence regarding morpho-orthographic and morpho-semantic decomposition in the early stages of visual word processing may partly be due to the high orthographic similarity between prime and target words. Although target words are usually presented in upper case letters in order to make them less similar to the lower case prime, there is still considerable overlap for many letters (see, for example the first two letters in *corner—CORN*). Bosnian language is an interesting test case here, as two different alphabetic writing systems are used in Bosnia and Herzegovina, which have only minimal visual overlap: Latin is the more frequent writing system, which is taught in Grade 1 and is mostly used in everyday contexts. However, from Grade 3 on all children are taught the Cyrillic alphabet and practice reading and spelling throughout their school career. By presenting the very same set of primes in Latin as well as Cyrillic, we aimed to reduce orthographic overlap between (Cyrillic) primes and (Latin) targets to a minimum.

In our masked priming experiment, we presented each target with Latin as well as Cyrillic primes. Target words presented in Latin (the more familiar orthography) were preceded by either (a) a suffixed word prime in Latin (e.g., žena-žene), (b) the same suffixed word prime in Cyrillic (e.g., žena- жене), (c) an unrelated prime in Latin (e.g., žena–igra), or (d) the same unrelated prime in Cyrillic (e.g., žena– игра). If morphological units are accessed during word reading in the highly transparent Bosnian orthography, we expected to see significant facilitation of morphological compared to unrelated primes. If early morphological processing during visual word recognition is semantically blind (e.g., Longtin & Meunier, 2005; Rastle et al., 2004), we would expect no significant effect of morphological priming for suffixed word primes in Cyrillic, as there is no orthographic overlap between prime and target. If, however, semantic information has an influence on the initial decomposition of words into morphemic constituents (e.g., Diependaele et al., 2011; Feldman et al., 2004, 2009, 2012), morphological priming for suffixed word primes should be obtained in Cyrillic as well as Latin.

In order to examine developmental mechanisms of morphological decomposition, we compared priming effects in fourth-grade children who have only just mastered the grapho-phonemic code of Cyrillic, sixth- and eighth-grade children and adults with different levels of accumulated orthographic lexicon in the two scripts (Latin and Cyrillic). The priming paradigm also allows to investigate whether morphological effects occur early or late during visual word processing (Casalis et al., 2009). In order to identify the timeline of priming effects for morphologically related primes, short (50 ms) and longer (250 ms) prime durations have been used. Morphological priming effects in adults have been found even for very short Stimulus Onset Asynchronies (SOAs) of 30 to 60 ms (Frost, Kugler, Deutsch, & Forster, 2005; Rastle et al., 2004). In the present study we applied a short prime duration of 50 ms, which should be sufficient to ensure that the youngest group of 4th graders could process the prime. Especially for the primes written in the less familiar writing system of Cyrillic, it seemed important to introduce a longer prime duration of 250 ms SOA as well, which allowed us to contrast early vs. late effects.

Methods

Participants

A total of 320 participants, all native speakers of Bosnian, took part in a priming experiment. Four age groups with 40 participants each were recruited: Students of Grades 4 (27 male and 13 female), 6 (20 male and 20 female), and 8 (20 male and 20 female), from two elementary schools located in Tuzla, in the northeastern part of Bosnia and Herzegovina, and a group of students from the University of Tuzla (4 boys and 36 girls). All participants had normal or corrected-to-normal vision. The Ministry of Education of Tuzla Canton approved all study procedures. Parents gave written permission for participation of their children and university students volunteered for the study. From each age group, half of the participants performed the experiment with the 50 ms prime time, and the other half performed the experiment with the 250 ms prime time. Participant characteristics are presented in Table 1.

Participants were typically developing readers with average reading skills assessed with a 1-min word reading test (Duranovic, 2013), presenting a list of 120 familiar Bosnian words (increasing in length and difficulty) in Latin script. The raw score was the number of words read correctly in 1 min. Since we were interested in typical reading development, poor readers who performed below the 25th percentile on the Latin 1-min reading test, were not admitted to the study. In order to get an impression of participants' reading abilities in Cyrillic, the items from the Latin test were converted to Cyrillic and participants were again asked to read as many words as possible within 1 min. No norms are available for the Cyrillic test version. Still, Table 1 shows that participants had reasonable reading abilities in Cyrillic script, although the number of words read correctly was almost twice as high in Latin in the younger groups and still about 40% higher in the older age groups.

Design and stimuli

Sixty-one Bosnian nouns in singular form were selected as targets (see "Appendix"). Their mean surface frequency (the number of times that a given word appears, Lau, Rozanova, & Phillips, 2007) was 303 occurrences per 1.5 million, based on the Oslo Corpus of Bosnian Texts (1997, http://www.Tekstlab.uio.no/Bosnian/Corpus.html#cont). Thirty-one of the targets were free stems (which are existing words themselves; e.g., "*sat*") and 30 targets were bound stems (the base morpheme of the noun is not identical to any existing word, i.e. „*sob*", and the singular noun is created by adding an inflectional suffix "*sob*" + "*a*" = "*soba*"). Target words were always presented in lower case Latin letters and paired with three different primes in Latin (morphological, orthographic, and unrelated) and two different primes in Cyrillic (morphological and unrelated). In the morphological condition, primes constituted suffixed forms of the targets. For the 31 free-stem targets, plural noun primes were created by adding a suffix (e.g.,

Table 1 Number of words read correctly in 1 min for each grade group

	Grade 4		Grade 6		Grade 8		University students	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age	8.95	.36	11.06	.44	13.02	.41	20.60	1.15
One-minute reading in Latin	58.53	13.48	73.30	15.87	93.40	15.66	108.33	9.80
One-minute reading in Cyrillic	28.18	14.45	40.78	18.99	63.50	25.37	65.40	34.11

“*sat* + *i*” = “*sati*”) and for the 30 bound-stem targets plural noun primes were created by replacing the singular suffix (e.g., “*sob - a*” + “*e*” = “*sobe*”). In the orthographic condition, primes comprised words that were morphologically unrelated but orthographically similar to the targets (e.g., “*glava*” and “*glavni*”), where the target and prime shared letters within the word or they shared either the initial or the final letters (see Colombo, 1986, for similar procedures). About 70% of the orthographic primes shared three or more letters with the target. In the unrelated condition, primes comprised words that were completely unrelated to the targets (e.g., “*glava*” and “*ništa*”). However, note that in many cases, the morphological primes had a larger visual overlap with the target word than the orthographic primes due to restrictions of the lexicon. To ensure that orthographic primes provided a sufficient level of control for orthographic similarity Levenshtein distance was used for assessing the orthographic similarity of prime and target. The Levenshtein distance between two words is the minimum number of single-character edits (insertions, deletions or substitutions) required to change one word into the other (Levenshtein, 1966). As evident from Table 2, Levensthein distance was indeed somewhat higher for the orthographic than the morphological condition, and this difference was significant ($p < .001$). Not surprisingly, Levenshtein distance was also clearly higher for unrelated primes than for the two other conditions (both $ps < .001$). The three sets of Latin primes were matched pairwise for length, stem, suffix, and bigram frequency (see Table 2).

The Cyrillic prime conditions used the words of the morphological and unrelated prime conditions in Cyrillic script. As orthographic overlap for Cyrillic items was minimal, no orthographic condition was created for Cyrillic. All words had regular grapheme-phoneme correspondences.

Each participant was assigned to a prime duration condition (50 or 250 ms) and was administered all conditions (three with Latin primes and two with Cyrillic primes) in two different sessions, so each participant was presented with all priming conditions. The experiment manipulated the five priming conditions (Latin morphological, orthographic and unrelated as well as Cyrillic morphological and unrelated) as repeated measures, and the prime duration (50 ms vs. 250 ms) and age (Grades 4, 6, 8 and university students) as group factors.

Table 2 Item characteristics per condition (Latin)

	Morphological		Orthographic		Unrelated		*df*	F	*p*
	Mean	SD	Mean	SD	Mean	SD			
Number of letters	5.71	1.31	5.42	1.29	5.65	1.32	2.14	.85	.43
Stem frequency	741	685	1277	2364	1048	1203	2.45	1.79	.17
Suffix frequency	20,040	18,055	22,651	16,758	18,785	15,221	2.24	.96	.42
Bigram frequency	17,806	1412	19,402	14,416	19,778	14,390	2.68	.33	.72
Levenshtein distance score	1.36	0.18	2.63	0.20	5.26	0.20	2.00	74,352.71	< .001

Procedure

Participants were tested individually, seated approximately 40 cm in front of a monitor in a quiet room. Stimulus presentationwas controlled by PsychoPy software (Peirce, 2007; 2009). Vocal responses were recorded by a microphone fitted to each participant by means of a headset. SV-1 Voice Key was used as a device designed specifically for experiments requiring a vocal response.

Participants were told that they would see a series of hash tags (####) followed by words presented in lowercase letters. Their task was to read aloud the words as quickly and as accurately as possible. The presence of primes was not mentioned to the participants. Stimuli were presented to each participant in a different random order, following ten practice trials. Each trial started with the presentation of a forward mask (####) that remained on the screen for 500 ms. The prime in Latin or Cyrillic was then presented in lowercase letters for 50 ms or 250 ms, followed by the target (always in Latin lowercase letters) which acted as a backward mask to the prime. The target words appeared in black on a white background (12-point Arial font) and remained on the screen for 2000 ms or until participants responded, which ever happened first. Response times were measured from appearance of the target word on the screen until the voice key was triggered.

Results

Due to the high transparency of Bosnian orthography, reading accuracy was close to ceiling across age groups, with only 0.06% errors on average. Thus, reading accuracy will not be further analysed.

Response latencies were analyzed for correct responses only. During preliminary data analysis, it turned out that due to an error in pseudorandomization, participants saw some items more than once while others were not presented. We thus checked carefully to what extent this error affected data quality. It turned out that between 1773 and 2365 items (instead of the originally planned 61 items × 40 participants per age group = 2440 items) were presented per condition and age group. The minimum number of items that any participant saw in one condition was 28 (out of 61) and the minimum number of participants per age group that saw a particular item ranged from 3 to 11 (out of 20). As a sufficient number of data points was available in each condition, we proceeded with the analysis. For items that were presented more than once, only the first presentation was included.

Data inspection also indicated, that a considerable number of responses (17.5% in the 50 ms prime condition and 22.4% in the 250 ms prime condition) were shorter than 300 ms. We assume that these RTs resulted from faulty voice key responses and excluded them from analysis. We also excluded responses above 3 *SD*s of the grade level mean (0.8% of the responses for 50 ms priming time and 0.9% for 250 ms priming time). Table 3 presents the number of items per condition and age group for which RTs were available after data trimming.

Reaction times (RTs) of accurate responses were analyzed by generalized linear mixed-effect models (GLMMs) in *R* (R Core Team, 2017) using the inverse

Table 3 Number of items per condition after data timing

	Grade 4	Grade 6	Grade 8	University students
Latin				
Morphological	2241	2046	2172	2341
Orthographic	2259	2066	2189	2364
Unrelated	2186	1985	2089	2273
Cyrillic				
Morphological	2041	1773	1791	2104
Unrelated	2279	2091	2218	2365

Gaussian distribution and identity link function (Lo & Andrews, 2015). GLMMs were fitted by the *mixed* function of the *afex* package (version 0.18-0, Singmann, Bolker, Westfall, & Aust, 2016), which is based on the package *lme4* (version 1.1-14, Bates, Maechler, Bolker, & Walker, 2015). In a first model we wanted to test whether priming effects in our sample are in line with earlier studies and focused on the Latin script prime conditions only. For this analysis, we entered grade (fourth, sixth, eighth, university), prime time (50 ms, 250 ms) and condition (morphological, orthographic, unrelated) as fixed effects including interaction terms. In the second model, we directly compared priming effects for the two different scripts (Latin vs. Cyrillic) for those conditions that were presented in both scripts (morphological vs. unrelated). More specifically, grade (fourth, sixth, eighth, university), prime time (50 ms, 250 ms), script (Latin, Cyrillic) and condition (morphological, unrelated) were entered as fixed effects including interaction terms. In each model we entered subjects and items as crossed random effects for which we specified random slopes for each within-subjects and within-items factor, respectively (see Barr, Levy, Scheepers, & Tily, 2013). Note that this type of analysis controls for effects of over additivity between age groups. To achieve better convergence, we removed random correlations (Barr et al., 2013). Likelihood ratio tests were used to compute p values for all fixed effects as implemented in the *mixed* function. To decompose significant main and interaction effects post hoc contrasts were performed using the *lsmeans* package (version 2.27-61, Lenth, 2016) and the Benjamini–Hochberg method for adjusting p values (Benjamini & Hochberg, 1995).

Prime effects for Latin morphological, orthographic and unrelated prime conditions

First we fit a GLMM for Latin script prime conditions only: Grade × Prime Time × Condition (Latin: morphological, orthographic, unrelated) (see Table 4). Figure 1 presents boxplots for each grade level and priming condition. We observed significant main effects for Grade, Prime time, and Condition, and a significant interaction between Prime time and Condition. All contrasts between grade levels were significant (4th–6th: $p = .0078$; all other contrasts $p \leq .0001$) except the contrast between 8th grade and and University students ($p = .09$). Contrasts were also significant between all Latin conditions

Table 4 Results of the GLMM for Latin script prime conditions only

Effect	*Df*	χ^2	*p*
Grade	3	33.10	< .0001
Prime time	1	6.74	.009
Condition	2	91.76	< .0001
Grade × Prime time	3	1.35	.72
Grade × Condition	6	1.53	.96
Prime time × Condition	2	24.55	< .0001
Grade × Prime time × Condition	6	7.33	.29

(morphological—orthographic: $p < .0001$; morphological—unrelated: $p < .0001$; orthographic—unrelated: $p = .0001$), faster in the orthographic than in the unrelated condition, and again faster in the morphological than the orthographic as well as unrelated condition. Post hoc contrasts for the Prime time × Condition interaction showed highly significant differences between morphological and orthographic as well as unrelated conditions for both prime durations ($p < .0001$). The contrast between the orthographic and the unrelated condition was significant

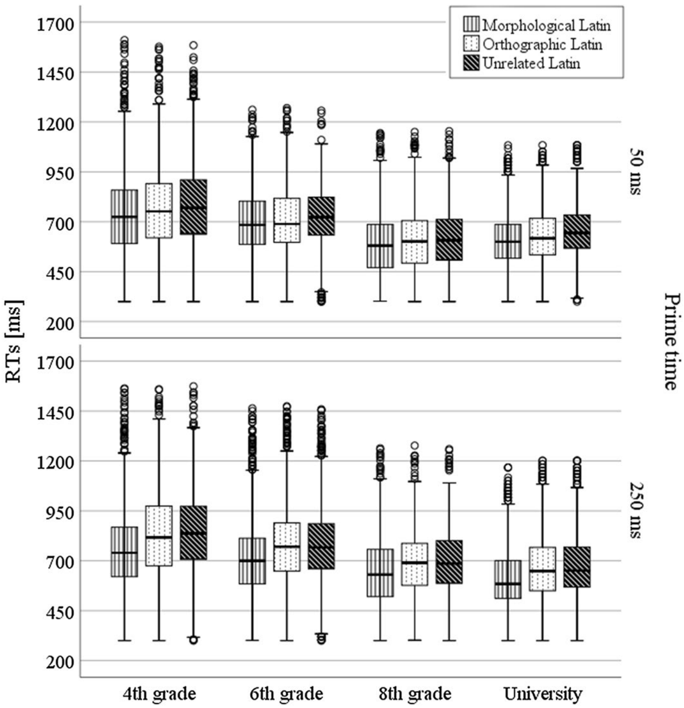

Fig. 1 Box plot of reaction times (RTs) as a function of grade, prime time and condition in Latin only. The median is represented as band inside the box. Individual points indicate outliers and stars indicate extreme outliers

at $p = .008$ in the 50 ms prime duration and marginally significant in the 250 ms prime duration ($p = .057$)..

While the differences between conditions were suggestive of morphological priming, it should be noted that priming condition was systematically confounded with visual-orthographic overlap between prime and target in our item set. This is particularly crucial for the comparison of morphological and orthographic conditions. In order to check whether the difference between these two conditions was indeed due to morphological segmentation, we ran a second GLMM model for these two conditions only, in which we introduced Levenshtein Distance as an additional factor (see Table 5). From this analysis, we excluded items with a Levenshtein Distance of 5 or 6 (comprising only 438 data points altogether), which only occurred in the orthographic condition. In this Grade × Prime Time × Condition × Levenshtein Distance model, Levenshtein Distance did neither show a significant main effect ($p = .31$), nor any interactions, while the condition effect was still highly significant ($p < .0001$).Thus, even when the visual overlap between prime and target is matched across the two conditions, participants profited more strongly from a prime that had a morphemic overlap with the target compared to a prime that was orthographically similar, but morphologically unrelated. The differences between Grade levels were again significant (all ps $< .0001$, except 4th–6th grade: $p = .031$, and 8th grade—university students: $p = .019$)..

In summary, the analysis of Latin conditions clearly confirmed earlier findings on morphological priming effects. Across all age groups investigated, RTs were always lower for target words that were preceded by a morphologically related prime compared to an unrelated prime. Importantly, while orthographic

Table 5 Results of the GLMM for Latin script, morphological and orthographic conditions only including Levenshtein distance

Effect	*Df*	χ^2	*p*
Grade	3	38.08	< .0001
Prime time	1	3.01	.08
Condition	1	17.16	< .0001
Levenshtein distance	3	3.58	.31
Grade × Prime time	3	1.92	.59
Grade × Condition	3	1.80	.61
Prime time × Condition	1	2.17	.14
Grade × Levenshtein Distance	9	5.72	.77
Prime time × Levenshtein Distance	3	3.65	.30
Condition × Levenshtein Distance	3	7.07	.07
Grade × Prime time × Condition	3	1.30	.73
Grade × Prime time × Levenshtein Distance	9	14.74	.10
Grade × Condition × Levenshtein Distance	9	7.05	.63
Prime time × Condition × Levenshtein Distance	3	1.37	.71
Grade × Prime time × Condition × Levenshtein Distance	9	14.04	.12

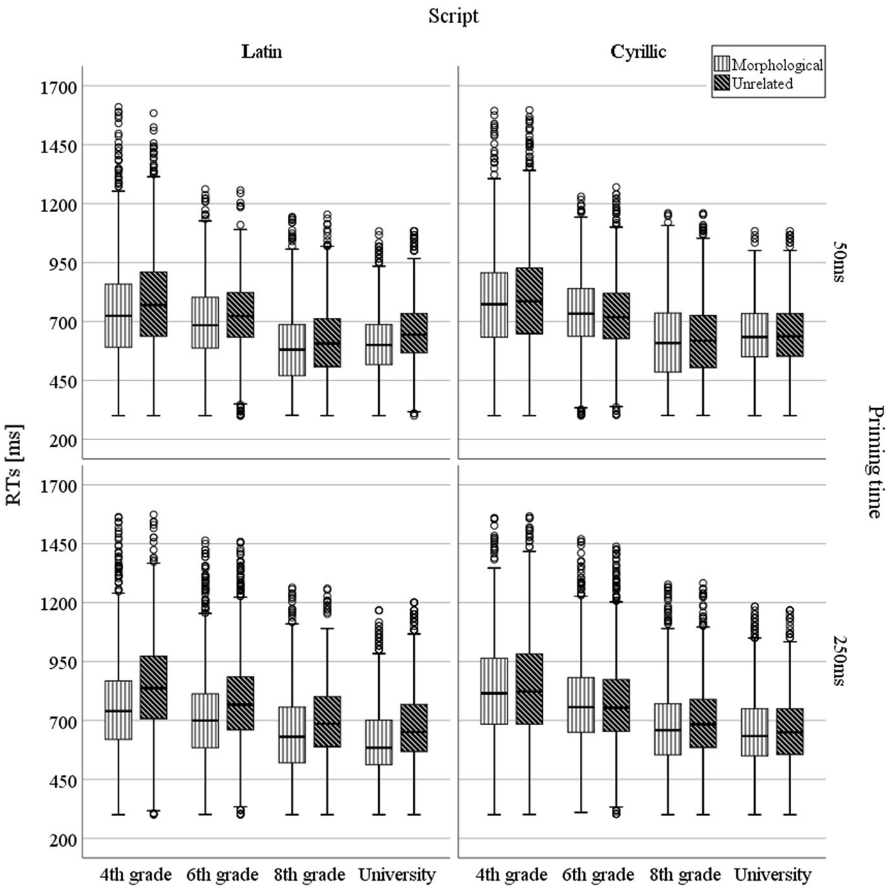

Fig. 2 Box plot of reaction times (RTs) as a function of grade, prime time, condition and script. The median is represented as band inside the box. Individual points indicate outliers and stars indicate extreme outliers

primes also induced lower RTs than unrelated primes, this effect was significantly smaller than the priming induced by morphological primes. The interaction with grade level was not significant ($p = .61$), suggesting that in the highly consistent Bosnian orthography morphological and orthographic priming effects are established by Grade 4. Even though the effect of morphological relatedness was still evident for items that were identical in orthographic overlap (as quantified by Levenshtein Distance), it is important to note, that the difference between Latin prime conditions was most likely influenced by differences in orthographic overlap. Thus, it will be interesting to see whether similar effects can be found for primes in Cyrillic script, which show the same morphological relatedness with target words, but no orthographic overlap.

Table 6 Results of the GLMM directly comparing priming effects for the two scripts

Effect	*Df*	χ^2	*p*
Grade	3	23.24	< .0001
Prime time	1	1.09	.30
Condition	1	62.64	< .0001
Script	1	30.56	< .0001
Grade × Prime time	3	0.95	.81
Grade × Condition	3	4.17	.24
Prime time × Condition	1	7.12	.008
Grade × Script	3	2.87	.41
Prime time × Script	1	0.00	> .99
Condition × Script	1	35.18	< .0001
Grade × Prime time × Condition	3	0.05	> .99
Grade × Prime time × Script	3	1.67	.64
Grade × Condition × Script	3	0.70	.87
Prime time × Condition × Script	1	6.67	.010
Grade × Prime time × Condition × Script	3	2.93	.40

Prime effects for morphological versus unrelated primes in Latin and Cyrillic

In another GLMM, we directly compared priming effects for the two scripts: Grade × Prime Time × Condition (morphological, unrelated) × Script (Latin, Cyrillic). Mean scores are presented in Fig. 2. The analysis revealed significant effects of Grade, Condition, and Script (see Table 6). Furthermore, the interactions Prime Time × Condition, Condition × Script, and Prime Time × Condition × Script were significant. All grade contrasts were significant (4th–6th: $p = .0069$; 8th—University: $p = 0029$, all other contrasts: $p < .0001$). Overall, response times in the morphological prime condition were significantly lower than in the unrelated prime condition ($p < .0001$) and response times were higher in Cyrillic compared to Latin ($p < .0001$).

The interactions with script were of particular relevance in this analysis: Although the condition effect was clearly smaller for primes in Cyrillic than in Latin (see Fig. 2), the contrast between morphological and unrelated condition was overall still significant for Cyrillic primes ($p = .0087$). However, when we ran contrasts separately per prime duration, the condition effect was only marginally significant in Cyrillic (50 ms: $p = .08$; 250 ms: $p = .06$) but still highly reliable in Latin (both ps $< .0001$).

Discussion

The main aim of the current study was to investigate morphological decomposition during visual word recognition in the highly transparent Bosnian orthography. This is important, as it might be assumed that in an orthography with highly transparent and reliable grapheme-phoneme correspondences, fast and automatic processing of larger junks like morphemes might not be needed. Nevertheless, in Latin, the script Bosnian readers are most familiar with, we found significantly lower response times for morphologically related primes than for unrelated as well as for orthographically similar primes. Thus, just like in more complex orthographies like English (e.g., Deacon, et al., 2010; Feldman, et al., 2002; Rastle, Davis, Marlsen-Wilson, & Tyler, 2000) or French (Casalis et al., 2009; Quémart, Casalis, & Colé, 2011), fluent word recognition in Bosnian entails fast and automatic decomposition of morphologically complex words.

In our study, priming effects were similarly large for short primes of only 50 ms duration and longer primes of 250 ms duration, indicating that morphological decomposition happens very early during the word recognition process (Beyersmann et al., 2011). With respect to the important issue of developmental mechanisms we observed that response times for word recognition decreased across the investigated age groups (Grades 4, 6, 8 and adults), while priming effects were mostly similar across age groups. Thus, our evidence indicates that in Bosnian orthography, morphological decomposition is well established after 4 years of formal reading instruction, while we did not find strong evidence for major developmental changes later on. It is, however, possible that our cross-sectional design was not sufficiently sensitive to identify minor developmental changes. It is also possible that a constant priming effect in relation to systematically decreasing reading times actually reflects changes in the developmental mechanisms underlying the priming effects. It will be important to further investigate developmental mechanisms of morphological decomposition longitudinally, starting with younger age groups. The main reason why we did not include younger age groups in the current study is that we wanted to exploit the fact that Bosnian language is written in two scripts, Latin and Cyrillic. While Latin is the dominant script, all children learn and practice reading in Cyrillic from Grade 3 on. Thus, we assumed that after more than 1 year of practice, fourth grade children should have sufficient reading skills to show priming effects in the less familiar writing system of Cyrillic as well. Investigating priming effects in Cyrillic is highly interesting, as it can help to differentiate between priming effects that are induced by visual-orthographic overlap and those that have a truly morpho-semantic basis. Indeed, we found a significant difference between morphological and unrelated priming conditions in both orthographies in both scripts, but this effect was clearly smaller in Cyrillic than in Latin script. When the condition effect was analysed separately per prime condition, it was actually no longer significant in Cyrillic, perhaps due to power issues.

It is quite impressive that a morphological priming effect is evident for Cyrillic primes, which do not have any visual overlap with the target, providing strong evidence that the effect is morphology based. In an earlier study with Serbian adults, Feldman et al. (2012) had actually reported similarly large facilitation effects for Latin and Cyrillic scripts. The fact that we found stronger effects for Latin than Cyrillic may be related to the larger visual overlap in the Latin compared to Cyrillic primes. We assume that it is also due to the fact that Cyrillic writing is more frequently used in Serbia than in the Federation of Bosnia and Herzegovina where the study was conducted. In order to exploit the bi-scriptal situation of Bosnian, future studies could reverse the script of primes and targets and present primes always in the more familiar Latin script, while targets could be presented in Latin as well as Cyrillic. This would ensure that participants have sufficient time to process words in the less familiar Cyrillic script. Another critical issue may be that most studies on morphological priming, including the one by Feldman et al. (2012) used a lexical decision paradigm, while we thought it more natural to let children and adults simply read targets aloud.

A number of methodological limitations should be considered when interpreting our findings. While in masked priming paradigms primes are typically presented in lower case and targets in upper case letters in order to reduce orthographic overlap, we chose to use the same (lower case) letter set in the Latin conditions. We could, however, show that morphological effects were evident when we controlled for orthographic overlap. Furthermore, visual similarity was minimal in the conditions with Cyrillic primes, and we still found evidence for morphological priming. As a matter of fact, earlier research showed that priming effects are similar in conditions with upper- and lowercase presentation of the target (Bowers, Vigiliocco, & Haan, 1998).

Second, in studies on English, pseudosuffixed items like *corner—CORN*, which are semantically unrelated, turned out to be of particular interest from a developmental perspective, as only older children and adults showed a priming effect for these items (Beyersmann et al., 2012), suggesting that with increasing reading experience similarity in form becomes more important. The rich morphological structure of Bosnian did not allow us to include such a pseudosuffixed condition as "pseudo-suffixed" words are very rare and of low frequency. They possibly exist in combination with derivation suffixes, but not with inflectional suffixes which were used in this study. And finally, as already mentioned, our decision to use a reading aloud paradigm, which seemed most natural, especially for the younger readers, may have induced unwanted noise based on articulatory processes. Lexical or semantic decision paradigms may be more adequate.

Thus, in summary, this first study on development of morphological decomposition in the biscriptal, phonologically highly transparent and morphologically rich Bosnian language provides tentative evidence that morphological priming effects are established by Grade 4 and may not undergo major developmental change later on. We attribute the minor facilitation effects of primes in Cyrillic mostly to low familiarity with this letter set in our Bosnian sample. The fact that we found significant priming in both scripts suggest that the observed effects are caused by morpho-semantic rather than morpho-orthographic overlap. Further investigation of reading acquistion in the bi-scriptal language of Bosnian is certainly worthwhile and can reveal important insights for the general theory of reading.

Appendix

Stimuli used in the experiment

Target	Suffixed word prime	Orthographic word prime	Unrelated word prime
žena	žene	želja	igra
	жене		игра
woman	women	wish	game
lice	lica	Lina	kada
	лица		када
face	faces	Lina	when
glava	glave	glavni	ništa
	главе		ништа
head	heads	main	nothing
voda	vode	vodi	ruke
	воде		руке
water	water	lead	hands
grupa	grupe	grada	misao
	групе		мисао
group	groups	city	thought
tijelo	tijela	lijepo	novine
	тијела		новине
body	bodies	nice	newspapers
srce	srca	sunce	gdje
	срца		гдје
heart	hearts	sun	where
slika	slike	velika	nalazi
	слике		налази
picture	pictures	large	findings
duša	duše	dugo	neko
	душе		неко
soul	souls	long	somebody
priča	priče	prije	mrak
	приче		мрак
story	stories	before	dark
granata	granate	granice	rješenje
grenade	гранате	borders	рјешење
	grenades		solution
majka	majke	Minka	teško
mather	мајке		тешко
	mathers	Minka	heavy
Azra	Azre	Amra	Bane
	Азре		Бане
Azra	Azras	Amra	Bane

Target	Suffixed word prime	Orthographic word prime	Unrelated word prime
djelo	djela	djeca	Bosna
	дјела		Босна
act	acts	children	Bosnia
soba	sobe	osoba	moja
	собе		моја
room	rooms	person	mine
godina	godine	govori	čovjek
	године		човјек
year	years	descourses	man
strana	strane	strah	posao
	стране		посао
side	sides	fear	job
pitanje	pitanja	stanje	vrijeme
	питања		вријеме
question	questions	condition	weather
mjesto	mjesta	umjesto	obično
	мјеста		обично
place	places	instead	usually
zemlja	zemlje	valja	kuće
	земље		куће
land	lands	roll	houses
država	države	prava	svijet
	државе		свијет
country	countries	rights	world
pismo	pisma	bismo	knjiga
	писма		књига
letter	letters	we would	book
zajednica	zajednice	najednom	identitet
	заједнице		идентитет
community	communities	suddenly	identity
društvo	društva	drugoj	potpuno
	друштва		потпуно
society	societies	another	completely
nacija	nacije	najprije	pogled
	нације		поглед
nation	nations	first of all	view
vlada	vlade	pada	radio
	владе		радио
government	governments	fall	radio
selo	sela	sebe	doba
	села		доба
village	villages	yourself	era
ulica	ulice	Alija	snage

Target	Suffixed word prime	Orthographic word prime	Unrelated word prime
	улице		снаге
street	streets	Alija	forces
zlo	zla	vrlo	kola
	зла		кола
evil	evils	jolly	car
istina	istine	istom	dječak
truth	истине		дјечак
	truths	the same	boy
noga	noge	onog	biće
	ноге		биће
leg	legs	that one	creature
stvar	stvari	strani	pamet
	ствари		памет
thing	things	extraneous	intellect
riječ	riječi	rijeke	ponovo
	ријечи		поново
word	words	rivers	again
noć	noći	novi	zato
	ноћи		зато
night	nights	new	because
vlast	vlasti	vrata	život
	власти		живот
authority	authorities	door	life
sat	sati	samo	neki
	сати		неки
watch	watches	only	certain
dan	dani	dati	puta
	дани	to give	пута
day	days		times
kraj	krajevi	kratko	uskoro
	крајеви		ускоро
end	ends	short	soon
primjer	primjeri	pripada	Sulejman
	примјери		Сулејман
example	examples	belong	Sulejman
problem	problemi	profesor	kultura
	проблеми		култура
problem	problems	professor	culture
sin	sinovi	sigurno	ponekad
	синови		понекад
son	sons	surely	once in a while
rad	radovi	ranije	hiljada
	радови		хиљада

Target	Suffixed word prime	Orthographic word prime	Unrelated word prime
work	works	earlier	thousand
proces	procesi	protiv	činjenica
	процеси		чињеница
process	processes	against	fact
prozor	prozori	prostor	Marija
	прозори		Марија
window	windows	space	Marija
stan	stanovi	stalno	pedeset
	станови		педесет
apartment	apartments	constantly	fifty
veče	večeri	Veskot	najmanje
	вечери		најмање
evening	evenings	Vescot	at least
ime	imena	imao	glas
	имена		глас
name	names	had	voice
ljubav	ljubavi	ljudi	Džafer
	љубави		Џафер
love	loves	people	Dzafer
mjesec	mjeseci	deset	slučaji
	мјесеци		случаји
month	months	ten	cases
odgovor	odgovori	odnosno	plemena
	одговори		племена
answer	answers	respectively	tribes
narod	narodi	naročito	pomoći
	народи		помоћи
nation	nations	particularly	helps
broj	brojevi	brzo	odjednom
	бројеви		одједном
number	numbers	quickly	at once
čas	časovi	čak	jedini
	часови		једини
hour	hours	even	single
niz	nizovi	nikako	dugoko
	низови		дубоко
row	rows	no way	deep
razgovor	razgovori	razlog	Sarajevo
	разговори		Сарајево
conversation	conversations	reason	Sarajevo
znak	znakovi	znati	konačno
	знакови		коначно
sign	signs	know	finally

Target	Suffixed word prime	Orthographic word prime	Unrelated word prime
sto	stolovi	stoljeća	porodica
	столови		породица
table	tables	centuries	family
miris	mirisi	mirno	nekada
	мириси		некада
smell	smells	peacefully	sometimes
red	redovi	recimo	unutar
	редови		унутар
row	rows	let's say	within
bol	bolovi	bosanski	moguće
	болови		могуħе
pain	pains	bosnian	possibly
izvor	izvori	izvan	nekako
	извори		некако
wellhead	wellheads	outside	somehow

References

Amenta, S., & Crepaldi, D. (2012). Morphological processing as we know it: An analytical review of morphological effects in visual word identification. *Frontiers in Psychology, 3,* 232.

Berko, J. (1958). The child's learning of English morphology. *Word, 14,* 150–177.

Beyersmann, E., Casalis, S., Ziegler, J., & Grainger, J. (2015). Language proficiency and morpho-orthographic segmentation. *Psychonomic Bulletin & Review, 22,* 1054–1061.

Beyersmann, E., Castles, A., & Coltheart, M. (2011). Early morphological decomposition during visual word recognition: Evidence from masked transposed-letter priming. *Psychonomic Bulletin & Review, 18,* 937–942.

Beyersmann, E., Castles, A., & Coltheart, M. (2012). Morphological processing during visual word recognition in developing readers: Evidence from masked priming. *The Quarterly Journal of Experimental Psychology, 65,* 1306–1326.

Beyersmann, E., Duñabeitia, J. A., Carreiras, M., Coltheart, M., & Castles, A. (2013). Early morphological decomposition of suffixed words: Masked-priming evidence with transposed-letter nonword primes. *Applied Psycholinguistics, 34,* 869–892.

Beyersmann, E., Iakimova, G., Ziegler, J. C., & Cole, P. (2014). Semantic processing during morphological priming: An ERP study. *Brain Research, 1579,* 45–55.

Bowers, J. S., Vigliocco, G., & Haan, R. (1998). Orthographic, phonological, and articulatory contributions to masked letter and word priming. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 1705–1719.

Burani, C., Marcolini, S., & Stella, G. (2002). How early does morpholexical reading develop in readers of a shallow orthography? *Brain and Language, 81,* 568–586.

Carlisle, J. F., & Stone, C. A. (2005). Exploring the role of morphemes in word reading. *Reading Research Quarterly, 40,* 428–449.

Casalis, S., Dusautoir, M., Colé, P., & Ducrot, S. (2009). Morphological effects in children's word reading: A priming study in fourth graders. *British Journal of Developmental Psychology, 27,* 761–766.

Cedic, I. (2001). *Osnovi gramatike bosanskog jezika (Basic grammar of Bosnian language)*. Sarajevo: Institut za jezik.

Colombo, L. (1986). Activation and inhibition with orthographically similar words. *Journal of Experimental Psychology: Human Perception and Performance, 12,* 226–234.

Crepaldi, D., Rastle, K., Coltheart, M., & Nickels, L. (2010). 'Fell' primes 'fall', but does 'bell' prime'ball'? Masked priming with irregularly-inflected primes. *Journal of Memory and Language, 63,* 83–99.
Dawson, N., Rastle, K., & Ricketts, J. (2018). Morphological effects in visual word recognition: Children, adolescents, and adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 44,* 645–654.
De Oliveira, B. S. F., & Reis Justi, F. R. (2017). Morphological priming development in Brazilian Portuguese-speaking children. *Psicologia: Reflexão e Crítica, 30,* 4.
Deacon, S. H., Campbell, E., Tamminga, M., & Kirby, J. (2010). Seeing the harm in harmed and harmful: Morphological processing by children in Grades 4, 6, and 8. *Applied Psycholinguistics, 31,* 759–775.
Defior, S., Alegria, J., Titos, R., & Martos, F. (2008). Using morphology when spelling in a shallow orthographic system: The case of Spanish. *Cognitive Development, 23,* 204–215.
Diependaele, K., Dunabeiti, J., & Keuleers, E. (2011). Fast morphological effects in first and second language word recognition. *Journal of Memory and Language, 64,* 344–358.
Diependaele, K., Sandra, D., & Grainger, J. (2005). Masked cross-modal morphological priming: Unravelling morpho-orthographic and morpho-semantic influences in early word recognition. *Language and Cognitive Processes, 20,* 75–114.
Diependaele, K., Sandra, D., & Grainger, J. (2009). Semantic transparency and masked morphological priming: The case of prefixed words. *Memory and Cognition, 37,* 895–908.
Duñabeitia, J. A., Perea, M., & Carreiras, M. (2008). Does darkness lead to happiness? Masked suffix priming effects. *Language and Cognitive Processes, 23,* 1002–1020.
Duranovic, M. (2013). Jednominutno citanje [One minute reading test]. In M. Duranovic & Z. Mrkonjic (Eds.), *Procjena disleksije [Dyslexia assessment].* Tuzla, Bosnia: Print-Com.
Duranovic, M. (2017). Spelling errors of dyslexic children in Bosnian language with transparent orthography. *Journal of Learning Disabilities, 50,* 591–601.
Feldman, L. B., Kostić, A., Gvozdenović, V., O'Connor, P. A., & del Prado Martín, F. M. (2012). Semantic similarity influences early morphological priming in Serbian: A challenge to form-then-meaning accounts of word recognition. *Psychonomic Bulletin & Review, 19,* 668–676.
Feldman, L. B., O'Connor, P. A., del Prado, M., & Martín, F. (2009). Early morphological processing is morphosemantic and not simply morpho-orthographic: A violation of form-then-meaning accounts of word recognition. *Psychonomic Bulletin & Review, 16,* 684–691.
Feldman, L. B., Rueckl, J., DiLiberto, K., Pastizzo, M., & Vellutino, F. R. (2002). Morphological analysis by child readers as revealed by the fragment completion task. *Psychonomic Bulletin & Review, 9,* 529–535.
Feldman, L. B., Soltano, E. G., Pastizzo, M. J., & Francis, S. E. (2004). What do graded effects of semantic transparency reveal about morphological processing? *Brain and Language, 90,* 17–30.
Frost, R., Kugler, T., Deutsch, A., & Forster, K. (2005). Orthographic structure versus morphological structure: Principles of lexical organization in a given 39 languages. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31,* 1293–1326.
Hasenäcker, J., Beyersmann, E., & Schröder, S. (2016). Masked morphological priming in German-speaking adults and children: Evidence from response time distributions. *Frontiers in Psychology, 7,* 929.
Hasenäcker, J., Beyersmann, E., & Schröder, S. (2020). Morphological priming in children: Disentangling the effects of school-grade and reading skill. *Scientific Studies of Reading*, pp 1–16.
Kirby, J. R., Deacon, S. H., Bowers, P. N., Izenberg, L., Wade-Woolley, L., & Parrila, R. (2012). Children's morphological awareness and reading ability. *Reading and Writing, 25,* 389–410.
Lau, E. F., Rozanova, K., & Phillips, C. (2007). Syntactic prediction and lexical surface frequency effects in sentence processing. *University of Maryland Working Papers in Linguistics, 16,* 163–200.
Lavric, A., Clapp, A., & Rastle, K. (2007). ERP evidence of morphological analysis from orthography: A masked priming study. *The Journal of Cognitive Neuroscience, 19,* 866–877.
Lavric, A., Elchlepp, H., & Rastle, K. (2012). Tracking hierarchical processing in morphological decomposition with brain potentials. *The Journalof Experimental Psychology: Human Perception and Performance, 38,* 811–816.
Lázaro, M., Camacho, L., & Burani, C. (2013). Morphological processing in reading disabled and skilled Spanish children. *Dyslexia: An International Journal of Research and Practice, 19,* 178–188.
Lázaro, M., Illera, V., & Sainz, J. (2016). The suffix priming effect in Spanish: Further evidence for an early morpho-orthographic parsing regardless of semantic content. *Quarterly Journal of Experimental Psychology, 69,* 197–208.
Lehtonen, A., & Bryant, P. (2005). Active players or just passive bystanders? The role of morphemes in spelling development in a transparent orthography. *Applied Psycholinguistics, 26,* 137–155.
Levenshtein, V. (1966). Binary codes capable of correcting deletions, insertions and reversals. *Cybernetics and Control Theory, 108,* 707–710.

Longtin, C.-M., & Meunier, F. (2005). Morphological decomposition in early visual word processing. *Journal of Memory and Language, 53,* 26–41.
Longtin, C.-M., Segui, J., & Hallé, P. A. (2003). Morphological priming without morphological relationship. *Language and Cognitive Processes, 18,* 313–334.
Lukatela, G., Mandic, Z., Gligorijevic, B., Kostic, A., Savic, M., & Turvey, M. T. (1978). Lexical decision for inflected nouns. *Language and Speech*, *21*, 166–173.
McCormick, S. F., Rastle, K., & Davis, M. H. (2008). Is there a 'fete' in 'fetish'? Effects of orthographic opacity on morpho-orthographic segmentation in visual word recognition. *Journal of Memory and Language, 58,* 307–326.
McCormick, S. F., Rastle, K., & Davis, M. H. (2009). Adore-able not adorable? Orthographic under specification studied with masked repetition priming. *European Journal of Cognitive Psychology, 21,* 813–836.
Meunier, F., & Segui, J. (2002). Cross-modal morphological priming in French. *Brain and Language, 81,* 89–102.
Oslo Corpus of Bosnian Texts. (1997). http://www.tekstlab.uio.no/Bosnian/Corpus.html. Accessed 12 March 2016.
Peirce, J. W. (2007). PsychoPy-Psychophysics software in Python. *The Journal of Neuroscience Methods, 162,* 8–13.
Peirce, J. W. (2009). Generating stimuli for neuroscience using PsychoPy. *Frontiers in Neuroinformatics, 2,* 10.
Schiff, R., Raveh, M., & Fighel, A. (2012). The development of the Hebrew mental lexicon: When morphological representations become devoid of their meaning. *Scientific Studies of Reading*, *16*, 383–403.
Penke, M. (2012). The acquisition of inflectional morphology. In A. Spencer & A. M. Zwicky (Eds.), *The handbook of morphology*. Oxford: Blackwell.
Perdijk, K., Schreuder, R., Baayen, R. H., & Verhoeven, L. (2012). Effects of morphological family size for young readers. *British Journal of Developmental Psychology, 30,* 432–445.
Prior, A. (2012). Reading in more than one language: Behavior and brain perspectives. In D. Molfese, Z. Breznitz, & O. Rubinsten (Eds.), *Reading, writing, mathematics and the brain: Listening to many voices* (pp. 131–156). Heidelberg: Springer.
Quémart, P., Casalis, S., & Colé, P. (2011). The role of form and meaning in the processing of written morphology: A priming study in French developing readers. *Journal of Experimental Child Psychology, 109,* 478–496.
Rabin, J., & Deacon, H. (2008). The representation of morphologically complex words in the developing lexicon. *Journal of Child Language, 35,* 453–465.
Rastle, K., & Davis, M. (2008). Morphological decomposition based on the analysis of orthography. *Language and Cognitive Processes*, *23*, 942–971.
Rastle, K., Davis, M. H., Marlsen-Wilson, W. D., & Tyler, L. K. (2000). Morphological and semantic effects in visual word recognition: A time-course study. *Language and Cognitive Processes, 15,* 507–537.
Rastle, K., Davis, M. H., & New, B. (2004). The broth in my brother's brothel: Morphoorthographic segmentation in visual word recognition. *Psychonomic Bulletin & Review, 11,* 1090–1098.
Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior, 14,* 638–647.
Verhoeven, L., & Perfetti, C. (2003). Introduction to this special issue: The role of morphology in learning to read. *Scientific Studies of Reading, 7,* 209–217.

Affiliations

Mirela Duranovic[1] · Melanie Gangl[2] · Sabrina Finke[2] · Senka Smajlagic[1] · Karin Landerl[2,3]

[1] Department of Speech-Language Pathology, University of Tuzla, Sarajevo, Bosnia and Herzegovina

[2] Institute of Psychology, University of Graz, Graz, Austria

[3] Department of Cognitive Science, Macquarie University, Sydney, NSW, Australia