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What cues do children use to infer the meaning of unknown words while reading? Empirical data from German-speaking third graders

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Abstract: During the development of reading skills in primary school, children begin to make guesses about unfamiliar words when reading a text. This process of lexical inference is an important source of new vocabulary acquisition. In the present study, 55 children with a wide range of reading skills and vocabulary knowledge were asked to infer the meaning of unknown words (i.e., pseudowords) inserted into a short story and to provide insight into their inferencing processes. The results show that children use a variety of cues. While learners with higher reading skills and vocabulary knowledge tend to be more successful inferencers and rely more on contextual cues, the evidence for the use of phonological cues is limited. Furthermore, in 20 percent of the cases, children were able to recall the meaning of a pseudoword already mentioned in the text.



Keywords: lexical inferencing; inferencing strategies; reading acquisition; vocabulary acquisition

1 Introduction

Written texts include a higher variety of words than oral language and contribute substantially to vocabulary growth during primary school (Nagy et al. 1985; Nagy and Scott 2000). When children acquire literacy skills, deriving the meaning of an

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unfamiliar word from its context is – among incidental learning¹ and explicit instruction – the most important source to extend their vocabulary (Cain 2007). This deriving process is also called “lexical inference”, a term coined by Second Language Acquisition (SLA) research (Haastrup 1991), where inferencing is an important topic (Wesche and Paribakht 2009).

However, lexical inference is particularly interesting for reading research as vocabulary and reading comprehension are associated through a reciprocal influence (e.g., Ouellette 2006). Children with a solid and large vocabulary have better phonological and orthographic word representations in their mental lexicon (Perfetti and Stafura 2014) and therefore have higher reading comprehension skills. Good readers read more, which in turn leads again to vocabulary growth by lexical inference (Matthew effect, Cain and Oakhill 2011) and refinement of their existing lexical entries (Nagy and Scott 2000). Moreover, good comprehenders make better use of context to infer the meaning of unknown words than poor comprehenders (Cain et al. 2004).

The process of lexical inferencing has been described by Bolger et al. (2008) as incremental, instance-based learning about word meaning from various contexts, which is modulated by several internal factors (vocabulary knowledge, reading skills etc.) and external factors (text factors; see below for more details).

In the present study, we focused on the role of these factors in children’s inferencing, addressing the following questions: What cues do children use in first language contexts and how often do they show up? How does lexical inferencing relate to learner factors such as vocabulary breadth, reading skills, and task factors such as repetition of the unknown word? These issues were addressed by means of age-appropriate texts in which well-known concepts were replaced with pseudo-words. Furthermore, incremental learning was investigated by reoccurrence of some of the pseudowords.

2 Lexical inference and its prerequisites

Lexical inferencing while reading is a field which has been studied extensively (for a meta-analysis see Swanborn and de Glopper 1999). Before discussing lexical inferencing, we first look briefly at the interaction between vocabulary and reading.

¹ Deriving word meaning and incidental learning from context differ in that the former explicitly aims at extracting the word meaning, which is not the case with the latter (e.g., Swanborn and de Glopper 2002).

2.1 Vocabulary and reading

While decoding, i.e., matching graphemes to the corresponding phonemes, is of course the basis of reading (e.g., Castles et al. 2009), vocabulary in form of word knowledge is the foundation of reading comprehension. In languages with a transparent orthography such as German, decoding is mastered after about one year of reading instruction by most children (Landerl and Wimmer 2008). After that, the influence of decoding on reading comprehension decreases when vocabulary is considered (e.g., Hjetland et al. 2019). In their “Reading Systems Framework” Perfetti and Stafura (2014) substantiate that understanding and integrating words into a mental text model is the core process of text comprehension. The mental lexicon – assuming that all the words in a text are known – performs two functions simultaneously. It serves the formal word identification and, based on the former, the retrieval of the word meaning and is thus the “bottleneck” of reading comprehension (Perfetti et al. 2005). Vocabulary is tightly linked to the retrieval of word meaning from the mental lexicon and is the best longitudinal indicator of reading comprehension (Quinn et al. 2015).

While these processes can be considered as lower-level reading processes, a set of higher-level factors determines text integration. Among them is inference building to provide text cohesion, which develops rapidly alongside reading acquisition. Interestingly, text-connecting inferences are highly related to reading comprehension, even when decoding, working memory, and general knowledge is controlled (Perfetti et al. 2005).

2.2 Lexical inferencing

Lexical inferencing, in form of inferring the meaning of an unknown word from different cues, is a special case of the more general inferencing procedure that works at different stages of text comprehension, including the newly established connections, leading to the interpretation of what is read (Wesche and Paribakht 2009).

Strategies employed by 30 children from Grade 2 to 6 to infer the meaning of an unknown word have been analysed by Fukkink (2005), who found four types of sequences. The child forms an initial hypothesis, which is either directly accepted, accepted after a check, or replaced by one or several other hypotheses, which are again checked and rejected or accepted. The author concluded that the sequence in which the first hypothesis is directly accepted generated most correct answers in all grades.

In terms of task factors, Nagy et al. (1987) investigated how fifth and seventh graders ($N = 352$) incidentally learn the meaning of real words of different length, part of speech, number of incidences, and of varying morphological and conceptual difficulty (familiarity of concept, ease of derivation, available synonyms or paraphrases) in narrative and expository texts of varying difficulty. At the word level, only conceptual difficulty played a significant role in whether the participants were able to retain the

word's meaning in the subsequent week. At a text level, in addition to the effect of average word length, the proportion of conceptually difficult words affected word learning. Word properties such as morphemes have also been investigated by McCutchen and Logan (2011), who showed that both fifth ($N = 88$) and eighth ($N = 74$) graders made use of familiar morphemes to infer the meaning of unknown words. In a study by Raudszus et al. (2021) fifth graders with L1 Dutch ($N = 59$) were asked to select one of four meanings for pseudowords (nouns, verbs, adjectives). Of each pseudoword item, there was a variant containing no morphological information, whereas the other variant contained an existing Dutch morpheme. Based on these results, the authors concluded that decoding plays an important role in accessing morphological information, whereas linguistic competence is crucial for contextual inferencing.

Therefore, the success of the demanding inference procedure is highly dependent on context cues. According to Fukkink (2005), these cues can be broadly divided in two groups, external and internal cues. External cues subsume the information that can be extracted from the context. They occur in form of precisions with respect to the target word (e.g., when one goes to bed, it is usually night-time) and as paraphrases or phrasemes ("they felt fatigued" or "leadenly it lowered itself on him", i.e., the tiredness), or in form of world knowledge ("being in a bad mood" when someone has played a trick on you). External cues can be contained in the immediate context such as in the sentence or in the wider context of a large text. Internal cues are the information that are extracted directly from the target word, such as morphological cues (in German, the verbal suffix "-en" indicates third person plural or an infinitive), and phonological cues (the target word has phonological similarity to a common word). Clear, easy to find external cues in the immediate context facilitate inference while more distant cues are unfavourable particularly for weak comprehenders (Cain et al. 2004). Advanced readers on the other hand have achieved automaticity in lower-level reading skills and cognitive capacities are available for the derivation of word meaning (Schwanenfluegel et al. 2006). Moreover, if internal cues, i.e., cues that are inherent to the word such as the word's form, sound pattern and the concreteness can be used, the inferencing is easier (Fukkink 2005).

Phonological cues are preferred by younger children, while older children are better able to cope with morphological and syntactic cues or external cues (e.g., Cremer et al. 2010). Age, intelligence, breadth and depth of vocabulary and reading skills do thus influence the inference success and can be summarised under "learner factors" (Haastrup 1991). Van Daalen-Kapteijns et al. (2001), for instance, found in a small-scale study that 11- to 12-year-old students with low vocabulary scores were able to infer an approximate notion of a word's meaning, but only high performers were able to refine it to a dictionary-like definition. In a multiple-choice paradigm with six possible solutions for pseudowords presented in several contexts, McKeown (1985) discovered that among fifth graders ($N = 30$) those with poor vocabulary showed more misunderstandings about the relationship between a word and its context and were less flexible in rejecting an incorrect hypothesis.

These studies vary considerably in terms of number, age, and type of participants, methodology, and contexts. They all show that primary graders use different strategies and cues to infer the meaning of unknown words while reading and indicate that the success of their use in lexical inferencing is influenced by learner factors such as age, vocabulary knowledge, and reading skills as well as task factors such as the integration of familiar morphemes, parts of speech, and text difficulty in terms of density of conceptual difficult words. However, studies that systematically examine the use of different cue types in relation to learner factors and task types are currently needed. In particular, the inclusion of decoding and reading comprehension in the learner factors and a sample composition of children with average vocabulary and reading skills may shed light on the relation between lower-level reading processes and inference ability.

2.3 Research questions

The aim of the present study was to gain insights in the procedure of lexical inferencing in German-speaking children by presenting them with a text in which words with familiar concepts were replaced by pseudowords. By doing so, we addressed the following research questions:

1. *Use of cues*: Which cues are used – in terms of frequency of use – to infer the meaning of an unknown word by German native speaking children at the onset of fluent reading? This is an open-ended question to be answered by descriptive means.
2. *The influence of learner factors*:
 - a. Do the children's reading skills, their vocabulary breadth, and their cognitive abilities affect their choice of inferential cues and their success in inferencing? Based on the literature, we hypothesise that the choice of inferencing cues is related to those factors. The higher the learner's skills, the more likely they are to go beyond phonological cues and use, for example, sentence context to infer word meanings (see e.g., Cremer et al. 2010).
 - b. Do the above-mentioned skills have an impact on inference success? We expect a strong association, as these skills provide relief in the reading process by freeing resources for inferencing.
3. *The influence of task factors*: Do pseudoword properties such as the word type noun and the phonological similarity to a familiar word as well as the repeated incidence of a pseudoword facilitate the inferencing process? Again, we presume that these factors positively influence the inferencing success, because they facilitate memorisation or integration of the pseudoword into the immediate or

general co-text. On the other hand, phonological similarity to a known word not fitting into the sentence should negatively impact the inferencing success as it can lead to wrong conclusions.

3 Methods

3.1 Participants and tests

3.1.1 Participants

The children participating in the current study were a subsample of the long-term study *Die Entwicklung von Wortschatz und Lesen. Eine Untersuchung auf der Unterstufe*, where vocabulary and reading development of primary school children in German-speaking Switzerland were investigated (project duration September 2017 – February 2022). In the long-term study, children's reading and vocabulary skills were assessed with standardised tests in their first year ($N = 343$), second year ($N = 412$) and third year ($N = 392$)² of primary school. All children attended primary school in medium-sized Swiss cities or in rural areas and had no diagnosed language development impairments.

The subsample ($N = 55$; 28 girls and 27 boys; mean age = 9 years, 7 months, $SD = 4.9$ months, range = 24.4 months) focused on in this paper consists of children in their third grade where basal reading skills are developed enough to focus on reading comprehension (Biemiller 2012). The children were Swiss German dialect or Standard German native speakers. When selecting the children of the subsample, one aim was to achieve a balanced urban-rural composition. A binomial test indicated that the proportion of children from urban areas of 0.45 did not diverge from those of rural background, 0.55, $p = 0.590$. The proportion of girls in the subsample ($N = 28$) did not differ from the main sample, $\chi^2(1, N = 335) = 0.63$, $p = 0.659$. Neither did the children of the subsample differ from those of the main sample in terms of their performance in word reading, $\chi^2(49, N = 335) = 47.46$, $p = 0.536$, in sentence reading, $\chi^2(31, N = 335) = 20.21$, $p = 0.931$, or in text reading, $\chi^2(25, N = 335) = 23.26$, $p = 0.562$. Similarly, no difference was found in vocabulary breadth, $\chi^2(83, N = 335) = 59.02$, $p = 0.979$, nor in non-verbal intelligence, $\chi^2(14, N = 335) = 20.80$, $p = 0.107$.

² Numbers differ given the addition of three classes in the second year and the addition of Second Language learners in the second year (Röthlisberger et al. 2021).

3.1.2 Tests

Vocabulary breadth was assessed with the German version of the Peabody Picture Vocabulary Test PPVT-4 (Lenhard et al. 2015). In this test, the child hears a word to which it is asked to assign one of four pictures. The test was halved (only the odd items) due to time constraints.

Reading comprehension was tested with the standardised German reading test ELFE II (Lenhard et al. 2018) measuring word, sentence, and text comprehension. In the three subtests, the pupils read as many units as possible in the given time. By matching pictures to a word, by inserting a missing word into a sentence or by answering questions about the text, the test shows whether they have understood what they have read.

Non-verbal intelligence was tested via a subtest of the CFT 20-R (Weiß 2006) with subtest 6, Matrices. The students' task here is to find the correct continuation to figural specifications within the given time. For more details on the tests see Röthlisberger et al. (2021).

Moreover, for the sub-sample of the present study, the reading speed (number of words per minute) was calculated as a further reading score (see Section 3.3).

3.2 Materials

3.2.1 Text

A short reading text reflecting the world of children was composed and was linguistically adapted to the children's level. The text was divided into five sections of similar length. The difficulty of the text and its sections was controlled with the German readability index "LIX" (Lenhard and Lenhard 2014-2022). The overall index was 34.91 (very low difficulty). The difficulty of the five parts was matched, $\chi^2(16, N = 5) = 20, p = 0.220$ (see Appendix 1). To ensure that words were unknown to all children, pseudowords were used to substitute real words in the text.³ The text tells the story of twins going on holidays with their parents in a camper van. One day, they find a kitten near a farm and play with it. Because they have to go back to their camper, they are sad to leave it behind. Under a false pretext, the mother turns back, asks permission to keep the kitten and finally surprises the twins with it.

3 Note that ascribing a new word form to a known concept is not problematic considering e.g., the mutual exclusivity constraint (e.g., Clark 2009) when not only constraints, but also social actions are considered crucial for vocabulary learning (Hirsh-Pasek et al. 2000).

3.2.2 Pseudowords

Pseudowords of different part of speech were created via WordGen (Duyck et al. 2004) and contained different cues: they resembled target words phonologically and/or were morphologically derivable (compounds or derivations) and/or their meaning was semantically inferable from the immediate (e.g., in collocations) and/or wider context. Three pseudowords were phonologically similar to real words to identify children rejecting a phonological interpretation when the word does not fit semantically and children focussing only on the word form. Seven of the ten pseudowords showed multiple occurrences (see Appendix 2 for details). They were inserted in different contexts (see Appendix 1).

3.2.3 Pre-tests

The familiarity of the concepts of the substituted real words was assessed in several pre-tests, which showed that these concepts were indeed familiar to native German-speaking third graders. The text with pseudowords and the procedure were piloted in the context of two Master's theses with 20 (Gsteiger 2018) and 15 third graders (Carapovic 2020). Based on their findings, text and method were considered age appropriate.

3.3 Test procedure

The children were instructed to read aloud a section of the text, summarise it, and finally answer questions in a semi-structured interview allowing for the methodology of retrospective verbal reports (Smith et al. 2020). Although this procedure of retrospective verbal reporting has limitations in terms of the accuracy with which children of this age can describe cognitive processes, it was deemed a valid instrument for this study given that primary graders have been shown to be capable of verbalising their thoughts while reading (Smith et al. 2020). First, children were asked to tell whether they knew all words in the section or whether there was a word which they did not understand. If they pointed out the pseudoword, they were asked whether they could describe its meaning using another word and explain their reasoning. No definitions or paraphrases were requested to limit the bias of verbalising skills. If they did not point out the pseudoword on their own, the interviewer asked whether they could tell what the word meant and how they inferred its meaning. Due to restricted school access following COVID-19 related school closures in spring 2020, this part of the project was conducted online using MS Teams with all children from May 2020 onwards. The children did not show any irritations with this

communicative setting. The text sections were presented with an open-source HTML presentation framework (reveal.js, version 3.9.2; El Hattab 2017).

3.4 Coding procedure

All interviews were audio-recorded (average length 30 min) and transcribed. The transcriptions were coded via MAXQDA 2020 (VERBI Software 2019) by two coders independently, but with frequent discussions, exchanges, and adaptations. The coding procedure itself was inductive, leading to several rounds of coding, team discussions, and recoding. In the end, each coder analysed the transcriptions of each child at least twice with all codes. The main coding categories and the dependent variables which are the focus of this paper are the *type of cues* children used and the *meaning* they ascribed to the pseudowords. Type of cues were categorised based on children's responses. Phonological cues, for instance, were identified when a child explained that the word sounded similar to a known word, and they would therefore translate the pseudoword with a similar sounding word (see Examples 1–5 for children answers and type of cues identified).

3.5 Scoring

To operationalise the variable of inferencing success, an inferencing score was calculated as follows: Correct inferences whose meaning fit the sentence at the first attempt on a semantic and syntactic level were awarded one point. If the first hypothesis was rejected and a correct conclusion was drawn on a second attempt, half of a point was awarded, and a correct inference on the third attempt was awarded one third of a point. If the answer was semantically correct but did not fit syntactically (e.g., the verb “zrügghah” ‘to return’ for the noun “Rückfiet” in “On the **rückfiet** [fiet back], Lars and Lena are sad [...]”) or if the answer did fit syntactically, but resulted in an awkward meaning (e.g., the adjective “plötzlich” ‘suddenly’ for “kute” in “**Kute**, Lars and Lena fall into bed.”), also half of a point was given.

3.6 Data analysis

Since the data consist basically of counts (“How many cues of kind x have been used?”), a linear regression model is not indicated. Poisson and negative binomial regression models are designed for count data. The former assumes that the conditional variances (the variances within the single predictor variables) and the

theoretical means coincide. Otherwise, under- or overdispersion prevails. Here, a negative binomial model was chosen due to the deviating distribution of the variances compared to the means of the present data, which do not justify the application of a Poisson model (Hilbe 2011; see Appendix 3 for the deviances). Negative binomial regression models (UCLA: Statistical Consulting Group 2021) were thus run with the package MASS (version 7.3–54; Ripley et al. 2021) using the `glm.nb` function for R version 3.6.3 (R Core Team 2020). Multiple comparison corrections were applied through Holm correction, the recommended default procedure for assumption free adjustment of *p*-values (Levin 1996).

4 Results

4.1 Cues used

A variety of cues the children used to infer the meaning of an unknown word was discerned. The frequency of the use of these cues is summarised in Figure 1. The figure shows that the most frequently used cues are sentence cues, chosen in two thirds of all cases (816 times). Answers such as “because it fits into the sentence” when asked how the children came up with the meaning were classified in this category. This answer can refer to either the use of syntactic cues such as the main verb, which was replaced by a pseudoword (they “osden” a meow) or semantic cues

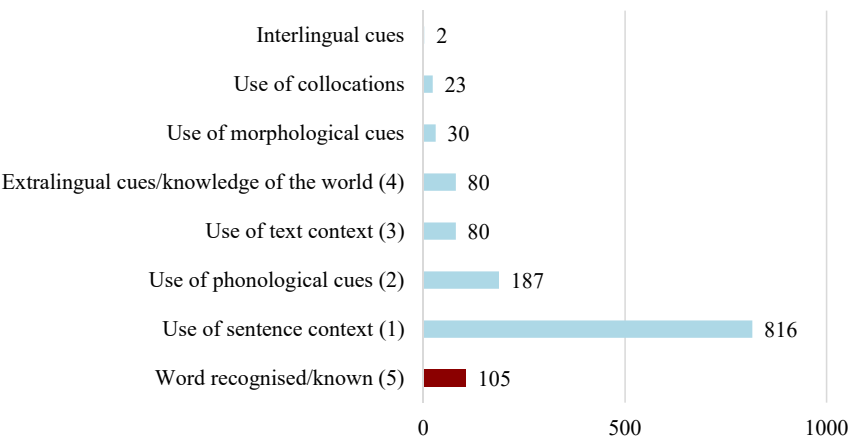


Figure 1: Type and number of inferencing cues used.

such as a pseudoword at the beginning of the sentence (“kute” they fall into bed). The use of phonological cues, such as “perk” (with a phonological resemblance to the German or English word “Park”) is the second most used type of cue (15 % of the cases, i.e., 187 times, with a large gap to the use of sentence context). The use of text context and extralingual cues were both coded in 7 % of the cases (80 times). While text context cues refer to a well-known sentence context, such as “whishing a good halen” (“night”), extralingual cues are based on children’s world knowledge. Morphological cues, e.g., composites were only considered in 2.5 % of the cases (30 times), and finally, collocational cues (“good halen”, i.e., “good night”) were used in 2 % of the cases (23 times). Due to the age of the children only two answers (0.2 %) show the use of interlingual cues. For more details about the cue types see below.

This summary indicates the variety of cues the children used involving intra-lingual (use of collocations, word context/morphological cues, text context, phonological cues, sentence context), extralingual (knowledge of the world) and interlingual cues. In 105 cases, children explained that they remembered the word from before, which was not considered as a cue.

To explain the use of the four most common cues, some examples⁴ are presented below.

The most frequent category of inferencing cues was *sentence context* (816 cases). Example (1) shows how the child responds to the question about the meaning of the pseudoword “osden” by referring to the sentence context (i.e., “While picknicking, the children **osden** a meow coming from a bush.”).

- (1) Noe: *hört.*
 hears.
 Interviewer: *mhm und wie chunnsch uf das?*
 mhm and how do you come up with that?
 Noe: *wüu ja nără, wüu năhăne schteit es miaue aso muess e- aso*
 muess ja irgendwo no hore stah wüus ja năr ghört.
 because yes then, because then is written a meowing so there
 has to there has to be written hear somewhere because they
 hear it.

The second most frequent category were *phonological (or orthographic cues)*⁵ (187 times). These were used mainly in the first paragraph with the pseudoword “osden” which resembles the German word “Osten” (‘east’) as shown in Example (2), which refers to the same sentence as Example (1).

⁴ The children’s names have been replaced.

⁵ Orthographic and phonological cues were coded by the same code, given that they were not possible to tease apart in explanations such as “because X is similar to Y”.

- (2) Andrina: *aso i weiss ni gnau bim picknicke oste aso “picknicken osden” ehm weiss i nid gnau öb ds, ehm sozsege das si z oste hei picknicket, aso richtig oste.*
 so I don't know exactly while picnicking east so “picnicking osden” uhm don't know exactly if it, so to speak that they picnicked in the east, so in the direction of the east.

In 80 answers, the *text context* the pseudoword was embedded in, was coded. In Example (3) the child translates the word “halen” to “night” by referring to the fact that they went to bed early, which was written several sentences above the sentence she currently focuses on (i.e., “Mum smiles at them and wishes them all a good **halen**.”).

- (3) Emma: *villech nacht.*
 maybe night.
 Interviewer: *ja, wie chunnsch uf nacht?*
 yeah, how do you come up with night?
 Emma: *wüu si villech ähm ja iz früech is bett gsi, gange sind und ehm nochher “und wünscht allen eine gute halen” und sie sind ja früech is bett gange.*
 because maybe they now went to bed early and uhm then “and wishes them a good night” and they went to bed early.

The use of *extralingual cues* referring to *world knowledge* was also coded in 80 cases. Example (4) shows how the child refers to extralingual knowledge when inferring the meaning of “perk” (i.e., “Lena looks out of the window and tries to guess in which direction they are *fieten*. To Grandma's? To the mountains or to the **Perk**?”) by stating that families usually go to the sea on holidays.

- (4) Marina: *meer.*
 sea.
 Interviewer: *meer ja, super, wie chunnsch uf das?*
 sea yeah, great, how did you come up with this?
 Marina: *wöu viu familie göh haut aube ads meer*
 because many families go to the sea sometimes.

The association of the pseudo-word “fieten” with the English expression “to be fit” (to go fast, or drive fast in this case), was for instance rated as an *interlingual cue*.

The last coded category in Figure 1 differs from the previous ones as it does not represent the use of a specific cue, but how often children *recognised* pseudowords already mentioned in the text. In 105 cases, i.e., in about 20 percent of the

occurrences, children were able to recall the meaning of a repeated pseudoword (Example 5).

- (5) Louise: *hm osdet (...) hört, ds heisst hört. ig weisses no voge, wege vori.*
 hum osdet (...) hears, this means hears. I know it from befo-before.

4.2 Learner factors

4.2.1 Overall data

Since, with the exception of the sentence context and the phonological cues, all other cues showed a low frequency, only the former two were analysed separately. The others were accounted for in the inference score.

The relationship of the independent variables to three dependent variables “use of sentence context cues”, “use of phonological cues” and “score” was determined with negative binomial regressions for each pair of dependent versus independent variables. The multicollinearity of the data caused by the highly correlated reading variables was taken into account by presenting models with only a single predictor each. Table 1 contains an overview of all models (see Appendix 3 for the descriptive statistics).

4.2.2 Sentence context and phonological cues

The independent variables showed generally weak relations with the use of sentence context cues and phonological cues. Among the insignificant regression coefficients, however, there are notable differences. Reading speed and ELFE sentence and text reading have higher regression coefficients with sentence context compared to ELFE word reading and vocabulary breadth. The relationship between the use of phonological cues and the independent variables is overall slightly negative but does not allow any conclusion to be drawn about poorer reading fluency and comprehension or lower vocabulary breadth in children who often use phonological cues.

With increased reading skills, children thus tend to use less phonological cues. Note that fewer use of sentence cues does not automatically imply a more frequent use of phonological cues as either other cues or a combination of cues is used.

4.2.3 Scores

With regard to the inferencing scores in Table 1, text reading and vocabulary breadth showed to be highly predictive, reading speed and sentence reading slightly

Table 1: Coefficients of the single binomial regression models.

Model	Intercept	Estimate	p-Value	Corrected p-Value	SE	95 % CI
Use of sentence context ~ reading speed	2.400	0.004	0.045*	0.215	0.156	[2.09–2.71]
Use of sentence context ~ ELFE word reading	2.394	0.007	0.145	0.290	0.214	[1.97–2.82]
Use of sentence context ~ ELFE sentence reading	2.422	0.014	0.065	0.215	0.157	[2.11–2.73]
Use of sentence context ~ ELFE text reading	2.444	0.019	0.043*	0.215	0.134	[2.18–2.71]
Use of sentence context ~ PPVT (vocabulary breadth)	2.353	0.002	0.350	0.350	0.371	[1.62–3.08]
Use of phonological cues ~ reading speed	1.241	–0.005	0.237	0.711	0.330	[0.59–1.88]
Use of phonological cues ~ ELFE word reading	1.176	–0.007	0.491	0.711	0.457	[0.29–2.05]
Use of phonological cues ~ ELFE sentence reading	1.406	–0.029	0.082	0.410	0.321	[0.77–2.03]
Use of phonological cues ~ ELFE text reading	1.300	–0.034	0.092	0.410	0.272	[0.75–1.83]
Use of phonological cues ~ PPVT (vocabulary breadth)	1.784	–0.006	0.254	0.711	0.807	[0.19–3.39]
Score ~ reading speed	1.887	0.005	0.007**	0.028*	0.148	[1.59–2.17]
Score ~ ELFE word reading	1.848	0.009	0.035*	0.070	0.204	[1.44–2.24]
Score ~ ELFE sentence reading	1.915	0.018	0.013*	0.039*	0.149	[1.62–2.20]
Score ~ ELFE text reading	1.866	0.030	<0.001***	0.006**	0.130	[1.61–2.12]
Score ~ PPVT (vocabulary breadth)	1.070	0.007	<0.001***	0.006**	0.336	[0.41–1.73]
Score ~ CFT (nonverbal intelligence)	2.010	0.028	0.097	0.097	0.161	[1.69–2.32]

Score refers to the inference scores: 1 = correct inference on the first attempt, 0.5 = correct inference on the second attempt, 0.3 = correct inference on the third attempt. Multiple comparison corrections method: Holm. The CIs refer to non-adjusted comparisons. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

predictive, while the non-verbal intelligence was not related to the inferencing scores. The inference scores were related to all reading comprehension variables, with text reading again showing the strongest relation. To visualise the relations between the inferencing score and its potential predictors, it was plotted as the dependent variable on the y-axis in the plots in Figure 2 with reading speed, CFT, PPVT-4, ELFE word reading, ELFE sentence reading and ELFE text reading as the independent variable on the x-axis.

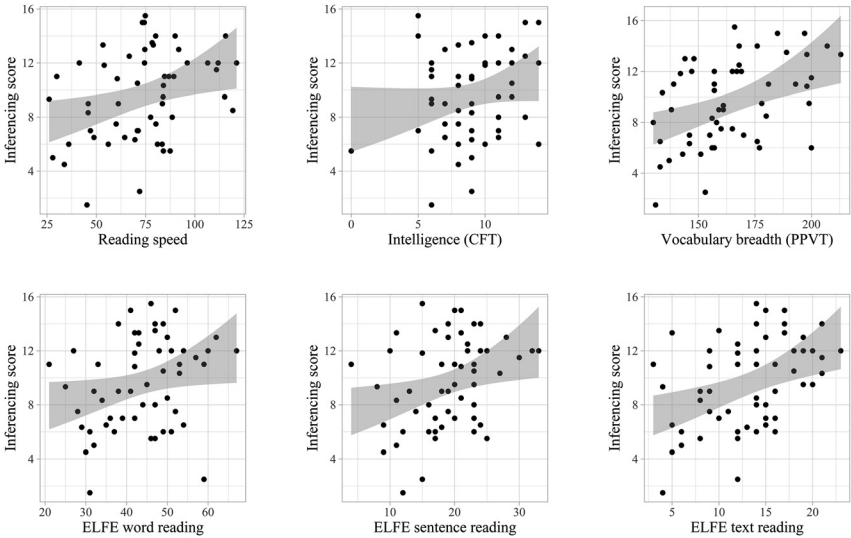


Figure 2: Negative binomial regression plots showing the distribution of the inferencing score across the independent variables. The grey area denotes ± 1 SE.

4.3 Task factors

As for the task factors, we were interested in the pseudoword properties, i.e., whether and how the part of speech, the phonological similarity to the intended meaning or to a word not fitting into the sentence had an influence on the inferencing score. Moreover, the influence of the repetition of the pseudoword stem on the inferencing score was assessed. For the last variable, the words were dichotomously divided into repetition “yes” versus “no”. This dichotomous evaluation was also applied to the variable phonological similarity with the target word or another word. Cases where at least the first and last phonemes or the first and the second phonemes matched were considered phonologically similar.

When analysing the boxplots in Figure 3, the long whiskers in all plots show high variability of inferencing scores within the sample. The absolute numbers across the categories for the boxplots can be consulted in Appendix 2.

Non-parametric Kruskal-Wallis tests were conducted with the inferencing score as dependent variable (see Table 2) where an effect of the pseudoword’s repetition was found, while the speech part, the phonological similarity to the intended meaning, and the phonological similarity to another word did not yield any effects.

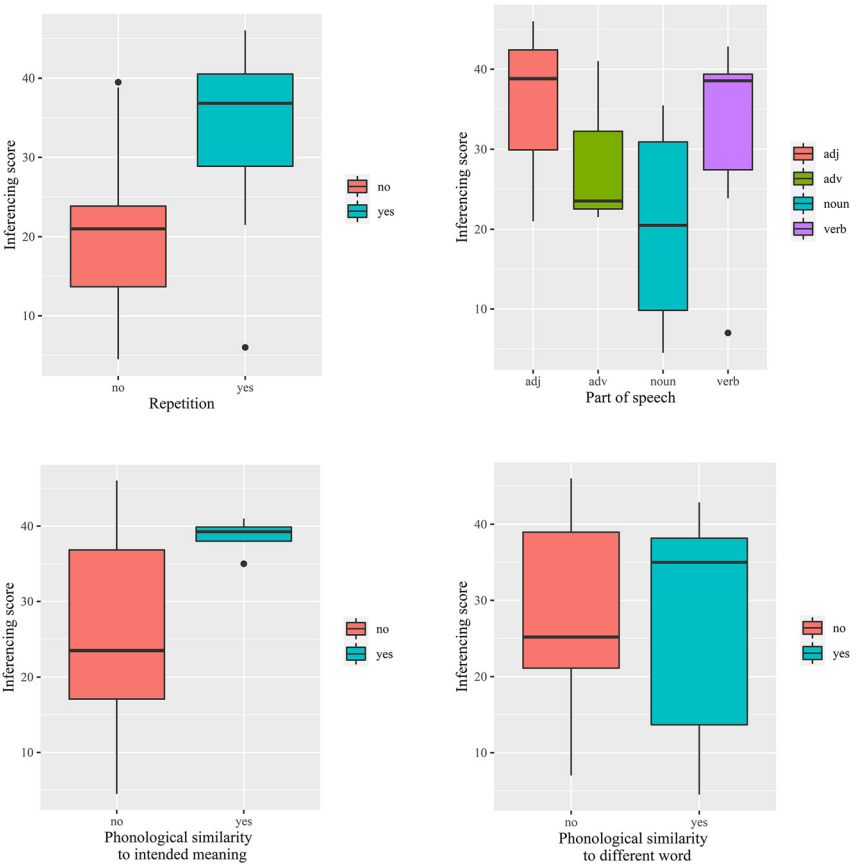


Figure 3: Boxplots for the inferencing scores across the variables of repetition, part of speech, phonological similarity to a word different from the intended meaning, and phonological similarity to the intended meaning.

Table 2: Kruskal-Wallis tests for pseudoword properties.

Kruskal-Wallis test	Chi square	df	p-Value
Repetition of pseudoword	3.84	1	0.050*
Part of speech	4.746	3	0.191
Phonological similarity to intended meaning	3.61	1	0.057
Phonological similarity to another real word	0.06	1	0.806

Kruskal-Wallis tests were conducted with the inference score as a dependent variable. * $p < 0.05$.

5 Discussion

In the present study, nine- to ten-year-old German-speaking children with average language abilities were presented with an age-appropriate story, in which key words with familiar concepts had been replaced by pseudowords with various features such as phonological similarity to the original or another real word, different part-of-speech, or number of incidences. The aim was to shed light on the cue types used by the children by controlling the influence of learner factors such as reading and vocabulary skills and to explore the impact of cue type use, the number of incidences, and learner factors on inference success.

The first research question was thus which cue types were used by the children to infer the meaning of an unknown word in a short reading text. Seven types of cues were identified, of which two, the sentence context and phonological cues, were used in more than 80 % of all cases. The use of sentence cues, by far the most frequently used cue type, has been observed in previous studies, although identifying the cue types was not explicitly investigated there. McKeown (1985) found that selection of a meaning's constraint from the context was the first step in inference. In the study of Fukkink (2005), the sequence “infer – check with context” was more frequent than sequences with several inferences before checking the context, substantiating the context as a central cue. In Nagy et al. (1987), the density of difficult words in the context had the greatest impact on successful inferring, a clear indicator that this context was used predominately.

The use of phonological similarity as an inference cue is mostly documented in SLA studies such as Namei (2004). However, McKeown (1985) reported this approach in her low-ability group as well. The relatively frequent use of phonological cues in the present study is most likely due to the relatively young age of the sample.

With regard to the less frequently used cues, the morphological cues are also documented (Bangel 2018; McCutchen and Logan 2011; Raudszus et al. 2021). The use of interlingual cues has to date only been observed in SLA research (Wesche and Paribakht 2009). Concerning the use of collocations in children for inferring word meanings, there is – as far as we know – no literature available, which opens an interesting field of research.

In the second research question we addressed whether the learner factors reading fluency and comprehension, vocabulary breadth, and intelligence affected the choice of cues (2a), as well as the inferencing success (2b). On the one hand, our results show an increased use of sentence context cues with higher scores in reading fluency and text reading (2a). These findings reflect results from previous studies. While in older children, vocabulary (McKeown 1985) and reading skills (Cain et al. 2004) rely more on contextual cues, children with lower reading skills do not

have enough cognitive capacities available to focus on the context (Schwanenfluegel et al. 2006).

On the other hand, all regression coefficients for vocabulary and reading indicate a – non-significant – but clearly negative relationship with the use of phonological cues, in line with findings by Cremer et al. (2010) and Namei (2004), according to which younger children with less vocabulary and reading knowledge tend to use more phonological cues.

As a caveat, however, it must be noted that the corrected p-values of the individual regressions on the use of sentence context and phonological cues are not significant, which is not the case with the subsequent regression coefficients on the inference score.

The role that vocabulary and reading have in inference success is very intriguing. Successful inferencing has shown to depend highly on vocabulary breadth, reading speed, and comprehension. Children with better reading skills may use the selected cues more efficiently due to faster reading and quicker grasping of the text sense (Biemiller 2012; Perfetti et al. 2005) and the higher availability of cognitive resources (Schwanenfluegel et al. 2006). Those with a larger vocabulary may activate and check rapidly lexical representations and be able to activate more candidates, reject them, retrieve a better candidate and check again (Fukkink 2005). Moreover, their lexical representations are more sophisticated, allowing them to refine the criteria for the candidate meanings (Van Dalen-Kapteijns et al. 2001).

Finally, the non-verbal intelligence did not significantly influence inferencing success, a result which was not expected, and which was probably induced by the choice of test. Due to time constraints, only the subtest which had the highest correlation to the total CFT score was chosen (Weiß 2006).

However, the results also show a great interindividual variation of the different scores (cf. Van Daalen-Kapteijns et al. 2001). There are a few children showing a high score in terms of successful inferencing, but only average scores in the above-mentioned vocabulary and reading tests. This suggests that although vocabulary skills and reading skills do help to infer the meaning of an unknown word, children also need to know how to cope with and apply different cues. Thus, even though children may have less reading skills as their peers, the knowledge of how to use inferencing cues may still help them successfully infer the meaning of an unknown word.

Lastly, we addressed the third research question whether a repeated occurrence of the pseudoword, or its features (such as part-of-speech, phonological similarity to the original word or to another existing word) played a role in terms of inferencing success.

The results show that children remembered the previously assigned meaning in about 20 % of repeated pseudoword occurrences in the text. This is in line with our

prediction and presents an interesting finding with respect to vocabulary learning through inferencing. L1-studies have shown considerable variation in terms of the number of encounters that a reader needs in order to learn a new word. While the present study does not aim to dive into the complexity of the question of incidental language learning (for a meta-analysis on the effects of repetition see Uchihara et al. 2019), the findings of the current study show, however, that many children are able to remember the meaning of an unknown word (for a known concept) from a previous section when the pseudoword is repeated only once. Whether these children would also be able to do so in a natural reading context, i.e., without questions from an interviewer pointing towards the pseudoword, and how long the words remain in memory are interesting questions for further studies.

Furthermore, the analysis on the pseudoword properties has shown that the phonological similarity to the intended meaning or to another existing word did not seem to be decisive for inferencing success.

In terms of part-of-speech, previous research by Liu and Nation (1985) for instance, has shown an impact of this variable. Although participants in their study were adults, the findings are interesting in that they show that verbs and nouns were more easily inferred correctly than adjectives and adverbs. In our sample, however, part of speech did not have an influence on inferencing success.

Phonological similarity to the intended meaning was only applicable for three pseudowords. The use of phonological cues was mostly leading to solutions that did not fit into the sentence on semantic and syntactic levels.

However, some limitations of the study need to be acknowledged. Given the low number of pseudowords due to the limited size of the reading text (required because of the age of the sample), pseudowords were not equally distributed across the different categories. Further research on the influence of pseudoword's features should be conducted.

A further limitation concerns the ability of children of this age to verbalise thinking steps in the inference process. When children explained how they came up with the meaning for the pseudoword, a frequent answer was “because it fits”, without being able to elaborate. This often led to questions in coding of the cue used. While in most cases, the answer was related to the use of sentence cues, there were individual cases where coding decisions were difficult. To prevent a strong influence of interpretation on these coding decisions, these cases were discussed thoroughly in the team. However, these difficulties also reveal a shortcoming of the semi-structured interview method: children with low oral language skills were more difficult to assess appropriately because they were not able to adequately describe their use of inference cues. The development of age-appropriate strategies for dealing with unfamiliar words necessary for comprehension would be supportive/helpful.

6 Conclusions

The skill of lexical inferencing is – from early (oral) language acquisition – an important prerequisite to increase the breadth and depth of vocabulary. Vocabulary supports all receptive and productive linguistic skills, including reading comprehension. Pupils who can use a variety of cues to map a reasonable meaning to an unknown word while reading have a greater probability of comprehending a text and thus of acquiring academic content.

We have shown that pupils with better reading skills and better vocabulary tend to be better at inferencing. This can be seen as example of the so-called Matthew effect, i.e., the principle that advantages lead to further advantages and disadvantages to further disadvantages: Those children who already have a head start succeed in using more sophisticated types of clues in decoding meaning and further extend their head start.

To sum up, our results show that the use of inferencing cues is refined with higher reading ability and vocabulary breadth. Overall, the research on cue types in children's inferring seems to be a promising field which should be investigated further to better understand children's inferencing processes and their importance for vocabulary development and reading comprehension and to establish materials for support.

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Appendix 1: Reading text⁶

Section 1

Die Zwillinge Lars und Lena sind schon ganz aufgeregt, denn heute fahren sie in die Ferien. Wohin genau wollen Mama und Papa aber noch nicht verraten. Plötzlich **osden** sie vor dem Haus ein lautes Hupen. Lars und Lena rennen zum Fenster. Vor dem Haus sehen sie Papa, der vor einem grossen Wohnmobil steht und ihnen fröhlich zuwinkt.

*The twins Lars and Lena are very excited because they are going on vacation today. But Mum and Dad don't want to tell them yet where they are going. Suddenly they **osden** a loud honking outside the house. Lars and Lena run to the window. In*

⁶ Pseudowords are bold here, whereas not highlighted in the original version for the children.

front of the house they see Dad standing in front of a big camper van and waving happily at them.

[LIX: 27.19, very low]

Section 2

Nachdem alles im Wohnmobil verstaut ist, startet Papa den Motor und die Reise beginnt. Lena schaut aus dem Fenster und versucht zu erraten, in welche Richtung sie wohl **fieten** werden. Zu Oma? In die Berge oder ans **Perk**? Vielleicht sogar bis nach China? Lars dagegen langweilt sich bereits, als das Wohnmobil die Autobahn erreicht hat. Zum Glück hat er vorgesorgt und seine Comicbücher eingepackt. Kaum hat er das erste fertiggelesen, ruft Papa auch schon „Wir sind da!“. Die erste **Halen** verbringt die Familie auf einem Campingplatz am See. Die Reise war aufregend und voller Strapazen. **Kute** fallen Lars und Lena ins Bett.

*After everything is stowed in the camper, Dad starts the engine and the journey begins. Lena looks out of the window and tries to guess in which direction they are **fieten**. To Grandma's? To the mountains or to the **perk**? Maybe even to China? Lars, on the other hand, is already bored when the camper reaches the motorway. Luckily, he has taken precautions and packed his comic books. As soon as he has finished reading the first one, Dad calls out, "We're here!" The family spends the first **halen** at a campsite by the lake. The journey was exciting and full of strains. **Kute**, Lars and Lena fall into bed.*

[LIX: 33.78, very low]

Section 3

Am nächsten Tag **fieten** sie weiter. Papa hat **greffe** Laune, da Lars ihm wieder einmal einen Streich gespielt und ihm zum Zmorge einen Kaffee mit Salz statt Zucker gebracht hat. Am Nachmittag **vagiemen** sie ihr Urlaubsziel, einen kleinen Campingplatz an der italienischen Küste. Kaum hat Papa das Wohnmobil auf dem Platz parkiert, ziehen Lars und Lena so **beihest** es geht ihr Schwimmzeugs an und hüpfen voller Freude ins **Perk**.

*The next day, they continue to **fieten**. Dad is in a **greffe** mood because Lars has once again played a trick on him and brought him a coffee with salt instead of sugar for breakfast. In the afternoon they **vagiemen** their holiday destination, a small campsite on the Italian coast. As soon as Dad has parked the camper van at the campsite, Lars and Lena put on their swimming gear as **beihest** as possible and jump into the **perk**.*

[LIX: 38.99, low]

Section 4

An einem sonnigen Tag macht die Familie eine Wanderung. Beim Picknicken **osden** die Kinder einmal ein Miauen aus einem Gebüsch. Sie drehen sich verwundert um und sehen, wie eine junge Katze **blitzbeihest** aus dem Gebüsch springt und auf sie zu rennt. Die Zwillinge spielen lange mit ihr und folgen ihr auf einen Bauernhof. Ein freundlicher Bauer erklärt den Kindern, dass die Katze Chili heisst und mit ihren Geschwistern auf dem Bauernhof lebt. Als es **Halen** wird, erklärt Mama, dass sie sich nun von Chili verabschieden müssen. Schweigend trotten die Zwillinge hinter Papa zurück zum Wohnmobil, während Mama **beihest** zurückläuft, da sie etwas vergessen hat.

*On a sunny day, the family goes for a hike. While picnicking, the children **osden** a meow coming from a bush. They turn around in surprise and see a young cat jump out of the bushes as **blitzbeihest** [beihest as a flash] and run towards them. The twins play with her for a long time and follow her to a farm. A friendly farmer explains to the children that the cat is called Chili and lives on the farm with her siblings. When **halen** comes, Mum explains that they must now say goodbye to Chili. Silently, the twins trot back to the camper behind Dad, while Mum runs back **beihest**, having forgotten something.*

[LIX: 40.82, low]

Section 5

Auf der **Rückfiet** sind Lars und Lena traurig und auch das grosse Gelato zum Dessert kann sie nicht aufmuntern. Nach dem Abendessen gehen die Eltern und die Kinder früh ins Bett, da alle **kute** sind. Mitten in der Stille **osdet** Lars plötzlich ein Miauen und auf einmal spürt er etwas Haariges an seinem Arm. Lenas Taschenlampe leuchtet auf und sie sehen Chili, der es sich zwischen ihnen gemütlich macht. Mama lächelt ihnen zu und wünscht allen eine gute **Halen**. Das ist das schönste **Bineahof** an unsere Ferien, denkt Lena und kuschelt sich an die zufrieden schnurrende Katze.

*On the **rückfiet** [fiet back], Lars and Lena are sad and even the big ice cream for dessert can't cheer them up. After dinner, the parents and children go to bed early because everyone is **kute**. In the middle of the silence, Lars suddenly **osdet** a meow and suddenly he feels something hairy on his arm. Lena's torch lights up and they see Chili making itself comfortable between them. Mum smiles at them and wishes them all a good **halen**. This is the nicest **bineahof** of our holidays, Lena thinks and snuggles up to the contentedly purring cat.*

[LIX: 34.72, very low]

Appendix 2: Pseudoword properties

Pseudo-word	Original word	English translation	Incidence	Part-of-speech	Phonologically similar to original word	Phonologically similar to another word	Compound/derivation	Occurs in collocations
greffe	schlecht	bad	1	adjective	no	no	no	yes
vagiemen	erreichen	reach	1	verb	no	no	no	no
Bineahof	Andenken	souvenir	1	noun	no	no	no	no
fieten/fiet	fahren/ Fahrt	travel by car	2	verb/noun	yes	no	yes	no
kute	müde	tired	2	adjective	no	no	no	no
osden	hören	hear	3	verb	no	yes	no	no
Perk	Meer	sea	3	noun	no	yes	no	no
Halen	Nacht	night	3	noun	no	no	no	yes
(blitz-) beihest	schnell	quickly	3	adverb	no	no	yes	yes

. All pseudowords are inferable from the sentence and/or text context.

Appendix 3: Descriptive statistics for intelligence, vocabulary and reading tests

	Min.	Max.	Mean	Standard deviation
CFT	0	14	9.00	2.75
PPVT-4	130	213	164.40	21.56
ELFE Word reading	21	67	43.73	10.14
ELFE Sentence reading	4	33	18.91	6.07
ELFE Text reading	3	23	13.11	5.05
Reading speed	26.05	121.17	73.46	23.70

Appendix 4: Deviances and critical values in Poisson Models

Model	Deviance ^a	Dispersion ratio	Pearson's χ^2	p-Value ^b
Use of sentence context ~ reading speed	99.16	1.77	93.60	< 0.001
Use of sentence context ~ ELFE word reading	102.38	1.80	95.18	< 0.001
Use of sentence context ~ ELFE sentence reading	100.06	1.77	93.83	< 0.001
Use of sentence context ~ ELFE text reading	103.58	1.84	97.60	< 0.001
Use of sentence context ~ PPVT (vocabulary breadth)	104.47	1.85	98.20	< 0.001
Use of phonological cues ~ reading speed	78.76	1.41	74.77	0.026
Use of phonological cues ~ ELFE word reading	80.02	1.44	76.10	0.020
Use of phonological cues ~ ELFE sentence reading	76.63	1.38	73.06	0.035
Use of phonological cues ~ ELFE text reading	78.68	1.39	73.75	0.031
Use of phonological cues ~ PPVT (vocabulary breadth)	79.00	1.44	76.07	0.021
Score ~ reading speed	60.73	1.07	56.47	0.347
Score ~ ELFE word reading	63.43	1.09	57.78	0.303
Score ~ ELFE sentence reading	61.83	1.10	58.03	0.295
Score ~ ELFE text reading	63.85	1.11	58.90	0.268
Score ~ PPVT (vocabulary breadth)	55.18	0.97	51.40	0.537
Score ~ CFT (intelligence score)	65.09	1.13	59.94	0.238

^aThe five-percent critical value for a chi-squared with 53 d.f. is 70.99. Deviance is based on that value; ^bDispersion ratio, Pearson's chisquare and p-values of the overdispersion test in the performance package (Lüdecke et al. 2021. Performance: An R Package for Assessment, Comparison and Testing of Statistical Models. Journal of Open Source Software, 6(60), 3139).

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