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The Effect of Segmentation Signs in Compounds on Reading Behavior: an Eye-Tracking Study

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Abstract: Two experiments were conducted to investigate the effects of visual segmentation, complexity, and context on the cognitive processing of compounds in Easy Language. By presenting compounds in different boundary conditions, we determined whether a segmentation cue facilitates the processing of compounds presented with and without contextual information. The study was conducted with unimpaired adults and with hearing-impaired pupils, representing one of the Easy Language target groups. The results indicate that visual segmentation facilitates processing of compounds for pupils with low literacy skills. However, they only benefit from segmentation when morpheme boundaries are marked in a subtle way, i.e., without strikingly deviating from the standard version. Pupils with higher literacy skills and unimpaired adults do not profit from segmentation. Even though hyphenation slows down compound processing for unimpaired readers, initial processing advantages of hyphenated over concatenated compounds emerged, which is explained by the fact that hyphenation forces a morpheme-based access and enables fast recognition of the compound's first constituent. However, it hinders readers from accessing the compound via the direct route and thus slows down the processing of the compound as a whole.

Keywords: German Easy Language, Eye tracking, Compound processing, Segmentation cues, Reading skills

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Introduction

In German, compounding is the most productive word formation process (cf. Wellmann 1991; Gaeta/Schlücker 2012). Especially in noun-compounding, virtually any noun can combine with any other to form a novel compound. German compounding is recursive, which means that the compound itself can again serve as the base for the word formation process, resulting in an even more complex structure (cf. Berg 2006). This "almost unconstrained ability for morphemes to be recombined to create new meaningful structures" (Libben 2008:71) yields the existence of almost infinite compounds: A chair in the dining room is referred to as a *diningroomchair* [Esszimmerstuhl], and a showroom, in which these chairs are displayed, can be referred to as *diningroomchairshowroom* [Esszimmerstuhl-ausstellungsraum].

One of the main characteristics of German compounding is that even in these polymorphemic compounds (i.e., compounds consisting of at least three free morphemes) all constituents are generally written without segmentation cues like interword spaces or hyphens. This absence of segmentation cues makes it more difficult for readers, especially for impaired readers, to process compounds, since they are unable to parafoveally parse compounds into their constituents (cf. Inhoff et al. 2000). To facilitate the processing of compounds for impaired readers, more and more texts are currently being offered in Easy Language, where the complexity of compounds is reduced by the insertion of visual structuring signs.

As there is overwhelming evidence that the lexical processing system "seeks to maximize opportunity by extracting all possible morpheme sets from an input string and by constructing all possible morphological representations" (Libben 2006:21), the aforementioned missing indications of the compound's branching structure in standard German are especially problematic in trimorphemic compounds that theoretically allow more than one hierarchical option, specifically left-branching and right-branching. In these compounds, the reader first has to figure out whether the middle part of the compound is associated with the first or the last constituent i.e., to construct its meaning, the reader has to assign a particular structure to the compound. These potential processing problems arising from concatenation of polymorphemic compounds are typical for German compounds. In English, for example, processing difficulties are minimized by an orthographic rule determining that, in trimorphemic compounds, an interword space must be present at the major morpheme boundary (cf. Libben 2008:77). Consider for example the compound "Fußballschuhe" [football shoes]. While in German the reader does not immediately know whether "Fußballschuhe" is a left-branching or a right-branching compounds (i.e. whether the major morpheme boundary is between the second and the third [Fußball-Schuhe] or between the first and the second constituent [Fuß-Ballschuhe]), in English, the space at the major morpheme boundary (football shoes) indicates that the compound is left-branching, consequently telling the reader that “shoes” is modified by the first two constituents.

Even though there is strong evidence that the processing of compounds requires the reader to identify and comprehend all single constituents (cf. Placke 2001; Bertram/Hyönä 2003; Kuperman et al. 2009; Bertram et al. 2011), there is little doubt that proficient readers do not have difficulties decoding complex concatenated compounds. When reading compounds with an ambiguous branching structure such as “Stadtparkplatz” [parking lot in the city], which can be read either as “Stadt Parkplatz” [parking lot in the city] or as “Stadtpark Platz” [a place in the city park], proficient readers make use of contextual information to identify the compound’s major and minor morpheme boundaries and to assign the compound its intended meaning. The context in which the compound is embedded therefore disambiguates its meaning and helps guide the reader’s choice of the appropriate meaning. However, the task of locating the correct morpheme boundary and doing so as quickly as possible may create substantial problems for people with reading impairments. This assumption was confirmed by several studies which provided evidence that people with reading impairments have more difficulties accessing compounds than monomorphemic words of equal length and frequency (cf. Delazer/Semenza 1998; Blanken 2000; Lorenz 2008; Lorenz et al. 2014; Seyboth 2014). The main reason for the increased processing costs impaired readers face when reading compounds is that they have to parse compounds into their constituents before being able to infer the meaning of the compound. The finding that people with reading impairments have a great deal of difficulty when segmenting compounds is also due to the fact that a large amount of German compounds happen to contain (pseudo-)morphemes in the orthography, i.e., they by chance contain morphemes which are not constituents of the compound (cf. Libben 2006). To illustrate, the compound “Altbaucharme” [charm of old buildings] is made of the constituents “Alt” [old], “Bau” [building], and “Charme” [charm]. However, the compound also contains two other free potential morphemes, namely “Bauch” [stomach] and “Arme” [arms]; yet, neither of these is a constituent of the compound. Therefore, when reading compounds with ambiguous segmentation options, readers might encounter words that are known to them, which, however, do not form part of the compound. These pseudo-constituents are consequently a barrier to the identification of the constituents and the comprehension of the compound. In Easy Language, these “structural difficulties” (Bredel/Maaß 2017:213) are prevented by signaling constituent boundaries with a segmentation sign.

Competing Approaches to Segmenting Compounds in Easy Language

Easy Language (EL) is a rule-based variety that is adapted to the needs of people with reading impairments (for an overview of the target groups see Bredel/Maaß 2016; Hansen-Schirra/Maaß 2020). Even though there is consensus in EL research that the marking of constituent boundaries decreases the time it takes for readers to locate and identify the compound's constituents, there is no consensus on the visual structuring sign that is to be used for segmenting compounds: The first practical rulebooks of EL (Inclusion Europe 2009; BITV 2.0 2011; BMAS 2013) recommend segmenting compounds with a hyphen followed by an uppercase character (Regen-Schirm [umbrella]). In spite of the lack of scientific proof and linguists' understanding that the rules are "assumptions based on practical experience in terms of what makes texts easier to comprehend" (Maaß 2020:74), the rule of segmenting compounds with a hyphen was officially enshrined in law in 2011 and implemented in a wide range of texts. In Germany, it was not until 2014 that EL attracted scientific interest. Since the practical guidelines were formulated without cognitive-scientific foundation, they do not provide a sufficiently precise and scientifically based approach to translating texts into EL (cf. Maaß 2020:78). As a result, developing a scientifically founded rulebook was a major research desideratum that was fulfilled by the Research Centre for Easy Language, which was founded at the University of Hildesheim. In 2016, the Research Centre published a first "comprehensive scientific basic work" (Maaß 2020:83) for EL (for further information see Bredel/Maaß 2016). The Research Centre disapproves of the intuitively based and orthographically incorrect hyphenated spelling, in which each constituent begins with an uppercase character. Instead, it suggests structuring compounds with a hyphenation point called *mediopoint* (Regen·schirm). In the scientifically based rulebook, the authors elaborate numerous linguistic, social, and educational disadvantages of segmenting compounds with a hyphen, the most important of which are outlined below (for a detailed discussion see Bredel/Maaß 2016; Maaß 2020).

One of the most notable shortcomings of using the hyphen as a structuring sign is that segmenting compounds with a hyphen contradicts German orthography. The deliberate use of incorrect German is problematic since it discredits the EL target groups (cf. Maaß 2020). In addition, the Research Centre argues that it is not only the target groups of EL that reject texts in which words are deliberately spelled incorrectly, but also the general public (cf. Bredel/Maaß 2017; Maaß 2020). The hyphenated version, which is not only incorrect but also deviates noticeably from the standard version, therefore "triggers strong repulsion in readers" (Hansen-Schirra/Maaß 2020:20). The misspelling of words also reduces the acceptability of EL, which in turn increases the risk of stigmatizing groups that are dependent on EL to access information. Furthermore, the reader internalizes false spellings, which is problematic not only because it triggers false learning impulses but also because it makes it harder for the reader to recognize the same word beyond EL texts. Therefore, segmenting compounds with a hyphen not only contradicts one of the main principles of EL, which is to avoid incorrect spelling, but it is also incompatible with the intended learning function of EL. Another shortcoming of using the hyphen as a segmentation sign is that the uppercase character after the hyphen encourages the reader to process the compound's constituents as individual nouns (cf. Bredel/Maaß 2017:225). While it is expected that this will not cause processing difficulties in transparent compounds, i.e., compounds "in which the meanings of each of the constituents are transparently represented in the meaning of the compound as a whole" (Libben et al. 2003:50), it is assumed that it is counterproductive for the processing of opaque compounds, i.e., compounds whose meaning cannot be derived from the meaning of its constituents; e.g. there is no meaning of "Löwen" [Lion] or "Zahn" [tooth] in "Löwenzahn" [dandelion] (for a discussion see Deilen 2020).

Instead, marking the morpheme boundaries with a mediopoint has the following advantages: In contrast to the hyphen, the mediopoint, combined with the lowercase character after the mediopoint, complies with German orthography. Therefore, it does not negatively impact the learning function EL is intended to fulfill. Another major advantage is that, since the mediopoint is smaller and less invasive, compounds segmented with a mediopoint do not deviate from the standard version to the same extent as compounds segmented with hyphen do. Consequently, using the mediopoint as a structuring sign may allow readers to recognize the same compounds beyond EL texts. Another key advantage is that unlike the hyphen, which is a well-known punctuation mark that is already used in other contexts, such as to separate syllables or to join two names, the mediopoint is not yet used in other contexts. However, one of the disadvantages of the mediopoint is that some screen readers still fail to recognize it as a visual structuring sign, so that the mediopoint is still not fully accessible. In addition, it still deviates from the standard version and identifies texts written in EL as such. So even though the mediopoint is considered "a functional and non-stigmatising alternative to segment compound nouns" (Hansen-Schirra/Maaß 2020:20), it still carries a certain risk of stigmatizing the target groups. Nevertheless, the correct spelling of words lowers the risk of committing readers to EL texts. To summarize, since the mediopoint enhances the perceptibility of the constituents without violating orthographic conventions, it is assumed that the mediopoint is more acceptable than the incorrect hyphen.

Seen from a theoretical perspective, there is little doubt that the marking of constituent boundaries facilitates access to the compound's constituents for people with low literacy skills. However, the empirical research efforts into cognitive processing of compounds in EL have only been undertaken over the past few years and the question of whether the theoretical advantages of the mediopoint can be verified by empirical evidence still needs to be investigated. Meeting this desideratum is crucial in contributing to the development of EL, because only once the advantages of the mediopoint are verified by empirical evidence, will it be possible to reliably question the current practice of segmenting compounds with a hyphen. The question of whether the hyphen or the mediopoint can more effectively assist people with low literacy skills in accessing compounds has only been addressed in a very limited number of studies to date, which we discuss next.

Empirical Research on Compound Processing in Easy Language (and beyond)

Considering the discussion about the pros and cons of hyphen and mediopoint, Wellmann (2020) conducted an eye-tracking study with women learning German as a second language. In a word-picture-matching test, they were presented with compounds, either segmented with a hyphen, segmented with a mediopoint or not segmented at all, and were asked to match them to one of the pictures while their eye movements were recorded. Her results confirmed that compounds with a mediopoint are processed faster than compounds that are either separated with a hyphen or not structured at all. Furthermore, the participants made fewer mistakes if words were separated with a mediopoint. The study can therefore be seen as empirical evidence in favor of the mediopoint. Wellmann's finding that segmenting compounds is beneficial in helping people with low literacy skills process compounds is consistent with the results of Gutermuth (2020). Gutermuth's (2020) eye-tracking study, which was conducted with people with cognitive impairment, migrants, and senior citizens, revealed that only migrants processed compounds with mediopoint significantly faster than unsegmented compounds. In addition, Pappert/Bock (2020) conducted a study with adults with intellectual disability and adults with functional illiteracy. Their lexical decision task, in which transparent and opaque compounds were either presented with a hyphen or not optically structured at all, revealed that for EL target groups segmentation of compounds with a hyphen eases lexical access to both transparent and opaque compounds. This outcome approves segmenting compounds irrespective of semantic transparency.

The studies by Wellmann (2020), Gutermuth (2020), and Pappert/Bock (2020) only investigated the cognitive processing of compounds with two constituents. Yet, following the line of reasoning in Bredel/Maaß (2016, 2017), the difficulties when processing compounds are mainly due to their complexity and length and the obstacle to overcome rises with increasing word length. One of the reasons why polymorphemic compounds cause more difficulties is that "with each new recursive step, the compound becomes more ad hoc, more syntactic, less lexicalized, [...] more difficult to interpret, memorize and produce, more dependent on its context, more limited in its meaning and use and more restricted to the written language" (Berg 2006:198). Nonetheless, studies on the processing of compounds with three or more constituents are still lacking, so that the rule of segmenting especially polymorphemic compounds with a mediopoint still awaits empirical testing. This desideratum constitutes the starting point for this study. Before presenting our experiments, we will first summarize some crucial findings of an eye-tracking study by Inhoff et al. (2000), which are of central importance to our hypotheses.

Even beyond EL research, the processing of polymorphemic compounds has received only little attention. The only eye-tracking study with unimpaired readers that has dealt with the question of how German compounds with more than two morphemes are processed was conducted by Inhoff et al. (2000). Inhoff et al. (2000) presented triconstituent compounds in three different boundary conditions: either concatenated (Einzelhandelsumsatz [retail sales]), with interword spaces between word boundaries (Einzel handels umsatz) or concatenated with the first letter of the constituents being marked by upper-case characters (EinzelHandelsUmsatz). While the first condition conformed to spelling conventions, the other two conditions violated spelling conventions. The study revealed that compounds with interword spaces between word boundaries were read faster than the other two conditions. Yet, unlike the first and second fixation, the final fixation on the compound was longest in the spaced condition, which indicated that compounds with interword spaces were disadvantaged in the final stage of processing. Interword spacing thus benefited the initial phase of compound reading as it facilitates locating and accessing the compound's constituents. At the same time, however, the insertion of interword spaces deprives readers from the marking of the compound's end, which hampers the identification of the constituents as a unified lexical unit. Hence, there is no visual cue indicating whether the constituent (a) is the compound's head, (b) is a part of the compound that modifies the head or, (c) already forms part of the following word. The standard and uppercase condition instead yielded "parallel results in the majority of comparisons" (Inhoff et al. 2000:45). They conclude that not only the morpheme boundaries but also the compound's end needs to be clearly marked to facilitate cognitive processing. However, since the study was only conducted with unimpaired readers, it does not allow for valid conclusions about the processing of compounds in people with reading impairments. Still, when applying the findings of Inhoff et al. (2000) to segmenting compounds with a mediopoint, it becomes evident that using the mediopoint as a structuring sign offers the advantage of marking the morpheme boundaries without violating spelling conventions, while at the same time indicating that the constituents belong to a conceptually unified compound (cf. Bertram et al. 2011).

The eye-tracking study presented here sets out to determine which method of segmentation (hyphen or mediopoint) is better suited to assist individuals with low literacy skills in accessing compounds. In addition, we investigate whether reading compounds without context differs from reading compounds with context. Based on the aforementioned studies and findings, we hypothesize that segmenting compounds is beneficial in helping readers with low literacy skills process compounds, with the processing benefit being greater for compounds segmented with a mediopoint than for compounds segmented with a hyphen. Since unimpaired readers are used to reading unsegmented compounds, we further assume that they do not benefit from segmentation of compounds. However, considering the theoretical advantages of the mediopoint, we still expect that also unimpaired readers process compounds segmented with a mediopoint faster than compounds segmented with an incorrect hyphen. For both impaired and unimpaired speakers we also hypothesize that the context facilitates lexical access to, and processing of, compounds.

Methods

Experiment 1

Material and study design

An initial list of 66 preselected compounds were presented to 25 undergraduate students, none of whom participated in the subsequent experiments. The students were asked to rate the familiarity and degree of abstractness of each compound. Based on the results of the rating study, we selected a set of equally familiar and equally concrete compounds. We chose 27 noun-noun compounds, nine of which contained two, three, and four morphemes. Compounds and morphemes were balanced for frequency and length. In addition, compounds were controlled for number of syllables, familiarity, and degree of abstractness.

The first eye-tracking-experiment was designed as a word-picture-matching test. Compounds were presented either concatenated or in one of two conditions in which morpheme boundaries were marked by structuring signs (hyphen or mediopoint). At the outset of the experiment, participants were informed that they would see words in the center of the screen while their eye movements were recorded. They were instructed to read the word silently. The word remained on the screen until the participants clicked the mouse button. Subsequently, the word was replaced by a picture slide consisting of three pictures and a question mark. Participants were asked to match the word to the appropriate picture or, in case they did not know the word, to click on the question mark. While one of the three pictures showed the content of the compound, the other two pictures showed the content of the compound's immediate constituents. The word-picture-matching task served as a poststimulus distractor task, which was not only used to distract the readers and to check comprehension but also to "give participants a clear purpose for reading the stimuli so that they pay attention to them for the duration of the experimental session" (Keating/Jegerski 2015). In addition to the 27 compounds presented in one of the three boundary conditions, 43 monomorphemic words with a varying number of syllables were used as distractor items.

Participants

Since so far very little is known about how compounds segmented with mediopoint are processed by unimpaired readers, our study was conducted not only with people with low literacy skills (referred to as the target group) but also with unimpaired readers. The experiment was first conducted with 48 unimpaired students. All students were native speakers of German. They received monetary compensation for their participation. In addition, 19 pupils with prelingual hearing impairments or deafness were recruited for this study. They were selected to represent one of the heterogenous target groups of EL. The pupils were aged 13- to 17-years and attended a school for the deaf and hearing impaired (7th to 10th grade). According to teacher and/or parental report, none of them had additional disabilities. When it comes to reading proficiency, deaf and hard-of-hearing pupils are a heterogenous group, which is mainly due to varying degrees of hearing loss, different kinds of hearing aids and implants, and different amount of language exposure. Since several studies (e.g., Holt et al. 1997; Mitchell/Karchmer 2003; Hennies 2009) have documented this diversity of reading proficiency in the deaf population, we assessed pupils' reading skills via the Salzburg Reading Screening for Grades 2 to 9 (Wimmer/Mayringer 2014/2016). Based on the results, we divided the pupils into two subgroups: pupils with higher literacy skills ($n = 9$) and pupils with lower literacy skills ($n = 9$). Splitting the target group into two subgroups allowed us to investigate how reading proficiency influences the need for compound segmentation (for details on the target group's reading proficiency see Deilen 2020).

Apparatus and procedure

Eye fixation patterns were recorded using a mobile SMI Eye Tracker at a sampling rate of 250 Hz. Participants were seated at a viewing distance of about 60 cm from the screen. Prior to the experiment, the eye-tracker was calibrated using a five-point calibration grid that extended over the screen. To this end, participants were instructed to fixate five dots that appeared sequentially on the screen. To verify the accuracy and stability of the fixation positions, the calibration procedure was followed by a validation process. Trials in which a blink occurred on the compound were deleted. Based on the approach of Inhoff/Radach (1998), fixations of less than 50 ms were also deleted. In addition, we only included participants with a tracking ratio of at least 80 %. Altogether, these criteria led to the exclusion of 14.04 % of the data.

Data analyses

The following eye movement measures were calculated for analysis: number of fixations, first fixation duration, total reading time, and rate of regressions. For analyzing the eye-tracking data, we fitted linear mixed-effects models (LMMs) with fixed and random effects using the package lme4 (Bates et al. 2019). Both items and participants were considered as random effects. Given the high number of possible model specifications and with that potentially occurring convergence problems, random effects were reduced, if necessary, to reach convergence (Matuschek et al. 2017). For model fitting we used the Restricted Maximum Likelihood Method to obtain unbiased estimates for fixed and random effects (cf. Fahrmeir et al. ^{2}2009). To select among candidate models with and without interaction terms, Akaike's information criterion (AIC) was used. By removing random effects that did not significantly increase the model goodness-of-fit and by choosing the model with the lowest AIC, we aimed to obtain a model structure that adequately describes the data while not being overly complex. For each dependent variable, a model was fitted containing the fixed main effects of "segmentation" (standard, hyphen, mediopoint), "number of morphemes" (2, 3,

4) and, if selected by AIC, their interactions. The significance level for statistical tests was selected as $\alpha = .05$, where the Bonferroni correction was used to reduce the likelihood of a type I error. Post-hoc contrasts were computed using the R package effects (Fox 2020). We fitted separate LMMs for unimpaired readers and the target group of EL. Given the heterogeneity of pupils with hearing impairments, we subsequently fitted separate LMMs for pupils with higher literacy skills and pupils with lower literacy skills, respectively.

Descriptive statistics of the data are reported in Table 1 (unimpaired readers), Table 2 (target group), Table 3 (pupils with lower reading skills), and Table 4 (pupils with higher reading skills) in the appendix.

Results

In the following we summarize the results of Experiment 1. Further details and non-significant differences are provided in the appendix.

Unimpaired readers

Analysis revealed a main effect of segmentation ($\beta = -0.539$, $t = -2.705$, $p = 0.007$) with unsegmented compounds being, ceteris paribus, fixated significantly less often than compounds segmented with a mediopoint. The interaction of three morphemes and hyphenation ($\beta = 11.773$, $t = 4.178$, $p < 0.001$) as well as the interaction between three morphemes and concatenation ($\beta = 0.582$, $t = 2.064$, $p = 0.039$) was significant, indicating that trimorphemic compounds with mediopoint were read with significantly less fixations than trimorphemic compounds with hyphen. The interaction between boundary condition and number of morphemes is depicted in Fig. 1. Bimorphemic unsegmented compounds were read with less fixations than bimorphemic compounds segmented with either hyphen or mediopoint (see Fig. 1). Four-member compounds, however, were read with mediopoint with more fixations than with hyphen or without any structuring sign; however, the differences were not significant (see Appendix 2). In addition, unsegmented compounds were read with significantly less fixations than hyphenated compounds ($\beta = 0.402$, $t = 3.493$, $p = 0.002$), with the difference being only highly significant for compounds with three morphemes ($\beta = -0.809$, t = -4.057, $p = 0.002$).

However, following the line of reasoning in Wolfer (2016), “if no effect can be shown, this does not mean that there really is no effect” (Wolfer 2016:179), rather, it means that the investigated sample is insufficient for demonstrating its significance. The fact that we “simply cannot detect the effect” (ibid.) is especially due to the conservative Bonferroni correction, which was used to reduce the chances of type I errors (i.e., the chances of obtaining false-positive results). This is achieved by lowering the alpha value to account for the number of comparisons being performed on a single data set. However, when performing a high number of comparisons, the conservative Bonferroni correction increases the risk of generating false negatives (type II errors). This in turn means that even strong tendencies, which are clearly present in our sample, may not be significant (cf. Bland/Altman 1995; Napierala 2012). Since up to 66 tests were performed on our data set and our sample was relatively small, the significance was unable to withstand the Bonferroni correction, even though strong tendencies were undoubtedly present.

Analysis of the rate of regressions showed a significant effect of hyphenation with the rate of regressions being significantly higher for compounds with a hyphen than for compounds with a mediopoint ($\beta = 3.258$, $t = 2.637$, $p = 0.008$). Unsegmented compounds were also read with less regressions than hyphenated compounds.

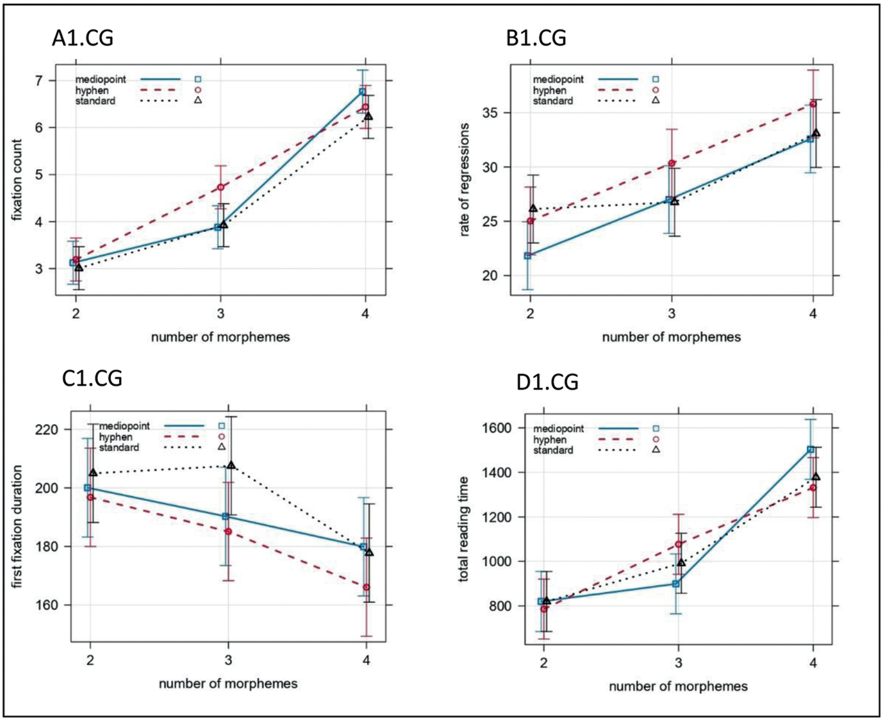

Fig. 1: Estimated effects of the number of morphemes on fixation count (panel A1.CG), rate of regressions (panel B1.CG), first fixation duration (panel C1.CG), and total reading time (panel D1.CG) for different segmentations. Vertical bars indicate 95 % confidence intervals.

No main effects of boundary conditions or interactions were found for first fixation duration. However, for compounds with two morphemes, the first fixation was marginally significantly longer than for compounds with four morphemes (β = 20.168, t = 1.790, p = 0.074). Post-hoc contrasts showed that no matter the number of morphemes, first fixation durations decreased when hyphens were inserted between constituents (see Fig. 1). Taken compounds with two, three, and four morphemes together, the first fixation for hyphenated compounds was marginally significantly shorter than for unsegmented compounds (β = -14.11, t = -2.173, p = 0.090).

The LMM on total reading time yielded a significant main effect of hyphenation (β = -171.76, t = -3.156, p = 0.002) and concatenation (β = -125.21, t = -2.301, p = 0,022) and significant interactions of hyphenation and compounds with two and three morphemes, indicating that the, ceteris paribus, significantly shorter reading time for hyphenated and unsegmented compounds was confined to compounds with four morphemes. The significant interaction of hyphenation and compounds with three morphemes revealed that trimorphemic compounds with mediopoint are read significantly faster than trimorphemic compounds with hyphen (β = 177.542, t = 3.262, p = 0.041). This interaction is depicted in Fig. 1.

Target group

The effect estimates indicate that unsegmented compounds were read with less fixations than compounds segmented with a mediopoint, whereas hyphenated compounds were read with more fixations than compounds with a mediopoint. The effects, however, were not significant. Analysis showed no significant main effect of segmentation on the rate of regressions either. However, for trimorphemic compounds with a mediopoint the rate of regressions was significantly lower than for trimorphemic compounds with a hyphen (β = 12.321, t = 3.685, p = 0.009). Fig. 2 shows that for both compounds with three and four morphemes, the target group jumped backwards least often in compounds segmented with a mediopoint.

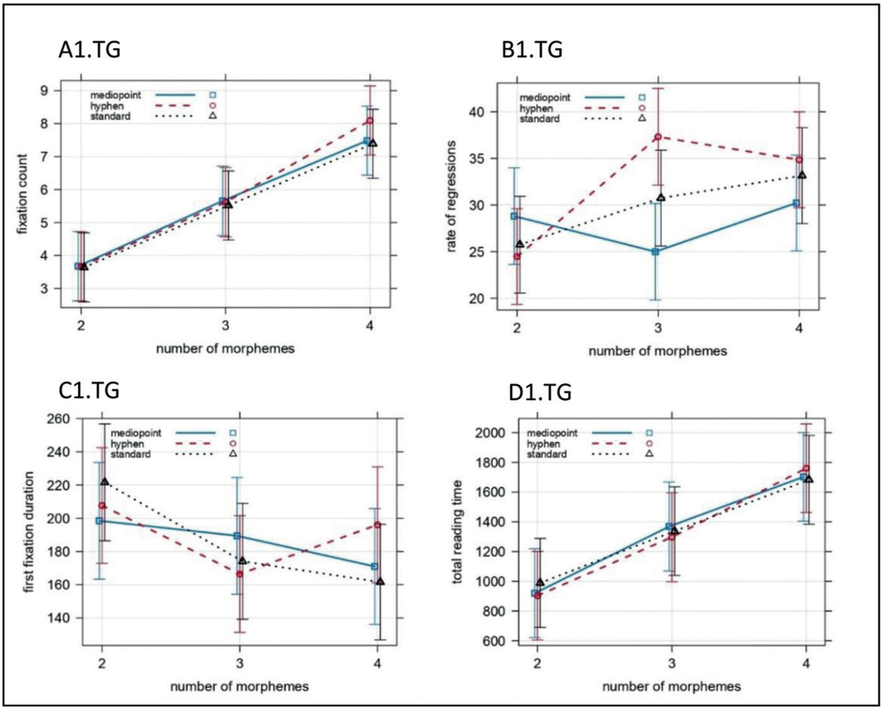

Fig. 2: Estimated effects of the number of morphemes on fixation count (panel A1.TG), rate of regressions (panel B1.TG), first fixation duration (panel C1.TG), and total reading time (panel D1. TG) for different segmentations. Vertical bars indicate 95 % confidence intervals.

Analysis yielded no significant main effect of the boundary condition on the first fixation duration and no significant main effect of boundary condition on the total reading time either.

Target group (pupils with lower literacy skills vs. pupils with higher literacy skills)
For pupils with lower literacy skills, the main effect of hyphenation on number of fixations indicated that hyphenated compounds were read with significantly more fixations than compounds with mediopoint (β = 2.037, t = 2.491, p = 0.013). For unsegmented compounds, the number of fixations was also higher than for compounds with mediopoint, but the effect was not significant. Analysis of the number of fixations for pupils with higher literacy skills showed a significant main effect of the boundary conditions indicating that, ceteris paribus, unsegmented compounds (β = -1.370, t = -3.230, p = 0.001) and hyphenated compounds (β = -0.815, t = -1.921, p = 0.056) are read with less fixations than compounds with mediopoint. The interaction between three morphemes and hyphenation (β

= 1.852, t = 3.086, p = 0.002) as well as the interaction between two morphemes and concatenation (β = 1.296, t = 2.160, p = 0.032) and three morphemes and concatenation (β = 1.444, t = 2.407, p = 0.017) was significantly positive, indicating that the higher number of fixations for compounds with mediopoint was confined to four morphemes (see Fig. 3).

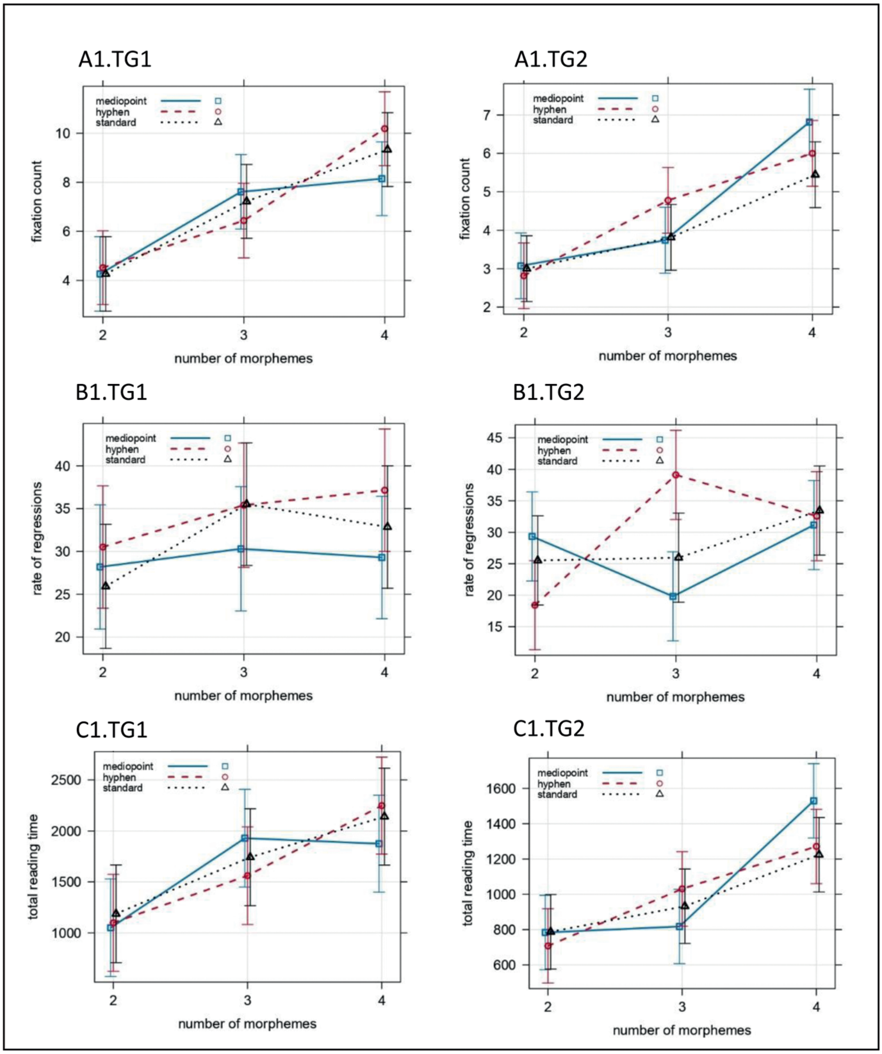

Fig. 3: Estimated effects of the number of morphemes on fixation count (panel A1.TG1, A1.TG2), rate of regressions (panel B1.TG1, B1.TG2), and total reading time (panel C1.TG1, C1.TG2) for pupils with lower literacy skills (left panels) and pupils with higher literacy skills (right panels) for different segmentations. Vertical bars indicate 95 % confidence intervals.

For low literacy pupils, the main effect of hyphenation on the rate of regressions ($\beta = 5.119$, $t = 1.953$, $p = 0.052$) indicated that the rate of regressions was marginally significantly higher for hyphenated compounds than for compounds with mediopoint. For unsegmented compounds, the rate of regressions was also higher than for compounds with mediopoint, however, the effect was not significant. Fig. 3 shows that irrespective of the number of morphemes, pupils jump backwards most often when compounds are hyphenated. For pupils with higher literacy skills, analysis did not yield a significant main effect of boundary conditions; still the effect estimates indicate that both hyphenated and unsegmented compounds elicit a higher rate of regressions than compounds with mediopoint. The interaction between two morphemes and hyphenation ($\beta = -12.333$, $t = -1.835$, $p = 0.068$) and three morphemes and hyphenation ($\beta = 17.889$, $t = 2.661$, $p = 0.008$) revealed that the higher rate of regressions for hyphenated compounds is confined to three and four morphemes (see Fig. 3).

For low literacy pupils, we found a marginally significant main effect of hyphenation ($\beta = 373.94$, $t = 1.832$, $p = 0.068$) on total reading time, indicating that hyphenated compounds are read slower than compounds with mediopoint. For unsegmented compounds, the total reading time was also longer than for compounds with mediopoint, but the effect was not significant. In addition, a significant interaction between three morphemes and hyphenation emerged ($\beta = -742.27$, $t = -2.546$, $p = 0.012$), indicating that the shorter reading time for compounds with mediopoint was restricted to compounds with two and four morphemes (see Fig. 3). For pupils with higher literacy skills, we found a significant main effect of hyphenation ($\beta = -258.40$, $t = -2.263$, $p = 0.025$) and concatenation ($\beta = -305.27$, $t = -2.674$, $p = 0.008$) on total reading time as well as significant interactions between three morphemes and hyphenation ($\beta = 471.63$, $t = 2.921$, $p = 0.004$), three morphemes and concatenation ($\beta = 420.19$, $t = 2.603$, $p = 0.010$) and a marginally significant interaction between two morphemes and concatenation ($\beta = 309.20$, $t = 1.915$, $p = 0.057$). The interactions reveal that the facilitatory effects of hyphenation and concatenation are confined to compounds with two and four morphemes (see Fig. 3). Trimorphemic compounds with mediopoint, in turn, elicit shorter reading times than trimorphemic concatenated and hyphenated compounds.

Furthermore, we found significant differences between pupils classified as having low reading skills and pupils classified as having higher reading skills, which not only backs up separating the target group into two groups, but also confirms the findings of previous eye-tracking studies (e.g., Häikiö et al. 2011; Hasenäcker et al. 2017). Firstly, less-skilled pupils read compounds with significantly (and on average 58.3 %) more fixations than pupils with more advanced reading skills ($z = -8.637$, $p < 0.001$, $r = 0.393$). Secondly, they jumped backwards significantly (and on average 12.1 %) more often than better-skilled pupils (z = -2.131, p = 0.033, r = 0.097) and read the compounds significantly (and on average 64.9 %) slower than better-skilled pupils (z = -8.539, p < 0.001, r = 0.389). Lastly, the first fixation duration differed significantly between less-skilled and better-skilled pupils (z = -3.182, p < 0.001, r = 0.145), with the first fixation being on average 13 % shorter for less-skilled pupils than for better-skilled pupils.

The fact that the first fixation duration, which represents early processing stages, was significantly shorter for less-skilled readers than it was for higher-skilled readers was at first surprising. This finding of a shorter first fixation for less-skilled readers was confirmed when comparing the first fixation for unimpaired readers and the target group, which revealed that the first fixation of the target group was significantly shorter than the first fixation of unimpaired readers (z = -2.963, p = 0.003, r = 0.071). This finding could suggest a short first fixation might not necessarily be indicative of a faster processing of compounds. We return to this assumption in the chapter "Additional Findings", where we also provide a possible explanation for it. The question of whether our findings regarding the first fixation converge with other studies on the processing of compounds is addressed in the discussion as well.

Discussion

With the first experiment we aimed to determine whether reducing compounds' complexity by inserting a segmentation sign has a facilitating effect on the processing of compounds. Our results demonstrated that segmentation of compounds disrupts reading among unimpaired readers. However, it seems that they process compounds with mediopoint faster than compounds with hyphen. Even though most of the results of the target group revealed as well that, overall, compounds with mediopoint are processed more easily than compounds with hyphen, we also found some discrepancies. In addition, the data did not allow us to answer the question of whether unsegmented compounds or compounds segmented with mediopoint were processed better, and thus the question of whether segmenting compounds is at all necessary to facilitate processing of compounds. Since these discrepancies are in all probability at least partly due to the pupils' heterogenous reading skills, it was necessary to take a closer look at the eye-tracking data of low-skilled and high-skilled pupils, respectively. By doing so, analysis revealed that for pupils with low literacy skills marking constituents' boundaries helped to reduce cognitive processing costs. In addition, we could prove that low-skilled readers generally processed compounds with a mediopoint faster than compounds with a hyphen. Since none of the pupils asked for the meaning of the mediopoint, we can deduce that even readers with low literacy skills understand the mediopoint intuitively (cf. Bredel/Maaß 2017:218 ff.) – which is an indispensable requirement for using it as a segmentation sign.

Furthermore, we found evidence that lower-skilled pupils especially profit from visual segmentation in four-member compounds. On the contrary, our data did not indicate that pupils with higher skills profited from segmented word forms. Only for trimorphemic compounds did we find a distinct processing advantage for compounds with mediopoint over unsegmented compounds. For compounds with two and four morphemes, however, we could neither prove a processing advantage over hyphenated compounds nor a processing advantage over unsegmented compounds.

Our results converge with the findings of Pappert/Bock (2020) in that they also indicate that readers with very low reading skills profit from visual segmentation of compounds. In addition, both studies have shown that unimpaired readers process unsegmented compounds better than segmented compounds. Our results are also consistent with the findings of Wellmann (2020), who showed that compounds with mediopoint are processed better than compounds with hyphen. However, since the experiment on word level also yielded some contradicting results, which did not confirm the hypotheses, and partly also indicated a processing advantage of the hyphen, we are still unable to rule out that also the hyphen yields some processing advantage. So far, we are also unable to answer the question of whether our findings converge with previous studies on the processing of compounds. The reason for this is that in most studies (except for the studies by Wellmann 2020 and Pappert/Bock 2020) compounds were not presented in isolation but embedded in sentences. Since there is overwhelming evidence that reading words embedded in context differs from reading the same words without context, we cannot assume that our findings generalize to normal reading. One of the main reasons for this is that sentence reading is a more dynamic and more natural "task in which a sequence of words is to be processed" (Inhoff et al. 2000:30) and in which the meaning of the compound is to be integrated in and partly assigned by the context. Since eye-tracking experiments on word and sentence level led to differing results in a wide range of studies (e.g., Vitu et al. 1990; O'Regan 1992), we designed a second experiment, in which we presented the same compounds again, but this time embedded in sentences. The aim of the second experiment was twofold: Firstly, we aim to investigate whether the findings on word level extend to normal reading, i.e., the effects of Experiment 1 also emerge when presenting compounds in sentences. Secondly, we address the question of whether compound processing is facilitated by contextual information, i.e., whether reading compounds in context, and with that in a less artificial and more ecologically valid situation, is easier than reading them without context. If this were the case, it would be possible that, as Pappert/Bock (2020) suggest, "context might help lexical identification and comprehension in less-skilled readers and render compound segmentation dispensable" (Pappert/Bock 2020:1122). Embedding the same compounds in sentences will also serve to reveal or rule out alternative factors that might explain the results on word level.

Experiment 2

The compounds were the same compounds presented in Experiment 1, but this time they were embedded in sentences. After reading the sentence, the participants were presented with a binary choice question and were asked to decide whether the sentence they had just read was meaningful or not. By using this binary choice question as a poststimulus distractor task, we ensured that the participant not only fixated but also cognitively processed the compound. To this end, it was necessary to include additional nonsense sentences, which were supposed to generate "no" responses in the binary choice question. The sentences containing a compound accounted for 27 of the 80 sentences presented to each participant. These 27 target sentences were mixed with 53 filler sentences, containing the same distractor items as in Experiment 1, and 10 nonsense sentences. In addition to controlling the sentence length, we also ensured that the word preceding and following the target word contained at least four characters. By controlling the length of the word before and after the compound, we reduced the risk of the compound being skipped. We also controlled the compound position, with the compound occupying neither the start nor the end of a sentence. The naturalness and comprehensibility of the sentences served as additional control variables. To ensure that the sentences were on average as natural and comprehensible as possible, we asked 25 undergraduate students to rate the naturalness and comprehensibility of a larger pool of sentences on a seven-point Likert scale. None of the students participated in the eye-tracking experiment.

Eye-tracking data were again analyzed by fitting LMMs. Model fitting was conducted in the same way as described in Experiment 1. In a next step, we included the context as an additional explanatory variable, which allowed us to compare the eye-tracking data for compounds that were read with and without context. We computed the same eye movement variables for analyses as in Experiment 1. About 13.47 % of the data were excluded before analyses due to insufficient tracking ratio, skipping of the target word, blinks or fixations being shorter than 50 ms.

Descriptive statistics of the data are reported in Table 5 (unimpaired readers), Table 6 (target group), Table 7 (pupils with lower reading skills), and Table 8 (pupils with higher reading skills) in the appendix.

Results

Unimpaired readers

The significant main effects indicated that compounds with hyphen were read with significantly more fixations than compounds with mediopoint (β = 0.518, t = 3.704, p < 0.001), whereas unsegmented compounds were read with significantly less fixations than compounds with mediopoint (β = -0.591, t = -4.220, p < 0.001) and hyphen (β = -0.706, t = -8.665, p < 0.001). Fig. 4 shows that no matter the number of morphemes, the number of fixations is always lowest if the compound is unsegmented, whereas the number of fixations is always highest when compounds are segmented with hyphen.

Furthermore, Fig. 4 shows that no matter the number of morphemes, hyphenated compounds caused the highest rate of regressions. Compared to unsegmented compounds, first fixation durations decreased for compounds with two, three, and four morphemes when hyphens were inserted. For the mediopoint, this was only true for trimorphemic compounds (see Appendix 2). In addition, the main effect of hyphenation on total reading time indicated that compounds with hyphen were read significantly slower than compounds with mediopoint (β = 130.08, t = 3.508, p < 0.001). On the other hand, the effect of concatenation indicated that unsegmented compounds were read significantly faster than compounds with mediopoint (β = -80.91, t = -2.178, p = 0.030). Fig. 4 shows that no matter the number of morphemes, unsegmented compounds always yield the shortest reading time whereas hyphenated compounds always yield the longest reading time.

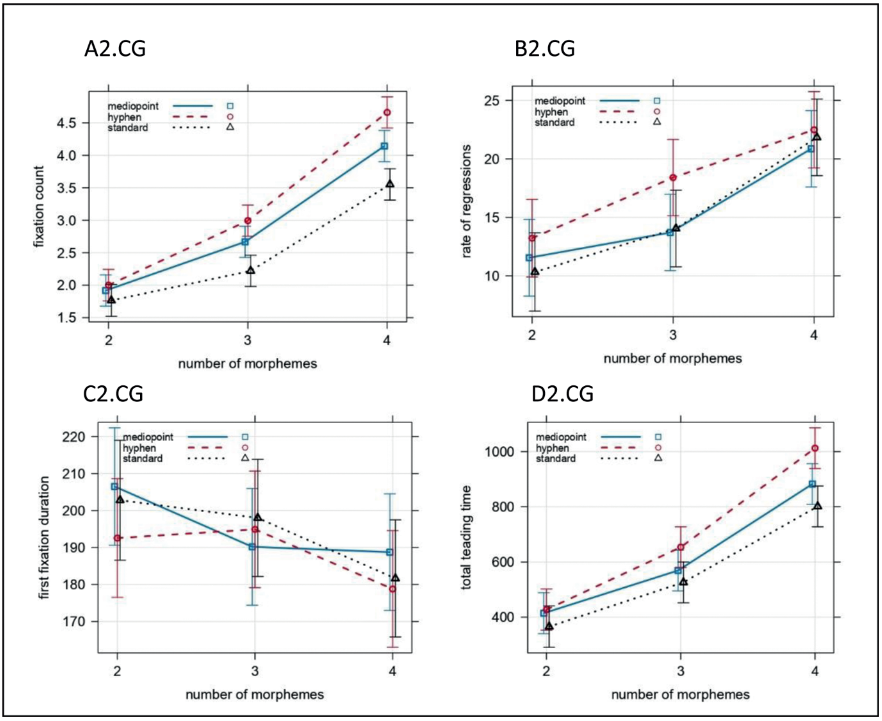

Fig. 4: Estimated effects of the number of morphemes on fixation count (panel A2.CG), rate of regressions (panel B2.CG), first fixation duration (panel C2.CG), and total reading time (panel D2. CG) for different segmentations. Vertical bars indicate 95 % confidence intervals.

Target group

For the target group, the marginally significant effect of concatenation indicates that unsegmented compounds were read with less fixations than compounds with mediopoint (β = -0.316, t = -1.700, p = 0.090) and hyphen (β = -0.614, t = 3.346, p = 0.003). Hyphenated compounds were read with more fixations than compounds with mediopoint, however, this was only true for compounds with three and four morphemes (see Appendix 2).

The rate of regressions is higher for both hyphenated and unsegmented compounds than for compounds with mediopoint. However, this is only true for compounds with three and four morphemes (see Fig. 5). Post-hoc contrasts also showed that for compounds with three and four morphemes, first fixation durations decreased when a segmentation sign was inserted between constituent words (see Fig. 5). However, none of the differences withstood the Bonferroni correction (see Appendix 2). The effect of segmentation on the total reading time was not significant either, however, Fig. 5 shows that hyphenated compounds yielded the longest reading time.

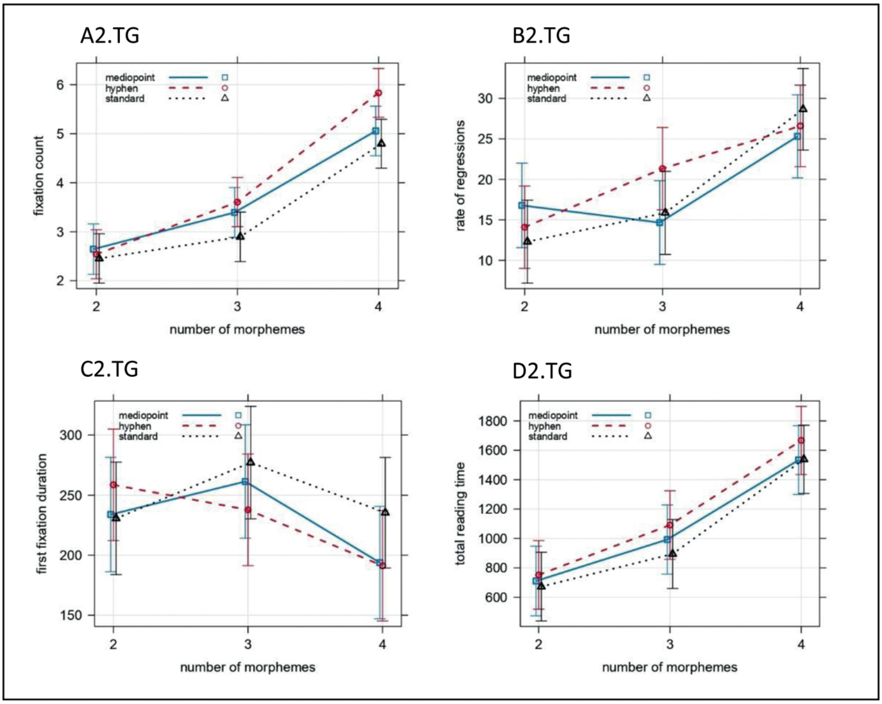

Fig. 5: Estimated effects of the number of morphemes on fixation count (panel A2.TG), rate of regressions (panel B2.TG), first fixation duration (panel C2.TG), and total reading time (panel D2.TG) for different segmentations. Vertical bars indicate 95 % confidence intervals.

Target group (pupils with lower literacy skills vs. pupils with higher literacy skills)

For pupils with lower literacy skills, the main effect of hyphenation revealed that hyphenated compounds were read with significantly more fixations than compounds with mediopoint (β = 1.276, t = 2.615, p = 0.010). For unsegmented compounds, the number of fixations was also higher than for compounds with mediopoint, but the effect was not significant. The interaction between two morphemes and hyphenation (β = -1.561, t = -2.253, p = 0.025) revealed that, unlike compounds with three and four morphemes, bimorphemic compounds with hyphen were read with less fixations than bimorphemic compounds with mediopoint. The effect, however, did not withstand the Bonferroni correction. The interaction is depicted in Fig. 6. For pupils with higher literacy skills, the main effect of concatenation revealed that they read unsegmented compounds with significantly less fixations than compounds with mediopoint (β = -0.532, t = -2.218, p = 0.028). Post-hoc contrasts also indicated that unsegmented compounds are read with less fixations than compounds with hyphen. For compounds with two and four morphemes, the number of fixations is lower for compounds with mediopoint than for compounds with hyphen, whereas for triconstituent compounds the number of fixations is slightly higher for compounds with mediopoint than for compounds with hyphen. However, none of the differences were significant (see Appendix 2).

When reading hyphenated compounds, low-skilled readers jump backwards marginally significantly more often than when reading compounds with mediopoint (β = 9.098, t = 1.880, p = 0.062). The rate of regressions is also higher for unsegmented compounds than for compounds with mediopoint, but the effect was not significant. However, the significant interaction of two morphemes and hyphenation (β = -15.495, t = -2.253, p = 0.025) revealed that the lower rate of regressions for compounds with mediopoint was confined to compounds with three and four morphemes. For pupils with higher reading skills, hyphenated compounds yielded the highest rate of regressions in compounds with two and three morphemes, whereas in compounds with four morphemes they yielded the lowest rate of regression. However, none of the differences were significant (see Appendix 2).

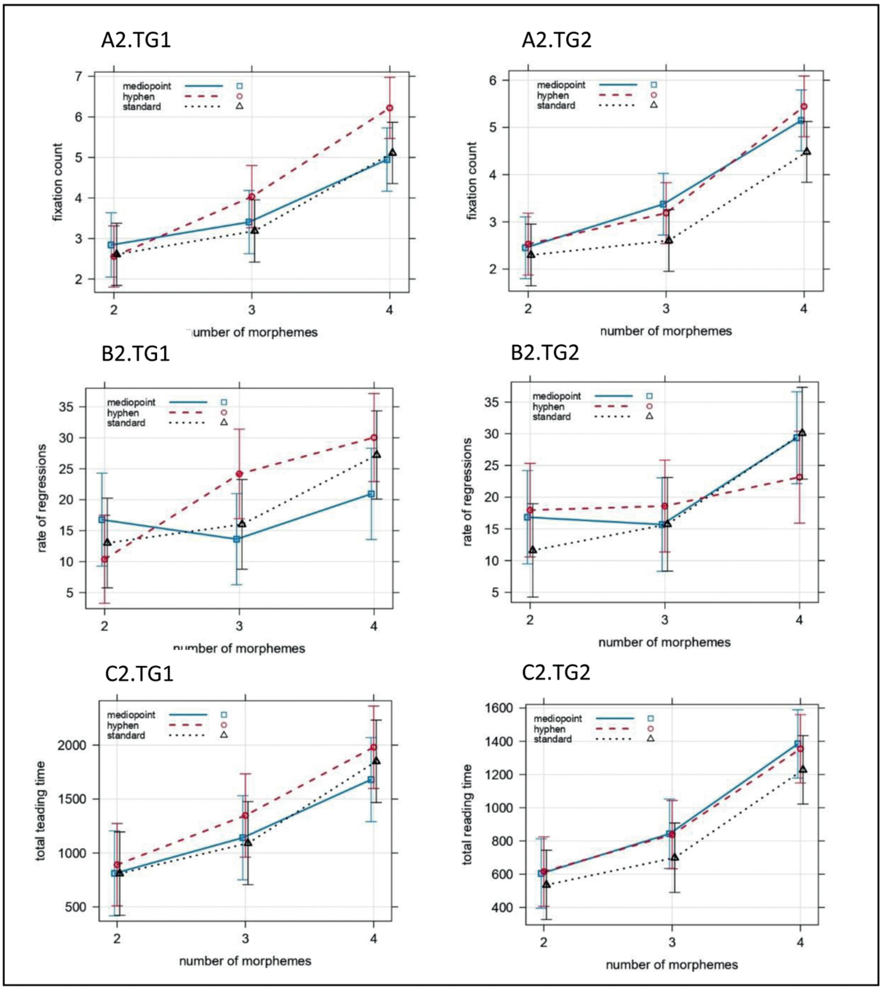

Fig. 6: Estimated effects of the number of morphemes on fixation count (panel A2.TG1, A2.TG2), rate of regressions (panel B2.TG1, B2.TG2), and total reading time (panel C2.TG1, C2.TG2) for pupils with lower literacy skills (left panels) and pupils with higher literacy skills (right panels) for different segmentations. Vertical bars indicate 95 % confidence intervals.

For low-skilled readers, the LMM on the first fixation duration did not reveal significant effects either. For high-skilled readers, however, the main effect of concatenation ($\beta = 68.94$, $t = 1.878$, $p = 0.062$) revealed that the first fixation was marginally significantly longer for unsegmented compounds than for compounds with mediopoint. For compounds with three and four morphemes, unsegmented compounds yield the longest first fixation, whereas for bimorphemic compounds there is almost no difference between the three boundary conditions. In addition, the effect estimates indicate that low-skilled readers read unsegmented and hyphenated compounds slower than compounds with mediopoint. Post-hoc contrasts confirmed that regardless of the number of morphemes, hyphenated compounds yield the longest reading time (see Appendix 2). For higher-skilled pupils, Fig. 6 shows that unsegmented compounds yield the shortest reading time, whereas there is almost no difference between compounds with hyphen and mediopoint.

Similar to Experiment 1, we found significant differences between pupils with higher reading skills and pupils with lower reading skills. Low-skilled pupils read the compounds with marginally significantly (and on average 10.7 %) more fixations than better-skilled pupils ($z = -1.794$, $p = 0.073$, $r = 0.083$). The different reading skills were confirmed by the significantly slower reading time ($z = -5.236$, $p < 0.001$, $r = 0.241$), with less-skilled pupils reading the compounds on average 45.2 % slower than better-skilled pupils. However, unlike Experiment 1, the first fixation was not shorter for low-skilled readers but (on average 2.1 %) longer than for high-skilled readers. The finding that the first fixation on sentence level was longer for less-skilled readers than for better-skilled readers was confirmed when comparing the first fixation duration for unimpaired readers and the target group, which revealed that the first fixation of the target group was significantly longer than the first fixation of unimpaired readers ($z = -5.934$, $p < 0.001$, $r = 0.143$). This tendency contradicts the finding of Experiment 1, in which the first fixation was significantly shorter for less-skilled readers than for better-skilled readers. We return to these results in the chapter "Additional Findings".

Contextual effects

As outlined at the beginning, we also investigated whether the context has a facilitating effect on the processing of compounds. Including the context as an additional explanatory variable in the LMM reveals that, for unimpaired readers, the context has a facilitating effect on compound reading: The number of fixations was significantly lower if compounds were presented with context ($\beta = 1.716$, $t = 27.060$, $p < 0.001$). Also, compounds with context were read significantly more often with only one fixation than compounds without context ($\beta = 0.164$, $t = 14.603$, $p < 0.001$). In addition, presenting compounds with context led to a significant decrease in regressions ($\beta = 12.465$, $t = 16.932$, $p < 0.001$) as well as to a significantly shorter total reading time ($\beta = 440.39$, $t = 25.410$, $p < 0.001$). For all three boundary conditions, all above mentioned effects were significant (see Appendix 3). Surprisingly, we did not find a significant effect of context on the first fixation duration.

For the target group, there is no doubt either that the context has a facilitating effect on compound reading. Analysis revealed that compounds with context were read with significantly less fixations than compounds without context (β = 1.981, t = 13.604, p < 0.001). Furthermore, we found a significant decrease in regressions for compounds presented with context (β = 10.595, t = 9.287, p < 0.001). The effects were significant for all three boundary conditions (see Appendix 3). In addition, compounds presented with context were read significantly faster than compounds without context, however, the effect was only significant for unsegmented compounds (β = 306.19, t = 4.376, p < 0.001) and compounds with mediopoint (β = 260.38, t = 3.684, p = 0.004). In contrast to unimpaired readers, the context also had a significant effect on the first fixation duration, with the first fixation being significantly longer if compounds were presented with context. However, the effect was only significant for unsegmented compounds (β = -62.346, t = -3.937, p = 0.001).

This facilitating effect of the context emerged for both low- and high-skilled readers. No matter the visual segmentation, the number of fixations was significantly lower in both groups if compounds were presented with context (see Appendix 3). We also found a significant decrease in regressions for compounds presented with context. For low-skilled readers, this effect was significant for all three boundary conditions. For high-skilled readers, however, the effect was only significant for concatenated and hyphenated compounds. In addition, the first fixation was significantly longer if compounds were presented with context (low-skilled pupils: β = 63.240, t = 4.503, p < 0.001, high-skilled pupils: β = 33.584, t = 2.833, p = 0.005). For low-skilled readers, the effect was marginally significant for concatenated and hyphenated compounds, whereas for high-skilled pupils the effect was only marginally significant for unsegmented compounds. In both groups, we also found a significantly shorter reading time for compounds with context (low-skilled pupils: β = -370.51, t = -5.500, p < 0.001, high-skilled pupils: β = -110.12, t = -2.537, p = 0.012). However, when looking at the effects for the boundary conditions separately, the effect was only significant in lower-skilled pupils and only for unsegmented compounds and compounds with mediopoint (see Appendix 3).

Discussion

The second experiment sought to determine whether segmenting compounds on sentence level facilitates processing. For unimpaired readers, the eye-tracking data revealed that they do not profit from segmentation. Analogously to Experiment 1, the data on sentence level confirmed as well that compounds with hyphen are processed significantly slower than compounds with mediopoint. Furthermore, we found evidence that no matter the visual segmentation, both unimpaired readers and low- and high-skilled readers of the target group process compounds significantly faster if presented with contextual information. Overall, the analysis also revealed that, just like unimpaired readers, the target group processes hyphenated compounds slower than unsegmented compounds. Similar to unimpaired readers, the target groups' eye-tracking data also revealed that processing compounds with a hyphen was more effortful than processing compounds with a mediopoint. When looking at the target group as a whole, however, we were not able to answer the question of whether unsegmented compounds or compounds with mediopoint were processed faster and consequently the question of whether segmenting compounds is at all necessary to facilitate processing of compounds in sentences. Therefore, it was beneficial to take a closer look at the data of low-skilled and high-skilled pupils, respectively. For low-skilled pupils, the data confirmed the conclusion drawn from Experiment 1: Not only on word but also on sentence level did low-skilled pupils profit from segmentation, however, this processing advantage only became clearly visible for compounds segmented with mediopoint. Using the hyphen, on the other hand, did not lead to verifiable processing benefits for low-skilled pupils.

To summarize, the mediopoint is an effective way to facilitate cognitive processing of compounds. We can thus conclude that not only from a theoretical but also from an empirical perspective does segmenting compounds with a mediopoint offer more advantages than segmenting compounds with an orthographically incorrect hyphen. At the beginning of this section (page 63), we mentioned that, due to the presumed facilitating effect of the context, it might be possible that "context might help lexical identification and comprehension in less-skilled readers and render compound segmentation dispensable" (Pappert/Bock 2020:1122). However, since our findings revealed that low-skilled readers also profited from segmentation when reading compounds in context, we could prove that, for our study, this assumption turns out to be incorrect. The data of pupils with higher literacy skills confirm the findings on word level, i.e., it seems that they do not have any problems with processing unsegmented compounds, which in turn means that they do not profit from segmentation. In this regard it seems to be true that segmenting compounds is dispensable for some of the EL target groups, i.e., those with relatively high reading skills.

Additional Findings

Analyses of unimpaired readers' first fixation duration yielded some unexpected results. While in both experiments the number of fixations, the rate of regressions and the total reading time indicated a processing advantage for unsegmented compounds, first fixations on compounds showed a marginally significant advantage for hyphenated compounds. The finding that hyphenated compounds received longer gaze durations but shorter first fixations, which at first might seem contradicting, is consistent with several other studies on the processing of compounds. For example, the studies of Placke (2001), Juhasz et al. (2005), Häikiö et al. (2011), and Bertram/Hyönä (2013) have shown that the insertion of segmentation cues decreased the duration of a compound's initial fixation but increased the duration of a compound's overall gaze duration. This initially surprising short first fixation duration for hyphenated compounds also converges with studies by O'Regan et al. (1984), Vitu et al. (1990, 1995), and Rayner et al. (1996), which highlighted that the first fixation was longer when it landed near the optimal landing position (word center) than when it landed further from the optimal landing position. When landing near the optimal landing position, the compound can already be recognized during the first fixation, which reduces the need for the reader to refixate the compound and decreases the total reading time, compared to compounds in which the first fixation lands on a less optimal landing position for word identification, i.e., further to the left.

By running a post-hoc analysis, we were able to confirm this proposed relationship between initial landing position and decomposed and direct access, respectively: When reading hyphenated compounds, the eyes' initial landing position was displaced more toward the beginning of the compound than it was for unsegmented compounds (β = -5.07, t = -0.844, p = 1.000). This result was supported by the significant correlation between initial landing position and first fixation (r = 0.190, p < 0.001), which indicates that the further the first fixation lands to the left, the shorter its duration. If, on the other hand, the first fixation landed further into the compound, as it is the case for unsegmented compounds, it is longer and thus indicative of holistic processing. This relationship between initial landing position and compositional or holistic processing, respectively, could also be proven for the target group: When reading hyphenated compounds, the eyes' initial landing position was shifted to the left, compared to reading unsegmented compounds (β = -11.83, t = -0.728, p = 1.000) and compounds with mediopoint (β = -14.21, t = -0.858, p = 1.000). In addition, the initial landing position correlated significantly with first fixation duration (r = 0.133, p = 0.004), indicating that the further the first fixation lands to the left, the shorter its duration. Therefore, we can infer that the hyphen affects the initial landing position and restricts the readers' attentional focus to the first constituent. In contrast, when reading unsegmented compounds, readers tend to direct the eyes toward the word's center, which is regarded as the optimal location for its recognition (cf. O'Regan/Lévy-Schoen 1987; Vitu et al. 1990). Therefore, their attention is stretched over the whole word, which enables direct access to the whole-word representation. Consequently, the longer first fixation indicates that the readers' eyes land further into the word, which enables them to directly process the compound as a whole. The fact that the reader does not only process the first morpheme, but instead the whole compound, also results in less refixations. Our results therefore provide substantial evidence that hyphenation enforces a compositional processing.

In hyphenated compounds, the reader tends to land on the first constituent and their attention is at first restricted to a shorter and more frequent unit, which leads to initial processing advantages (i.e., a shorter first fixation) for hyphenated compounds. However, the subsequent processing stages are "disrupted by the presence of a hyphen at the constituent boundary, presumably due to encouraging sequential processing in case where simultaneous constituent processing and with that rapid access to whole-word representation is a viable option" (Bertram/Hyönä 2013:161).

Following the line of reasoning in the aforementioned studies, we argue that hyphenation of compounds is beneficial for lexical decomposition and for accessing the compound's first constituent, which is reflected by the shorter first fixation, compared to concatenated compounds. However, as the total reading time and the number of fixations reflect, the enforced focusing on the first constituent only requires additional processing time and is detrimental for accessing the compound via the more rapid and usually preferred direct route. Instead of accessing the whole-word representation, the reader has to access (at least) two representations and is subsequently required to assemble the individual words together, which requires additional processing effort (cf. Bertram/Hyönä 2013). Therefore, the hyphen is a useful segmentation cue in that it signals to the reader parafoveally where one constituent ends and another begins. One of the downsides of the hyphen, however, is that it forces the reader to limit his/her attention predominantly to the first constituent, even though without the hyphen the reader would be capable of simultaneously extracting and processing visual information of the following constituents (cf. Bertram/Hyönä 2013). Concatenated compounds instead allow for quick activation of the whole compound.

Against this background, we are now also able to explain why the first fixation in Experiment 1 is significantly longer for participants with higher literacy skills than for participants with lower literacy skills. Considering that unimpaired readers read the compounds significantly faster and with significantly less fixations than impaired readers, the result that the first fixation duration increases with reading proficiency was at first surprising. However, given the theoretical framework and findings of previous studies, it has now become apparent that a longer first fixation, combined with a shorter total reading time and a lower number of fixations, indicates that the compound is accessed directly by its whole-word representation. The significant differences between the groups therefore allow for the conclusion that, in contrast to impaired readers, unimpaired readers process compounds primarily via the whole-word representation, which is reflected by a longer first fixation, a shorter reading time, and lower number of fixations. However, the previous theoretical explanations have demonstrated that the hyphenation of compounds is detrimental for its direct access, which in turn would imply that both impaired and unimpaired readers access hyphenated compounds via morphological decomposition. But if both groups process the compound via the morpheme-based route, how is it possible that the first fixation is significantly longer in readers with higher reading skills? To answer this question, we looked at the differences for the three boundary conditions separately. By doing so, it became apparent that the difference in first fixations was significant for concatenated compounds (z = -2.587, p = 0.010, r = 0.107) and marginally significant for compounds with mediopoint (z = -1.770, p = 0.077, r = 0.073). However, for hyphenated compounds the unimpaired readers' first fixation was only minimally and not significantly longer than the impaired readers' first fixation (z = -0.757, p = 0.449, r = 0.031), which supports the assumption that both impaired and unimpaired readers process hyphenated compounds via morphological decomposition and that hyphenation is detrimental to accessing the compound via the direct route.

When presenting compounds in sentences, a different pattern emerged. Here, the first fixation was, in contrast to Experiment 1, longer for less-skilled readers than for high-skilled readers. This tendency emerged not only when comparing the first fixation duration within the target group, but also when comparing the first fixation duration for unimpaired readers and the target group. As noted before, this tendency contradicts the finding of Experiment 1, in which the first fixation was significantly shorter for less-skilled readers than for better-skilled readers, which was taken as an indication of a morpheme-based processing of the compound. However, as shown above, a significantly shorter first fixation is only indicative of a morpheme-based access if it appears in combination with a significant higher number of fixations and a significant longer total reading time. Since the unimpaired readers read the compounds with significantly less fixations and significantly faster, the significantly shorter first fixation can, in this experiment, not be regarded as evidence for a morpheme-based processing of the compound. Instead, the results indicate that, in combination with a significantly lower number of fixations and a significantly shorter reading time, a significantly shorter first fixation indicates that if compounds are presented in sentences, unimpaired readers process compounds significantly faster than impaired readers at all processing stages. We assume that this unrestricted processing benefit for higher-skilled readers when reading compounds in context is due to their larger inventory of frames, higher reading skills, and context experiences, which enables them to make more use of parafoveal information and thus to recognize and process compounds faster than less experienced readers (see also Bredel/Maaß 2016).

Discussion

In Easy Language, four guidelines postulate that compounds are to be optically segmented with either hyphen or mediopoint to facilitate lexical access to the compound's constituents. However, empirical research efforts into cognitive processing of compounds in EL are still lacking. To address this research gap, we conducted two eye-tracking experiments evaluating the effect of visual segmentation (hyphen and mediopoint), number of morphemes, and context on the processing on compounds in unimpaired readers and in deaf and hard-of-hearing pupils. The study demonstrated that the benefit of segmentation is dependent on reading proficiency. While less-skilled readers of the EL target group clearly benefited from segmentation of compounds, it seems that for deaf and hard-of-hearing students with higher literacy skills, segmentation of compounds is unnecessary. Moreover, we provided empirical evidence that segmenting compounds with a mediopoint offers more processing advantages than segmenting compounds with an orthographically incorrect hyphen – at least for unimpaired readers and low-skilled pupils with hearing impairment. Furthermore, our results indicate that reading compounds without context differs from reading compounds with context and that the context facilitates the processing of compounds regardless of readers' reading proficiency.

Our findings support the assumption of Pappert/Bock (2020) that “the need for compound segmentation will interact with reading proficiency” (Pappert/Bock 2020:1123). The result that unimpaired readers do not benefit from segmentation signs also converges with the study by Pappert/Bock (2020), which demonstrated that segmentation of compounds disrupts the reading process for unimpaired readers (cf. ibid.:1110). We were able to explain this result by showing that the hyphen forces a morpheme-based access and is therefore detrimental for the holistic processing of the compound. Consequently, the hyphen is a useful segmentation cue in that it enables fast recognition of the compound's first constituent. However, since the hyphen restricts the readers' attentional focus to the first constituent and enforces sequential processing of the compounds' constituents, it hinders them from accessing the compound via the direct route and consequently slows down the processing of the whole compound word. Concatenated compounds instead are usually processed via the more rapid direct route, in which the whole-word representation of the compound is activated. This pattern of results can best be explained by hybrid models of compound processing (e.g., Schreuder/Baayen 1995; Libben 2006; or Kuperman et al. 2009). When processing compounds, both constituent and whole-word information can be activated, which implies that the morpheme-based route competes with the direct look-up of the compound. Since less-skilled readers usually process compounds via the morpheme-based route, they are more dependent on visual cues marking the morpheme boundaries. Higher-skilled readers predominantly process compounds in a holistic fashion, thus making use of all constituents available in the foveal and parafoveal span.

Our findings for unimpaired readers, however, partly stand in contrast to eye-tracking findings by Bertram/Hyönä (2003) and Bertram/Hyönä (2013), who demonstrated that adult readers benefit from hyphenation in long compounds. This finding is explained by the fact that long compounds do not fully fit in the foveal area, where visual acuity is at its best. Therefore, when reading long compounds, adult readers often resort to the decomposition route, starting by identifying and processing the first constituent. Since hyphenation facilitates the identification of the first and all other constituents, adult readers benefit from visual segmentation in long compounds, in which they initially access the first constituent anyway. However, we were unable to reliably show a facilitating effect of hyphenation in long compounds for unimpaired readers. These differences may be accounted for by language-specific characteristics, since none of the studies were conducted with German compounds. As Häikiö et al. (2009) suggest, "it may well be that the size of specific components of the perceptual span are language specific (Rayner, 1998)" (Häikiö et al. 2009:171) and that the development and use of the letter identity span differs between languages. So far, we still do not know whether unimpaired readers process long German compounds which extend beyond foveal vision via the decompositional or the holistic route. However, we do know that, even if processed via decomposition, unimpaired readers do not profit from hyphenation. This might be due to the fact that they are more familiar with reading concatenated long compounds than hyphenated long compounds and when reading hyphenated compounds, they presumably only expect a hyphen at the major morpheme boundary (as it is used in the word "Mehrzweck-Küchenmaschine" [multipurpose food processor]) and not between every constituent. Therefore, they are disrupted by the presence of hyphens at every morpheme boundary (Mehr-Zweck-Küchen-Maschine).

Our finding that recipients from the target group with higher literacy skills do not seem to profit from segmentation converges with findings from previous eye-tracking studies on the processing of compounds (e.g., Gutermuth 2020; Häikiö et al. 2011). Following the line of reasoning in Gutermuth (2020) and Maaß (2020), we suggest that this missing processing benefit for higher-skilled pupils can be explained by the process-based capacity model for EL (Gutermuth 2020) and with that, by the interaction of linguistic levels. We presented compounds only in isolated form or within simple sentences, which implies that the complexity at the phrasal, syntactic, and textual levels was maximally reduced. Reducing the complexity at three out of four levels to a minimum might relieve the overall processing capacity, meaning more cognitive resources are available that can be used for the processing of complex morphological structures (i.e., unsegmented compounds). Therefore, our findings support the framework proposed by Gutermuth (2020), who stated that the easier the texts, the more capacity remains for the processing of unsegmented compounds. Based on the proposal of Gutermuth (2020), it is possible that, for higher-skilled readers, visual segmentation is unnecessary if compounds are embedded in a text which is characterized by a low complexity at the phrasal, syntactic, and textual level, whereas in a text which is characterized by a more complex syntax, segmentation of compounds can contribute to relieving the capacity at the morphological level. Investigating this trade-off, i.e., determining the extent to which the complexity at other linguistic levels influences the need for segmentation of compounds, certainly provides a promising avenue for future research.

Ethics and Conflict of Interest

The study was approved by the ethics committee of the Deutsche Gesellschaft für Sprachwissenschaft (DGfS) (German Linguistic Society) (Note No. 2019-01–190823). The authors report no conflict of interest regarding the publication of this paper.

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Appendix

Appendix 1: Descriptive statistics

1.1 Experiment 1

Table 1: Descriptive statistics for unimpaired readers

	2 morphemes			3 morphemes			4 morphemes		
	stand.	hyphen	mediop.	stand.	hyphen	mediop.	stand.	hyphen	mediop.
fixation count	3.01 (1.36)	3.19 (1.51)	3.14 (1.3)	3.92 (2.13)	4.73 (2.42)	3.88 (1.66)	6.23 (3.06)	6.44 (2.19)	6.77 (2.53)
rate of regressions (%)	26.13 (22.61)	25.03 (21.33)	21.83 (20.53)	26.75 (19.54)	30.35 (18.48)	27 (19.84)	33.09 (14.91)	35.81 (11.83)	32.58 (12.53)
first fixation duration (ms)	205 (118.3)	196.79 (93.15)	199.82 (129.8)	207.55 (118.59)	185.1 (83.22)	190.28 (89.01)	177.76 (72.54)	166.07 (76.24)	179.9 (70.77)
total reading time (ms)	819.9 (495.3)	785.63 (469.88)	822.74 (470.75)	991.47 (697.86)	1076.64 (655.38)	899.1 (408.85)	1377.9 (833.19)	1331.36 (565.74)	1503.12 (665.13)

Table 2: Descriptive statistics for the target group

	2 morphemes			3 morphemes			4 morphemes		
	stand.	hyphen	mediop.	stand.	hyphen	mediop.	stand.	hyphen	mediop.
fixation count	3.68 (1.71)	3.67 (2.00)	3.72 (1.49)	5.52 (2.85)	5.58 (2.15)	5.7 (4.56)	7.39 (3.43)	8.09 (4.07)	7.48 (3.11)
rate of regres-sions (%)	25.85 (22.21)	24.46 (21.97)	28.91 (21.06)	30.74 (17.62)	37.30 (14.42)	25.09 (19.43)	33.15 (14.64)	34.85 (13.94)	30.22 (12.51)
first fixation duration (ms)	222.08 (196.06)	207.68 (149.93)	198.95 (148.06)	174.09 (95.15)	166.66 (73.31)	189.89 (85.16)	161.57 (57.02)	196.07 (156.18)	170.98 (81.26)
total reading time (ms)	1002.91 (509.14)	903.07 (569.66)	933.49 (494.42)	1337.23 (771.77)	1290.09 (719.71)	1382.32 (1285.6)	1682.55 (927.44)	1759.91 (925.68)	1702.14 (784.37)

Table 3: Descriptive statistics for pupils with lower reading skills

	2 morphemes			3 morphemes			4 morphemes		
	stand.	hyphen	mediop.	stand.	hyphen	mediop.	stand.	hyphen	mediop.
fixation count	4.38 (1.79)	4.52 (2.33)	4.38 (1.65)	7.22 (2.95)	6.42 (2.37)	7.73 (5.7)	9.33 (3.43)	10.19 (4.28)	8.15 (3.28)
rate of regres-sions (%)	26.19 (22.15)	30.52 (22.92)	28.46 (21.77)	35.52 (13.62)	35.42 (16.33)	30.58 (16.89)	32.85 (13.27)	37.15 (14.46)	29.3 (13.8)
first fixation duration (ms)	208.24 (212.86)	172.7 (143.79)	204.59 (175.37)	166.96 (113.79)	141.5 (76.31)	182.79 (68.9)	151.31 (58.79)	169.86 (68.4)	172.87 (83.52)
total reading time (ms)	1226.55 (573)	1098.6 (707.74)	1089.14 (589.86)	1742.04 (849.1)	1559.43 (866.1)	1968.87 (1615.11)	2140.85 (1009.04)	2248.7 (988.16)	1874.76 (743.37)

Table 4: Descriptive statistics for pupils with higher reading skills

	2 morphemes			3 morphemes			4 morphemes		
	stand.	hyphen	mediop.	stand.	hyphen	mediop.	stand.	hyphen	mediop.
fixation count	3 (1.33)	2.81 (1.11)	3.07 (0.96)	3.81 (1.33)	4.78 (1.58)	3.74 (1.53)	5.44 (2.1)	6 (2.51)	6.81 (2.83)
rate of regressions (%)	25.52 (22.69)	18.41 (19.55)	29.33 (20.76)	25.96 (19.99)	39.11 (12.36)	19.81 (20.53)	33.44 (16.14)	32.56 (13.28)	31.15 (11.27)
first fixation duration (ms)	235.41 (181.48)	242.66 (150.35)	193.52 (119.22)	181.21 (73.49)	190.89 (62.5)	196.72 (99.2)	171.84 (54.34)	222.28 (208.85)	169.09 (80.49)
total reading time (ms))	787.54 (323.35)	707.54 (284.94)	783.61 (326.8)	932.42 (390.98)	1030.73 (415.06)	817.5 (349.2)	1224.25 (546.78)	1271.11 (523.5)	1529.52 (799.77)

1.2 Experiment 2

Table 5: Descriptive statistics for unimpaired readers

	2 morphemes			3 morphemes			4 morphemes		
	stand.	hyphen	mediop.	stand.	hyphen	mediop.	stand.	hyphen	mediop.
fixation count	1.76 (0.99)	2.01 (1.07)	1.92 (0.92)	2.22 (1.05)	2.99 (1.29)	2.67 (1.15)	3.54 (1.37)	4.66 (1.87)	4.14 (1.44)
rate of regressions (%)	10.19 (18.99)	13.32 (20.72)	11.57 (19.51)	14.01 (20.3)	18.4 (19.81)	13.7 (19.06)	21.81 (17.52)	22.48 (16.11)	20.86 (16.54)
first fixation duration (ms)	203.2 (99.64)	192.56 (77.68)	206.49 (117.74)	197.93 (98.16)	194.91 (77.25)	190.2 (92.58)	181.71 (98.56)	178.8 (71.99)	188.76 (82.95)
total reading time (ms)	368.5 (252.2)	428.64 (281.04)	415.59 (117.74)	526.71 (469.42)	653.58 (355.02)	569.12 (303.6)	799.47 (443.89)	1012.36 (471.04)	882.28 (320.64)

Table 6: Descriptive statistics for the target group

	2 morphemes			3 morphemes			4 morphemes		
	stand.	hyphen	mediop.	stand.	hyphen	mediop.	stand.	hyphen	mediop.
fixation count	2.46 (1.36)	2.55 (1.17)	2.66 (1.33)	2.9 (1.66)	3.6 (1.56)	3.39 (1.4)	4.8 (2.05)	5.83 (2.55)	5.06 (1.8)
rate of regressions (%)	12.23 (19.73)	14.04 (18.69)	16.58 (19.37)	15.79 (18.84)	21.3 (19.74)	14.55 (19.03)	28.65 (15.55)	26.59 (16.33)	25.27 (14.84)
first fixation duration (ms)	231.01 (114.45)	257.95 (146.2)	234.24 (171.82)	277.5 (213.55)	238.74 (134)	262.23 (235.1)	235.39 (200.58)	191.22 (88.67)	195.8 (76.24)
total reading time (ms)	682.1 (611.67)	755.66 (557.71)	727.12 (562.15)	904.57 (683.21)	1097.5 (625.31)	1002.24 (547.12)	1538.56 (886.6)	1667.02 (820.01)	1546.13 (884.7)

Table 7: Descriptive statistics for pupils with lower reading skills

	2 morphemes			3 morphemes			4 morphemes		
	stand.	hyphen	mediop.	stand.	hyphen	mediop.	stand.	hyphen	mediop.
fixation count	2.62 (1.5)	2.56 (1.34)	2.88 (1.42)	3.19 (1.98)	4.04 (1.82)	3.4 (1.56)	5.11 (1.95)	6.22 (2.75)	4.96 (1.7)
rate of regressions (%)	12.96 (20.65)	10.37 (15.77)	16.42 (19.3)	15.96 (18.3)	24.12 (18.74)	13.48 (20.38)	27.22 (15.41)	30.04 (15.9)	20.84 (15.56)
first fixation duration (ms)	234.02 (133.22)	281.37 (162.98)	247.98 (217.46)	272.61 (246.61)	235.49 (149.21)	270.71 (304.12)	219.37 (172.93)	175.42 (83.25)	210.2 (98.33)
total reading time (ms)	828.2 (781.73)	890.37 (697.73)	859.59 (688.1)	1109.74 (816.43)	1366.94 (731.32)	1167.36 (682.56)	1849.56 (1006.71)	1979.85 (873.39)	1721.3 (844.24)

Table 8: Descriptive statistics for pupils with higher reading skills

	2 morphemes			3 morphemes			4 morphemes		
	stand.	hyphen	mediop.	stand.	hyphen	mediop.	stand.	hyphen	mediop.
fixation count	2.31 (1.23)	2.54 (0.99)	2.46 (1.24)	2.62 (1.24)	3.19 (1.15)	3.38 (1.27)	4.48 (2.14)	5.44 (2.31)	5.15 (1.92)
rate of regres-sions (%)	11.5 (19.14)	17.85 (20.94)	16.73 (19.82)	15.62 (19.71)	18.59 (20.64)	15.58 (17.99)	30.07 (15.86)	23.15 (16.31)	29.37 (13.12)
first fixation duration (ms)	228.09 (94.63)	233.62 (124.99)	221.55 (118.34)	282.39 (179.34)	241.87 (120.34)	254.09 (147.03)	251.4 (227.09)	207.02 (92.62)	182.46 (45.74)
total reading time (ms)	536 (328.26)	615.75 (317.33)	604.84 (389.07)	699.41 (445.12)	838.04 (353.93)	843.48 (312.97)	1227.56 (622.89)	1354.18 (636.09)	1383.94 (905.83)

Appendix 2: Post-hoc comparisons

2.1 Unimpaired readers (Experiment 1)

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
fixation count	mediop. – hyphen	-0.197	0.115	-1.714	0.261
	mediop. – standard	0.205	0.115	1.777	0.227
	hyphen – standard	0.402	0.115	3.493	0.002
	mediop. 2 – hyphen 2	-0.067	0.200	-0.336	1.000
	mediop. 2 – standard 2	0.117	0.200	0.588	1.000
	hyphen 2 – standard 2	0.184	0.199	0.925	1.000
	mediop. 3 – hyphen 3	-0.851	0.199	-4.271	0.001
	mediop. 3 – standard 3	-0.043	0.199	-0.214	1.000
	hyphen 3 – standard 3	0.809	0.199	4.057	0.002
	mediop. 4 – hyphen 4	0.326	0.199	1.637	1.000
	mediop. 4 – standard 4	0.539	0.199	2.705	0.249
	hyphen 4 – standard 4	0.213	0.199	1.068	1.000

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
regressions	mediop. – hyphen	-3.26	1.24	-2.632	0.026
	mediop. – standard	-1.52	1.24	-1.226	0.661
	hyphen – standard	1.74	1.24	1.407	0.479
	mediop. 2 – hyphen 2	-3.206	2.15	-1.493	1.000
	mediop. 2 – standard 2	-4.305	2.15	-2.005	1.000
	hyphen 2 – standard 2	-1.099	2.14	-0.513	1.000
	mediop. 3 – hyphen 3	-3.348	2.14	-1.562	1.000
	mediop. 3 – standard 3	0.248	2.14	0.116	1.000
	hyphen 3 – standard 3	3.596	2.14	1.678	1.000
	mediop. 4 – hyphen 4	-3.227	2.14	-1.506	1.000
	mediop. 4 – standard 4	-0.504	2.14	-0.235	1.000
	hyphen 4 – standard 4	2.723	2.14	1.271	1.000
first fixation duration	mediop. – hyphen	7.43	6.50	1.143	0.760
	mediop. – standard	-6.69	6.50	-1.029	0.912
	hyphen – standard	-14.11	6.49	-2.173	0.090
	mediop. 2 – hyphen 2	3.28	11.3	0.291	1.000
	mediop. 2 – standard 2	-4.93	11.3	-0.437	1.000
	hyphen 2 – standard 2	-8.20	11.2	-0.729	1.000
	mediop. 3 – hyphen 3	5.18	11.2	0.460	1.000
	mediop. 3 – standard 3	-17.27	11.2	-1.535	1.000
	hyphen 3 – standard 3	-22.45	11.2	-1.996	1.000
	mediop. 4 – hyphen 4	13.82	11.2	1.229	1.000
	mediop. 4 – standard 4	2.14	11.2	0.190	1.000
	hyphen 4 – standard 4	-11.68	11.2	1.039	1.000
total reading time	mediop. – hyphen	9.49	31.4	0.302	1.000
	mediop. – standard	10.95	31.4	0.348	1.000
	hyphen – standard	1.46	31.4	0.047	1.000
	mediop. 2 – hyphen 2	34.247	54.5	0.628	1.000
	mediop. 2 – standard 2	0.010	54.5	0.000	1.000
	hyphen 2 – standard 2	-34.238	54.4	-0.629	1.000
	mediop. 3 – hyphen 3	-177.542	54.4	-3.262	0.041
	mediop. 3 – standard 3	-92.368	54.4	-1.697	1.000
	hyphen 3 – standard 3	85.174	54.4	1.565	1.000
	mediop. 4 – hyphen 4	171.760	54.4	3.156	0.059
	mediop. 4 – standard 4	125.212	54.4	2.301	0.777
	hyphen 4 – standard 4	-46.548	54.4	-0.855	1.000

2.2 Target group (Experiment 1)

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
fixation count	mediop. – hyphen	-0.189	0.273	-0.693	1.000
	mediop. – standard	0.089	0.273	0.328	1.000
	hyphen – standard	0.278	0.272	1.022	0.992
	mediop. 2 – hyphen 2	0.009	0.473	0.020	1.000
	mediop. 2 – standard 2	0.038	0.476	0.079	1.000
	hyphen 2 – standard 2	0.028	0.473	0.060	1.000
	mediop. 3 – hyphen 3	0.041	0.476	0.086	1.000
	mediop. 3 – standard 3	0.139	0.473	0.293	1.000
	hyphen 3 – standard 3	0.098	0.473	0.206	1.000
	mediop. 4 – hyphen 4	-0.611	0.471	-1.297	1.000
	mediop. 4 – standard 4	0.093	0.471	0.197	1.000
	hyphen 4 – standard 4	0.704	0.471	1.494	1.000
regressions	mediop. – hyphen	-4.20	1.92	-2.188	0.088
	mediop. – standard	-1.87	1.92	-0.975	0.991
	hyphen – standard	2.33	1.92	1.215	0.675
	mediop. 2 – hyphen 2	4.341	3.33	1.304	1.000
	mediop. 2 – standard 2	3.057	3.34	0.914	1.000
	hyphen 2 – standard 2	-1.284	3.33	-0.386	1.000
	mediop. 3 – hyphen 3	-12.321	3.34	-3.685	0.009
	mediop. 3 – standard 3	-5.748	3.33	-1.728	1.000
	hyphen 3 – standard 3	6.572	3.33	1.975	1.000
	mediop. 4 – hyphen 4	-4.630	3.31	-1.398	1.000
	mediop. 4 – standard 4	-2.926	3.31	-0.884	1.000
	hyphen 4 – standard 4	1.704	3.31	0.514	1.000
first fixation duration	mediop. – hyphen	-3.758	13.5	-0.278	1.000
	mediop. – standard	0.546	13.5	0.040	1.000
	hyphen – standard	4.304	13.5	0.319	1.000
	mediop. 2 – hyphen 2	-9.18	23.4	-0.392	1.000
	mediop. 2 – standard 2	-23.13	23.5	-0.984	1.000
	hyphen 2 – standard 2	-13.95	23.4	-0.596	1.000
	mediop. 3 – hyphen 3	22.99	23.5	0.978	1.000
	mediop. 3 – standard 3	15.36	23.4	0.657	1.000
	hyphen 3 – standard 3	-7.63	23.4	-0.326	1.000
	mediop. 4 – hyphen 4	-25.09	23.3	-1.078	1.000
	mediop. 4 – standard 4	9.41	23.3	0.404	1.000
	hyphen 4 – standard 4	34.49	23.3	1.482	1.000

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
	mediop. – hyphen	10.17	69.2	0.147	1.000
	mediop. – standard	-6.22	69.2	-0.090	1.000
	hyphen – standard	-16.39	69.1	-0.237	1.000
	mediop. 2 – hyphen 2	16.5	120	0.137	1.000
	mediop. 2 – standard 2	-69.4	120	-0.576	1.000
	hyphen 2 – standard 2	-85.9	120	-0.716	1.000
total reading time	mediop. 3 – hyphen 3	71.8	121	0.596	1.000
	mediop. 3 – standard 3	31.2	120	0.260	1.000
	hyphen 3 – standard 3	-40.6	120	-0.339	1.000
	mediop. 4 – hyphen 4	-57.8	119	0.484	1.000
	mediop. 4 – standard 4	19.6	119	0.164	1.000
	hyphen 4 – standard 4	77.4	119	0.648	1.000

2.3 Pupils with lower reading skills (Experiment 1)

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
	mediop. – hyphen	-0.373	0.477	-0.782	1.000
	mediop. – standard	-0.265	0.477	-0.556	1.000
	hyphen – standard	0.108	0.475	0.227	1.000
	mediop. 2 – hyphen 2	-0.253	0.826	-0.306	1.000
	mediop. 2 – standard 2	0.000	0.833	0.000	1.000
	hyphen 2 – standard 2	0.253	0.826	0.306	1.000
fixation count	mediop. 3 – hyphen 3	1.171	0.834	1.405	1.000
	mediop. 3 – standard 3	0.389	0.826	0.472	1.000
	hyphen 3 – standard 3	-0.782	0.826	-0.947	1.000
	mediop. 4 – hyphen 4	-2.037	0.818	-2.491	0.485
	mediop. 4 – standard 4	-1.185	0.818	-1.449	1.000
	hyphen 4 – standard 4	0.852	0.818	1.042	1.000

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
regressions	mediop. – hyphen	-5.12	2.64	-1.936	0.162
	mediop. – standard	-2.21	2.64	-0.835	1.000
	hyphen – standard	2.91	2.64	1.105	0.811
	mediop. 2 – hyphen 2	-2.326	4.60	-0.506	1.000
	mediop. 2 – standard 2	2.269	4.64	0.489	1.000
	hyphen 2 – standard 2	4.596	4.60	0.999	1.000
	mediop. 3 – hyphen 3	-5.090	4.65	-1.096	1.000
	mediop. 3 – standard 3	-5.211	4.60	-1.133	1.000
	hyphen 3 – standard 3	-0.121	4.60	-0.026	1.000
	mediop. 4 – hyphen 4	-7.852	4.56	-1.723	1.000
	mediop. 4 – standard 4	-3.556	4.56	-0.780	1.000
	hyphen 4 – standard 4	4.296	4.56	0.943	1.000
first fixation duration	mediop. – hyphen	25	18.9	1.326	0.559
	mediop. – standard	11	18.9	0.585	1.000
	hyphen – standard	-14	18.8	-0.744	1.000
	mediop. 2 – hyphen 2	31.264	32.7	0.956	1.000
	mediop. 2 – standard 2	-3.646	33.0	-0.111	1.000
	hyphen 2 – standard 2	-34.910	32.7	-1.068	1.000
	mediop. 3 – hyphen 3	40.813	33.0	1.236	1.000
	mediop. 3 – standard 3	15.209	32.7	0.465	1.000
	hyphen 3 – standard 3	-25.604	32.7	-0.783	1.000
	mediop. 4 – hyphen 4	3.015	32.4	0.093	1.000
	mediop. 4 – standard 4	21.559	32.4	0.666	1.000
	hyphen 4 – standard 4	18.544	32.4	0.573	1.000
total reading time	mediop. – hyphen	-18.2	119	-0.153	1.000
	mediop. – standard	-72.1	119	-0.606	1.000
	hyphen – standard	-53.9	119	-0.454	1.000
	mediop. 2 – hyphen 2	-49.1	206	-0.238	1.000
	mediop. 2 – standard 2	-137.4	208	-0.661	1.000
	hyphen 2 – standard 2	-88.3	206	-0.428	1.000
	mediop. 3 – hyphen 3	368.3	208	1.769	1.000
	mediop. 3 – standard 3	187.2	206	0.908	1.000
	hyphen 3 – standard 3	-181.1	206	-0.879	1.000
	mediop. 4 – hyphen 4	-373.9	204	-1.832	1.000
	mediop. 4 – standard 4	-266.1	204	-1.304	1.000
	hyphen 4 – standard 4	107.8	204	0.528	1.000

2.4 Pupils with higher reading skills (Experiment 1)

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
fixation count	mediop. – hyphen	0.012	0.245	0.050	1.000
	mediop. – standard	0.457	0.245	1.865	0.191
	hyphen – standard	0.444	0.245	1.814	0.213
	mediop. 2 – hyphen 2	0.259	0.424	0.611	1.000
	mediop. 2 – standard 2	0.074	0.424	0.175	1.000
	hyphen 2 – standard 2	-0.185	0.424	-0.436	1.000
	mediop. 3 – hyphen 3	-1.037	0.424	-2.444	0.550
	mediop. 3 – standard 3	-0.074	0.424	-0.175	1.000
	hyphen 3 – standard 3	0.963	0.424	2.270	0.870
	mediop. 4 – hyphen 4	0.815	0.424	1.921	1.000
	mediop. 4 – standard 4	1.370	0.424	3.230	0.051
	hyphen 4 – standard 4	0.556	0.424	1.309	1.000
regressions	mediop. – hyphen	-3.26	2.74	-1.188	0.709
	mediop. – standard	-1.54	2.74	-0.562	1.000
	hyphen – standard	1.72	2.74	0.625	1.000
	mediop. 2 – hyphen 2	10.926	4.75	2.299	0.808
	mediop. 2 – standard 2	3.815	4.75	0.803	1.000
	hyphen 2 – standard 2	-7.111	4.75	-1.496	1.000
	mediop. 3 – hyphen 3	-19.296	4.75	-4.060	0.002
	mediop. 3 – standard 3	-6.148	4.75	-1.293	1.000
	hyphen 3 – standard 3	13.148	4.75	2.766	0.221
	mediop. 4 – hyphen 4	-1.407	4.75	-0.296	1.000
	mediop. 4 – standard 4	-2.296	4.75	-0.483	1.000
	hyphen 4 – standard 4	-0.889	4.75	-0.187	1.000
first fixation duration	mediop. – hyphen	-32.17	19.4	-1.656	0.298
	mediop. – standard	-9.71	19.4	-0.500	1.000
	hyphen – standard	22.46	19.4	1.156	0.747
	mediop. 2 – hyphen 2	-49.14	33.7	-1.460	1.000
	mediop. 2 – standard 2	-41.89	33.7	-1.245	1.000
	hyphen 2 – standard 2	7.26	33.7	0.216	1.000
	mediop. 3 – hyphen 3	5.83	33.7	0.173	1.000
	mediop. 3 – standard 3	15.51	33.7	0.461	1.000
	hyphen 3 – standard 3	9.68	33.7	0.288	1.000
	mediop. 4 – hyphen 4	-53.19	33.7	-1.581	1.000
	mediop. 4 – standard 4	-2.75	33.7	-0.082	1.000
	hyphen 4 – standard 4	50.44	33.7	1.499	1.000

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
total reading time	mediop. – hyphen	40.4	65.9	0.613	1.000
	mediop. – standard	62.1	65.9	0.943	1.000
	hyphen – standard	21.7	65.9	0.330	1.000
	mediop. 2 – hyphen 2	76.07	114	0.666	1.000
	mediop. 2 – standard 2	-3.93	114	-0.034	1.000
	hyphen 2 – standard 2	-80.00	114	-0.701	1.000
	mediop. 3 – hyphen 3	-213.23	114	-1.868	1.000
	mediop. 3 – standard 3	-114.93	114	-1.007	1.000
	hyphen 3 – standard 3	98.30	114	0.861	1.000
	mediop. 4 – hyphen 4	258.40	114	2.263	0.884
	mediop. 4 – standard 4	305.27	114	2.674	0.290
	hyphen 4 – standard 4	46.86	114	0.410	1.000

2.5 Unimpaired readers (Experiment 2)

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
fixation count	mediop. – hyphen	-0.309	0.081	-3.808	< 0.001
	mediop. – standard	0.397	0.081	4.886	< 0.001
	hyphen – standard	0.706	0.082	8.665	< 0.001
	mediop. 2 – hyphen 2	-0.082	0.142	-0.579	1.000
	mediop. 2 – standard 2	0.154	0.142	1.080	1.000
	hyphen 2 – standard 2	0.236	0.143	1.647	1.000
	mediop. 3 – hyphen 3	-0.326	0.140	-2.334	0.711
	mediop. 3 – standard 3	0.447	0.140	3.194	0.052
	hyphen 3 – standard 3	0.773	0.140	5.524	< 0.001
	mediop. 4 – hyphen 4	-0.518	0.140	-3.704	0.008
	mediop. 4 – standard 4	0.591	0.140	4.220	0.001
	hyphen 4 – standard 4	1.109	0.140	7.918	< 0.001

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
regressions	mediop. – hyphen	-2.664	1.26	-2.107	0.106
	mediop. – standard	-0.029	1.27	-0.022	1.000
	hyphen – standard	2.635	1.27	2.074	0.115
	mediop. 2 – hyphen 2	-1.672	2.21	-0.757	1.000
	mediop. 2 – standard 2	1.223	2.22	0.551	1.000
	hyphen 2 – standard 2	2.895	2.23	1.296	1.000
	mediop. 3 – hyphen 3	-4.695	2.18	-2.154	1.000
	mediop. 3 – standard 3	-0.339	2.18	-0.155	1.000
	hyphen 3 – standard 3	4.356	2.18	1.995	1.000
	mediop. 4 – hyphen 4	-1.624	2.18	-0.745	1.000
	mediop. 4 – standard 4	-0.970	2.18	-0.444	1.000
	hyphen 4 – standard 4	0.654	2.18	0.300	1.000
first fixation duration	mediop. – hyphen	6.39	6.22	1.030	0.909
	mediop. – standard	1.00	6.22	0.161	1.000
	hyphen – standard	-5.39	6.24	-0.864	1.000
	mediop. 2 – hyphen 2	13.94	10.8	1.286	1.000
	mediop. 2 – standard 2	3.70	10.9	0.339	1.000
	hyphen 2 – standard 2	-10.24	11.0	-0.934	1.000
	mediop. 3 – hyphen 3	-4.71	10.7	-0.440	1.000
	mediop. 3 – standard 3	-7.79	10.7	-0.727	1.000
	hyphen 3 – standard 3	-3.08	10.7	-0.287	1.000
	mediop. 4 – hyphen 4	9.95	10.7	0.930	1.000
	mediop. 4 – standard 4	7.10	10.7	0.662	1.000
	hyphen 4 – standard 4	-2.85	10.7	-0.266	1.000
total reading time	mediop. – hyphen	-75.8	21.5	-3.525	0.001
	mediop. – standard	57.6	21.6	2.668	0.023
	hyphen – standard	133.4	21.6	6.169	< 0.001
	mediop. 2 – hyphen 2	-12.9	37.6	-0.343	1.000
	mediop. 2 – standard 2	48.8	37.8	1.292	1.000
	hyphen 2 – standard 2	61.7	38.0	1.623	1.000
	mediop. 3 – hyphen 3	-84.5	37.1	-2.277	0.826
	mediop. 3 – standard 3	43.0	37.2	1.156	1.000
	hyphen 3 – standard 3	127.4	37.2	3.429	0.023
	mediop. 4 – hyphen 4	-130.1	37.1	-3.508	0.017
	mediop. 4 – standard 4	80.9	37.2	2.178	1.000
	hyphen 4 – standard 4	211.0	37.2	5.679	< 0.001

2.6 Target group (Experiment 2)

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
fixation count	mediop. – hyphen	-0.298	0.185	-1.612	0.323
	mediop. – standard	0.315	0.186	1.700	0.270
	hyphen – standard	0.614	0.183	3.346	0.003
	mediop. 2 – hyphen 2	0.104	0.322	0.323	1.000
	mediop. 2 – standard 2	0.190	0.323	0.589	1.000
	hyphen 2 – standard 2	0.087	0.319	0.271	1.000
	mediop. 3 – hyphen 3	-0.211	0.320	-0.659	1.000
	mediop. 3 – standard 3	0.497	0.322	1.545	1.000
	hyphen 3 – standard 3	0.708	0.319	2.222	0.965
	mediop. 4 – hyphen 4	-0.777	0.317	-2.449	0.530
	mediop. 4 – standard 4	0.260	0.317	0.820	1.000
	hyphen 4 – standard 4	1.037	0.314	3.303	0.037
regressions	mediop. – hyphen	-1.750	2.00	-0.873	1.000
	mediop. – standard	-0.020	2.01	-0.010	1.000
	hyphen – standard	1.730	1.99	0.871	1.000
	mediop. 2 – hyphen 2	2.691	3.49	0.770	1.000
	mediop. 2 – standard 2	4.478	3.51	1.276	1.000
	hyphen 2 – standard 2	1.786	3.46	0.517	1.000
	mediop. 3 – hyphen 3	-6.658	3.47	-1.916	1.000
	mediop. 3 – standard 3	-1.199	3.49	-0.344	1.000
	hyphen 3 – standard 3	5.459	3.46	1.579	1.000
	mediop. 4 – hyphen 4	-1.284	3.44	-0.373	1.000
	mediop. 4 – standard 4	-3.339	3.44	-0.970	1.000
	hyphen 4 – standard 4	-2.056	3.41	-0.603	1.000
first fixation duration	mediop. – hyphen	0.492	17.7	0.028	1.000
	mediop. – standard	-18.045	17.8	-1.014	0.933
	hyphen – standard	-18.537	17.6	-1.054	0.877
	mediop. 2 – hyphen 2	-24.69	30.9	-0.798	1.000
	mediop. 2 – standard 2	3.24	31.1	0.104	1.000
	hyphen 2 – standard 2	27.93	30.6	0.913	1.000
	mediop. 3 – hyphen 3	23.60	30.8	0.767	1.000
	mediop. 3 – standard 3	-15.78	30.9	-0.511	1.000
	hyphen 3 – standard 3	-39.37	30.6	-1.287	1.000
	mediop. 4 – hyphen 4	2.57	30.5	0.084	1.000
	mediop. 4 – standard 4	-41.60	30.5	-1.365	1.000
	hyphen 4 – standard 4	-44.16	30.2	-1.464	1.000

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
total reading time	mediop. – hyphen	-91.1	68.5	-1.330	0.552
	mediop. – standard	43.8	68.7	0.638	1.000
	hyphen – standard	135.0	67.9	1.988	0.142
	mediop. 2 – hyphen 2	-41.45	119	-0.347	1.000
	mediop. 2 – standard 2	38.44	120	0.321	1.000
	hyphen 2 – standard 2	79.9	118	0.676	1.000
	mediop. 3 – hyphen 3	-98.56	119	-0.830	1.000
	mediop. 3 – standard 3	98.05	119	0.822	1.000
	hyphen 3 – standard 3	196.61	118	1.664	1.000
	mediop. 4 – hyphen 4	-133.43	118	-1.134	1.000
	mediop. 4 – standard 4	-4.98	118	-0.042	1.000
	hyphen 4 – standard 4	128.46	116	1.103	1.000

2.6 Pupils with lower reading skills (Experiment 2)

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
fixation count	mediop. – hyphen	-0.539	0.284	-1.901	0.176
	mediop. – standard	0.095	0.284	0.336	1.000
	hyphen – standard	0.635	0.278	2.279	0.071
	mediop. 2 – hyphen 2	0.285	0.493	0.578	1.000
	mediop. 2 – standard 2	0.232	0.497	0.466	1.000
	hyphen 2 – standard 2	-0.053	0.482	-0.111	1.000
	mediop. 3 – hyphen 3	-0.627	0.492	-1.275	1.000
	mediop. 3 – standard 3	0.219	0.492	0.446	1.000
	hyphen 3 – standard 3	0.846	0.487	1.738	1.000
	mediop. 4 – hyphen 4	-1.276	0.488	-2.615	0.344
	mediop. 4 – standard 4	-0.165	0.488	-0.337	1.000
	hyphen 4 – standard 4	1.111	0.478	2.326	0.754

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
regressions	mediop. – hyphen	-4.41	2.82	-1.567	0.356
	mediop. – standard	-1.64	2.82	-0.580	1.000
	hyphen – standard	2.78	2.76	1.005	0.949
	mediop. 2 – hyphen 2	6.398	4.90	1.307	1.000
	mediop. 2 – standard 2	3.759	4.93	0.762	1.000
	hyphen 2 – standard 2	-2.639	4.79	-0.551	1.000
	mediop. 3 – hyphen 3	-10.538	4.88	-2.159	1.000
	mediop. 3 – standard 3	-2.384	4.88	-0.488	1.000
	hyphen 3 – standard 3	8.154	4.83	1.688	1.000
	mediop. 4 – hyphen 4	-9.098	4.84	-1.879	1.000
	mediop. 4 – standard 4	-6.283	4.84	-1.298	1.000
	hyphen 4 – standard 4	2.815	4.74	0.594	1.000
first fixation duration	mediop. – hyphen	9.40	28.8	0.327	1.000
	mediop. – standard	-1.09	28.8	-0.038	1.000
	hyphen – standard	-10.48	28.2	-0.371	1.000
	mediop. 2 – hyphen 2	-35.84	50.0	-0.717	1.000
	mediop. 2 – standard 2	13.78	50.4	0.273	1.000
	hyphen 2 – standard 2	49.62	48.9	1.014	1.000
	mediop. 3 – hyphen 3	33.96	49.9	0.681	1.000
	mediop. 3 – standard 3	-3.16	49.9	-0.063	1.000
	hyphen 3 – standard 3	-37.12	49.4	-0.752	1.000
	mediop. 4 – hyphen 4	30.07	49.5	0.608	1.000
	mediop. 4 – standard 4	-13.88	49.5	-0.281	1.000
	hyphen 4 – standard 4	-43.95	48.4	-0.907	1.000
total reading time	mediop. – hyphen	-195.4	112	-1.749	0.245
	mediop. – standard	-38.9	112	-0.348	1.000
	hyphen – standard	156.5	110	1.427	0.465
	mediop. 2 – hyphen 2	-80.3	194	-0.414	1.000
	mediop. 2 – standard 2	1.6	196	0.008	1.000
	hyphen 2 – standard 2	81.9	190	0.431	1.000
	mediop. 3 – hyphen 3	-206.3	194	-1.065	1.000
	mediop. 3 – standard 3	50.9	194	0.263	1.000
	hyphen 3 – standard 3	257.2	192	1.342	1.000
	mediop. 4 – hyphen 4	-299.7	216	-1.559	1.000
	mediop. 4 – standard 4	-169.4	216	-0.881	1.000
	hyphen 4 – standard 4	130.3	216	0.693	1.000

2.7 Pupils with higher reading skills (Experiment 2)

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
fixation count	mediop. – hyphen	-0.063	0.239	-0.264	1.000
	mediop. – standard	0.532	0.240	2.218	0.083
	hyphen – standard	0.595	0.239	2.489	0.041
	mediop. 2 – hyphen 2	-0.077	0.419	-0.183	1.000
	mediop. 2 – standard 2	0.154	0.419	0.367	1.000
	hyphen 2 – standard 2	0.231	0.419	0.550	1.000
	mediop. 3 – hyphen 3	0.190	0.416	0.457	1.000
	mediop. 3 – standard 3	0.769	0.419	1.834	1.000
	hyphen 3 – standard 3	0.579	0.416	1.394	1.000
	mediop. 4 – hyphen 4	-0.296	0.411	-0.720	1.000
	mediop. 4 – standard 4	0.667	0.411	1.620	1.000
	hyphen 4 – standard 4	0.963	0.411	2.340	0.726
regressions	mediop. – hyphen	0.732	2.85	0.257	1.000
	mediop. – standard	1.496	2.85	0.524	1.000
	hyphen – standard	0.765	2.85	0.269	1.000
	mediop. 2 – hyphen 2	-1.115	4.97	-0.224	1.000
	mediop. 2 – standard 2	5.231	4.97	1.051	1.000
	hyphen 2 – standard 2	6.346	4.97	1.276	1.000
	mediop. 3 – hyphen 3	-2.912	4.93	-0.591	1.000
	mediop. 3 – standard 3	-0.039	4.97	-0.008	1.000
	hyphen 3 – standard 3	2.874	4.93	0.583	1.000
	mediop. 4 – hyphen 4	6.222	4.88	1.275	1.000
	mediop. 4 – standard 4	-0.704	4.88	-0.144	1.000
	hyphen 4 – standard 4	-6.926	4.88	-1.419	1.000
first fixation duration	mediop. – hyphen	-7.83	21.4	-0.366	1.000
	mediop. – standard	-34.57	21.5	-1.610	0.326
	hyphen – standard	-26.74	21.4	-1.249	0.639
	mediop. 2 – hyphen 2	-12.07	37.4	-0.323	1.000
	mediop. 2 – standard 2	-6.46	37.4	-0.173	1.000
	hyphen 2 – standard 2	5.62	37.4	0.150	1.000
	mediop. 3 – hyphen 3	13.14	37.1	0.354	1.000
	mediop. 3 – standard 3	-28.30	37.4	-0.757	1.000
	hyphen 3 – standard 3	-41.44	37.1	-1.118	1.000
	mediop. 4 – hyphen 4	-24.56	36.7	-0.669	1.000
	mediop. 4 – standard 4	-68.94	36.7	-1.878	1.000
	hyphen 4 – standard 4	-44.38	36.7	-1.209	1.000

Dependent Variable	Contrast	Estimate	Std. Error	t-ratio	p-value
total reading time	mediop. – hyphen	8.07	80.6	0.100	1.000
	mediop. – standard	123.09	80.9	1.522	0.388
	hyphen – standard	115.02	80.6	1.427	0.465
	mediop. 2 – hyphen 2	-10.92	141	-0.077	1.000
	mediop. 2 – standard 2	68.83	141	0.488	1.000
	hyphen 2 – standard 2	79.75	141	0.566	1.000
	mediop. 3 – hyphen 3	5.36	140	0.038	1.000
	mediop. 3 – standard 3	144.07	141	1.022	1.000
	hyphen 3 – standard 3	138.70	140	0.993	1.000
	mediop. 4 – hyphen 4	29.76	138	0.215	1.000
	mediop. 4 – standard 4	156.37	138	1.131	1.000
	hyphen 4 – standard 4	126.62	138	0.916	1.000

Appendix 3: Contextual effects

3.1 Unimpaired readers

		β	Std. Error	t-ratio	p -value	sig
$LMM^{fixation\ count}$	standard	1.889	0.110	17.165	< 0.001	***
	hyphen	1.574	0.110	14.340	< 0.001	***
	mediop.	1.687	0.110	15.391	< 0.001	***
$LMM^{regressions}$	standard	13.299	1.28	10.401	< 0.001	***
	hyphen	12.338	1.27	9.679	< 0.001	***
	mediop.	11.765	1.27	9.242	< 0.001	***
$LMM^{first\ fixation\ duration}$	standard	2.600	6.43	0.405	1.000	
	hyphen	-6.203	6.41	-0.968	1.000	
	mediop.	-5.068	6.40	-0.792	1.000	
$LMM^{total\ reading\ time}$	standard	501.11	30.0	16.679	< 0.001	***
	hyphen	367.04	29.9	12.255	< 0.001	***
	mediop.	453.37	29.9	15.157	< 0.001	***

3.2 Target group

		β	Std. Error	t-ratio	p -value	sig
$LMM^{fixation\ count}$	standard	2.172	0.252	8.634	< 0.001	***
	hyphen	1.808	0.251	7.210	< 0.001	***
	mediop.	1.963	0.254	7.726	< 0.001	***
$LMM^{regressions}$	standard	10.990	1.97	5.571	< 0.001	***
	hyphen	11.533	1.97	5.865	< 0.001	***
	mediop.	9.230	1.99	4.633	< 0.001	***
$LMM^{first\ fixation\ duration}$	standard	-62.346	15.8	-3.937	0.001 ***	
	hyphen	-38.873	15.8	-2.462	0.210	
	mediop.	-43.449	16.0	-2.716	0.101	
$LMM^{total\ reading\ time}$	standard	306.19	70.0	4.376	< 0.001	***
	hyphen	150.89	69.7	2.163	0.462	
	mediop.	260.38	70.7	3.684	0.004 **	

3.3 Pupils with lower reading skills

		β	Std. Error	t-ratio	p -value	sig
$LMM^{fixation\ count}$	standard	3.378	0.414	8.168	< 0.001	***
	hyphen	2.798	0.412	6.787	< 0.001	***
	mediop.	3.087	0.422	7.313	< 0.001	***
$LMM^{regressions}$	standard	12.80	2.75	4.652	< 0.001	***
	hyphen	12.87	2.74	4.692	< 0.001	***
	mediop.	12.54	2.81	4.466	< 0.001	***
$LMM^{first\ fixation\ duration}$	standard	-66.251	24.2	-2.734	0.098	.
	hyphen	-68.655	24.2	-2.842	0.070	.
	mediop.	-54.432	24.7	-2.201	0.424	
$LMM^{total\ reading\ time}$	standard	450.7	116	3.886	0.002	***
	hyphen	233.3	116	2.018	0.662	
	mediop.	430.9	118	3.641	0.005	**

3.4 Pupils with higher reading skills

		β	Std. Error	t-ratio	p -value	sig
$LMM^{fixation\ count}$	standard	0.966	0.253	3.817	0.002	**
	hyphen	0.819	0.252	3.245	0.019	*
	mediop.	0.898	0.253	3.548	0.006	*
$LMM^{regressions}$	standard	9.197	2.82	3.258	0.018	*
	hyphen	10.218	2.81	3.632	0.005	**
	mediop.	6.167	2.82	2.185	0.441	
$LMM^{first\ fixation\ duration}$	standard	-58.40	20.5	-2.844	0.070	.
	hyphen	-9.25	20.5	-0.452	1.000	
	mediop.	-33.27	20.5	-1.621	1.000	
$LMM^{total\ reading\ time}$	standard	161.20	75.3	2.140	0.494	
	hyphen	67.88	75.1	0.904	1.000	
	mediop.	101.58	75.3	1.348	1.000	