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Syllables and inflectional morphemes in early Finnish readers: Evidence from eye movements

Tuomo Häikiö & Seppo Vainio

Department of Psychology, University of Turku

Corresponding author: Tuomo Häikiö, Department of Psychology, University of Turku, FIN-20014 Turku, Finland; E-mail: tuilha@utu.fi

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Abstract

Finnish is a language with simple syllable structure but rich morphology. It was investigated whether syllables or morphemes are preferred processing units in early reading. To this end, Finnish 1st and 2nd grade children read sentences with embedded inflected target words while their eye movements were registered. The target words were either in essive or inessive/adessive (i.e., locative) case. The target words were either non-hyphenated, or had syllable-congruent or syllable-incongruent hyphenation. For the locatives, the syllable-incongruent hyphenation coincided with the morpheme boundary but this was not the case for the essives. It was shown that the 2nd graders were slowed down by hyphenation to a larger extent than 1st graders. However, there was no slowdown in gaze duration for either age group when the syllable-incongruent hyphen was morpheme-congruent. These findings suggest that Finnish readers utilize morpheme-level information already during the 1st grade.

Keywords: syllables, morphemes, reading development

Introduction

According to several theories of reading development, early readers first encode words by using letter-size units but start to utilize larger units as their reading skills develop (e.g., Ehri, 1995; 2005; Ehri & McCormick, 1998, Frith, 1985). This same idea is captured by the multiple-route model of orthographic processing (Grainger & Ziegler, 2011); beginning readers read words on a letter-by-letter basis but afterwards develop skills that enable them to use larger chunks (such as syllables and morphemes) that can be either phonologically or orthographically mediated. While syllables (e.g., *en* and *ter* in *enter*) are the phonological building blocks of words, they do not have semantic content. On the other hand, morphemes are the smallest units of language that carry meaning (e.g., *houses* has two morphemes, *house*, and *s* denoting plural). They can be characterized as having a more direct, orthographically mediated link to semantics. As reading skills develop, readers start to utilize orthographic information to a larger extent while the use of phonological information takes the backseat (e.g., Grainger, Lété, Bertand, Dufau, & Ziegler, 2012; Tiffin-Richards & Schroeder, 2015). This does not mean that readers only use one of these routes; the system is flexible and via simultaneous activation skilled readers can recognize any word by using any of the possible routes (Grainger et al., 2012).

It has been established that both syllables and morphemes are used by children in a relatively early phase of reading (e.g., Colé, Bouton, Leuwers, Casalis, & Sprenger-Charolles, 2011; Colé, Magnan, & Grainger, 1999; Häikiö, Bertram, & Hyönä, 2011; Häikiö, Bertram, & Hyönä, 2016; Häikiö, Hyönä, & Bertram, 2015; Hasenäcker & Schroeder, 2017; Lázaro, Acha, de la Rosa, García, & Sainz, 2017; Maïonchi-Pino, Magnan, & Écalle, 2010; Quémart, Casalis, & Duncan, 2012). For instance, French 1st grade children were facilitated by a previously presented target syllable when reading a word, even though this was restricted to high-frequency syllables (Colé et al., 1999; Maïonchi-Pino, 2010). Similarly, Finnish 1st graders reading sentences were disrupted to a larger extent when the syllable structure was violated by inserting a hyphen within a syllable than when the

hyphen was between the syllables (Häikiö et al., 2015). These findings demonstrate that syllables are utilized at least to some extent already during the 1st grade. With regard to morphemes, Quémart et al. (2012) demonstrated that French 3rd graders were disrupted by the presence of morphemes in reading pseudowords for a lexical decision task. For Finnish, slow 2nd graders were facilitated by a hyphen between morphemes in compound words but this was not true for more skilled and older readers (Häikiö et al., 2011). Furthermore, Spanish 2nd graders read words faster when the suffix was of high frequency (Lázaro et al., 2017). Finally, French 2nd graders were not slowed down in word reading when there was a space either at the syllable or morpheme boundary but that they were disrupted when this space was at a non-boundary (Colé et al., 2011). These findings suggest that morphemes are utilized in reading already during the 2nd grade at least to some extent.

Even though the use of syllables and morphemes has been studied extensively, there are only a couple of studies that have directly compared them in reading. As mentioned above, Colé et al. (2011) did not find differences in word processing between the conditions separating letters in a word on basis of syllables or morphemes, suggesting flexible processing of units already during the 2nd grade. Recently, Hasenäcker & Schroeder (2017) studied German 2nd and 4th grade children who had to make a lexical decision to letter strings that contained a colon (:) either at the syllable or morpheme boundary. The 2nd graders were faster to respond when the colon was at the syllable boundary than when it was not. In the pseudoword condition, their performance was not affected by a colon at the morpheme boundary. On the contrary, the 4th graders were slower to reject the pseudowords when the colon was at the morpheme boundary. These findings suggest that younger German children primarily process words via syllables whereas older German children can utilize morphemic decomposition. This was in contrast with the findings of Colé et al. (2011), who witnessed morpheme-level processing already at 2nd grade. Hasenäcker & Schroeder (2017) argued that these differences might stem from cross-linguistic differences. They reasoned that the distinction between syllables and morphemes might be more pronounced in French than German, thus explaining the divergent

findings. At any rate, it is highly likely that there are cross-linguistic differences in the way different units are processed during early reading.

Finnish, the language of the present study, is a highly transparent language with very rich morphology. While the syllable structure is very straight-forward, any noun can in principle have as many as 2000 inflectional forms (Karlsson & Koskenniemi, 1985). While some frequent words may be read using sight vocabulary, readers need to decompose vast majority of words in a language like this. While Finnish children do utilize syllable-level information in reading, they are disrupted to some extent by syllable-level hyphenation already during the 1st grade (Häikiö et al., 2015, 2016). This happens despite Finnish children being exposed to syllable-level hyphenation during early reading instruction. With regard to morphemes, Häikiö et al. (2011) demonstrated that slow 2nd graders were facilitated by morpheme-level hyphenation in compounds.

In the present study, early Finnish readers read sentences for comprehension while their eye movements were registered. While Colé et al. (2011) and Hasenäcker & Schroeder (2017) assessed processing of derived words, in the present study we will look into inflected words. To our knowledge, this is the first time the relationship of syllables and inflectional morphemes in early reading has been assessed in sentence reading. To directly compare syllables with morphemes, there were bimorphemic target words for half of which the last syllable boundary coincided with the morpheme boundary and for the other half it did not. More precisely, in the essive case (marked with the suffix *–na/-nä*), the last syllable boundary is always also the morpheme boundary (e.g., *ky-nä-nä*, 'as pen'). On the contrary, for example, in the inessive case, the first letter of the morpheme suffix *–ssa* ('in something') is part of the previous syllable. For instance, in word *kynässä*, 'in pen', there are syllables *ky*, *näs*, and *sä*, but the morphemes are *kynä*, and *ssä*. This division was used in order to disentangle syllable-level and morpheme-level information; in addition to the non-hyphenated control condition (e.g., *kynä*, 'pen'), we used either syllable-congruent (e.g., *ky-nä-nä*) or syllable-incongruent hyphenation (e.g., *ky-nän-ä*). When the syllable and morpheme boundaries did not

coincide (e.g., *ky-nä-ssä*), the syllable-incongruent hyphenation was morpheme-congruent. If early readers prefer syllable-level information to morpheme-level information, they should be disrupted to a larger extent by syllable-incongruent but morpheme-congruent hyphenation. If, on the other hand, children already prefer morpheme-level information to syllable-level information, they should not be disrupted by syllable-incongruent but morpheme-congruent hyphenation.

Method

Participants

Thirty monolingual 1st graders (15 boys, on average 7;10 years, range 7;4-8;4) and 30 monolingual 2nd graders (13 boys, on average 8;10 years, range 8;4-9;4) were recruited from a Finnish elementary school. They had received approx. 8 months or 1 year 8 months of formal reading instruction (1st and 2nd graders, respectively). All participants had normal or corrected-to-normal vision. Written permission from children's parents was acquired prior to the experiment. The participants received candy or stickers as reward for participation.

Apparatus

Eye movements were recorded monocularly with a table-mounted model of Eyelink 1000+ (SR Research, Canada) with 1000 Hz sampling rate. A chin-and-forehead rest was used to minimize head movements. The texts were presented on a 24-inch BenQ XL2420Z computer screen (refresh rate of 100 Hz, resolution 1920*1080).

Materials

Fifty-six words were selected from a pool of potential target words for which 21 staff members at the department of Psychology in the University of Turku had rated the age of acquisition (AoA) and familiarity of the nominative forms with a paper-and-pencil test. AoA had been rated on a 7-point

scale ("At what age did you learn the word?"; 1 = 0-2 years, 2 = 3-4 years, 3 = 5-6 years, 4 = 7-8 years, 5 = 9-10 years, 6 = 11-12 years, 7 > 12 years). Average AoA ratings for each word were calculated on basis of the individual ratings. Only words with a maximum average 4 were considered for inclusion in the study. Familiarity had been rated on a 5-point scale ("How often do you encounter or use the word?"; ranging from "very seldom" to "very often"). The selected words were early acquired bisyllabic or trisyllabic monomorphemic words (average word length 5.46 characters, range 4-7 characters; average AoA rating 2.45, range 1.33-3.83).

Since each participant would see each word only once (i.e., half of the experimental material), the words were divided into two groups with matched word length, AoA, and familiarity so that each word had a matching pair in the other group, in order to make sure that for each word seen in one condition there was a matched word for the other condition. The target words were embedded in sentences. Two sentences were created for each target word, one in which the target word was in essive case (*-na/-nä*, 'as something'), and another in which the target word was either in inessive (*-ssa/-ssä*, 'in something') or adessive (*-lla/-llä*, 'on something' or 'with something') case (dubbed the locative case in the following). The inessive case was chosen as in Finnish it is the only case where the morpheme and syllable boundaries coincide consistently. In contrast, inessive and adessive were chosen as the morpheme and syllable boundaries never coincide in these cases. It needs to be noted that inessives are considerably more frequent than essives, not only in the newspaper corpus (in our database of 22.7 million tokens (Laine & Virtanen, 1999), 5.1% of the words are in the inessive case, and 2.3% in the essive case), but also in previous Finnish child corpus analyses for both input and output (e.g., Kirjavainen & Lieven, 2011). For this reason, we also used adessives, which are somewhat more frequent (3.4% in our corpus) than essives but the difference is not as pronounced as for inessives. When inessives and adessives were treated separately in the analyses, the pattern of the results was similar to the analyses presented here. Therefore, we have collapsed the two locative cases into one. For each word pair, the sentences were identical up to word N+1 (see Table 1). Since the

essives and locatives convey different meanings, sentence frames differed between the cases (see Table 2). The target word never appeared in the beginning or the end of the sentence. In total, there were 56 essive, 28 inessive, and 28 adessive sentences. Eight Turku University employees rated the naturalness of the sentences on a 7-point Likert scale. On average, the sentences were rated quite natural (on average 5.85, range 3.38-6.88). The locative sentences (6.45) were rated as more natural than the essive sentences (5.27), $p < .001$. This is related to locatives being more frequent than essives.

Next to the non-hyphenated control sentences, two hyphenated versions of the sentences were created, one with syllable-congruent hyphenation throughout the sentence, and another where the hyphenation was syllable-congruent throughout the sentence apart from the target word, in which there was one syllable-incongruent hyphen. In the essive case, the last hyphen was moved one character space further (e.g. *ky-nä-nä -> ky-nän-ä*, 'as a pen') so that the first two or three syllables formed a proper word (a genitive form). In the locative case, the last hyphen was moved one character space earlier (e.g. *ky-näs-sä -> ky-nä-ssä*, 'in pen') so that the first two or three syllables formed the stem of the word.

The sentences were distributed on three lists so that every third participant read a total of 20 control, 18 syllable-congruent, and 18 syllable-incongruent sentences, another third read 18 control, 20 syllable-congruent, and 18 syllable-incongruent sentences, and the rest read 18 control, 18 syllable-congruent, and 20 syllable-incongruent sentences. Every second participant saw the first word in the essive case, the second word in the locative case and so on, and every other participant vice versa. Each participant saw each target word only once, either in the essive (28 occurrences) or locative (28 occurrences) case. The sentences were divided into two blocks. The presentation order was counterbalanced between the participants. In both blocks, there were also 10 filler sentences. The order of the sentences was randomized within blocks. Example sentences are presented in Table 2.

[Insert Tables 1, and 2 about here.]

The sentences were presented in a proportional Calibri Light font with size 36. The hyphens were font size 18 with the baseline shift of 4 pixels upwards. With a viewing distance of 60 cm one character subtended 0.11-0.61 degrees of visual angle. The sentences were all single-line sentences with a maximum of 67 characters per line presented so that the upper-left corner of the text was approximately at the (480, 360) screen coordinate.

Procedure

Participants were instructed to read sentences for comprehension at their own pace. They were further told that after varying intervals they would get a true/false statement (15 in total) about the sentence they just read, for which they had to indicate whether it was true or false. Almost every participant responded to the statements with a minimum of 80% accuracy with the exception of two 1st graders who were excluded from the analyses due to low reading skill. Furthermore, the participants were told that some of the sentences would be hyphenated while the others not, and that there might be some errors in the text, but that they should read as good as possible despite this. The eye-tracker was calibrated using a three-point calibration grid extending over the sentence area. Before each sentence, the participant fixated on a circle at the left side of the screen, after which the sentence appeared. The experiment proper was preceded by four practice sentences.

Dependent variables and predictors

The eye fixation data was analyzed for the target words using three standard eye movement variables as dependent variables; First Fixation Duration (FFD), Gaze Duration (i.e., summed duration of fixations on the target word before exiting it for the first time; GD), and Total Fixation Duration (i.e., summed duration of fixations on the target word; TFD).

The critical predictor variables were SYLLABLE BOUNDARY CUE with three levels, *control*, *syllable-congruent* hyphenation, and *syllable-incongruent* hyphenation, and CASE with two levels, *essive*, and *locative*. As for participant variables, we included GRADE.

Statistical considerations

Three 1st graders were excluded from the analyses, two due to low reading skill, and one due to failed calibration due to eye glasses. Four 1st graders did not complete the whole experiment but since they reached the second block, their data was included in the analyses. Sentences for which there was track loss either due to technical problems or disturbance during the course of reading were excluded. This lead to the exclusion of 44 trials for the 1st grade, and 20 trials for the 2nd grade. In total, there were 3075 trials included in the analyses (1459 and 1616 for the 1st and 2nd grade, respectively).

The duration measures were log-transformed to normalize the data. Furthermore, values 2.5 SDs smaller or larger than the participant mean were excluded separately for each condition. This lead to the exclusion of 1.3%, 2.2%, and 0.7% of the data for FFD, GD, and TFD, respectively.

We used multiple regression mixed-effects modelling with participants and items as crossed random effects. Furthermore, the predictor variables were entered in the random structure. As the models with maximal random structure failed to converge, we had to use less stringent random structure. The final random structures are reported in Appendix 2. We will report the results of the omnibus analysis using effects coding and Type III sum of squares. Furthermore, post hoc contrasts were conducted for Syllable Boundary Cue and interactions when they were significant or close to significant. The mixed-effects analyses were conducted using the lme4 package (version lme4_1.1.14; Bates, Maechler, Bolker, & Walker, 2015) and the contrasts were calculated using the glht() function of the multcomp package (version multcomp_1.4-7; Hothorn, Bretz, & Westfall, 2008) for R statistical software (version 3.4.2; R Core Team, 2017). The models including their full model

syntax are reported in the Appendix 2. The 95% confidence intervals were computed using Wald estimation.

Results

The non-transformed means and standard deviations for the dependent variables are presented in Table 3.

[Insert Table 3 about here.]

[Insert Figures 1, and 2 about here.]

First Fixation Duration. There were significant main effects of grade and syllable boundary cue (SBC). 1st graders' first fixations were longer than 2nd graders', B= .076, CI 95% [.026, .126]. Both the syllable-congruent and syllable-incongruent words elicited shorter first fixations than controls, $z = 2.08$, $p = .037$, and $z = 2.91$, $p = .004$, respectively. There were no interactions.

Gaze Duration. There were main effects of SBC, grade, and case. Both words with syllable-congruent and syllable-incongruent words were read slower than control words, $z = -2.16$, $p = .031$, and $z = -2.85$, $p = .004$, respectively. 1st graders had longer GDs than 2nd graders, B = .372, [.239, .504], and locatives were read faster than essives, B = .063, [.036, .089]. The main effect of SBC was qualified by a significant interaction between SBC and grade, and a marginal interaction between SBC and case. The nature of the interactions is depicted in Figures 1 and 2, in which the effect size of SBC is plotted (positive values denote slowdown in comparison to the control condition, negative values speedup). With regard to the grade x SBC interaction, SBC did not affect 1st graders' reading, all $|z| < 1$. For 2nd graders, there was a slowdown caused by SBC; both the syllable-congruent and syllable-incongruent words elicited longer gaze durations than controls, $z = -3.97$, $p < .001$, and $z = -4.61$, $p < .001$, respectively. As seen in Figure 1, this effect was more reliable for words with syllable-

incongruent hyphenation. With regard to case, essives were read slower in both the syllable-congruent and syllable-incongruent condition, z = -2.58, p = .010, and z = -3.56, p < .001, respectively, but this was not the case for locatives, all $|z| < 1$.

Total Fixation Duration. The main effects of SBC, grade, and case were significant. Syllable-incongruent hyphenation elicited longer TFDs than controls and syllable-congruent words, z = -2.91, p = .004, and z = -2.24, p = .025, respectively. 1st graders had longer TFDs than 2nd graders, B = .371, [.244, .498]. Furthermore, locatives were read faster than essives, B = .138, [.114, .162]. Finally, there was a significant grade x case interaction. While locatives elicited shorter TFDs for both grades, the effect was more pronounced for the 2nd graders than 1st graders, B = .524, [.437, .610], and B = .307, [.220, .394], respectively.

Discussion

In the present study, Finnish 1st and 2nd graders read sentences with inflected target words. In the critical conditions, the target words were hyphenated so that the last hyphen was either syllable-congruent (e.g., *ky-nä-nä*) or syllable-incongruent (e.g., *ky-nän-ä*). The syllable-incongruent words were either morpheme-congruent (in the locative case, e.g., *ky-nä-ssä*, in which the first s of the morpheme suffix *-ssä* is part of the previous syllable) or morpheme-incongruent (in the essive case, e.g., *ky-nän-ä*, in which the n of the morpheme suffix *–nä* is also the first letter of the final syllable). It was shown that 2nd graders were slowed down by hyphenation to a larger extent, and that this effect was more reliable for the syllable-incongruent words. Overall, there was no slowdown in GD when the syllable-incongruent hyphen was morpheme-congruent (i.e., for locatives).

The lack of an effect in the syllable-incongruent but morpheme-congruent condition in GD suggests that early Finnish readers utilize morpheme-level information in word decoding. The lack of a three-way interaction suggests that this is already true for 1st graders. When the hyphen was incongruent with both syllables and morphemes, there was a slowdown in TFD due to hyphenation

disrupting processing of larger units than letters. These findings suggest that early Finnish readers are flexible in using both phonological syllable-level and orthographic morpheme-level units in word decoding. These findings are in line with those of Colé et al. (2011), who showed that French 2nd graders are flexible in using both syllables and morphemes in reading. However, our results seemingly go against those of Hasenäcker & Shcroeder (2017), who did not find morpheme-level effects for 2nd graders. The most likely reason for this discrepancy is that in the present study we used inflected words whereas Hasenäcker and Schroeder used derived words. It is likely that morphology plays a larger role in inflected than derived words, at least in Finnish. For instance, it has been demonstrated that while adult readers routinely process the morphemes in inflected words, this is not always the case in derived words (e.g., Bertram, Laine, & Karvinen, 1999). Instead, it may be the case that the derived words are sometimes processed as wholes (e.g., *kirjasto*, 'library'), not via their parts (*kirja+sto*, 'book'+suffix for forming a collective noun). This is not true for the inflected words. Furthermore, even though inflections are also used in German, the inflectional morphology is richer in Finnish. For example, the suffixes used in the present study would be presented as prepositions in German (i.e., as separate words and not as morphemic suffixes). This more pronounced role of inflections may cause readers to extract morphological information already at an earlier stage in Finnish than in German.

There was a difference between the cases in the syllable-congruent condition in GD. For the essives, there was a slowdown in relation to control condition but for the locatives there was no such effect. We think this stems from locatives being more frequent morphemes than essives. When a word has a more frequent suffix, the activation from the word parts makes the reading more fluent than with a less frequent suffix. Even when hyphenation disrupts word reading, simultaneous activation from a frequent morpheme may even out this effect. This finding further demonstrates the role of morphemes already during the 1st grade. This would also be in line with the finding that words with more frequent suffixes are read faster by Spanish 2nd graders (Lázaro et al., 2017). As children have

been exposed to words with locatives to a larger degree, one may also argue that they have developed sight vocabulary for some words in their locative forms. However, as our locative target words had an average surface frequency of 1.27 per million, it is not likely that our findings are largely affected by the heightened use of sight vocabulary.

Apart from the frequency differences, there are other possible confounds in the materials of the present study. For the locatives, the hyphen was moved towards the word beginning in the syllable-incongruent condition whereas for the essives it was moved towards the word ending. For the essives, this formed a pseudo-word boundary at the syllable-incongruent boundary (i.e, the letter string prior to the syllable-incongruent hyphen could be perceived as a genitive). This was done in order to keep the conditions relatively comparable. To have a pure comparison, one should compare the same case in different conditions but due to the nature of the language this is impossible. At any rate, this may have affected the word processing differently in the syllable-incongruent conditions as one could easily see the stem of the word in the locative case but a genitive form in the essive case. This may offer an alternative explanation for the slower performance in the syllable-incongruent essives. Readers may process the extra meaning for the letter string, which in turn slows down their reading. However, even this explanation suggests that early Finnish readers utilize morpheme-level information, as the letter string in question was a bimorphemic word. Furthermore, as essives and locatives required using different carrier sentences, this may have affected the target word processing. However, the sentence beginnings were kept as neutral as possible, and the target word location was very similar between the conditions (on average 3.52, and 3.43 for essives and locatives, respectively). Therefore, we do not think these differences account for the differential processing of the cases with regard to SBC in GD.

Finally, hyphenation speeded up first fixations regardless of the congruency; early decoding was facilitated by small units being explicitly signaled. We think the lack of the congruency effect is

due to the manipulation being located close to the word ending which is likely not attended during initial word decoding for early readers.

All in all, word decoding is flexible even for Finnish 1st graders; they can utilize both syllable-level and morpheme-level information. This goes well in line with the multiple-route model of orthographic processing (Grainger & Ziegler, 2011). However, more research is needed to find out under which circumstances these units become active.

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Table 1. Example of a sentence pair. The target word is in bold.

Example number	Sentence
Example 1	Irinan mukaan **kynässä** oli jotain vikaa.
Translation (Example 1)	*Irina-GEN according-to **pen-INE** was something wrong.*
	*'According to Irina, **in pen** there was something wrong.'*
Example 2	Irinan mukaan **otsassa** oli mustelma.
Translation (Example 2)	*Irina-GEN according-to **forehead-INE** was bruise.*
	*'According to Irina, **on forehead** there was a bruise.'*

Table 2. Example sentences for one target word. The target word is in bold.

Condition	Sentence
Essive (control)	Oudossa tarinassa miehen **kynänä** olikin pöllön sulka.
Essive (syllable-congruent)	Ou-dos-sa ta-ri-nas-sa mie-hen **ky-nä-nä** o-li-kin pöl-lön sul-ka.
Essive (syllable-incongruent)	Ou-dos-sa ta-ri-nas-sa mie-hen **ky-nän-ä** o-li-kin pöl-lön sul-ka.
Essive (translation)	*Strange-INE story-INE man-GEN **pen-ESS** was-also owl-GEN feather.* *'In the strange story, **as** man's **pen** there was an owl's feather.'*
Locative (control)	Irinan mukaan **kynässä** oli jotain vikaa.
Locative (syllable-congruent)	I-ri-nan mu-kaan **ky-näs-sä** o-li jo-tain vi-kaa.
Locative (syllable-incongruent)	I-ri-nan mu-kaan **ky-nä-ssä** o-li jo-tain vi-kaa.
Locative (translation)	*Irina-GEN according-to **pen-INE** was something wrong.* *'According to Irina, **in pen** there was something wrong.'*

Table 3. Non-transformed means and standard deviations (in parentheses) for the dependent variables in milliseconds.

	Essive						Locative					
	Control		Syllable-congruent		Syllable-incongruent		Control		Syllable-congruent		Syllable-incongruent	
Variable	Grade 1	Grade 2	Grade 1	Grade 2	Grade 1	Grade 2	Grade 1	Grade 2	Grade 1	Grade 2	Grade 1	Grade 2
First Fixation Duration	400 (288)	289 (130)	358 (254)	285 (121)	344 (233)	277 (116)	370 (294)	295 (127)	345 (224)	280 (118)	338 (238)	272 (104)
Gaze Duration	1961 (1336)	849 (676)	1916 (1274)	1016 (654)	2174 (1558)	1089 (865)	1843 (1322)	768 (578)	1836 (1264)	842 (548)	1895 (1574)	810 (475)
Total Fixation Duration	2486 (1708)	1289 (900)	2425 (1607)	1256 (734)	2874 (2129)	1480 (1053)	2084 (1440)	910 (669)	2075 (1266)	932 (554)	2253 (1757)	952 (595)

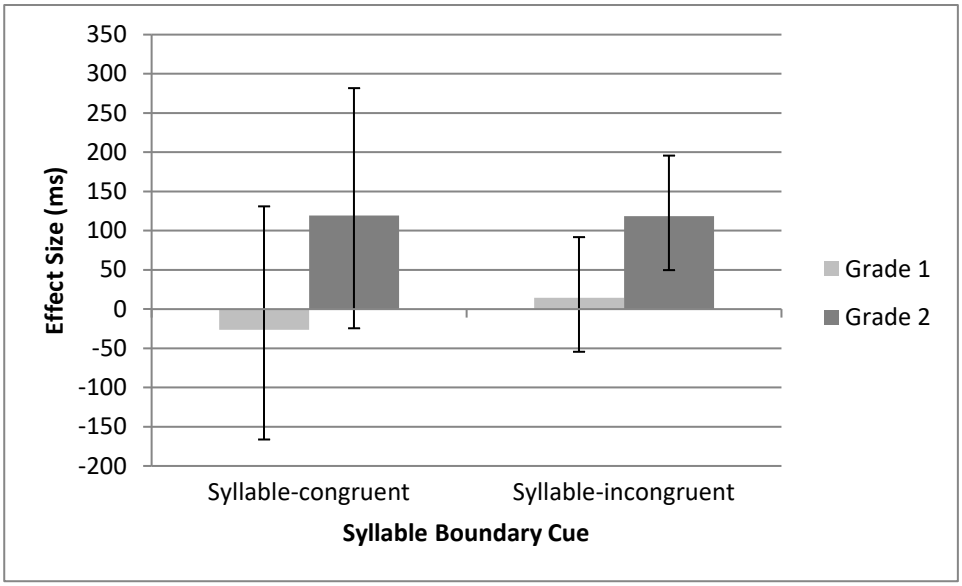

Figure 1. The effect size of Syllable Boundary Cue in relation to the control condition as a function of Grade on Gaze Duration (in ms). Positive values mean slowdown. The error bars denote the 95% confidence intervals.

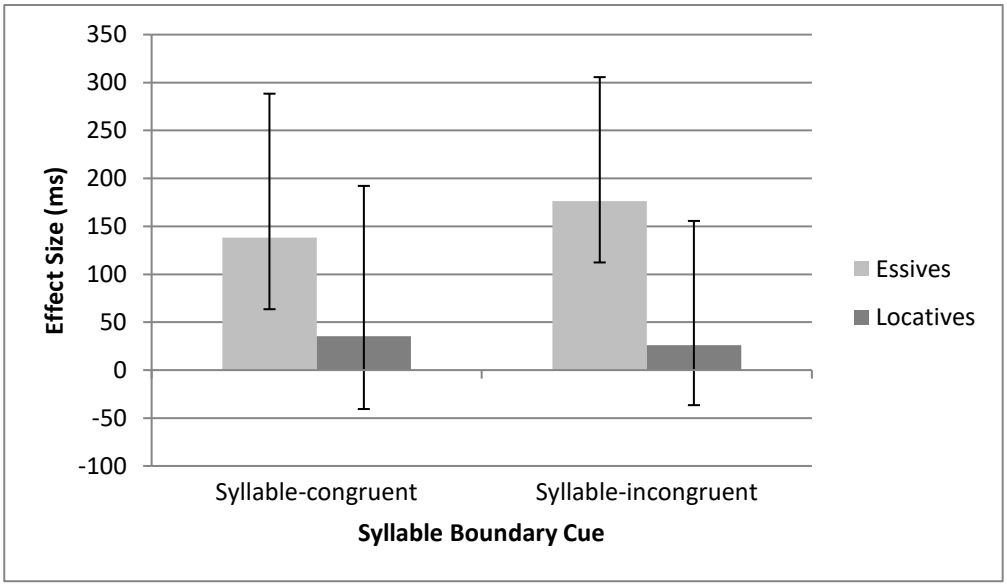

Figure 2. The effect size of Syllable Boundary Cue in relation to the Control condition as a function of Case on Gaze Duration (in ms). Positive values mean slowdown. The error bars denote the 95% confidence intervals.

Appendix 1

Lists of materials.

[Insert Tables A1-A2 about here.]

Appendix 2

Models for each measure.

[Insert Tables A3-A5 about here.]

Table A1. Target words in each condition and frequencies of each word form. For essives, the syllable-incongruent condition is also morpheme-incongruent. For locatives, the syllable-incongruent condition is morpheme-congruent.

Nominative	Essive			Locative			Form frequency			
	Control	Syllable-congruent	Syllable-incongruent	Control	Syllable-congruent	Syllable-incongruent	Stem	Genitive	Essive	Locative
banaani	banaanina	ba-naa-ni-na	ba-naa-nin-a	banaanilla	ba-naa-nil-la	ba-naa-ni-lla	0.88	0.62	0.00	0.00
haamu	haamuna	haa-mu-na	haa-mun-a	haamulla	haa-mul-la	haa-mu-lla	1.32	0.40	0.26	0.00
haava	haavana	haa-va-na	haa-van-a	haavassa	haa-vas-sa	haa-va-ssa	3.04	3.22	0.00	0.22
hillo	hillona	hil-lo-na	hil-lon-a	hillolla	hil-lol-la	hil-lo-lla	0.35	0.35	0.00	0.13
huilu	huiluna	hui-lu-na	hui-lun-a	huilussa	hui-lus-sa	hui-lu-ssa	3.26	0.75	0.00	0.04
huivi	huivina	hui-vi-na	hui-vin-a	huivissa	hui-vis-sa	hui-vi-ssa	1.01	0.40	0.00	0.04
hunaja	hunajana	hu-na-ja-na	hu-na-jan-a	hunajalla	hu-na-jal-la	hu-na-ja-lla	1.50	1.37	0.04	0.66
juusto	juustona	juus-to-na	juus-ton-a	juustossa	juus-tos-sa	juus-to-ssa	3.44	2.86	0.04	0.18

jäätelö	jäätelönä	jää-te-lö-nä	jää-te-lön-ä	jäätelössä	jää-te-lös-sä	jää-te-lö-ssä	1.59	2.60	0.04	0.13
kaakao	kaakaona	kaa-ka-o-na	kaa-ka-on-a	kaakaolla	kaa-ka-ol-la	kaa-ka-o-lla	0.53	0.48	0.00	0.00
kahvi	kahvina	kah-vi-na	kah-vin-a	kahvissa	kah-vis-sa	kah-vi-ssa	6.43	11.59	0.04	0.22
kameli	kamelina	ka-me-li-na	ka-me-lin-a	kamelilla	ka-me-lil-la	ka-me-li-lla	0.57	1.59	0.04	0.18
kamera	kamerana	ka-me-ra-na	ka-me-ran-a	kamerassa	ka-me-ras-sa	ka-me-ra-ssa	8.11	8.02	0.04	0.22
kattila	kattilana	kat-ti-la-na	kat-ti-lan-a	kattilassa	kat-ti-las-sa	kat-ti-la-ssa	2.82	1.85	0.00	2.69
kello	kellona	kel-lo-na	kel-lon-a	kellolla	kel-lol-la	kel-lo-lla	184.14	7.93	0.00	0.22
kirahvi	kirahvina	ki-rah-vi-na	ki-rah-vin-a	kirahvissa	ki-rah-vis-sa	ki-rah-vi-ssa	0.57	0.18	0.00	0.00
kitara	kitarana	ki-ta-ra-na	ki-ta-ran-a	kitarassa	ki-ta-ras-sa	ki-ta-ra-ssa	7.09	3.79	0.00	0.18
korva	korvana	kor-va-na	kor-van-a	korvalla	kor-val-la	kor-va-lla	2.69	2.11	0.09	2.95
kynä	kynänä	ky-nä-nä	ky-nän-ä	kynässä	ky-näs-sä	ky-nä-ssä	3.39	1.32	0.00	0.04
laiva	laivana	lai-va-na	lai-van-a	laivalla	lai-val-la	lai-va-lla	31.28	53.66	0.18	14.76

lehmä	lehmänä	leh-mä-nä	leh-män-ä	lehmällä	leh-mäl-lä	leh-mä-llä	6.83	15.37	0.09	0.48
liima	liimana	lii-ma-na	lii-man-a	liimalla	lii-mal-la	lii-ma-lla	0.75	0.44	0.13	0.31
linna	linnana	lin-na-na	lin-nan-a	linnassa	lin-nas-sa	lin-na-ssa	18.81	44.67	0.00	15.29
luola	luolana	luo-la-na	luo-lan-a	luolalla	luo-lal-la	luo-la-lla	1.85	1.59	0.00	0.13
majava	majavana	ma-ja-va-na	ma-ja-van-a	majavalla	ma-ja-val-la	ma-ja-va-lla	0.35	0.22	0.00	0.00
makkara	makkarana	mak-ka-ra-na	mak-ka-ran-a	makkaralla	mak-ka-ral-la	mak-ka-ra-lla	2.38	3.30	0.04	0.26
muovi	muovina	muo-vi-na	muo-vin-a	muovilla	muo-vil-la	muo-vi-lla	2.47	2.29	0.00	0.88
naapuri	naapurina	naa-pu-ri-na	naa-pu-rin-a	naapurilla	naa-pu-ril-la	naa-pu-ri-lla	8.33	17.80	2.60	0.22
naru	naruna	na-ru-na	na-run-a	narulla	na-rul-la	na-ru-lla	1.59	0.97	0.00	1.23
naula	naulana	nau-la-na	nau-lan-a	naulalla	nau-lal-la	nau-la-lla	1.89	1.54	0.00	0.09
nenä	nenänä	ne-nä-nä	ne-nän-ä	nenässä	ne-näs-sä	ne-nä-ssä	5.46	8.11	0.00	0.79
nuotio	nuotiona	nuo-ti-o-na	nuo-ti-on-a	nuotiolla	nuo-ti-ol-la	nuo-ti-o-lla	3.96	2.33	0.00	0.93

otsa	otsana	ot-sa-na	ot-san-a	otsassa	ot-sas-sa	ot-sa-ssa	1.45	0.53	0.00	1.10
pahvi	pahvina	pah-vi-na	pah-vin-a	pahvissa	pah-vis-sa	pah-vi-ssa	0.48	0.66	0.00	0.00
patteri	patterina	pat-te-ri-na	pat-te-rin-a	patterissa	pat-te-ris-sa	pat-te-ri-ssa	0.97	1.10	0.00	0.09
peukalo	peukalona	peu-ka-lo-na	peu-ka-lon-a	peukalossa	peu-ka-los-sa	peu-ka-lo-ssa	1.72	1.54	0.00	0.04
pihvi	pihvinä	pih-vi-nä	pih-vin-ä	pihvissä	pih-vis-sä	pih-vi-ssä	1.54	1.10	0.09	0.04
pipo	pipona	pi-po-na	pi-pon-a	pipossa	pi-pos-sa	pi-po-ssa	1.45	0.48	0.00	0.09
pisara	pisarana	pi-sa-ra-na	pi-sa-ran-a	pisarassa	pi-sa-ras-sa	pi-sa-ra-ssa	2.95	0.48	0.13	0.00
poliisi	poliisina	po-lii-si-na	po-lii-sin-a	poliisilla	po-lii-sil-la	po-lii-si-lla	200.26	145.42	1.37	8.33
poro	porona	po-ro-na	po-ron-a	porolla	po-rol-la	po-ro-lla	1.94	2.20	0.31	0.18
pusero	puserona	pu-se-ro-na	pu-se-ron-a	puserolla	pu-se-rol-la	pu-se-ro-lla	1.81	0.88	0.00	0.04
ruoho	ruohona	ruo-ho-na	ruo-hon-a	ruohossa	ruo-hos-sa	ruo-ho-ssa	4.01	1.06	0.00	0.00
ruusu	ruusuna	ruu-su-na	ruu-sun-a	ruusussa	ruu-sus-sa	ruu-su-ssa	5.24	7.44	0.09	0.18

ruuvi	ruuvina	ruu-vi-na	ruu-vin-a	ruuvilla	ruu-vil-la	ruu-vi-lla	0.40	0.22	0.00	0.00
saha	sahana	sa-ha-na	sa-han-a	sahassa	sa-has-sa	sa-ha-ssa	5.20	6.48	0.04	0.00
salama	salamana	sa-la-ma-na	sa-la-man-a	salamassa	sa-la-mas-sa	sa-la-ma-ssa	9.16	4.41	0.57	0.09
satula	satulana	sa-tu-la-na	sa-tu-lan-a	satulalla	sa-tu-lal-la	sa-tu-la-lla	0.75	0.18	0.00	0.04
sauna	saunana	sau-na-na	sau-nan-a	saunalla	sau-nal-la	sau-na-lla	12.51	10.44	0.04	0.84
suklaa	suklaana	suk-laa-na	suk-laan-a	suklaassa	suk-laas-sa	suk-laa-ssa	1.37	0.84	0.04	0.09
sumu	sumuna	su-mu-na	su-mun-a	sumussa	su-mus-sa	su-mu-ssa	3.48	1.37	0.04	2.78
suola	suolana	suo-la-na	suo-lan-a	suolalla	suo-lal-la	suo-la-lla	9.34	5.42	0.31	5.68
tasku	taskuna	tas-ku-na	tas-kun-a	taskussa	tas-kus-sa	tas-ku-ssa	0.62	0.35	0.00	6.21
tuoli	tuolina	tuo-li-na	tuo-lin-a	tuolilla	tuo-lil-la	tuo-li-lla	4.10	3.17	0.04	1.67
vadelma	vadelmana	va-del-ma-na	va-del-man-a	vadelmassa	va-del-mas-sa	va-del-ma-ssa	0.44	0.62	0.00	0.04
ystävä	ystävänä	ys-tä-vä-nä	ys-tä-vän-ä	ystävällä	ys-tä-väl-lä	ys-tä-vä-llä	21.41	6.70	2.03	0.26

Note: Frequencies are per million. Genitive frequency is included since the essive case minus the last letter is the same as the genitive form.

Table A2. Sentences used in the study. Target words in bold.

Essive sentence	Locative sentence
Venla yllättyi, kun hänen **banaanina** pitämänsä maku olikin persikkaa.	Aamu on kiva aloittaa **banaanilla** ja lasillisella maitoa.
Pidin piirrosta **haamuna** enkä mörkönä.	Elokuvassa olleella **haamulla** oli erikoinen nimi.
Kirjan mukaan isona **haavana** pidettiin kolmen sentin pituista haavaa.	Jari pelkäsi, että **haavassa** oli pöpöjä.
Sadun mies halusi palkan **hillona** eikä rahana.	En usko, että **hillolla** voi korvata puuttuvan sokerin.
Siskon leikin **huiluna** toimi keppi.	Tässä **huilussa** on kova ääni.
Kuulin naisesta, jonka **huivina** oli iso lakana.	Äidin hakemassa **huivissa** oli kukkasia.
Kuulin eilen, että isoisän **hunajana** pitämä herkku olikin tavallista sokeria.	Luin lehdestä, että **hunajalla** on hyviä vaikutuksia.
Ravintolan uutena **juustona** oli Emmentalia.	Simon mukaan **juustossa** oli outo maku.
Emmin leikissä **jäätelönä** sai toimia vaahtomuovi.	Harmi, että **jäätelössä** on kookosta.
Äidin **kaakaona** pitämä juoma olikin kahvia.	Kaverukset istuivat **kaakaolla** tosi pitkään.
Kuulin naisesta, jonka **kahvina** oli kaarnasta tehtyä mehua.	Äidin hakemassa **kahvissa** oli maitoa.
Jaana keksi, että **kamelina** voisi vakoilla turisteja.	Kuulin, että **kamelilla** oli ollut kova nälkä.

Timo selitti, että puhelinta käytettiin **kamerana** sen tarkkuuden takia.	Isä kertoi, että **kamerassa** on uusi akku.
Lahjaa pidettiin hienoimpana **kattilana** koko maassa.	Tädin mukaan **kattilassa** on lämmintä keittoa.
Hienona **kellona** voidaan pitää vaikka taskukelloa.	Tarinassa olleella **kellolla** oli pitkä historia.
Tarinassa kerrottiin **kirahvina** esiintyneestä seeprasta.	Lahjaksi saadussa **kirahvissa** oli jotain vikaa.
Joonas selitti, että **kitarana** voisi käyttää tennismailaa.	Tiedän, että **kitarassa** on kaunis ääni.
Olisipa outoa herätä **korvana** tai silmänä!	Opettaja kertoi, miksi **korvalla** ei voinut kuulla hiljaisia ääniä.
Oudossa tarinassa miehen **kynänä** olikin pöllön sulka.	Irinan mukaan **kynässä** oli jotain vikaa.
Sadussa miehen **laivana** toimi suuri amme.	Näytti siltä, että **laivalla** oli paljon ihmisiä.
Sadussa miehen **lehmänä** toimi pellistä tehty robotti.	Näytti siltä, että **lehmällä** oli jano.
Veljen mukaan **liimana** toimii jopa purkka.	Vika saatiin korjatuksi **liimalla** ja maalilla.
Kirjan mukaan isona **linnana** pidettiin vain kuninkaan linnaa.	Jari pelkäsi, että **linnassa** oli kummitus.
Pidin piirrosta **luolana** enkä vanhana mökkinä.	Elokuvassa olleella **luolalla** oli erikoinen nimi.
Kuulin eilen, että isoisän **majavana** pitämä eläin olikin saukko.	Luin lehdestä, että **majavalla** on leveä häntä.
Venla yllättyi, kun hänen **makkarana** pitämänsä ruoka olikin kasvisruokaa.	Aamu on kiva aloittaa **makkaralla** ja lasillisella maitoa.
Isän mukaan vuoden **muovina** palkittu keksintö oli huono.	Isä kertoi, että **muovilla** pystyi suojaamaan kasvit.

Tero kertoi, että **naapurina** on vanha mies.	Janne kertoi, että **naapurilla** oli hieno auto.
Anne mietti, että **naruna** voisi käyttää ongensiimaa.	Niina sanoi, että **narulla** pystyi tekemään temppuja.
Veljen mukaan **naulana** toimii vaikka paksu neula.	Vika saatiin korjatuksi **naulalla** ja maalilla.
Lumiukon **nenänä** oli iso porkkana.	Harmi, että **nenässä** on räkää.
Äidin **nuotiona** pitämä loimotus olikin pieni tulipalo.	Kaverukset istuivat **nuotiolla** tosi pitkään.
Oudossa tarinassa miehen **otsana** olikin kaalinlehtiä.	Irinan mukaan **otsassa** oli mustelma.
En usko, että **pahvina** esitelty aine olisi kestävää.	Minkä takia **pahvissa** on hampaanjälkiä?
Tarinassa kerrottiin **patterina** esiintyneestä veturista.	Lahjaksi saadussa **patterissa** oli jotain vikaa.
Emmin leikissä **peukalona** sai toimia pikkuveli.	Harmi, että **peukalossa** on haava.
Siskon leikin **pihvinä** toimi puun lehti.	Tässä **pihvissä** on herkullinen maku.
Lumiukon **pipona** oli siskon vanha pipo.	Harmi, että **pipossa** on reikä.
Joonas selitti, että **pisarana** voisi myös leijua tuulen mukana.	Tiedän, että **pisarassa** on tosi vähän vettä.
Tero kertoi, että **poliisina** on kiva olla.	Janne kertoi, että **poliisilla** oli hieno auto.
Anne mietti, että **porona** voisi elää vapaana.	Niina sanoi, että **porolla** pystyi ratsastamaan.
Tiinan **puserona** sai toimia vanha mekko.	Minnan uudella **puserolla** oli jotain likaa.
"Ei tämä **ruohona** toimi", sanoi nainen leikattuaan vihreää pahvia.	Iina sanoi, että **ruohossa** on ihana tuoksu.

En usko, että **ruusuna** esitelty kukka oli kovin vanha.	Minkä takia **ruususssa** on piikkejä?
Isän mukaan vuoden **ruuvina** palkittu keksintö oli huono.	Isä kertoi, että **ruuvilla** pystyi kiinnittämään taulun seinään.
Aiemmin **sahana** saatettiin käyttää puukkoa.	Peten mukaan **sahassa** ei ole ehjää terää.
Timo selitti, että puhelinta käytettiin **salamana** sen näytön kirkkauden takia.	Isä kertoi, että **salamassa** on paljon sähköä.
Jaana keksi, että **satulana** voisi käyttää täkkiä.	Kuulin, että **satulalla** oli ollut monta omistajaa.
Hienona **saunana** voidaan pitää vaikka savusaunaa.	Tarinassa olleella **saunalla** oli pitkä historia.
Ravintolan uutena **suklaana** oli tummaa suklaata.	Simon mukaan **suklaassa** oli outo maku.
Aiemmin **sumuna** saatettiin pitää jopa sadepilviä.	Peten mukaan **sumussa** ei pysty juoksemaan.
Sadun mies halusi palkan **suolana** eikä rahana.	En usko, että **suolalla** voi peittää pahan maun.
"Ei tämä **taskuna** toimi", sanoi nainen huppua katsellessaan.	Iina sanoi, että **taskussa** on hiekkaa.
Olisipa outoa herätä **tuolina** tai pöytänä!	Opettaja kertoi, miksi **tuolilla** ei saanut keikkua.
Lahjaa pidettiin hienoimpana **vadelmana** koko maassa.	Tädin mukaan **vadelmassa** on paljon vitamiineja.
Tiinan **ystävänä** sai usein karkkia.	Minnan uudella **ystävällä** oli kissa.

Table A3. First fixation duration: Results from the model `lmer(ffd~sbc*grade*case+(1+sbc|participant)+(1+grade|item),data)`

	χ^2	*df*	*p*
Fixed effects			
(Intercept)	47697.80	1	< .001
SBC	8.90	2	.011
Grade	8.82	1	.003
Case	2.15	1	.142
SBC x Grade	1.20	2	.548
SBC x Case	0.15	2	.929
Grade x Case	1.41	1	.234
SBC x Grade x Case	2.21	2	.331
Random effects			
Participants	372.16	6	< .001
Items	28.06	3	< .001

Note: SBC = Syllable Boundary Cue.

Table A4. Gaze duration: Results from the model `lmer(gaze~sbc*grade*case+(1+sbc+case|participant)+(1+grade|item),data)`

	χ^2	*df*	*p*
Fixed effects			
(Intercept)	10450.06	1	< .001
SBC	9.20	2	.010
Grade	30.39	1	< .001
Case	21.40	1	< .001
SBC x Grade	15.71	2	< .001
SBC x Case	4.97	2	.083
Grade x Case	1.36	1	.244
SBC x Grade x Case	1.72	2	.422
Random effects			
Participants	1610.50	10	< .001
Items	53.46	3	< .001

Note: SBC = Syllable Boundary Cue.

Table A5. Total fixation duration: Results from the model `lmer(tfd~sbc*grade*case+(1+sbc+case|participant)+(1+grade|item),data)`

	χ^2	*df*	*p*
Fixed effects			
(Intercept)	12129.71	1	< .001
SBC	9.06	2	.011
Grade	32.78	1	< .001
Case	128.82	1	< .001
SBC x Grade	0.65	2	.721
SBC x Case	2.30	2	.316
Grade x Case	19.07	1	< .001
SBC x Grade x Case	0.26	2	.878
Random effects			
Participants	2162.50	10	< .001
Items	140.61	3	< .001

Note: SBC = Syllable Boundary Cue.