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Young Children's Ability to Distinguish Thematic Relations: Development and Predictive Value for Early Reading

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Abstract

Thematic relations are important semantic features in the young child's lexicon. So far, it is unclear how the ability to distinguish different strengths of thematic relations develops, whether this ability depends on specific word characteristics (homonyms), and whether it is linked to reading acquisition. In this longitudinal study, 62 children were asked to judge which of two words (i.e., *thunder*, *fire*) matched a presented context sentence (i.e., *Miriam sees the lightning*.) in a thematic judgment task. The strength of the thematic relation of the distractors to the target sentence (associated, unrelated) and types of context words (homonyms, non-homonyms) were varied. Children's performance was more accurate and developed faster in the unrelated than in the association condition. Furthermore, children were more accurate in homonym compared to non-homonym responses. Moreover, children's thematic judgment abilities predicted their later reading skill over other important precursor abilities of reading, including listening comprehension.

Keywords: semantics; thematic relations; homonymy; longitudinal study; reading acquisition

1. Introduction

Semantic knowledge is an important component of human cognition that plays a key role in the interpretation of natural objects, interactions, and abstract concepts such as language (McRae & Jones, 2013). Therefore, semantic knowledge is fundamental to learning new abilities. There is evidence that young children in particular are likely to use thematic relations (e.g., tiger-zoo; related by contiguity) to organize semantic knowledge in their lexicon (e.g., Berger & Donnadieu, 2006, 2008; Hashimoto, Mc Gregor, & Graham, 2007; Scheuner, Bonthoux, Cannard, & Blaye, 2004).

Given the importance of thematic knowledge in early childhood, the ability to distinguish different thematic relations could also influence another important milestone of children's development in modern societies: reading acquisition. However, even though semantic knowledge is a basic component in theories of reading (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Goswami & Ziegler, 2005; Perfetti & Hart, 2002), effects of thematic knowledge on emergent literacy have--to our knowledge--not been studied.

Regarding adults, some studies have shown that good readers or spellers are more proficient in distinguishing thematically related words than poor readers or spellers (Andrews & Bond, 2009; Perfetti & Hart, 2002; Perfetti, 2007). However, these studies focused on thematic relations among homonyms, that is words with the same phonological and orthographic representations but distinct semantic mappings (e.g., *ball*; toy or dance event). The studies showed that good reading and spelling ability was linked to the ability to distinguish separate homonym meanings and their respective thematic relations to other words. However, it has remained unclear whether this ability is also linked to children's reading acquisition. We still do not know whether and how children's thematic knowledge is linked to their development of literacy skills.

In this study, we aimed to investigate how thematic knowledge develops in early childhood, whether there are differences in the development of thematic knowledge regarding homonyms compared to non-homonyms, and how thematic knowledge is connected to literacy development. We present results from a longitudinal study across 30 months in which we followed young children's ability to distinguish thematic relations of words to contexts with homonyms or non-homonyms, and analyzed whether this was linked to later reading abilities.

1.1.Thematic Knowledge in Early Childhood

The knowledge of meaning is a basic component of human cognition (McRae & Jones, 2013). A recent review on the structure of semantic knowledge (Mirman, Landrigan, & Britt, 2017) suggests that semantic representations are organized in two systems of meaning relations: A taxonomic system that is based on rules of similarity (i.e., shared features; tiger-cat) and a thematic system that is based on rules of contiguity (i.e., co-occurrence; tiger-zoo).

Research on the development of semantic knowledge has shown that already 24-month-old infants display taxonomic and thematic relations between words in their lexicon (Arias-Trejo & Plunkett, 2013). Furthermore, a study by Hills, Maouene, Riordan and Smith (2010) found that the co-occurrences of words (thematic relation) in early child-caregiver communication was linked to children's later vocabulary development. Moreover, some studies suggest that young children are more likely to evaluate semantic connections between words based on thematic but not on taxonomic relations (Berger & Donnadieu, 2006, 2008; Hashimoto et al., 2007; Scheuner et al., 2004).

For example, Hashimoto and colleagues (2007) reported that six-year old children were more likely to use thematic than taxonomic descriptions in a cognitively demanding semantic judgment task. Thus, at this age lexical access to thematic relations seems to involve

less effort than access to taxonomic relations. These findings suggest that the ability to know and distinguish thematic relations between words might be an early indicator for the stability of a semantic network in a child's lexicon. However, little is known about the development of thematic relations with regard to the acquisition of, and access to, different strengths of relations across development, and how they relate to other abilities that are acquired during early childhood, such as literacy abilities.

1.2. Effects of Thematic Knowledge on Reading

Semantic knowledge is not only a very important skill for the general human cognitive system (McRae & Jones, 2013) but it is also important for the acquisition of more abstract communication tools such as reading. Reading requires the ability to link objects and concepts to their semantic representation in script. Every lexical theory of reading includes a semantic component (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Goswami & Ziegler, 2005; Perfetti & Hart, 2002). However, the structure of this semantic component is often underspecified.

For example, in the psycholinguistic grain size theory by Ziegler and Goswami (2005), the semantic component represents the storage of concepts that children retrieve if they successfully convert phonological into orthographical representations. While orthographic and phonological components are further specified, the semantic component is not. Moreover, the lexical quality hypothesis (Perfetti & Hart, 2002) states that high quality semantic representations in the lexicon are important for reading and reading comprehension abilities - but no exact definition of high-quality representations is given.

While little is known about the influence of the quality of semantic representations on reading in children, some studies have explored the quality of semantic representations in adult reading processes. For example, Andrews and Bond (2009) presented a context sentence and a probe word to participants. Probe words were varied based on their thematic

relation to the sentence, and participants were asked to judge whether the probe had occurred in the sentence. Poor spellers found it more difficult to reject thematically related words than good spellers. Thus, these results point to a link between thematic knowledge and reading. Andrews and Bond (2009) and others (Perfetti, 2007; Perfetti & Hart, 2002) focused on thematic relations of *homonyms*.

A homonym is a specific type of word that has overlapping orthographic and phonological lexical representations, but maps onto two or more distinct semantic concepts (e.g., *ball*; toy or dance event). Participants' performance on this task might not only depend on their ability to distinguish between different thematically related words but also on their ability to store and access the two meanings of a homonym separately.

Evidence for separate lexical entries of distinct homonym meanings has been found for adults (e.g., Klepousniotou et al., 2008) and in children aged four and five years, but not in children aged three years (Doherty, 2000; Srinivasan & Snedeker, 2013). This indicates that the separate storage of distinct homonym meanings is not innate but develops in early childhood. However, so far, no study has clarified whether this development and the ability to separate homonym meanings is linked to reading acquisition in early childhood.

1.2.1 Thematic Knowledge and Reading Acquisition

In general, the link between thematic knowledge and reading in children has rarely been studied. For example, Nation and Snowling (1999) found that priming effects in a lexical decision task administered to 10-year-olds were stronger if words were taxonomically and thematically related. Furthermore, they found that children with reading comprehension difficulties relied more on thematic relations for lexical retrieval than children without reading difficulties. Thus, there seems to be a link between thematic knowledge and reading difficulties - but this has neither been studied for reading acquisition nor with regard to access to different strengths of thematic relations.

Some prediction studies with young children have investigated the effects of semantic skills on reading. Semantic precursor abilities in these studies include grammatically complex tasks, like listening comprehension tasks on the sentence or text level but not thematic knowledge (e.g., Ennemoser, Marx, Weber, & Schneider, 2012; Leppänen, Aunola, Niemi, & Nurmi, 2008; Nation, Cocksey, Taylor, & Bishop, 2010; Nation et al., 2010). Furthermore, these studies only found effects of semantic knowledge on more complex reading comprehension tasks at the sentence or text level at later stages of reading acquisition - without clarifying how semantic knowledge is linked to early reading abilities. It is thus still unclear whether thematic knowledge predicts reading abilities, particularly at an early stage.

1.3 Rationale of the Present Study

In this study, we aimed to contribute to the literature and the general understanding of the connection between thematic knowledge and reading acquisition by investigating the development of thematic knowledge in early childhood, and how it is linked to early reading development. To this end, we created a thematic judgment task in which different strengths of thematic relations had to be judged with regard to contexts, including homonyms and non-homonyms. We manipulated the strength of thematic relations with a co-occurrence measure based on child-directed literature, which is a novel method, as most previous studies have used adult association ratings to identify thematic relations. Furthermore, we investigated whether an early assessment of this ability before school entry could predict later word reading skills over and above common predictors of reading abilities, including listening comprehension at the sentence level.

The thematic judgment task was an auditory task following a forced-decision design. Children were asked to match one of two words (A: matching word; B: distractor) to a sentence (i.e., *Miriam sees the lightning*.). The matching word (A) was the same in all conditions and occurred frequently together with the provided context (i.e., *lightning*,

thunder). There were two conditions which differed with regard to the presented distractor (B). In an "association" condition, the distractor word was also associated to the target word but to a smaller degree (i.e., *lightning*, *fire*). By contrast, in an "unrelated" condition the target word was not associated with the target (i.e., lightning, *letter*). In addition, the context sentences either used a non-homonym (i.e., *Miriam sees the lightning*) or a homonym (i.e., *Felix kicks the ball*). In trials with homonyms, the matching word was associated with the dominant meaning of the homonym (i.e., ball [as a toy], *foot*) while the distractor in the associated condition was related to the non-dominant meaning of the homonym (i.e., ball [as a dance event], *queen*). The task was administered to the children twice before and twice after school entry.

We expected that it would be more difficult for the children to select the matching word in the association condition, as the distractor was also related to the context sentence. In addition, we also expected that children's performance would generally improve across development but would show a stronger improvement in the association condition. This hypothesis was based on the assumption that children continuously learn to differentiate between different strengths of thematic relations as their lexicon grows. Furthermore, we explored whether children showed different responses to context sentences containing homonyms in comparison to sentences containing non-homonyms. Finally, we expected children's thematic judgement ability before school entry to predict early word reading abilities at the end of first grade in addition to common reading precursors such as letter sound knowledge and phonological abilities (see Leppänen et al., 2008).

2. Method

2.1. Participants

Data for this analysis comes from the longitudinal project PLAiT (Prerequisite Language Abilities in the Transitional Phase) which explored the development of language

processing in104 children from kindergarten until the end of first grade in Germany. In this paper, we present results from a task that was assessed at four measurement points: 10 months (T1) and 4 months (T2) before school entry as well as 2 months (T3) and 10 months (T4) after school entry. Participants were recruited from seven cooperating Early Childhood Education and Care (ECEC) institutions. Children attended one of 18 groups in these institutions and a signed consent form of a primary care giver was required.

We collected full data sets at all time points from 62 children. Twenty children (ca. 5 % at each measurement point) dropped out due to circumstances that are typical in longitudinal study designs (relocating, missing assessments due to illness or vacations, not completing all tasks at an assessment). In addition, 22 children left the study after T2 right before school entry. The reason for this is that school entry is only loosely regulated in Berlin. Therefore, parents can optionally enroll their child at school at the age of five, six, or seven years. Even though all parents initially indicated that they wanted their child to start school the following year, a substantial number of parents later revised their initial decision.

In order to ensure that the power of the analysis was still sufficient, we conducted a power analysis for mixed effects models (Westfall, 2016) and used the model specification provided in section 3.1. Results indicated sufficient power to detect even small effects (e.g., a power of .995 for Cohen's $d = 0.45$). Thus, despite the high drop-out rate, the power of our analysis was high.

The final sample comprised 62 children (27 girls) from middle to high socioeconomic backgrounds (as assessed by collecting information about the occupational status of their parents; HISEI: $M = 68.30$; $SD = 11.47$; Ganzeboom, De Graaf, & Treiman, 1992; Ganzeboom, 2010). Furthermore, these children scored within the normal range in a standardized test of nonverbal intelligence (BUEVA-III; Esser & Wyschkon, 2016) and vocabulary (PDSS; Kauschke & Siegmüller, 2009). The children's mean age was 5;4 (years;

months, *SD*= 2.99 months) at T1, 5;10 (*SD* = 3.07 months) at T2, 6;4 (*SD*= 3.08 months), at T3, and 7;0 (*SD* = 3.11 months) at T4. Before school entry, testing took place in a quiet room in the child's ECEC institution. After children had entered school, testing took place at our research institute (82 %), the child's school (13 %) or the child's home (5 %). Children were tested in individual sessions and received a small toy in return for their participation.

2.2. Thematic Judgment Task

An auditory thematic judgment task was designed to assess children's thematic judgment ability. First, a target sentence was presented (example 1: *Miriam sees the lightning.*; example 2: *Felix kicks the ball.*). After this, two words A and B were presented. A was a matching word (example 1: *thunder;* example 2: *foot*) and B was one of two types of distractors (example 1: *fire* or *letter*; example 2: *queen* or *pasta*). Children were asked to name the word which went best with the presented sentence. A-responses (i.e., example 1: *thunder*; example 2: *foot*) were scored as correct.

The task followed a 2 (within-item: Type of Relation) x 2 (between-item: Type of Word) design. Regarding the Type of Relation factor, half of the trials included the matching word (A) and one type of distractor (B) that was weakly associated with the context (i.e., example 1: *fire*; example 2: *queen*) and were part of the associated condition. The other half of the trials included the matching word (A) and a distractor (B) that did not co-occur with the presented context (example 1: *letter*; example 2: *pasta*) and was called unrelated condition. Regarding the Type of Word factor, half of the sentences used a non-homonym (example 1: *Miriam sees the lightning*.) and half of the trials used a homonym (example 2: *Felix kicks the ball*.). In the homonym items, distractors in the association condition were associated with the non-dominant meaning of the homonym (i.e., *queen*; distantly related to ball as a dance event).

There was a pause of 1500 ms between the presentation of the sentence and the first word and a pause of 500 ms between the presentations of the first and second word. The order of presentation of item A and B within each trial and the order of Type of Relations (distractors) across trials were varied for each target sentence using a Latin square design. To avoid repetition effects, children were assigned to a different list at each measurement point. The stimuli were presented using Inquisit (v. 3.1.0.6.) on a DELL Latitude 520 laptop computer. After finishing four practice trials with feedback, 32 test trials were presented without feedback in a randomized order. All responses were recorded by an experimenter.

2.2.1. Materials. The stimuli were based on 32 SVO-structured sentences, objects serving as reference words. Subjects of the sentences were common German children's names, half of them male and half female. In addition, we selected 96 words (32 matching words, and 32 associated distractors, 32 unrelated distractors). Materials were selected from the childLex database for German children's literature (Schroeder, Würzner, Heister, Geyken, & Kliegl, 2015). The childLex corpus consists of 500 child-directed fictional and non-fictional books covering a variety of topics (e.g., sports, princesses, magic, and fairy tales). All sentences, target words and distractor words are provided in Tables A1 and A2 in the Appendix.

2.2.1.1. Thematic relations. We calculated a measure *t* (see Equation 1) which quantified the frequency of co-occurrence for two words within a sentence (Church, Gale, Hindle & Hanks, 1991, p.125). The score is based on the number of sentences in the corpus (N), the number of sentences in which the two words appear together ($f(XY)$), and the number of sentences in which each of the words appears ($f(X), f(Y)$). The minimum value of the *t*-score is 1, which indicates that two words are unrelated. The maximum of the *t*-score is infinite.

$$t = \frac{\frac{f(XY)}{N} - \frac{f(X)f(Y)}{N^2}}{\frac{\sqrt{f(XY)}}{N}}$$

Objects of the sentences (reference words) served as the basis of our manipulation of thematic relations. For example, the *t*-score of the co-occurrence of the lemma *lightning* and the lemma *thunder* in childLex is 5.20. The *t*-score for the co-occurrence of *lightning* and *fire* in childLex is 2.42. Therefore, *thunder* is thematically more closely related to *lightning* than *fire*. In addition, the *t*-score for the co-occurrence of *lightning* and *letter* is 1. Therefore, *lightning* and *letter* are thematically unrelated. The object of the target sentence (i.e., *lightning*) also appeared frequently with the verb of the target sentence (i.e., *to see*), *t*-score = 5.15.

All matching words had a *t-score* greater than 3. Distractors of the association condition had a *t-score* that varied between 2 and 3, and distractors in the unrelated condition had a *t-score* of 1, i.e., they were not thematically related to the reference word. The mean *t*-scores for matching words and both types of distractors are summarized in Table 1. Matching words co-occurred significantly more often with the reference word than distractors in the association, *t*s(31) > 15.68, *p*s <.001 and unrelated condition, *t*s(31) > 32.80, *p*s <.001. Distractors in the association condition also co-occurred significantly more often with the reference word than distractors in the unrelated condition, *ts*(31) > 17.12, *ps* <.001.

2.2.1.2. Homonyms. Half of the objects of the context sentences were homonyms (e.g., *Felix kicks the* ***ball***.) that had identical orthographic forms (i.e., they were homographs) and also shared the same pronunciation (i.e., they were homophones) but represented two different meanings. The context sentence always referred to the dominant meaning of the homonym. The dominance of multiple meanings was estimated based on the *t*-scores of all related words to the homonym. For example, if the majority of words in the highest range of the *t*-score (> 3) for the word *ball* were related to football (e.g., *goal*, *foot)*, then the meaning

of *ball* as a toy was assumed to be the dominant meaning. In the case of *ball*, only a minority of highly related words connected to *ball* as a dance event so this meaning was assumed to be non-dominant. The matching word always referred to the dominant meaning of the homonym (e.g., in the *ball* example, the matching word referred to the toy) while the distractor in the association condition referred to the non-dominant meaning of the homonym (i.e., *queen*), and the unrelated distractor referred to none of the two meanings of the homonym (i.e., *pasta*).

The *t*-scores of the matching words and both types of distractors were matched between non-homonyms and homonyms, all *t*s < 2, all *p*s >.05 (see Table 1). To validate our decisions concerning dominant and non-dominant homonym meanings, we asked 12 parents who had children at a similar age as the participating children at T1 (M = 5;2, years; months, SD = 9.66 months) to rate how familiar their children were with the words used in this study. The rating was conducted on a scale from 0 to 2. According to parents' estimations, their children were significantly more familiar with the dominant meanings, M = 1.81, SD = 0.50 than with the non-dominant meanings, M = 1.30, SD = 0.80, Δ = 0.51, $t(15) = 3.56$, $p < .001$.

2.2.1.3. Familiarity and length. All words appeared highly frequently in the childLex corpus, M = 2.12, SD = 0.61 (normalized lemma frequencies per million, log-transformed to the base of 10). In addition, the familiarity ratings (0-2) of parents with children at the same age (see above) indicated that children of this age group were generally familiar with the words, M = 1.84, SD = 0.47. Furthermore, we limited the length of the words by excluding words with more than three syllables. Lemma frequency and number of syllables were matched across conditions, all *t*s < 2, all *p*s >.05. Frequency and length in the different sets of words and distractors are provided in Table 1.

Table 1. *Item Specifications of the Thematic Judgment Task*

	Examples	Co-occurrence [a]		Frequency[b]		N of Syllables	
		M	*SE*	*M*	*SE*	*M*	*SE*
Non-Homonyms	Miriam sees the lightning.						
Matching word	thunder	5.11	0.29	2.05	0.13	1.44	0.16
Associated word	fire	2.62	0.09	2.11	0.08	1.63	0.13
Unrelated word	letter	1	0.00	2.11	0.08	1.56	0.13
Homonyms	Felix kicks the ball.						
Matching word	foot	4.92	0.32	2.23	0.16	1.44	0.12
Associated word	queen	2.08	0.13	1.75	0.15	1.63	0.16
Unrelated word	pasta	1	0.00	1.86	0.13	1.56	0.13

Note. [a] *t*-score calculated based on the co-occurrence in a sentence domain in childLex with the object of the target sentence; [b] normalized lemma frequency per million in childLex, log transformed to the base of 10.

2.3. Predictors of Reading and Reading Assessment

Letter-sound knowledge, phonological working memory, and a sentence comprehension task were assessed at T1 in order to investigate whether children's performance on the thematic judgment task predicted their later reading skills over and above other typical precursor reading skills. The ability to distinguish strengths of thematic relations was assessed by the experimental thematic judgment task described in detail above. Letter-sound knowledge was assessed by using a computerized experimental task in which children were presented with a phoneme and had to select the correct letter from two presented letters. Phonological working memory was assessed by means of a standardized digit recall task (BUEVA; Esser & Wyschkon, 2002). Sentence comprehension was assessed by a standardized test in which children had to select one out of three pictures representing the meaning of a sentence (TSVK; Siegmüller, Kauschke, van Minnen, & Bittner, 2010). Word reading ability was assessed via a standardized word-picture matching task (WLLP-R; Schneider, Blanke, Faust, & Küspert, 2011) at the end of first grade (T4). The dependent variable of all measures was the sum of correct responses. Descriptive statistics and reliabilities (which were acceptable to good) are displayed in Table 2.

Table 2. *Descriptive Statistics and Reliabilities of Covariates, Reading Predictors and Reading Abilities*

Task	*M*	*SD*	*Range*	*Max*	*α*
Word Reading Abilities	36.44	17.99	7 – 78	80	.97
Thematic Judgment	24.71	5.18	13 – 32	32	.85
Sentence Comprehension	24.53	3.94	16 – 31	36	.65[a]
Letter Sound Knowledge	23.35	5.48	10 – 32	32	.83
Phonological Working Memory	20.81	4.62	11 – 30	52	.80

Note. Values represent the number of correct responses; [a] reported as .94 in the test's manual.

3. Results

3.1. Development of Children's Ability to Distinguish Thematic Relations

First, we analyzed children's development of the ability to distinguish among different types of thematic relations as a function of word type. We used a generalized linear mixed-effects approach because mixed-effects models allow to simultaneously take the variances of both participants and items into account (Baayen, Davidson, & Bates, 2008).

Responses were analyzed using generalized linear mixed effects models with a logit link and a binomial error distribution (*glmer* function from R-package {*lme4*}; Bates et al., 2015). The logit transformation is a commonly used nonlinear transformation for binary responses (see Cohen, Cohen, Aiken, & West, 2003). Due to the nature of this transformation, responses at the boundaries of the response spectrum (0 and 1) are spread out in order to linearize relationship and avoid ceiling effects. To ease interpretation, we back-transformed all results when reported in the text. Response accuracy was defined as the percentage of correctly identified matching words for each provided context sentence. Responses were scored as correct if children chose the matching word (A; example 1: *thunder*; example 2: *foot*) instead of one of the types of distractors (B; example 1: *fire* or *letter*; example 2: *queen* or *pasta*) to match the provided context (example 1: *Miriam sees the lightning.*; example 2: *Felix kicks the ball.*) Descriptive statistics of all four measurement points are provided in Table 3.

In the *glmer* model, participants and items were treated as crossed random effects. Time was treated as a fixed continuous variable (T1: -10, T2: -4, T3: 2, T4:10; 0 = school entry). Type of Relation (2: association vs. unrelated) and Type of Word (2: homonyms vs. non-homonyms) were included as fixed factors using effects coding. Phonological working memory was included in the model in order to control for task demands. Omnibus effects were calculated based on type-III model comparisons (*Anova* function from R package {*car*};

Fox & Weisberg, 2011). Post-hoc analyses were carried out using single-degree-of-freedom contrasts, using the *glht* function in the {*multcomp*} package. Prior to the analysis, accuracy rates on the item level were compared between an adult control sample ($N = 20$; male = 11; age: $M = 25.2$ years; $SD = 3.24$ years) and children's responses across all time points. Based on the comparison, responses in the association condition of two context sentences (*Tor* and *Planet*) were excluded due to low accuracy rates (see Tables A3 and A4 in the Appendix).

Table 3. *Percentage of Correctly Identified Matching Words in the Thematic Judgment Task*

	T1	T2	T3	T4
Condition	*M(SE)*	*M (SE)*	*M (SE)*	*M (SE)*
Non-Homonyms				
Association	71.02	82.14	85.06	87.16
	(2.46)	(1.93)	(1.74)	(1.60)
Unrelated	79.25	86.26	91.83	94.08
	(2.04)	(1.63)	(1.20)	(1.00)
Homonyms				
Association	78.51	84.41	87.42	90.45
	(2.13)	(1.79)	(1.59)	(1.35)
Unrelated	81.88	92.40	93.14	95.91
	(1.90)	(1.15)	(1.08)	(0.80)

Note. Response accuracy and standard errors represent the percentage of correct responses in each condition and at each time point.

The results of the mixed-effect model analysis are displayed in Table 4. First, there was a main effect of Time. Children's overall performance improved between measurement

points. At T1, children chose the matching word on average in 78.42% (*SE* = 2.13) of the trials. Between T1 and T2, performance improved by 8.29% with an average score of 86.71% (*SE* = 1.62). Between T2 and T3, children improved by 3.1%, *M* = 89.82% (*SE* = 1.38). Between T3 and T4, children further improved by Δ = 2.41% and their response accuracy was now close to ceiling, 92.23% (*SE* = 1.17).

Table 4. *Omnibus Effects in the Thematic Judgment Task across Development*

Effect	χ^2	*Df*	*p*
Intercept	669.31	1	<.001
Phonological Working Memory	0.88	1	n.s.
Time	163.70	1	<.001
Type of Relation	86.73	1	<.001
Type of Word	9.05	1	<.01
Time x Type of Relation	9.47	1	<.01
Time x Type of Word	0.21	1	n.s.
Type of Relation x Type of Word	0.31	1	n.s.
Time x Type of Relation x Type of Word	0.23	1	n.s.

Note. χ^2 for effects using Type III sum of squares; >.05 = ns.; <.01 = **; <.001 = ***.

Next, there was a main effect of Type of Relation. Across all four time points, response accuracy was higher in the unrelated, *M* = 92.85% (*SE* = 1.12) than in the association condition, *M* = 86.03% (*SE* = 1.7; Δ = 6.83%). Furthermore, there was a main effect for Type of Word. Overall, response accuracy in trials with homonyms, *M* = 92.85%

(*SE* = 1.12), was higher than in trials with non-homonyms, *M* = 90.46% (*SE* = 1.34; Δ = 2.39%).

Finally, there was an interaction effect of Time and Type of Relation. This interaction was driven by the fact that the simple main effect of Time was larger in the unrelated condition, $\beta = 0.08$, *SE* = 0.01, $t = 10.01$, $p < .001$ than in the association condition, $\beta = 0.05$, *SE* = 0.01, $t = 8.04$, $p < .001$ (see Figure 1; differences of effects: $\beta = 0.03$, *SE* = 0.01, $t = 3.08$, $p < .01$).

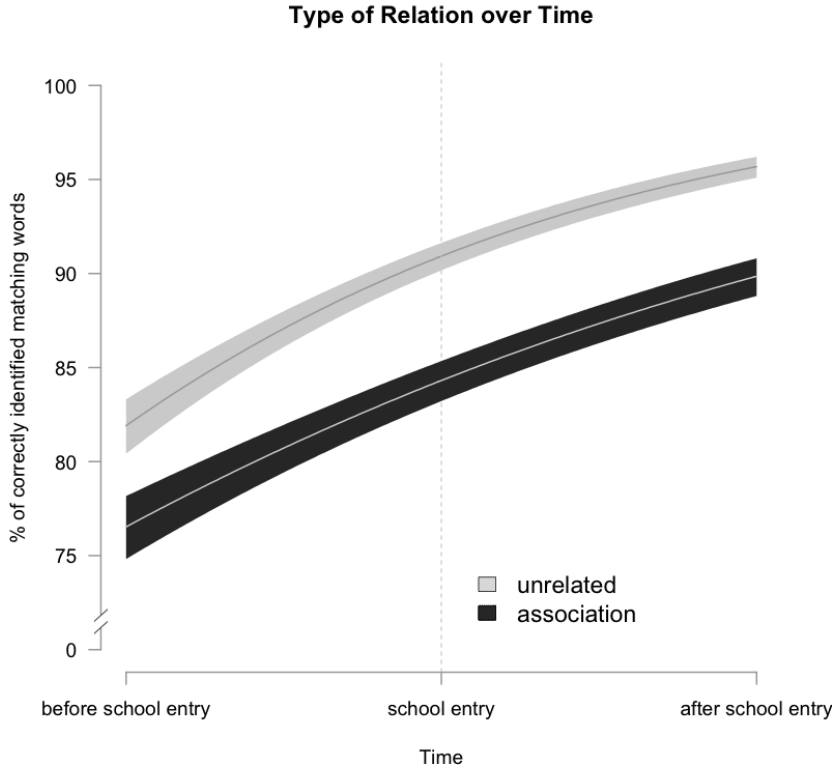

Figure 1. Development across Time in the Type of Relation and Type of Word conditions.

In summary, children performed above chance level in the thematic judgment task at the beginning of the study and improved significantly over time. Responses were generally more accurate in the unrelated than the association condition, and children also improved more over time in this condition. In addition, accuracy for homonyms was generally higher

than for non-homonyms but children showed no differences in the rate of development for either type of word.

3.2. Prediction of Reading Abilities

In a second step, we tested whether children's early thematic judgment skills predicted word reading abilities (assessed at the end of grade 1) over and above three typical precursor skills: letter sound knowledge, phonological working memory, and sentence comprehension (all assessed 10 months before school entry). In particular, we were interested in comparing the effects of children's ability to distinguish between different thematic relations to the effects of a sentence comprehension task, which is commonly used as a measure of children's semantic ability. We therefore computed children's overall response accuracy in the thematic judgment task by averaging over all conditions, and then computed the bivariate correlations between all measures (see Table 5). The pattern of correlations showed that thematic judgment ability correlated moderately with sentence comprehension but no other variables. In addition, reading ability showed significant correlations with thematic judgment, letter-sound knowledge, and phonological working memory but not with sentence comprehension.

Table 5. *Correlations of Reading, Semantic Assessments and Reading Predictors*

Measures	1	2	3	4	5
1.Reading	1				
2.Thematic Judgment	.26*	1			
3.Sentence Comprehension	.16	.38**	1		
4.Letter Knowledge	.46***	.07	.18	1	
5.Phonological Working Memory	.31*	-.05	.06	.26*	1

Note. * $p < .05$, ** $p < .01$, *** $p < .001$.

Next, we fitted a multiple regression model using letter-sound knowledge, phonological working memory, thematic judgment ability, and sentence comprehension as predictor variables, and word reading skill as the outcome variable. All variables were *z*-transformed before they were included in the analysis. The results of this analysis are displayed in Table 6. The regression model explained a substantial amount of variance in word reading at the end of first grade, R^2= 32.11; $F(4,57) = 6.74$, $p < .001$. Letter-sound knowledge had the largest effect on early word reading but thematic judgment also had a significant effect. By contrast, sentence comprehension did not explain any variance in word reading abilities. In summary, children's word reading ability was predicted by children's ability to distinguish different thematic relations but not by sentence comprehension abilities. This was surprising because both variables were moderately correlated.

Table 6. *Reading Abilities Predicted by Thematic Judgment, Sentence Comprehension, and Reading Predictors*

Variables	*B*	*SE B*	*t*	*p*
Thematic Judgment	0.27	0.12	2.31	< .05
Sentence Comprehension	-0.03	0.12	-0.28	n.s.
Letter-Sound Knowledge	0.40	0.12	3.51	< .01
Phonological Working Memory	0.22	0.11	1.92	n.s.

Note. Variables were z-transformed before they were included in the model.

In a next step, we wanted to know whether the effect was driven by a specific component of semantic processing. We therefore calculated separate correlations between word reading abilities and response accuracy in the different conditions of the thematic

judgments task, i.e. for homonyms and non-homonyms, the association and the unrelated condition. Results showed that responses in the association condition (r = .25, t = 2.01, p < .05) and in the homonyms condition (r = .28, t = 2.29, p < .05) correlated with reading abilities, while responses in the unrelated condition (r = .23, t = 1.88, p = .07) and the non-homonyms condition (r = .22, t = 1.71, p = .09) showed smaller effects.

In order to explicitly test whether the correlations in the different conditions were significantly different, we computed *t*-tests for pairwise correlations (see Cohen, Cohen, West, & Aiken, 2003) that account for intercorrelations between the various conditions (which was generally high: r ~ .70-.88). Results showed that effects in none of the conditions differed significantly (all ts < 0.9 all ps > .85). Thus, the effect of the thematic judgment task is quite homogenous and is not specifically related to performance in one of the conditions.

4. Discussion

In this longitudinal study, German-speaking children were asked to decide whether a matching word (e.g., *thunder*) or one of two types of distractors (associated: *fire*; unrelated: *letter*) fit better to a provided context sentence with a reference word (i.e., *Miriam sees the lightning).* We manipulated the strength of thematic relations using a corpus-based co-occurrence measure. In addition, sentences either contained a homonym (i.e., *ball*) or a non-homonym (i.e., *lightning*) as a reference word. The task was administered to the same group of children at two time points before and two time points after school entry. We investigated how children's ability to distinguish different strengths of thematic relations develops and whether it predicts their later reading skills. We will discuss these two aspects separately.

4.1. Development of Thematic Judgment

As expected, children's performance in the thematic judgment task improved significantly over time. We cannot relate this finding to previous studies, as to our knowledge the development of thematic relations has not been investigated for young children in a

longitudinal design before. However, previous studies demonstrated that even very young children can identify thematic relations (Arias-Trejo & Nation, 2013; Hashimoto et al., 2007). From a usage-based perspective, one would expect to see improvements in this ability over time because thematically related words are encountered more often in shared contexts. For example, children's ability to decide that *thunder* matches the sentence '*Miriam sees the lightning*.' better than the word *fire* will increase over time if *thunder* is encountered proportionally more frequently than *fire* in the context of *lightning* in the child's language environment. That is, owing to an increasing exposure to the thematic structure of their language environment, children are able to build up a more stable and differentiated semantic network, which results in better performance. This is in line with findings from previous studies that have linked exposure to child-directed speech to the growth of semantic networks and the structure of children's mental lexicon (Hills et al, 2010; Hills, Maouene, Maouene, Sheya, & Smith, 2009; Steyvers & Tenenbaum, 2005).

In this study, we based item selection on the co-occurrences of words in child-directed literature. Thus, the strength of thematic relations was based on the words' occurrence in books that are regularly used to entertain and teach young children. Our results show that this was a sensible approach, as children performed above chance level in the thematic judgment task even at the first measurement point. Therefore, children's development in the semantic judgement task might specifically be linked to the frequency of shared story book reading. Child-caregiver, child-educator and child-peer conversations are certainly other important sources of language input for learning thematic relations (see Hills et al., 2010).

In line with our expectations, children performed better when the distractor was unrelated to the context of the sentence. This was a stable effect across time, showing that children were able to distinguish strengths of thematic relations. Contrary to our expectations, growth in performance was larger in the unrelated than in the association condition. We had

expected near ceiling scores in the unrelated condition at all time points, which would lead to a stronger improvement in the association condition. However, this was not the case. For example, at the first time point, children concluded that the word *pasta* fitted better to the sentence *Felix kicks the ball* than the word *foot* in about 20% of all trials. This indicates that this task is not easy for young children. Six months later, children still made the same decision only in about 9 % of the trials. Our results thus demonstrate that children improve rapidly in this condition.

Our results also show that even at the age of five, children are not yet able to routinely distinguish unrelated words from related words. Similar effects have been reported in semantic priming studies with infants (e.g., Arias-Trejo & Plunkett, 2013; Styles & Plunkett, 2009) and adults (e.g., McNamara, 2005). In particular, Arias-Trejo and Plunkett (2013) have argued that the influence of unrelated items in semantic priming is explained by lexical restructuring during active periods of vocabulary growth (see also Mayor & Plunkett, 2014). According to this account, semantic relations are reorganized during vocabulary expansion and the thematic relation between associated words becomes blurred, which leads to increased false-alarm rates in the unrelated condition.

Still, our findings can hardly be fully explained by the above account, see in particular the strong improvement of children's responses in the unrelated condition during a time period of presumably intense vocabulary growth. We think that effects of nonlinear lexical growth might have an additional impact (e.g., Hills et al, 2009; Steyvers & Tenenbaum, 2005). In particular, studies on children's vocabulary development have shown that new words are not acquired in a linear fashion but proportional to their frequency of occurrence in the language environment. This might be particularly important for children's performance in the unrelated condition. For example, if a child encounters the word *letter* and the context '*Miriam sees the lightning'* twice and the word *thunder* 10 times within the same context in

the same time frame, the strength of their relations differs by a factor of 5, which might not be a very salient difference. Imagine, however, that after a year, *thunder* has been encountered 40 times in this particular context while *letter* has only been encountered four times. Now the strength of the relation between the words with the context differs by the factor 10 and the strength of relation has grown closer four times as fast for *thunder* than for *letter*. Thus, the distance between the relations of the two words with the context becomes more salient over time.

Simultaneously, the relations of weakly associated words with the reference words evolve as well. For example, if a child encounters the word *fire* in the context of '*Miriam sees the lightning*' five times, the factor of the distance of relation to the matching word (*thunder*) is 2. If after a year, fire has appeared with the context 25 times (and *thunder* 40 times), the distance of relations still differs by the factor 1.6. The closeness of the weakly associated words to the context has then grown slightly stronger and more distracting. By comparison, unrelated words have become more distant. Thus, both the increasing distraction by associated words and the growing distance to unrelated words contribute to a stronger development in judgments about unrelated words, and overall lead to stronger and more differentiated thematic relations in the lexicon.

The strong growth of accuracy values in the unrelated condition brought children's responses near ceiling at the end of first grade. Our study focused on a limited time span of development and it is difficult to determine whether developmental trajectories would shift later when vocabulary growth slows down and it is presumably easier to reject unrelated items. Thus, more studies on the development of thematic judgment are needed to determine how growth of thematic relations continues.

Moreover, children's performance was better for homonyms than for non-homonyms. This finding is in line with the assumption that children have separate lexical representations

for the two meanings of a homonym. Accordingly, *ball* as a toy and as a dance event are treated like separate words (e.g., Doherty, 2000; Srinivasan & Snedeker, 2013). As the matching word always referred to the more frequently used meaning of the homonym and the distractor to the less frequently used meaning, there is less interference for homonyms in the association condition if children store the two homonym meanings separately. If children had treated the homonyms as a single entry, response accuracy would either have been similar to performance for non-homonyms or poorer. The difference in performance on homonyms and non-homonyms was stable over time. Thus, we assume that homonyms were treated as separate entries from the beginning, which correlates with the assumption that separate lexical entries develop at around the age of four years (Doherty, 2000; Srinivasan & Snedeker, 2013).

Although we found similar developmental trajectories for homonyms and non-homonyms, descriptive values indicated that children might improve more rapidly in the unrelated condition if the reference word was a homonym. Thus, there might be some subtle and long-term differences between children's development on homonyms and non-homonyms that could not be detected within a two-year time span.

4.2. Thematic Judgment Ability as an Early Predictor of Reading Abilities

In line with our expectations, children's early thematic judgment abilities predicted their word reading skills at the end of first grade over other common predictors of early reading. By contrast, a sentence comprehension task as it is typically used to study children's early comprehension abilities on the sentence level did not predict later reading, although both tasks were moderately correlated. This finding is important because effects of thematic knowledge on beginning literacy have not been reported before, particularly on the word level (e.g., Ennemoser et al., 2012; Leppänen et al, 2008; Nation et al., 2010).

A semantic priming study with 10-year-olds showed that poor comprehenders rely more strongly on thematic relations than average readers when accessing semantic representations during reading (Nation & Snowling, 1999). While this indicates a connection between reading abilities and thematic knowledge, it has not been clarified whether the reliance on thematic knowledge was related specifically to reading comprehension impairments or affected typical reading development in general. The effect of thematic judgment on early reading abilities found in this study supports the latter assumption that thematic knowledge in general is connected to reading acquisition. We did not investigate how the development of early thematic knowledge can be fostered, and how it is linked to reading difficulties and later reading comprehension abilities.

In previous studies on the impact of semantic knowledge on emergent literacy, semantic knowledge was measured by broad assessments of listening (Ennemoser et al., 2012) and sentence comprehension (Leppänen et al., 2008 Nation et al., 2010). In this study, listening comprehension – despite being connected to thematic judgment - had no predictive effect on word reading abilities at the end of first grade. This result corroborates previous studies and points to the possibility that grammatically complex comprehension tasks are linked to grammatically complex reading tasks due to the shared degree of complexity. Thus, a lack of connection to early reading abilities might be linked to the complexity of the semantic process the task taps into. Despite what was reported in the task manual (see Table 2), reliability of this task in this group of participants was low compared to other precursor abilities. It would therefore be fruitful to see replications of this study with a more reliable listening comprehension task.

In a follow-up analysis, we further investigated the question whether one component of children's early semantic processing was particularly related to their reading skills at the end of first grade. Results showed some variability in the correlations of children's

performance in the four conditions. However, after considering the intercorrelations between the various measures, their effects did not differ significantly from each other. Thus, the effects of children's semantic skills on reading seem to be homogenous and are not specifically linked to any condition of the task, although they clearly differed in their overall level of difficulty. It is, however, important to consider that item and sample size of our study were not ideal for an assessment of such subtle differences. Further research would be needed to draw any definite conclusions.

4.3. Conclusion

In sum, we investigated the development of young children's ability to distinguish different types of thematic relations, and whether this varied across homonyms and non-homonyms. Furthermore, we investigated whether the ability to distinguish between different thematic relations can predict later reading skills on the word level. Results show that children strongly improved in their ability to distinguish between different strengths of thematic relations in early childhood. In addition, children's thematic judgment abilities before school entry predicted their word reading abilities at the end of first grade in addition to letter-sound knowledge, and in addition to listening comprehension abilities. We conclude that the accessibility and usability of thematic knowledge in a young child's lexicon has an impact on reading acquisition. This is currently not reflected in theories of reading and reading development (e.g., Perfetti & Hart, 2002; Ziegler & Goswami, 2005) or prediction studies, and should be investigated further.

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6. References

Aitchison, J. (2012). *Words in the Mind: An Introduction to the Mental Lexicon* (4th Ed.). Oxford, UK: Blackwell.

Andrews, S., & Bond, R. (2009). Lexical expertise and reading skill: Bottom-up and top-down processing of lexical ambiguity. *Reading and Writing*, *22*(6), 687-711. doi:10.1007/s11145-008-9137-7

Arias-Trejo, N., & Plunkett, K. (2013). What's in a link: Associative and taxonomic priming effects in the infant lexicon. *Cognition*, *128*(2), 214-227. doi: 10.1016/j.cognition.2013.03.008

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*(4), 390-412. doi: 10.1016/j.jml.2007.12.005

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1-48. doi: 10.18637/jss.v067.i01

Beck, I., & McKeown, M. (1991). Conditions of Vocabulary Acquisition. In R. Barr, M. L. Kamil, P. Mosenthal, & P. D. Pearson (Eds.), *Handbook of Reading Research* (Vol. 2, pp. 789–814). New York: Longman.

Berger, C., & Donnadieu, S. (2006). Categorization by schema relations and perceptual similarity in 5-year-olds and adults: A study on vision and audition. *Journal of Experimental Child Psychology*, *93*, 304-321. doi: 10.1016/j.jecp.2005.10.001

Berger, C., & Donnadieu, S. (2008). Visual/auditory processing and categorization preferences in 5-year old children and adults. *Current Psychology Letters: Behaviour, Brain and Cognition*, *24*, 40-51.

Church, K., Gale, W., Hanks, P., & Kindle, D. (1991). Using Statistics in Lexical Analysis. In *Lexical acquisition: exploiting on-line resources to build a lexicon* (pp.115-164). Mahwah, NJ, USA: Erlbaum Associates.

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*. Mahwah, New Jersey: Lawrence Erlbaum and Associates Publishers.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: a dual route cascaded model of visual word recognition and reading aloud. *Psychological Review*, *108*(1), 204-256. doi: 10.1037/0033-295X.108.1.204

Doherty, M. J. (2000). Children's Understanding of Homonymy: Metalinguistic Awareness and False Belief. Journal of Child Language, 27(02), 367-392.

Ennemoser, M., Marx, P., Weber, J., & Schneider, W. (2012). Spezifische Vorläuferfertigkeiten der Lesegeschwindigkeit, des Leseverständnisses und des Rechtschreibens. [Precursor Abilities of reading fluency, reading comprehension and spelling] *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie*, *44*, 53-67. doi: 10.1026/0049-8637/a000057

Esser, G., & Wyschkon, A. (2002). *Basisdiagnostik für Umschriebene Entwicklungsstörungen im Vorschulalter: BUEVA*. [core diagnostic tool for circumscribed developmental disorders for preschool] Göttingen: Beltz.

Esser, G., Wyschkon, A. (2016). *Basisdiagnostik Umschriebener Entwicklungsstörungen im Vorschulalter – Version III* [core diagnostic tool for circumscribed developmental disorders for preschool – third edition] *(BUEVA-III).* Göttingen: Hogrefe.

Fox, J. & Weisberg, S. (2011). *An {R} companion to applied regression* (2nd Edition). Thousand Oaks CA: Sage. URL: http://socserv.socsci.mcmaster.ca/jfox/Books/Companion

Ganzeboom, H. B., De Graaf, P. M., & Treiman, D. J. (1992). A Standard International Socio-Economic Index of Occupational Status. *Social Science Research*, *21*(1), 1-56. doi:10.1016/0049-089X(92)90017-B

Ganzeboom, H. B. G. (2010, May). *A new International Socio-Economic Index (ISEI) of occupational status for the International Standard Classification of Occupation 2008 (ISCO-08) constructed with data from the ISSP 2002-2007.* Paper presented at the Annual Conference of International Social Survey Programme, Lisbon.

Goswami, U., Ziegler, J. C., & Richardson, U. (2005). The effects of spelling consistency on phonological awareness: A comparison of English and German. *Journal of Experimental Child Psychology*, *92*(4), 345-365. doi: 10.1016/j.jecp.2005.06.002.

Hashimoto, N., McGregor, K. K., & Graham, A. (2007). Conceptual organization at 6 and 8 years of age: Evidence from the semantic priming of object decisions. *Journal of Speech, Language, and Hearing Research*, *50*(1), 161-176. doi:10.1044/1092-4388(2007/014)

Hills, T. T., Maouene, M., Maouene, J., Sheya, A., & Smith, L. (2009). Longitudinal Analysis of Early Semantic Networks Preferential Attachment or Preferential Acquisition?. *Psychological Science*, *20*(6), 729-739.

Hills, T. T., Maouene, J., Riordan, B., & Smith, L. B. (2010). The associative structure of language: Contextual diversity in early word learning. *Journal of Memory and Language*, *63*(3), 259-273. doi: 10.1016/j.jml.2010.06.002

Inquisit (Version 3.1.0.6.) [Computer Software]. Seattle, WA: Millisecond Software.

Kauschke, C., & Siegmüller, J. (2010). Patholinguistische Diagnostik bei Sprachentwicklungsstörungen (PDSS) (Vol. 4). München: Elsevier, Urban & Fischer Verlag.

Klepousniotou, E., Titone, D., & Romero, C. (2008). Making sense of word senses: the comprehension of polysemy depends on sense overlap. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*(6), 1534-1543. doi: 10.1037/a0013012

Leppänen, U., Aunola, K., Niemi, P., & Nurmi, J. E. (2008). Letter knowledge predicts Grade 4 reading fluency and reading comprehension. *Learning and Instruction*, *18*(6), 548-564. doi: 10.1016/j.learninstruc.2007.11.004

Mann, V., & Wimmer, H. (2002). Phoneme awareness and pathways into literacy: A comparison of German and American children. *Reading and Writing*, *15*(7), 653-682. doi: 10.1023/A:1020984704781

Mayor, J., & Plunkett, K. (2014). Infant word recognition: Insights from TRACE simulations. *Journal of Memory and Language*, *71*(1), 89-123. doi: 10.1016/j.jml.2013.09.009

McNamara, T. P. (2005). Semantic priming: Perspectives from memory and word recognition. New York: Psychology Press.

McRae, K., & Jones, M. N. (2013). Semantic memory. In D. Reisberg (Ed.) *The Oxford handbook of cognitive psychology* (pp. 206-219). New York, NY: Oxford University Press.

Mirman, D., Landrigan, J. F., & Britt, A. E. (2017). Taxonomic and thematic semantic systems. *Psychological Bulletin*. Advance online publication. doi: 10.1037/bul0000092

Näslund, J. C., & Schneider, W. (1996). Kindergarten letter knowledge, phonological skills, and memory processes: Relative effects on early literacy. *Journal of Experimental Child Psychology*, *62*(1), 30-59. doi: 10.1006/jecp.1996.0021

Nation, K., & Snowling, M. J. (1999). Developmental differences in sensitivity to semantic relations among good and poor comprehenders: Evidence from semantic priming. *Cognition*, *70*(1), B1-B13. doi: 10.1016/S0010-0277(99)00004-9

Nation, K., Cocksey, J., Taylor, J. S., & Bishop, D. V. (2010). A longitudinal investigation of early reading and language skills in children with poor reading comprehension. *Journal of Child Psychology and Psychiatry*, *51*(9), 1031-1039. doi: 10.1111/j.1469-7610.2010.02254.x

Perfetti, C. A., & Hart, L. (2002). The lexical quality hypothesis. In Verhoeven, Elbro & Reitsma (Eds.), *Precursors of functional literacy*, (pp. 67-86). Amsterdam/ Philadelphia: John Benjamins Publishing Company.

Perfetti, C. (2007). Reading ability: Lexical quality to comprehension. *Scientific Studies of Reading*, *11*(4), 357-383. doi: 10.1080/10888430701530730

R Development Core Team (2008). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org.

RStudio Team (2015). *RStudio: Integrated Development for R*. RStudio, Inc., Boston, MA URL http://www.rstudio.com/.

Scheuner, N., Bonthoux, F., Cannard, C., & Blaye, A. (2004). The role of associative strength and conceptual relations in matching tasks in 4-and 6-year-old children. *International Journal of Psychology*, *39*(4), 290-304. doi: 10.1080/00207570344000394

Schneider, W., Blanke, I., Faust, V., & Küspert, P. (2011). Würzburger Leise Leseprobe-Revision (WLLP-R) [Würzburger silent reading test - revised]. Göttingen: Hogrefe.

Schroeder, S., Würzner, K. M., Heister, J., Geyken, A., & Kliegl, R. (2015). childLex: A lexical database of German read by children. *Behavior Research Methods*, *47*(4), 1085-1094. doi:10.3758/s13428-014-0528-1

Siegmüller, J., Kauschke, C., van Minnen, S., & Bittner, D. (2010). *Test zum Satzverstehen von Kindern* [Test of sentence comprehension of children] *(TSVK)*. München: Elsevier, Urban & Fischer Verlag.

Srinivasan, M. & Snedeker, J. (2013). Polysemy and the Taxonomic Constraint: Children's Representation of Words that Label Multiple Kinds, *Language Learning and Development*, *00*, 1–32. doi: 10.1080/15475441.2013.820121

Steyvers, M., & Tenenbaum, J. B. (2005). The Large-Scale Structure of Semantic Networks: Statistical Analyses and a Model of Semantic Growth. *Cognitive Science*, *29*(1), 41-78. doi: 10.1207/s15516709cog2901_3

Styles, S. J., & Plunkett, K. (2009a). How do infants build a semantic system? *Language and Cognition*, *1*, 1–24. doi: 10.1515/LANGCOG.2009.001

Wagensveld, B., van Alphen, P., Segers, E., & Verhoeven, L. (2012). The nature of rhyme processing in preliterate children. *British journal of educational psychology*, *82*(4), 672-689. doi: 10.1111/j.2044-8279.2011.02055.x

Westfall, J. (2016). PANGEA: Power Analysis for General Anova designs. [Working Paper]. University of Texas at Austin. Retrieved from: http://jakewestfall.org/publications/pangea.pdf (09.05.2018)

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: a psycholinguistic grain size theory. *Psychological Bulletin*, *131*(1), 3-29. doi: 10.1037/0033-2909.131.1.3

7. Appendix

Table A1. *All Target Sentences, Matching Words and Distractors of the Thematic Judgment Task for Non-Homonyms in German and English.*

No	Target Sentences	Matching Words	Associated Words[a]	Unrelated Words[a]
1	Jan schaut auf die Wolke. *Jan looks at the cloud.*	Regen *rain*	Berg *mountain*	Lippe *lip*
2	Simon bedeckt das Eis. *Simon covers the ice.*	Schnee *snow*	Sommer *summer*	Monster *monster*
3	Lea lässt die Spinne. *Lea leaves the spider.*	Netz *web*	Käfer *bug*	Kamm *comb*
4	Anja rutscht auf dem Stuhl. *Anja wobbles on the chair.*	Platz *seat*	Lehrer *teacher*	Schiff *ship*
5	Roland kriecht unter den Busch. *Roland crawls under the bush.*	Zweig *twig*	Pfad *path*	Sprache *speech*
6	Christoph sieht den Planet. *Christoph sees the planet.*	Stern *star*	Mond[c] *moon*	Zettel *note*
7	Kim muss zum Palast. *Kim needs to go to the palace.*	König *king*	Garten *garden*	Meter *meter*
8	Hans ruft den Ritter. *Hans calls the knight.*	Schwert *sword*	Turnier *tournament*	Sitz *seat*
9	Martha isst das Salz. *Martha eats the salt.*	Pfeffer *pepper*	Brot *bread*	Versuch *attempt*
10	Jakob nimmt den Hut. *Jacob takes the hat.*	Zauberer *wizard*	Tasche *bag*	Klasse *class*
11	Georg sammelt den Pilz. *George picks the mushroom.*	Wald *forest*	Stein *stone*	Hals *throat*
12	Karen fährt in den Bahnhof. *Karen drives into the train station.*	Zug *train*	Straße *street*	Stirn *forehead*
13	Miriam sieht den Blitz. *Miriam sees the lightning.*	Donner *thunder*	Feuer *fire*	Brief *letter*
14	Hanna verfolgt die Spur. *Hanna follows the trace.*	Boden *soil*	Himmel *sky*	Freundin *friend*
15	Rex frisst die Pflanze. *Rex eats the plant.*	Baum *tree*	Sonne *sun*	Zahn *tooth*
16	Lucie denkt an den Traum. *Lucie thinks of the dream.*	Nacht *night*	Bild *picture*	Küche *kitchen*

Note. [a] distractors. [c] responses in association condition excluded from analysis.

Table A2. *All Target Sentences, Matching Words and Distractors of the Thematic Judgment Task for Homonyms in German and English.*

No	Target Sentences	Matching Words	Associated Words[a]	Unrelated Words[a]
1	Felix kickt den Ball. *Felix kicks the ball. (toy/ dance event)*	Fuß *foot*	Königin *queen*	Nudel *pasta*
2	Daniel geht zur Bank[b]. *Daniel goes to the bank. (bank/ bench)*	Geld *money*	Park *park*	Spiegel *mirror*
3	Christina schießt mit dem Bogen[b]. *Christina shoots with the bow. (bow/ sheet)*	Pfeil *arrow*	Schrift *script*	Faden *thread*
4	Jutta schläft auf der Decke[b]. *Jutta sleeps on the blanket. (blanket/ ceiling)*	Kissen *pillow*	Vorhang *curtain*	Witz *joke*
5	Jana hält die Feder[b]. *Jana holds the feather. (feather/ spring)*	Vogel *bird*	Rad *wheel*	Flasche *bottle*
6	Auf Torsten sitzt die Fliege[b]. *The fly sits on Torsten. (insect/ bow tie)*	Kopf *head*	Hemd *shirt*	Märchen *fairytale*
7	Sascha bringt das Futter[b]. *Sascha brings the fodder. (fodder/ lining)*	Pferd *horse*	Jeans *jeans*	Stich *sting*
8	Anne rennt durch den Gang[b]. *Anne runs through the corridor. (corridor/ gear)*	Treppe *stairs*	Motor *engine*	Löffel *spoon*
9	Yannick kräht wie ein Hahn[b]. *Yannick crows like a rooster. (rooster/ tap)*	Huhn *chicken*	Wasser *water*	Freund *friend*
10	Bastian fängt die Maus. *Bastian catches the mouse. (rodent/ computer device)*	Ratte *rat*	Taste *key*	Brust *breast*
11	Oliver öffnet den Riegel. *Oliver opens the bar. (bar of a lock/ of chocolate)*	Tür *door*	Stück *piece*	Onkel *uncle*
12	Johanna kommt im Rock[b]. *Johanna comes wearing a skirt. (clothing/ musical genre)*	Frau *woman*	Stimme *voice*	Jahr *year*
13	Maja sieht durch die Scheibe[b]. *Maja looks through the window pane. (window pane/slice)*	Fenster *window*	Gurke *cucumber*	Poster *poster*
14	Svenja sitzt am See[b]. *Svenja sits at the lake. (lake/ocean)*	Ufer *shore*	Meer *sea*	Ecke *corner*
15	Michael steht am Stamm[b]. *Michael stands at the trunk. (trunk/ tribe)*	Rinde *bark/rind*	Häuptling *tribe chief*	Zahl *digit*
16	Alex macht das Tor[b]. *Alex makes the goal. (goal/ gate)*	Spiel *game*	Burg [c] *castle*	Magen *stomach*

Note. [a] distractors; [b]homonyms in German but not in English or in both languages but with different meanings in English. [c] responses in association condition excluded from analysis.

Table A3. *Mean and standard errors of accuracy responses of adults per item.*

Sentences	Association		Unrelated	
Non-Homonyms	*M*	*SE*	*M*	*SE*
1	1	0	1	0
2	1	0	0.89	0.07
3	1	0	1	0
4	0.89	0.07	1	0
5	1	0	1	0
6[a]	0.33	0.11	0.89	0.07
7	1	0	1	0
8	0.78	0.1	1	0
9	0.89	0.07	0.78	0.1
10	1	0	1	0
11	1	0	1	0
12	0.89	0.07	1	0
13	1	0	1	0
14	1	0	1	0
15	1	0	0.89	0.07
16	0.89	0.07	1	0
Homonyms	*M*	*SE*	*M*	*SE*
1	1	0	1	0
2	0.78	0.1	1	0
3	1	0	1	0
4	1	0	1	0
5	1	0	1	0
6	0.78	0.1	1	0
7	1	0	1	0
8	1	0	1	0
9	1	0	1	0
10	1	0	1	0
11	1	0	1	0
12	1	0	1	0
13	1	0	1	0
14	1	0	1	0
15	0.89	0.07	1	0
16[a]	0.67	0.11	1	0

Note. $N = 20$; The table corresponds to Tables A1 and A2; [a]items excluded from analysis.

Table A4. *Mean and standard errors of accuracy responses of children per item and across all time points.*

Sentences	Association		Unrelated	
Non-Homonyms	*M*	*SE*	*M*	*SE*
1	0.86	0.04	0.94	0.03
2	0.64	0.06	0.91	0.04
3	0.82	0.05	0.94	0.03
4	0.77	0.05	0.85	0.05
5	0.86	0.04	0.91	0.04
6[a]	0.31	0.06	0.98	0.02
7	0.92	0.03	0.92	0.04
8	0.48	0.06	0.93	0.03
9	0.69	0.06	0.75	0.06
10	0.73	0.06	0.76	0.05
11	0.92	0.03	0.95	0.03
12	0.91	0.04	0.97	0.02
13	0.75	0.06	0.85	0.04
14	0.89	0.04	0.75	0.06
15	0.89	0.04	0.61	0.06
16	0.89	0.04	0.91	0.04
Homonyms	*M*	*SE*	*M*	*SE*
1	0.93	0.03	0.93	0.03
2	0.72	0.06	0.95	0.03
3	0.95	0.03	0.93	0.03
4	0.92	0.03	0.93	0.03
5	0.89	0.04	0.9	0.04
6	0.72	0.06	0.82	0.05
7	0.92	0.03	0.96	0.03
8	0.88	0.04	0.91	0.04
9	0.94	0.03	0.91	0.04
10	0.91	0.04	0.95	0.03
11	0.62	0.06	0.78	0.05
12	0.82	0.05	0.88	0.04
13	0.97	0.02	0.95	0.03
14	0.62	0.06	0.95	0.03
15	0.78	0.05	0.91	0.04
16[a]	0.37	0.06	0.71	0.06

Note. The table corresponds to Tables A1 and A2; [a] Items excluded from analysis.