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Online processing of causal relations in beginning first and second language readers

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ABSTRACT

We investigated online processing of causal relations in beginning first (L1) and second language (L2) readers (8–10 years old). By means of eye-tracking, we measured children's processing times of two-clause sentences including a causal relation. Two text-related factors were investigated: coherence marking (i.e., presence vs. absence of the Dutch connective *omdat* 'because') and linear order of clauses (i.e., cause-effect vs. effect-cause). In addition, syntactic knowledge was included as a child-related factor of interest. The results showed that coherence marking and individual differences in syntactic knowledge influenced children's online sentence processing. In contrast to L1 readers, the absence of a connective led to longer sentence processing times for L2 readers with lower syntactic knowledge; they experienced more difficulty with processing sentences in which no connective was present. Apparently, L2 readers with limited syntactic knowledge benefit from coherence marking provided by a connective, which allows them to establish the causal coherence relation between clauses in a more efficient way. Reversing the linear order of clauses did not affect children's online sentence processing. This study provides an initial step towards the use of online measures to examine sentence processing in beginning L1 and L2 readers aimed at gaining more insight into L2 reading comprehension difficulties.

1. Introduction

1.1. Background to the study

Being able to comprehend written text is a highly important skill. However, children who are confronted with the challenging task of learning to read in their second language, such as children from language minorities for whom the language of instruction at school differs from their home language, often experience reading comprehension difficulties (Droop & Verhoeven, 2003; Lesaux, Lipka, & Siegel, 2006; Mancilla-Martinez & Lesaux, 2010). These children can be referred to as second language readers (L2 readers), since they acquire their second language mainly from their school environment and usually this is the only language in which they learn to read at school. Previous studies have shown that L2 readers' reading comprehension difficulties are probably not a consequence of poor decoding skills; their decoding skills are found to be in the average range (Geva & Zadeh, 2006; Mancilla-Martinez & Lesaux, 2010) and develop at a more or less equal rate compared to L1 readers (Lesaux & Siegel, 2003; Verhoeven, 2000). By contrast, there is a large discrepancy in the linguistic proficiency of L1 and L2 readers, for instance in terms of their vocabulary and syntactic knowledge in the target language (Melby-Lervåg & Lervåg, 2014). Previous research has shown that oral language skills are important for reading comprehension performance and development, even more so for L2 readers (Droop & Verhoeven, 2003; Lervåg & Aukrust, 2010). L2 readers' reading comprehension difficulties can already be observed early in the process of learning to read (Verhoeven, 2000). In these early stages, beginning readers move from reading isolated words to reading sentences and short texts in which they have to integrate word meanings in the context of a sentence or a text, also referred to as word-to-text integration (WTI; Perfetti, Yang, & Schmalhofer, 2008). For WTI processes to take place, both text and reader characteristics play an important role.

There are textual factors that can help the reader to construct a coherent mental representation of a text. One textual factor in that respect is the use of linguistic markers, such as connectives. Connectives (i.e., conjunctions such as *because*, *therefore*) are cohesive devices that signal the relation between clauses; they are critical to the construction of a coherent text representation (Cain & Nash, 2011). Connectives can be classified according to the type of relationship they signal (i.e., additive, adversative, causal, and temporal), as put forward by Halliday and Hasan (1977) based on their extensive analysis of connective devices. Connectives can guide the reader in how to construct meaning by coding coherence relations, for instance when processing sentences

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with causal relations (Canestrelli, Mak, & Sanders, 2013; Sanders & Noordman, 2000). In particular, less-skilled adolescent readers appear to benefit from the presence of (causal) connectives (Land, 2009; Van Silfhout, Evers-Vermeul, Mak, & Sanders, 2014). Furthermore, Cain and Nash (2011) showed that connectives even support online text processing in 8- and 10-year-old less-experienced monolingual readers whose knowledge and comprehension of connectives are still developing. However, the question is whether linguistic markers, such as connectives, also support L2 readers with limited proficiency in their second language. On the one hand, based on studies showing that less-skilled readers particularly benefit from linguistic markers in the text, one could argue that this would also hold for L2 readers with poor reading comprehension performance. Connectives may help these readers to identify text structure and to establish a coherent mental model (Degand & Sanders, 2002). On the other hand, one may predict that because of their limited linguistic proficiency in the target language, L2 readers are not competent enough to benefit from the coherence marking provided by connectives. That is to say, connectives are relatively infrequent in texts and may pose extra challenges in terms of both vocabulary knowledge and the type of inter-clausal relationship they signal (Crosson, Lesaux, & Martiniello, 2008). In a study with L2 readers of English, Crosson and Lesaux (2013) showed that bilingual fifth-graders lagged behind their monolingual peers in knowledge of several types of connectives, and that the influence of connectives on reading comprehension varied by readers' linguistic background (i.e., L1 vs. L2). An explanation put forward in line with the findings of Degand and Sanders (2002) is that L2 readers need to be proficient enough in their second language in order to benefit from the coherence marking provided by connectives.

Another relevant textual factor with respect to processing causal relations is word order, or more specifically, linear order. To illustrate, the two following sentences differ in linear order: 1) *Because Tom worked hard, he passed the exam*, 2) *Tom passed the exam, because he worked hard*. The first sentence has an iconic order (i.e., cause-effect), whereas the second sentence has a non-iconic order (i.e., effect-cause). Previous studies have shown contrasting findings with respect to the effect of linear order on online processing. On the one hand, it is assumed that an iconic order facilitates processing: if the order of clauses corresponds to the order of causality in the world, it is easier to understand the sentence (Noordman & De Blijzer, 2000). This is confirmed by a study of Noordman and Vonk (1998), who used several experimental texts containing a causal relation expressed in two different orders. On the other hand, there are also studies showing that non-iconic sentences are easier to process, rather than iconic sentences (e.g., Graesser, Singer, & Trabasso, 1994; Magliano, Baggett, Johnson, & Graesser, 1993). These studies suggest that readers are more likely to make knowledge-based inferences about causal antecedents (i.e., *Tom passed the exam, so he must have worked hard*), than about effects or consequences (i.e., *Tom worked hard, so he must have passed the exam*). One explanation put forward for these incongruent findings relates to the differences in predictability of the causal relations that are investigated (Noordman & Vonk, 1998), which can be either a consequence of the specific relations expressed in the sentence (some relations are more predictable than others; Mak & Sanders, 2013) or the cognitive/linguistic capacities of the reader (some readers make better predictions than others; Martin et al., 2013). With respect to the latter, it should be noted that in previous studies university students were involved for whom the predictability of causal relations is relatively high in general. It might well be the case that for beginning readers, and especially beginning L2 readers with limited linguistic proficiency in the target language, a beneficial effect of non-iconic sentences over iconic sentences only prevails when the causal relation is highly predictable in itself. Another explanation lies in the amount of word order flexibility languages permit (Kaiser & Trueswell, 2004). In the case of L2 readers, it has indeed been demonstrated that facilitating effects may occur if the language structure or syntax of their second language is congruous with their first language (Bialystok, Luk, & Kwan, 2005; Durgunoglu, 2002; Nagy, Mcclure, & Mir, 1997).

Apart from the text, characteristics of the reader play a crucial role in online text processing. Children's syntactic knowledge is often mentioned as an important predictor for reading comprehension performance (e.g., Oakhill, Cain, & Bryant, 2003). Moreover, the meta-analysis of Jeon and Yamashita (2014) showed that for L2 reading comprehension, L2 syntactic knowledge was the strongest correlate. That is to say, the reader needs to have accurate syntactic knowledge for understanding the syntactic structure of a sentence. These parsing processes are required for comprehension (Perfetti & Stafura, 2014). Of particular relevance is the case of L2 readers, since their L2 oral language skills, including syntactic knowledge, are shown to stay behind compared to L1 readers (Droop & Verhoeven, 2003; Lesaux et al., 2006), which may in turn influence their online sentence processing.

In order to gain more insight into children's WTI processes at the sentence level, online measures can be recommended that expose reading comprehension while it happens (Perfetti & Stafura, 2014). Previous studies using event-related potentials (ERPs) as an online measure to examine the integration processes in adult readers revealed processing differences between L1 and L2 readers (Kaan, Kirkham, & Wijnen, 2016; Martin et al., 2013). However, there are hardly any studies in which online measures have been used to compare online sentence processing in young L1 and L2 readers. Although eye-tracking is used more often in recent research on children's language and literacy skills (Blythe & Joseph, 2011), its use is limited to older, more experienced readers in upper primary school (e.g., De Leeuw, Segers, & Verhoeven, 2016; Van der Schoot, Vasbinder, Horsley, & Van Lieshout, 2008) and secondary education (Van Silfhout et al., 2014). The few studies on online sentence processing that focused on beginning readers (8–10 years old) were also restricted to monolingual children and focused on age differences rather than variation in linguistic proficiency (Cain & Nash, 2011; Wannacott, Joseph, Adelman, & Nation, 2015). In order to provide more insight into L2 readers' comprehension problems, it is essential to investigate the effect of textual and child-related factors on online sentence processing in beginning L1 and L2 readers.

1.2. The present study

In the present study, we used an online sentence reading task including two-clause Dutch sentences with a causal relation (e.g., *Because Tom was hungry, he ate an apple*) in order to investigate two textual factors related to syntactic structure (i.e., coherence marking and linear order of clauses) in two groups of beginning readers: Dutch monolingual children with Dutch as their first language (L1 readers) and Turkish-Dutch bilingual children with Dutch as their second language (L2 readers). In addition to children's language background (i.e., L1 vs. L2), we investigated the role of individual differences in syntactic knowledge as a child-related factor of interest for online sentence processing. Eye-tracking was used to measure children's sentence processing times. Taking a closer look at the native Turkish-speaking children as L2 readers of Dutch, two points should be noted. First, they were expected to have lower L2 syntactic knowledge than the L1 readers (cf. Droop & Verhoeven, 2003; Lipka & Siegel, 2007), which may in turn influence the extent to which they make use of connectives during processing and comprehending sentences. Second, their first language (i.e., Turkish) has a more flexible word order (Nilsson, 1991), which may influence the extent to which alternating word order (or linear order of clauses) affects their online text processing and comprehension in L2.

The following research question was central to the present study: To what extent are beginning L1 and L2 readers' online processing times of sentences with causal relations influenced by (a) coherence marking, (b) linear order of clauses, and (c) individual differences in syntactic knowledge? For coherence marking, we expected that beginning readers would benefit from the presence of connectives, and that L2 readers with lower syntactic knowledge in particular would have more difficulty with processing sentences in which no connective is present. For linear order, we expected that non-iconic sentences would be easier to process than iconic sentences, when the predictability of the causal relations is high. In that respect, two contrasting expectations can be formulated for the L2 readers. On the one hand, the facilitating effect of non-iconic sentences may be larger for the L2 readers given their experience with flexibility in word order in their first language. On the other hand, the facilitating effect of non-iconic sentences may be less profound in L2 readers, because their limited linguistic proficiency in their second language, such as lower syntactic knowledge, limits them in making predictions about causal antecedents.

2. Method

2.1. Participants

The participants were third-grade children from eight primary schools in the Netherlands. We included third-graders, because they can be categorized as beginning readers (i.e., they have completed only two years of formal reading instruction), nevertheless their word reading skills are sufficiently developed to allow for reliable eye-movement recording during reading. Based on information retrieved from the teachers, monolingual children with Dutch as their home language (L1 readers) and bilingual children with Turkish as their home language (L2 readers) with accurate word decoding skills were selected to participate in this study. The total sample included 46 third-grade children, aged between eight and ten years old (M = 9;0, SD = 0;6): 27 Dutch monolingual children (14 girls and 13 boys; age: M = 8;11, SD = 0;6) and 19 Turkish-Dutch bilingual children (10 girls and 9 boys; age: M = 9;0, SD = 0;6). All children had normal or corrected-to-normal vision and none of them were diagnosed with dyslexia. One child was excluded from the study due to calibration problems. Participation was voluntary and written parental consent and children's oral assent were obtained. Prior to the start of the study, ethical approval was obtained from our institution's ethics committee.

All children came from monolingual Dutch schools, meaning that all L2 readers were immersed in a Dutch language context at school and received formal reading instruction in Dutch only. In the Netherlands, Turkish is the largest cultural minority (CBS Statistics Netherlands, 2015). Children from this cultural minority grow up in a situation of emerging bilingualism in families with lower socioeconomic status (SES) in general. A parental questionnaire and interviews with the children showed that the Turkish-Dutch children in our sample were all born in the Netherlands and for most of these children either both their parents (42.9%) or one of their parents (47.8%) was born in Turkey. The Turkish-Dutch children as well as their parents indicated that at least one of the parents spoke primarily Turkish with the child. This is in line with other studies including young L2 learners from Turkish families in the Netherlands (Blom, Küntay, Messer, Verhagen, & Leseman, 2014; De Zeeuw, Schreuder, & Verhoeven, 2013; Scheele, Leseman, & Mayo, 2010; Janssen, Segers, McQueen, & Verhoeven, 2015). Although Turkish is their first language, by the end of the second grade Dutch usually becomes their dominant language (Verhoeven, 2000). In our sample this is confirmed by the fact that the majority of the L2 learners (62.3%) selected Dutch as their preferred language over Turkish. Moreover, all children indicated that they read in Dutch at home; only four of them were also literate in Turkish.

We calculated children's SES by averaging their parents' level of education (see Table 1), measured on a four-point scale ranging from 1 (*primary school*) to 4 (*higher education or university*). As expected based on studies with a comparable sample (e.g., Blom et al., 2014; De Zeeuw et al., 2013; Janssen et al., 2015), the L2 readers had lower SES than the L1 readers on average (t(44) = 3.55, p = .001, d = 0.99). In addition, we compared the L1 readers and L2 readers on several other background variables that were considered relevant to the current study in order to check for between-group differences (see Table 1). To measure children's word decoding skills, we administered the One Minute Test, form A (Brus & Voeten, 1979), which is a measure of decoding efficiency. As expected, no differences were found in decoding efficiency between the L1 readers and L2 readers (t(44) = 0.27, p = .790, d = 0.09). To measure children's verbal working memory and short-term memory skills, the Dutch version of the forward and backward digit span from the Wechsler Intelligence Scale for Children (WISC-III; Kort et al., 2005) was used. The L1 readers and L2 readers did not differ with respect to these cognitive skills; verbal short-term memory (t(44) = 0.79, p = .094, d = 0.56), and verbal working memory (t(44) = − 1.18, p = .247, d = 0.35). Furthermore, we collected children's scores on two standardized tests for vocabulary knowledge and reading comprehension, which are paper-and-pencil tasks including seventy and fifty multiple-choice question, respectively. These tests are administered yearly in class by the teacher as part of the national Dutch student-monitoring system in primary schools developed by the Dutch National Institute for Educational Measurement (CITO). As expected, the L2 readers scored significantly lower than the L1 readers on vocabulary knowledge (t(44) = 5.01, p < .001, d = 1.46) and reading comprehension (t(44) = 2.38, p = .022, d = 0.70) (see Table 1).

Table 1
Descriptive statistics for background variables split by language background.

Background variables	L1 readers (n = 27)		L2 readers (n = 19)	
	Min-max	*M* (*SD*)	*Min-max*	*M* (*SD*)
SES**	1.5–4	3.0 (0.7)	1–4	2.2 (0.9)
Decoding skills	34–87	58.5 (12.3)	45–73	57.6 (7.4)
Verbal short-term memory	4–10	7.3 (1.4)	5–9	6.6 (1.1)
Verbal working memory	2–7	4.1 (1.2)	3–6	4.5 (1.1)
CITO vocabulary knowledge > ***	32–63	48.3 (8.8)	17–56	33.7 (11.1)
CITO reading comprehension*	2–48	23.9 (11.4)	− 9-48	15.1 (13.6)

Note. Scores for the CITO Reading Comprehension test can be negative, since this is a norm-based (standardized) score that is used throughout primary school (1st grade: M = −2.4, SD = 15.6); 4th grade: M = 33.1, SD = 13.2). The mean score for the monolingual children in the present study was comparable to the standardized score in third grade (M = 22.3, SD = 13.9).
*p < .05. **p < .01. ***p < .001.

2.2. Materials

2.2.1. Online reading task

To investigate sentence processing, we created an online reading task that was based on a design used by Pearson (1974). The task included 16 items, which were two-clause Dutch sentences written in past tense, consisting of seven to eleven words. In order to minimize the influence of vocabulary knowledge, the items only included words that were assumed to be already familiar to the third-grade children based on a Dutch wordlist for six-year olds (Schaerleakens, Kohnstamm, & Lejaegere, 1999). Furthermore, all items included a causal content relation (i.e., the clauses are related because of their propositional content reflecting a real-world causality between two events/states in the world) rather than an epistemic causal relation (i.e., the clauses are related by the speaker's reasoning) (Noordman & De Blijzer, 2000). As a first factor of interest, we investigated coherence marking; half of the items included the Dutch connective *omdat* 'because' to explicitly signal the causal relation between the two clauses, whereas in the remaining items no connective was present and therefore the relation between clauses was more implicit. As a second factor of interest, we looked at the linear order of clauses; half of the sentences had a (iconic) cause-effect order and in the remaining sentences the order was reversed to a (non-iconic) effect-cause order. Crossing these two textual factors (2 × 2 design) resulted in four within-subjects conditions (see Table 2). Each participant was presented with four items in each condition, so 16

Table 2
Overview of the four within-subject conditions in the online reading task.

Nr.	Sentence	Coherence marking	Linear order
1	Tom at een appel, omdat hij honger had. [Tom ate an apple, because he was hungry.]	Connective present	Effect-cause
2	Omdat Tom honger had, at hij een appel. [Because Tom was hungry, he ate an apple.]	Connective present	Cause-effect
3	Tom at een appel. Hij had honger. [Tom ate an apple. He was hungry.]	Connective absent	Effect-cause
4	Tom had honger. Hij at een appel. [Tom was hungry. He ate an apple.]	Connective absent	Cause effect

items in total (see Appendix for an overview of all items). The items were presented in pseudorandomized order. The children were instructed to read aloud the sentences that were successively presented on the eye-tracking screen. Comprehension questions were used to check whether children understood the causal relation between the two clauses (*'Why did Tom eat an apple?'*). According to our expectations based on the high predictability of the causal relations, children's performance on these comprehension questions was at ceiling; hardly any response was incorrect. Therefore, these off-line comprehension data were not subjected to statistical analyses.

2.2.2. Syntactic knowledge

A grammaticality judgment task was used to assess children's syntactic knowledge (Verhoeven, Keuning, Horsels, & Van Boxtel, 2013). This digital task consists of 55 sentences that were presented auditorily. After listening to each sentence, the children had to indicate whether the sentence was grammatically correct or incorrect by clicking on a green or red button respectively. In total, 17 sentences were grammatically correct and the remaining 38 sentences were grammatically incorrect because of incorrect inflection of nouns (10 sentences), incorrect verb conjugation (10 sentences), incorrect order of words (10 sentences), or incorrect subject-verb agreement (8 sentences). The total score is determined by the number of items answered correctly with a maximum score of 55 (Cronbach's $\alpha = .79$ in the present study). As expected, the L2 readers ($M = 38.2$, $SD = 6.0$) scored significantly lower on this task than the L1 readers ($M = 41.9$, $SD = 5.3$) ($t(44) = 2.22$, $p = .032$, $d = 0.65$).

2.3. Apparatus

During the online reading task, children's eye movements were recorded with a Tobii PRO TX300 eye-tracking system (Tobii AB, Danderyd, Sweden). This is a portable, screen-based eye-tracker that captures gaze data at the sampling rate of 300 Hz by using a binocular tracking technique. Children were seated in front of the eye-tracker with a distance of approximately 65 cm between their eyes and the monitor (23 inch with a resolution of 1920 × 1080). Single-line sentences were successively presented in the monospaced font Courier New (bold, 16 point) in black against a light grey background. A nine-point calibration procedure was used to locate the position of children's eyes and the quality was assessed by visual inspection. In case of poor quality with respect to accuracy and/or precision, recalibration was conducted. During the task, the microphone was used to record children's reading and answering. As an eye-tracking measure, we calculated the total fixation duration in milliseconds (i.e., total time spent reading; Juhasz & Pollatsek, 2011) for each sentence, based on children's eye movements. Total fixation duration is a measure of later processing rather than early processing (e.g., first fixation duration), therefore total fixation duration is assumed to be a more relevant measure for investigating WTI processes in the current study, since we aimed to capture all integration processes at the sentence level. Apart from this aim, also the design of the study makes it more relevant to focus on online processing at the sentence level rather than the clause level, given that clauses were not directly comparable in terms of content, position and length as a consequence of necessary manipulations of both coherence marking and linear order. In comparison to a self-paced reading paradigm, eye-tracking technology is preferable in terms of ecological validity, because it allows for natural reading patterns and does not interfere with the reading process.

2.4. Procedure

Children were individually tested during two sessions of approximately twenty minutes in a quiet room at their school. The two sessions were at the same day or two consecutive days. In the first session, the children completed the online reading task while their eye movements were recorded. The children were informed that the study was aimed to investigate reading comprehension in the third grade. They were instructed to read aloud at their normal rate, while comprehending what they were reading, because each sentence would be followed by a comprehension question. The task was preceded by a short practice trial and a calibration procedure to locate the position of the eyes. As soon as the child completed reading the sentence, the experimenter pressed a button and then the comprehension question appeared. After answering this question, a neutral screen with the item number in the center of the screen was presented for 2000 milliseconds and then the next sentence appeared. In order to prevent these beginning readers from a cognitive overload and to stay focused on their reading comprehension, we decided to let the children read aloud (which is very common for children at this stage of reading development) and let the experimenter press the button after each item. For the purpose of maximizing ecological validity, we decided not to use a chinrest. Voice recording allowed for checking children's comprehension performance afterwards. In the second session, children's syntactic knowledge, decoding skills and cognitive skills were measured by means of standardized tests. Afterwards, the children received a small present.

2.5. Data analysis

We conducted linear mixed effects regression analysis (Baayen, Davidson, & Bates, 2008) with crossed random effects for subjects and items using the lme4 package (version 1.1.11; Bates, Maechler, Bolker, & Walker, 2015) for the R computing environment (version 3.4.0 Revised; R Core Team, 2016). The outcome variable was the average processing time per word. That is to say, we looked at the total fixation duration (in milliseconds) for each sentence and calculated the average processing time per word in order to correct for differences in sentence length (due to our manipulation of connective presence). All values two standard deviations above or below item *and* subject mean were excluded from the analysis (cf. Van Silfhout et al., 2014). According to these criteria we excluded 2.3% of the data (i.e., 17 cases: 12 cases for L1 readers and 5 cases for L2 readers). As fixed effects we included connective (0 = connective present, 1 = connective absent), order (0 = cause-effect, 1 = effect-cause), and language background (0 = L1 reader, 1 = L2 reader) as dummy coded variables, and syntactic knowledge as a continuous variable. Random effects were fit using a maximal random effects structure (Barr, Levy, Scheepers, & Tily, 2013). This included random intercepts for subjects and items, by-subject random slopes for connective, order and their interaction, and by-item random slopes for language background, syntactic knowledge and their interaction. Log-transformations were performed for processing time as the outcome variable in order to meet the normality requirements for linear modeling (Baayen, 2008). Models were fit using a maximum likelihood technique. A fixed effect was considered significant if the absolute value of the *t*-statistic was larger than or equal to 2.0 (Gelman & Hill, 2007). In addition, *p*-values were estimated from the *t*-

Table 3
Summary of the linear mixed effects regression analysis for processing time.

	Fixed effects			*Random effects*	
				By subject	*By item*
Parameters	*β*	*SE*	*t*	*SD*	*SD*
(Intercept)	−6.781	0.218	31.17	0.112	0.128
Connective (absent vs. present)	−0.005	0.195	−0.02	0.042	–
Order (effect-cause vs. cause-effect)	−0.276	0.186	−1.49	0.020	–
LB (L2 vs. L1)	−0.333	0.296	−1.13	–	0.060
SK	−0.010	0.005	−1.94	–	0.001
Connective × order	0.206	0.278	0.74	0.063	–
Connective × LB	0.513	0.252	2.04*	–	–
Order × LB	0.456	0.235	1.94	–	–
Connective × SK	0.002	0.004	0.44	–	–
Order × SK	0.005	0.004	1.38	–	–
LB × SK	0.007	0.007	1.01	–	0.001
Connective × order × LB	−0.554	0.355	−1.56	–	–
Connective × order × SK	−0.005	0.006	−0.81	–	–
Connective × LB × SK	−0.013	0.006	−2.03*	–	–
Order × LB × SK	−0.011	0.006	−1.88	–	–
Connective × order × LB × SK	0.014	0.009	1.56	–	–

Note. Connective = connective presence/absence, order = linear order of clauses, LB = language background, SK = syntactic knowledge. Three factors were dummy coded as follows: connective (0 = present, 1 = absent), order (0 = cause-effect, 1 = effect-cause), and language background (0 = L1 reader, 1 = L2 reader).
Model formula: log(RT) ~ Connective ∗ Order ∗ LB ∗ SK + (1 + Order ∗ Connective | subject) + (1 + LB ∗ SK | item).
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

distribution based on a formula put forward by Linck and Cunnings (2015) (see also Baayen, 2008, p. 248).

3. Results

The results of the linear mixed effects analysis are shown in Table 3. The results indicated that there were no significant main effects for connective, order, language background, and syntactic knowledge on children's processing time (all *t*'s < 1.94). However, for the first text-related factor of interest (coherence marking), there was a significant two-way interaction effect for Connective × Language background (see Fig. 1A) and also a significant three-way interaction effect for Connective × Language background × Syntactic knowledge (see Fig. 1B). With respect to the second text-related factor of interest (linear order of clauses), no significant effects were found (all *t*'s < 1.94).

In order to clarify and determine the direction of the two interaction effects for coherence marking, the linear mixed effects analysis was split up into sub-analyses for L1 and L2 readers. For the L1 readers, there were no significant main effects for connective ($\beta = -0.007$, $SE = 0.19$, $t = -0.04$, $p = .971$) and syntactic knowledge

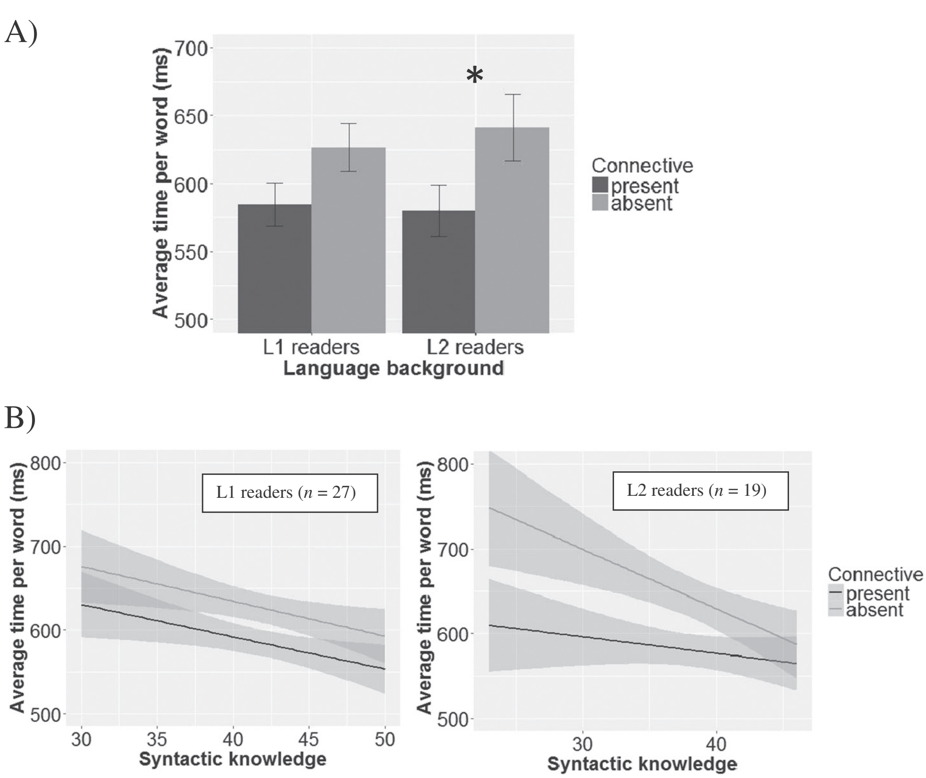

Fig. 1. Visualization of two-way interaction effect Connective × Language background (means and standard errors in upper chart A) and three-way interaction effect Connective × Language background × Syntactic knowledge (regression lines in lower charts B) split by language group.

($\beta = -0.010$, $SE = 0.01$, $t = -1.73$, $p = .085$) and no interaction effect for Connective × Syntactic knowledge ($\beta = 0.002$, $SE < 0.01$, $t = 0.45$, $p = .652$). For the L2 readers, however, there was a significant main effect for connective ($\beta = 0.550$, $SE = 0.23$, $t = 2.39$, $p = .017$), but not for syntactic knowledge ($\beta = -0.001$, $SE < 0.01$, $t = -0.26$, $p = .796$), and a significant interaction effect for Connective × Syntactic knowledge ($\beta = -0.012$, $SE = 0.01$, $t = -2.25$, $p = .025$). The interaction effect (see Fig. 1B) showed that the lower L2 readers' syntactic knowledge, the larger the differences were in processing times of sentences with and without a connective. In other words, L2 readers with lower syntactic knowledge had longer processing times for sentences without a connective than for sentences with a connective.

4. Discussion

In this study, we examined online sentence processing in third-grade monolingual Dutch children (L1 readers) and bilingual Turkish-Dutch children (L2 readers). We investigated to what extent their online processing times of sentences with causal relations were influenced by (a) coherence marking, (b) linear order of clauses, and (c) individual differences in syntactic knowledge. The results showed that both textual and child-related factors influenced beginning readers' online sentence processing. That is, individual differences in children's syntactic knowledge accounted for the effect of coherence marking on online sentence processing for L2 readers, but not for L1 readers.

Regarding the first text-related factor (a) coherence marking, we expected that beginning readers would benefit from the presence of a connective and that this would be particularly true for L2 readers with lower syntactic knowledge. However, in contrast to previous studies showing that connectives support young, monolingual readers' text processing and comprehension (Cain & Nash, 2011; Land, 2009; Van Silfhout et al., 2014), we did not find a main effect of coherence marking in the present study. One explanation for this discrepancy concerns the context in which the connectives were presented. In previous studies the connectives were presented in short stories (Cain & Nash, 2011) or expository texts (Van Silfhout et al., 2014), which are more challenging compared to the relatively short and simple sentences as used in the present study. In order to minimize the effect of vocabulary knowledge, the sentences contained all familiar words, there was little variation in sentence structure, and the predictability of the causal relations was high. Possibly, most children were able to establish the causal relations in these relatively easy sentences in an efficient way without further textual support. Other explanations relate to the level of analysis and the reading mode. It may be the case that our sentence-level measure was not sensitive enough to detect a main effect of coherence marking. Whereas previous eye-tracking studies with advanced readers found speed-up effects in the region directly after the connective (Cozijn, Noordman, & Vonk, 2011; Van Silfhout et al., 2014), we looked at a more global sentence-level measure of processing speed (see also Cain & Nash, 2011) to capture all integration processes across the sentence. This may have led to a lack in sensitivity. To illustrate, Cozijn et al. (2011) found a speed-up effect directly after the connective and a slow-down effect at the end of the sentence, which may be cancelled out when investigating processing times for the total sentence. Also, the oral reading mode in the current study may have led children to make less regressive eye movements (Vorstius, Radach, & Lonigan, 2014), which mainly accounted for the effects of coherence marking found by Van Silfhout et al. (2014) with a silent reading mode.

In accordance with our expectations, the findings showed that coherence marking did affect online sentence processing times for L2 readers with lower syntactic knowledge, as indicated by the interaction between (a) coherence marking and (c) syntactic knowledge. For the L2 readers, the effect of coherence marking was influenced by individual differences in syntactic knowledge; the lower their syntactic knowledge, the larger the differences in processing times for sentences with and without a connective. The longer processing times for sentences without a connective suggest that L2 readers with lower syntactic knowledge experienced more difficulty with processing causal relations when no connective was present. An explanation that can be put forward is that Dutch syntactic knowledge, which is related to children's linguistic proficiency in general, helps L2 readers to establish the causal coherence relation between two clauses in a more efficient way. Apparently, beginning L2 readers with lower syntactic knowledge benefit from explicit textual support, because they experience more difficulty when integrating information during online sentence processing, which is also found in other studies with young L2 learners (e.g., Felser, Roberts, Marinis, & Gross, 2003) and poor comprehenders (e.g., Barnes, Ahmed, Barth, & Francis, 2015). In line with the recent study of Colenbrander, Kohnen, Smith-Lock, and Nickels (2016), our findings demonstrate the importance of considering individual differences, not only in vocabulary knowledge but also in syntactic knowledge, when investigating and remedying poor reading comprehension.

With respect to the second text-related factor (b) linear order of clauses, the results showed that reversing the linear order of clauses did not affect children's online processing time and there was no facilitating effect for the L2 readers. Based on the more flexible word order in their first language (i.e., Turkish) (Nilsson, 1991), we expected a facilitating effect for L2 readers. However, more research is needed to gain insight into possible transfer effects from L2 readers' first language on online processing in their second language. Furthermore, we did not find support for our prediction that non-iconic (i.e., effect-cause) sentences would be easier to process than iconic (i.e., cause-effect) sentences, based on previous studies (Graesser et al., 1994; Magliano et al., 1993). This might be due to the restricted power in terms of the number of items included in the present study. Another explanation concerns the predictability of the causal relations as a consequence of either the items or the participants in our study. Possibly the high predictability of the causal relations that were used in the current study did not allow for differences in processing times between iconic and non-iconic sentences. Furthermore, the beginning readers in our sample had less linguistic experience, in particular the L2 readers, compared to the university students in previous studies. As a consequence, they may not predict upcoming words during sentence comprehension to the same extent, as found in the study of Martin et al. (2013).

It is important to note that design differences between the current study and previous studies may have consequences for the interpretation of the present findings. First, the children were instructed to read aloud in our study, which may have consequences for the comparability with previous studies with older, more experienced (adult) readers in which silent reading was performed. Because of the young age and the relative little reading experience of the third-grade children in our sample, we aimed to minimize the cognitive load imposed by the sentence reading task as much as possible by instructing them to read aloud, allowing the experimenter to press a button to move to the next item as soon as children finished reading. Although some caution may be warranted due to differences at the operational level, comparisons with previous studies at a conceptual level are still possible, because our choice for the oral reading mode is not likely to affect our results substantially for several reasons: a) the reading mode was similar across items and conditions; b) these young readers are used to reading aloud, which is common practice for reading instruction and assessment in primary education, and the L1 and L2 readers in our study did not differ in word decoding skills; c) most importantly, Van den Boer, Van Bergen, and De Jong (2014) investigated oral and silent reading in fourth-grade children and concluded that the two reading modes are fairly similar with respect to the underlying cognitive skills.

Second, we did not relate children's online processing times to their off-line comprehension performance, in contrast to other studies (e.g., Barnes et al., 2015; De Leeuw et al., 2016; Van Silfhout et al., 2014; Wannacott et al., 2015). Previous studies have already shown that there is a relation between fast reading and better comprehension (Rayner, Chace, Slattery, & Ashby, 2006), and in our study there was also a moderate negative correlation between children's online processing times and their comprehension score on a standardized test for reading comprehension ($r = .32$, $p = .031$). Instead, our focus was on children's online processing and possible differences in that respect between L1 readers and L2 readers. As expected, all children scored at ceiling on the comprehension questions, which allowed us to investigate the efficiency of their online processing rather than the accuracy.

Third, in line with Cain and Nash (2011) who found a speed-up effect of the presence of a connective for the sentence as a whole, we looked at children's processing times at the sentence-level in order to capture all integration processes across the sentence, whereas previous studies have found effects of coherence marking on particular regions of the sentence (Canestrelli et al., 2013; Cozijn et al., 2011; Van Silfhout et al., 2014). It may be the case that coherence marking affected children's processing in a way that was not fully captured by our sentence-level measure. Therefore, we cannot ascertain that L1 readers' processing has not been affected at all. In the current study, not only coherence marking, but also linear order and children's syntactic knowledge were factors of interest. Due to our manipulation of linear order of clauses, the clauses were not comparable in terms of length and position and therefore, a clause-by-clause analysis would not provide reliable effects. Furthermore, syntactic knowledge as a child characteristic of interest was expected to be related to the sentence as a whole rather than a specific region.

For future research it would be informative to further explore the factors that were central to the present study. With respect to coherence marking, it would be interesting to investigate whether similar effects are found when including a larger variety of connectives and a larger number of items, which also allows for more fine-grained analyses at specific regions of the sentence. In the current study we explicitly chose to investigate one specific Dutch causal connective (i.e., *omdat* 'because') which was assumed to be known by all children in our study. As a next step, however, future research should also include other connectives or types of connectives, with some types being more difficult than others (Knott & Sanders, 1998; Sanders, Spooren, & Noordman, 2000), following the studies of Cain and Nash (2011) and Crosson et al. (2008). In that respect, children's syntactic knowledge may also play an important role in comprehending and using more complex connectives during reading. To further explore the effect of word order, it would be relevant to use causal relations that differ in predictability and to refine the assessment of children's syntactic knowledge, for instance by focusing on children's syntactic knowledge specific to word order violations or by including a measure of L2 readers' syntactic knowledge in their first language. The study by Vulchanova, Foyn, Nilsen, and Sigmundsson (2014) showed that lexical knowledge in children's first language was related to sentence comprehension in their second language. In our study, the L2 readers varied in the extent to which they used their first language at home, which could mean that possible transfer effects of children's first language were more profound in children with higher linguistic proficiency in their first language.

To conclude, the present study demonstrates that both textual and child-related factors influence children's online processing of causal relations. With regards to word-to-text integration processes, this study shows how online measures, such as eye-tracking, can reveal individual differences in online sentence processing of beginning L1 readers and L2 readers that are related to their syntactic knowledge. In contrast to previous studies stating that L2 readers may not be proficient enough to take advantage of coherence markers in the text (Crosson & Lesaux, 2013; Degand & Sanders, 2002), our findings indicate that the presence of a connective can actually help L2 learners with lower syntactic knowledge to establish coherence relations more efficiently as long as they understand the semantic relation expressed by those connectives. By showing that coherence marking can also aid text processing in beginning L2 readers with lower syntactic knowledge, the present study adds on the study of Cain and Nash (2011), who concluded that connectives aid text processing in typically developing readers. Although future research is needed to support and elaborate on these findings, this study provides an initial step towards the use of online measures to gain insight into differences in online sentence processing of beginning L1 and L2 readers, which may partly account for L2 readers' comprehension problems. With respect to implications for educational practice, this study indicates that apart from focusing on decoding skills and vocabulary knowledge, it is also important to pay attention to knowledge and use of connectives as well as to stimulate children's syntactic knowledge in the early stages of reading development.

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Appendix A

Table A
Items in the online reading task.

1A. Omdat *Teun* honger had, at hij een *wafel*. [Because Teun was hungry, he ate a waffle.]
1B. *Joep* at een *appel*, omdat hij honger had. [Joep ate an apple, because he was hungry.]
1C. *Daan* had honger. Hij at een *tosti*. [Daan was hungry. He ate a tosti.]
1D. *Guus* at een *lolly*. Hij had honger. [Guus ate a lolly. He was hungry.]
Comprehension question: Waarom at (…) een (…)? [Why did (…) eat a/an (…)?]

2A. Omdat *Roos* dorst had, dronk ze een glas *cola*. [Because Roos was thirsty, she drank a glass of coke.]
2B. *Suus* dronk een glas *water*, omdat ze dorst had. [Suus drank a glass of water, because she was thirsty.]
2C. *Tess* had dorst. Ze dronk een glas *melk*. [Tess was thirsty. She drank a glass of milk.]
2D. *Maud* dronk een glas *thee*. Ze had dorst. [Maud drank a glass of tea. She was thirsty.]
Comprehension question: Waarom dronk (…) een glas (…)? [Why did (…) drink a glass of (…)?]

3A. Omdat *Mark* jarig was, kreeg hij een *fiets* van zijn ouders. [Because it was Mark's birthday, he got a bike from his parents]
3B. *Bart* kreeg een *trein* van zijn ouders, omdat hij jarig was. [Bart got a train from his parents, because it was his birthday.]
3C. *Jens* was jarig. Hij kreeg een *piano* van zijn ouders. [It was Jens's birthday. He got a piano from his parents.]
3D. *Nick* kreeg een *gitaar* van zijn ouders. Hij was jarig. [Nick got a guitar from his parents. It was his birthday.]
Comprehension question: Waarom kreeg (…) een (…) van zijn ouders? [Why did (name) got a (noun) from his parents?]

4A. Omdat *Sara* gevallen was, had ze veel pijn aan haar *neus*. [Because Sara had fallen, she hurt her nose.]

4B. *Lara* had veel pijn aan haar *been*, omdat ze gevallen was. [Lara hurt her leg, because she had fallen.]
4C. *Anja* was gevallen. Ze had veel pijn aan haar *pols*. [Anja had fallen. She hurt her wrist.]
4D. *Lisa* had veel pijn aan haar *knie*. Ze was gevallen. [Lisa hurt her knee. She had fallen.]
Comprehension question: Waarom had (…) veel pijn aan haar (…)? [Why did (…) hurt her (…)?]

Note. Each item consisted of two clauses that were separated by either a comma or full stop. In A-items: connective = present, order = cause-effect. In B-items: connective = present, order = effect-cause. In C-items: connective = absent, order = cause-effect. In D-items: connective = absent, order = effect-cause. Within each of the four blocks words in italics are varied by item to prevent priming effects. The names used are frequent Dutch names and within each block they are matched on gender and number of syllables. The nouns used in each block are from a similar semantic category and are about the same length and frequency.

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