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Empirical Research

When “One” Can Be “Two”: Cross-Linguistic Differences Affect Children’s Interpretation of the Numeral One

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Abstract

In English, a lexical distinction is drawn between the indefinite determiner “a” and the numeral “one”. English-speaking children also interpret the two terms differently, with an exact, upper bounded interpretation of the numeral “one”, but no upper bounded interpretation of the indefinite determiner “a”. Unlike English, however, German does not draw a distinction between the indefinite determiner and the numeral one but instead uses the same term “ein/e” to express both functions. To find out whether this cross-linguistic difference affects children’s upper bounded interpretation of “ein/e”, we tested German-speaking children and adults in a truth-value-judgment task and compared their performance to English-speaking children. Our results revealed that German-speaking children differed from both English children and German adults. Whereas the majority of German adults interpreted “ein/e” in an upper bounded way (i.e. as exactly one, not two), the majority of German-speaking children favored a non-upper bounded interpretation (thus accepting two as a valid response to “ein/e”). German-speaking children’s proportion of upper bounded responses to “ein/e” was also significantly lower than English children’s upper bounded responses to “one”. However, German children’s rate of upper bounded responses increased once a number-biasing context was provided. These findings suggest that German-speaking children can interpret “ein/e” in an upper bounded way but that they need additional cues in order to do so. When no such cues are present, German-speaking children differ from both German-speaking adults and from their English-speaking peers, demonstrating that cross-linguistic differences can affect the way speakers interpret numbers.

Keywords: numerical cognition, number acquisition, indefinite determiner, language acquisition, number words, language and cognition

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Various properties of language can influence children’s numerical skills (e.g. Dowker & Nuerk, 2016; Pixner, Moeller, Hermanova, Nuerk, & Kaufmann, 2011; Sarnecka, 2014). One of these properties is the transparency of a language’s counting system (e.g. Dowker & Roberts, 2015). For instance, while the Welsh language makes use of a highly regular counting system where numbers like twenty-one are expressed as ‘two tens one’, the English counting system is rather irregular (Dowker, Bala, & Lloyd, 2008; Dowker & Roberts, 2015). This cross-linguistic difference also seems to affect children’s number skills. For instance, Welsh-speaking children outperformed English-speaking children in a non-verbal number line estimation task, suggesting that differences in the transparency of a counting system can have an impact on children’s number representations (Dowker & Roberts, 2015). Additional evidence for the effect of cross-linguistic variation on number acquisition comes from differences in the grammatical marking of number. For instance, unlike English, languages like Slovenian or Arabic do not only draw a grammatical distinction between singular and plural, but they also make use of a dual form (i.e., marking sets of two, Almoammer et al., 2013). When compared to English-speaking peers, children learning Slovenian or Arabic were faster in acquiring the meaning of the number word *two*, suggesting that differences in the way languages encode grammatical number lead to concomitant differences in the acquisition of number knowledge (Almoammer et al., 2013; Marušič et al., 2016). What is more, unlike the tripartite system in Slovenian or the singular-plural distinction in English, languages like Chinese or Japanese do not mark number grammatically at all (Le Corre, Li, Huang, Jia, & Carey, 2016; Sarnecka, Kamenskaya, Yamana, Ogura, & Yudovina, 2007). Chinese and Japanese-speaking children have also been found to be significantly delayed in learning the number word *one* compared to English-speaking children, presumably due to the cross-linguistic difference in obligatory singular and plural marking (Le Corre et al., 2016; Sarnecka et al., 2007).

In addition to singular-plural morphology, other peculiarities of the English language may facilitate English-speaking children's relatively early acquisition of the numeral *one*. For example, the exact same word that is used in a counting sequence (i.e. *one*, two, three, ...) is also used for modifying number in a noun phrase (e.g. *one* apple). This overlap in form may highlight the cardinal properties of *one*, even when this expression is used outside of a counting context. What is more, English draws a distinction between the numeral *one* and the indefinite determiner *a*. While the latter is usually reserved for an indefinite interpretation, *one* mostly foregrounds the singularity of an entity (meaning exactly one, not more or less). The distinction between *a* and *one* also seems to be reflected in English-speaking children's interpretation of the two terms. That is, whereas English children did not accept two strawberries as a correct response to the question 'Is there one strawberry in the red circle?', the same children considered two strawberries as correct when they were asked 'Is there a strawberry in the red circle?' (Barner, Chow, & Yang, 2009). English-speaking children thus interpreted the numeral *one* but not the determiner *a* in an upper bounded way, suggesting that the lexical distinction between the two terms may aid children in deriving an exact interpretation of the number word *one* (as in exactly *one*, not two).

However, not all languages draw a distinction between the indefinite determiner *a* and the numeral *one* (e.g. Sarnecka et al., 2007). In German, for instance, the exact same term (*ein/e*) is used both as an indefinite determiner (e.g. *eine* Erdbeere 'a strawberry') and for modifying number in a noun phrase (e.g. *eine* Erdbeere 'one strawberry'). Furthermore, although the German count word *eins* 'one' – used in a counting routine – is similar to the inflected numeral *ein/e*[i], it is not identical (as is the case for English). These cross-linguistic differences between English and German raise the question whether German-speaking children's interpretation of *ein/e* is different from English-speaking children's interpretation of *one*. Since German conflates the indefinite and numeral meaning of *a* and *one* in the same expression (i.e. *ein/e*) but uses a different form in a counting routine, German-speaking children may face more difficulties in assigning an exact, upper bounded meaning to this term than English children.

In order to compare German- and English-speaking children's upper bounded response rates and to find out how German-speaking children interpret *ein/e*, we tested German children in a truth-value-judgment task (TVJT) that closely matched the task administered to English-speaking children by Barner and colleagues (2009). Since in German *ein/e* is ambiguous and provides less cues for singularity than *one* in English, we reasoned that German-speaking children's upper bounded response rates for *ein/e* might be lower than English-speaking children's response rates for *one*. Alternatively, the ambiguity of German *ein/e* could be irrelevant for children's upper bounded interpretations. In this case, German-speaking children should interpret *ein/e* in an exact, upper bounded way, comparable to English-speaking children's interpretation of *one*. To establish a baseline for German-speaking children, we also tested German-speaking adults in the same TVJT, thereby assessing whether German adults interpreted the ambiguous term *ein/e* in an upper bounded way (i.e. exactly one, not more) or rather in a vague, indefinite way.

Experiment 1

Method

Participants

Thirty-seven German-speaking children (mean age: 4;09 years, *SD* = 14 months) were tested in a truth-value-judgment-task (TVJT). All children were monolingual speakers of German and were recruited via local networks and personal contacts. Children displayed no evidence of physical, cognitive, or language impairments and none of the children had a history of hearing impairments. Additionally, 31 adult speakers of German were tested (mean age: 40,3 years, *SD* = 10,6). Adults were monolingual speakers of German. An overview of the participants is presented in Table 1. All participants were compensated for their participation by a little gift. Informed written consent was obtained from all parents or caretakers. The study was approved by Cologne University's Medical Ethics committee.

Table 1

Overview of German-Speaking Participants

			Chronological age in years (y;mm)	
Group	***n***	**Sex**	**Range**	***M***
Children	37	17 female	2;11 – 6;11	4;09
Adults	31	23 female	24 – 63	40;3

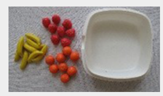
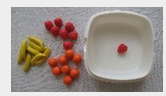
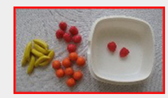
In order to compare German-speaking children's performance to English-speaking children, we also included the data of 32 English-speaking children as reported by Barner and colleagues (2009). English-speaking children's average chronological age was 3;09 years (range 2;04 – 6;07 years, see Barner et al., 2009).[ii]

Materials and Procedure

The truth-value-judgment task (TVJT) for German-speaking children was designed to closely match the TVJT administered to English-speaking children by Barner and colleagues (2009). Stimuli included a white plastic bowl and three different kinds of small plastic fruits (i.e., 8 strawberries, 8 oranges, and 8 bananas). The fruits were presented in separate piles organized by kind. To ensure that children could distinguish the different kinds, the experimenter first pointed to an exemplar of each kind and asked questions like 'Do you know what this is?' or 'Can you tell me what this is?'. As soon as the children demonstrated knowledge of each fruit type, the experimenter explained the task to the participant. For each trial, the experimenter moved a certain number of strawberries into the bowl and asked the participant a Yes/No question using the quantifier *eine* ('a/one') (also see Barner et al., 2009).[iii] Since the grammatical gender of the term *Erdbeere* 'strawberry' is feminine in German, the feminine form *eine* (as opposed to *ein*) was used. During the trial which was critical for the current purpose, the experimenter put two strawberries into the bowl and asked the participant "Ist da eine Erdbeere in der Schüssel?" "Is there a/one strawberry in the bowl?" (see Table 2). While the rejection of this question would indicate an exact, upper bounded interpretation of *eine*, accepting two strawberries would signify a vague, non-upper bounded interpretation. Both response options are theoretically feasible. However, although two strawberries are a logically valid response to *eine* (if there are two strawberries, there is also one), this interpretation is not in line with an exact, upper bounded interpretation of this term. After each trial, the fruit tokens were returned to their original piles. The order of trials was counterbalanced between participants.

Table 2

Different Conditions for the TVJT

Numeral / determiner	Question	Number of presented objects		
eine (a/one)	*"Is there a/one strawberry in the bowl"*			

Note. The critical condition for the current study is highlighted in red.

Results

German-Speaking Participants

To establish a baseline, we examined adult speakers' response rates during the TVJT. All of the German-speaking adults (100%) correctly accepted one token as a correct response to *eine.* Likewise, all of the adults (100%) correctly rejected zero tokens as a response to *eine*. During the critical trial, the majority of German-speaking adults (68%) rejected two strawberries as a valid response to *eine,* thus showing an upper bounded interpretation of this term (i.e. exactly one, not two).

Like German-speaking adults, all of the German-speaking children (100%) correctly accepted one token and correctly rejected zero tokens as a response to *eine*. However, during the critical trial, only a minority of German-speaking children (11%) rejected two strawberries as a valid response whereas the majority of children (89%) judged two strawberries as correct. When comparing German adults' and children's response patterns during the critical trial, a chi-square test revealed that German children accepted two strawberries significantly more often than German adults, $\chi^2(1) = 23.5$, $p < .001$, $\varphi = .59$ (see Figure 1). These findings demonstrate that – unlike the majority of German-speaking adults – German children did not interpret *eine* in an upper bounded way (i.e. not as exactly one).

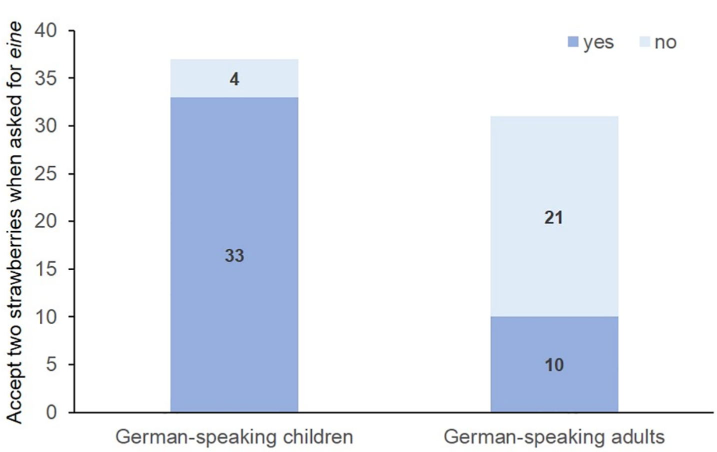


Figure 1. Number of German-speaking adults and children who accepted or rejected two strawberries as a response to *eine* during the critical trial (i.e., when two strawberries were presented).

To examine whether children's upper bounded comprehension of *eine* depended on age, a logistic regression was performed with children's age as the independent variable and their response to the question "Is there a/one strawberry in the bowl?" as the dependent variable (i.e. their yes vs. no responses during the critical trial). Results revealed no significant effect of age on the rate of upper bounded responses to *eine* (standardized $\beta = -.16$, *ns*), suggesting there is no developmental trajectory in the age group examined here.

Cross-Linguistic Comparison Between German and English

During the critical trial (i.e. when two strawberries were presented), only 16% of the English-speaking children accepted two items as a correct response when asked for *one* strawberry (Barner et al., 2009). Conversely, the majority of the English children (84%) rejected two strawberries as a response to *one*, thus showing an upper bounded interpretation of this term (cf. Barner et al., 2009). When asked for *a* strawberry, on the other hand, the majority of English-speaking children (78%) accepted two tokens as a valid response and only the minority (22%) rejected two strawberries (Barner et al., 2009).

When comparing German adults' proportion of upper bounded responses to *eine* with English-speaking children's upper bounded responses to *one* (data retrieved from Barner et al., 2009), no significant difference was observed during the critical trial, $\chi^2(1) = 2.4$, *ns*, $\varphi = .20$. Thus, despite the fact that some of the German adults did not adhere to an upper bounded response strategy when asked for *eine*, their performance appeared to be similar to English-speaking children's responses to *one*. That is, both English-speaking children and German-speaking adults arrived at an upper bounded interpretation of *one* or *eine*, suggesting that in the tested experimental set-up German *eine* is predominantly interpreted as exactly one by adult speakers.

However, when comparing children's performance, German-speaking children's interpretation of *eine* differed significantly from English-speaking children's interpretation of *one*. Whereas 84% of the English-speaking children rejected two tokens as a correct response to *one*, only 11% of the German-speaking children did so for *eine*. Thus, German-speaking children accepted two tokens significantly more often as a response to *eine* than their English-speaking peers did for *one*, $\chi^2(1) = 37.5$ (Yates $\chi^2(1) = 34.6$), $p < .001$, $\varphi = .74$ (see Figure 2). At the same time, there was no difference between German and English children's interpretation of the quantifier *all* (i.e., 100% of the German children and 91% of the English-speaking children correctly accepted 8 tokens as a correct response to *all*, Yates $\chi^2(1) = 1.7$, *ns*, $\varphi = .16$). These findings indicate that the difference between German and English-speaking children was specific to their varying interpretations of the quantifier *eine* vs. *one* and did not generalize to other quantifiers such as *all*. When compared to English-speaking children's responses to the indefinite determiner *a*, there was no significant difference between German and English children's acceptance rates of two tokens during the critical trial, (i.e. 78% of the English children vs. 89% of the German children), $\chi^2(1) = 1.6$, (Yates $\chi^2(1) = 0.9$), *ns*, $\varphi = .15$. These findings suggest that German children – unlike German adults – tend to interpret *eine* as an indefinite determiner rather than as a numeral.

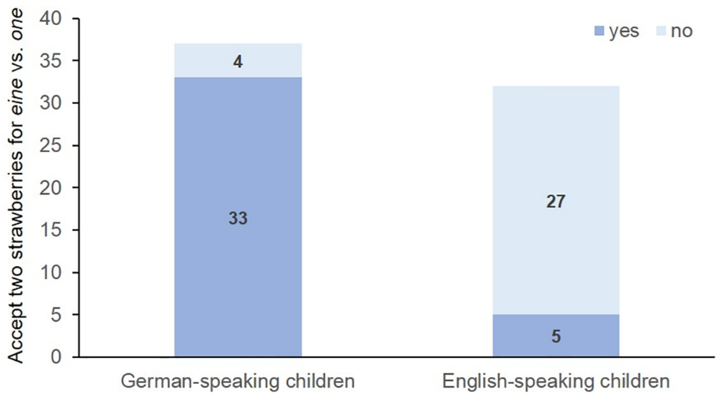


Figure 2. Number of German-speaking children and English-speaking children regarding their acceptance and rejection rates for two strawberries as a response to *eine* (German) and *one* (English) during the critical trial. The data of the English-speaking sample was retrieved from Barner and colleagues (2009).

Discussion

When evaluating German adults' data as a baseline, our findings reveal that adult speakers of German interpreted *eine* in an exact, upper bounded way, comparable to English-speaking children's interpretation of *one*. This finding indicates that German adults predominantly interpreted *eine* to mean exactly one (not more). However, since around 30% of the adults did not interpret *eine* in an upper bounded way, this result suggests that even German-speaking adults may be affected by the ambiguous nature of the term *eine*. Still, whereas the majority of adults interpreted *eine* as consistent with the exact numeral *one* in the administered TVJT, German-speaking children differed quite drastically from this response pattern. Thus, the great majority of children interpreted *eine* in a vague, non upper bounded way (by also accepting two tokens as a valid response to this term). These findings demonstrate that German-speaking children's intuitions differ from German adults' interpretation of *eine*. However, although the observed difference between children and adults seems to hint at a developmental trajectory with a gradual emergence of upper boundedness for *eine*, our data revealed no indication of an effect of children's age. This was true despite the broad age range considered in our study, suggesting that German-speaking children may arrive at an upper bounded interpretation of *eine* only rather late in development.

Crucially, German-speaking children's performance also differed from English-speaking children's interpretation of *one*. Whereas English-speaking children already derived an upper bounded interpretation of *one*, the same was not true for German-speaking children who predominantly opted for a non-upper bounded interpretation of *eine*. This difference is even more remarkable since the German-speaking children tested here were older than the group of English-speaking children examined by Barner and colleagues (2009). Additionally, the effect size of the cross-linguistic chi square test can be considered quite high (i.e. $\varphi = .74$), further emphasizing differences between English- and German-speaking children. While English-speaking children appeared to benefit from the unambiguous term *one,* German children did not yet derive an exact, upper bounded interpretation of the ambiguous term *eine*. Thus, German-speaking children's interpretation of *eine* neither seemed to be compatible with German-speaking adults' interpretation of the same term nor with English-speaking children's interpretation of *one*.

In a next step, we sought to examine German-speaking children's interpretation of *eine* more closely. In particular, the goal was to determine whether German-speaking children can arrive at an exact, upper bounded interpretation of this term when additional cues are provided. We therefore tested another cohort of German-speaking children in a TVJT with the same critical condition. However, this time, children were first introduced to a numerical context by being asked for other numerals (such as two or three). We reasoned that if English-speaking children indeed benefit from additive cues foregrounding an exact interpretation of *one*, German-speaking children should likewise profit from a disambiguating context that stresses an exact interpretation of *eine*. At the same time, the inclusion of other numerals (like two) allows for examining whether German children's low proportion of upper bounded responses is specific to *eine* or whether it extends to other numerals. To examine German children's interpretations of *eine* beyond binary response options, we also tested children's number knowledge in a Give-*one* task.

Experiment 2

Method

Participants

Twenty-one German-speaking children (mean age: 4;11 years, *SD* = 9 months, range: 3;08 - 6;00, 12 female) were tested in a number-biasing TVJT and a Give-*one* task. The average age of this cohort did not differ significantly from the group of German-speaking children tested in Experiment 1 (average age: 4;09 years, $t(56)$ = 0.46, p = .65, *ns*, *Cohen's d* = .13). All children were monolingual speakers of German and were recruited via local daycare centers. Children displayed no evidence of physical, cognitive, or language impairments and none of the children had a history of hearing impairments. Vision was normal or corrected to normal.

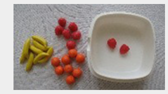
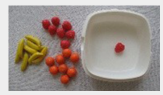
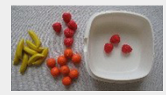
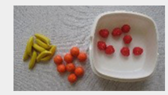
Materials and Procedure

Two tasks were administered: A modified version of the TVJT and a Give-*one* task examining number knowledge. Children performed these tasks during two different sessions with at least one day in between. The order of tasks was counterbalanced. Half of the children were first tested in the TVJT and the other half started with the Give-*one* task.

Number-biasing TVJT — The task was identical to Experiment 1 apart from the following: Unlike in Experiment 1, children were first asked whether there were two (or alternatively three) strawberries in the bowl, thereby introducing a number context. Table 3 displays the number of objects presented on each trial and the question asked. The order of trials varied between participants, with half of the participants being presented with the sequence (two, *eine*, three) and the other half with the sequence (three, *eine*, two). As in Experiment 1, during the critical trial the experimenter put two strawberries into the bowl and asked the participant "Ist da eine Erdbeere in der Schüssel?" "Is there a/one strawberry in the bowl?".

Table 3

Different Conditions for the Number-Biasing TVJT

Item	Number	Question	Number of presented objects		
1	*zwei (two)*	*"Are there two strawberries in the bowl?"*			
2	*eine (a/one)*	*"Is there a/one strawberry in the bowl"*			
3	*drei (three)*	*"Are there three strawberries in the bowl"*			

Note. The critical trial is highlighted in red.

The Give-one task — The Give-*one* task was based on Wynn's Give-*n* task (e.g. Wynn, 1990; Wynn, 1992). Children were first introduced to a puppet dog. The experimenter told the child that the dog was hungry and that it was hoping to be fed by the child. Stimuli consisted of a white plastic bowl and eight plastic lemons. The child was then asked to feed the dog by putting a specific number of lemons into the bowl. Questions were of the form: "Kannst du dem Hund *n* Zitronen geben?" "Can you give the dog *n* lemons?" While we tested numbers from one to six, here the focus was on eine (*a/one*) which was always requested first. Children were asked to put one item (i.e. *eine* Zitrone 'a/one lemon') into the bowl. This way, the task allows for determining how children interpret *eine* when they are not restricted to binary yes-no responses but when they can actively produce sets themselves.

Results

Number-Biasing TVJT

Eine — As in Experiment 1, all of the German-speaking children (100%) correctly accepted one token and correctly rejected zero tokens as a response to '*eine*'. Unlike in Experiment 1, however, the majority of German-speaking children (62%) now showed an exact interpretation of *eine*. Whereas in Experiment 1 only 11% of the German children rejected two strawberries as a response to *eine*, the proportion increased to 62 percent when German children were first exposed to a number context. When comparing the two groups of German-speaking children from Experiment 1 vs. 2, a logistic regression with the two experiments as a factor and age as a covariate revealed a significant difference between the two experimental groups (standardized β = -2.59, p < .001), but no significant effect of age on children's upper bounded interpretations of *eine* (standardized β = -0.02, *ns*). Thus, when additional cues were provided (Experiment 2), German-speaking children adhered to an upper bounded interpretation of *eine* significantly more often than if not (Experiment 1). The divergence between Experiment 1 and 2 cannot be accounted for by differences in age between the two groups since the effect of age was not significant in the logistic regression and participants' average ages were comparable across the two tasks (i.e. 57 vs. 59 months respectively).

When compared to German-speaking adults, German children's upper bounded responses in the number-biasing context (62%) did not differ from adults' response patterns in Experiment 1 (68% upper bounded responses), $\chi^2(1) = 0.2$, p = .66, *ns*, φ = .06.

Other numbers — All of the German-speaking children correctly accepted two tokens as a response to the number two. Likewise, 100% of the children correctly rejected zero tokens when asked whether there were two strawberries in the bowl. Apart from one child, none of the other children accepted three items as correct when asked for two strawberries, indicating that the majority of children (95%) interpreted this number in an exact, upper bounded way. A similar pattern emerged for the number three. That is, 100% of the children accepted three items as a correct response. Only one child accepted one item as a correct response to the number three, whereas the rest of the children (95%) rejected this claim. Apart from two children, 90% of the participants correctly rejected more than three items as a response when asked for three items.

Overall, these results indicate that most of the children already derived an upper bounded interpretation of the numbers two and three. The proportion of upper bounded responses to two and three was also higher than German children's upper bounded responses to *eine* (even when children were biased towards a more number-like interpretation of this term). A McNemar's test revealed significantly higher rejection rates for three tokens as a response for the numeral two compared to two tokens as a response for the numeral *eine*, $\chi^2(1) = 5.1$, $p = .02$, $\varphi = .50$. Similarly, children's proportion of upper bounded responses was significantly higher for the number three as opposed to *eine*, $\chi^2(1) = 3.1$, $p = .04$ (one-tailed), $\varphi = .39$.

Give-one — Our results revealed that all of the German-speaking children (100%) gave exactly one token when asked for *eine*. Thus, none of the children gave more or fewer items on any of the trials, suggesting that children always interpreted *eine* in an upper bounded way when they produced sets themselves. This was true despite the fact that 38% of the same children accepted two tokens as a correct response to *eine* during the number-biasing TVJT. Thus, children's responses differed between the two tasks administered, with a higher proportion of upper bounded responses in the Give-*one* task compared to the number-biasing TVJT, $\chi^2(1) = 6.1$, $p = .01$, $\varphi = .54$.

Discussion

Our results suggest that the majority of German-speaking children can arrive at an upper bounded interpretation of *eine* when they are provided with a numerical context. That is, when highlighting number as a salient feature of the TVJT task, German-speaking children's performance was no longer different from adults' interpretations. These findings suggest that converging cues that emphasize the cardinal (i.e. exact) properties of *eine* can indeed be beneficial for deriving an exact, upper bounded, interpretation of this term. However, although a greater proportion of German-speaking children interpreted *eine* as exact in a number-biasing context, the preference for upper bounded responses was still less pronounced for *eine* than for other numbers such as *two* or *three*. German children therefore tended to interpret *eine* in a more lenient way, even when a numerical context was provided. *Eine* thus seems to differ from other numbers, presumably due to its ambiguous nature which may bias German children into a vague, indefinite interpretation of this term. What is more, whereas approximately 40% of the children still showed no upper bounded interpretation of *eine* in the number-biasing TVJT, the same children never gave more than one token as a response to *eine* during the Give-*one* task. These findings suggest that children's non-upper bounded interpretation of *eine* may be task-dependent and particularly pronounced in binary judgment tasks.

General Discussion

Whereas English-speaking children seem to benefit from the lexical distinction between the indefinite determiner *a* and the numeral *one*, with only the latter being assigned an exact interpretation (Barner et al., 2009), the same does not hold true for German. Unlike English, the German language does not draw a distinction between the indefinite determiner and the numeral *one* but instead uses the same term serving both functions. As a consequence, German-speaking children do not yet seem to interpret *ein/e* in an upper bounded way when no additional cues are provided. German-speaking adults, on the other hand, predominantly interpreted *ein/e* in an upper bounded way, suggesting that the experimental context of the TVJT invites an exact, upper bounded interpretation of the term *ein/e*. German children may therefore not have reached the same level of interpretation as German-speaking adults. Crucially, German children's lack of upper bounded responses did not generalize to other numerals (such as two or three), demonstrating that difficulties in assigning an upper bounded meaning were restricted to the ambiguous term *ein/e*. This finding is even more remarkable because in spoken German it is possible to also use an abbreviated form *n/e* that can serve as an indefinite determiner but not as a numeral (Thieroff & Vogel, 2012). However, although we did not present participants with the brief form *ne* which would have been more likely to elicit a non-upper bounded response, German children were still extremely biased towards a vague interpretation of *ein/e*. Thus, despite the fact that *ein/e* implies singularity (and is interpreted as meaning exactly one by the majority of German adults), German-speaking children did not yet derive an exact interpretation of this term when tested in a TVJT. It thus appears that for German-speaking children the indefinite properties of *eine* are more salient. In line with this observation, a longitudinal study by Bittner suggests that German children first produce *ein/e* in the function of the indefinite determiner (Bittner, 1999). However, further longitudinal research is needed to confirm this proposal.

Despite the fact that German-speaking children were older than English-speaking children, German children produced significantly fewer upper bounded responses with respect to *ein/e* than English-speaking children did for *one*. Crucially, the observed differences between German and English-speaking children were specific to their varying interpretations of the quantifier *eine* vs. *one* and did not generalize to other quantifiers such as *all*. Thus, when tested in a comparable paradigm, German-speaking children appeared to lag behind English children's level of upper bounded responses for *one*, presumably due to cross-linguistic differences. However, the observed discrepancy could be caused by various differences between the two languages. The most likely candidate seems to be the distinction between the indefinite determiner *a* and the numeral *one* which is present in English but not in German (at least not to the same degree). However, German also deviates from English in using a different form when reciting *one* in a count list (i.e. *eins*) versus modifying this number in a noun phrase (i.e. *ein/e*, also see Introduction). The same does not apply to higher numerals in German that are identical in both contexts. Since German-speaking children displayed no difficulties in assigning upper bounded interpretations to higher numbers like *two* or *three* compared to *eine*, it is possible that the overlap between counting and modifying number in a noun phrase is crucial for children's levels of number comprehension. Yet, other findings are at odds with this assumption. For instance, despite the fact that both English and Chinese use the same words for counting and modifying number in a noun phrase, English-speaking children were still faster in becoming *one-knowers* compared to Chinese children (Le Corre et al., 2016). However, these findings do not rule out that a combination of different cues can influence children's number acquisition.

While our results stress the role of cross-linguistic differences regarding the interpretation of numbers, they are agnostic to the question whether differences between German and English affect the point in time when children become one-knowers (i.e. when they are able to reliably give one token as a response to *one* but fail at requests for higher numbers, cf. Wynn, 1990). In order to find out whether English-speaking children become one-knowers earlier than German-speaking children, much younger age groups have to be tested and directly compared to each other (like in Almoammer et al., 2013 or Le Corre et al., 2016). While future studies should investigate this possibility in more detail, here we provide first evidence that cross-linguistic differences between English and German seem to affect children's interpretation of the numeral one.

Although German-speaking children interpreted *ein/e* in a vague way, our findings showed that they derived an upper bounded interpretation of *ein/e* when additional cues were provided. In particular, German children consistently gave one token but never more when asked for *ein/e* during the Give-*one* task. In this context, children did not only produce sets themselves but they were also more or less prompted to the fact that a specific number of tokens was required in order to feed the dog (namely the number requested by the experimenter). These results demonstrate that German children's interpretation of *ein/e* can vary depending on the (experimental) context. In the same vein, German children's upper bounded interpretation of *ein/e* also increased during the TVJT once a number-biasing context was provided. That is, when children expected the TVJT to be about numbers, they were more likely to produce upper bounded responses to *ein/e* than when this expectation was not encouraged. While in our second experiment we raised this expectation by first asking children about higher numbers like two or three, it is likely that various alternative cues could have led to similar results. For instance, emphasizing the word EIN/E by using a contrastive pitch accent would have also foregrounded the exact properties of this term and may have yielded similar results.

Taken together, our findings suggest that German-speaking children can interpret *ein/e* in an exact, upper bounded way but they need additional cues to do so. In English the term *one* is most frequently reserved for a cardinal interpretation – as opposed to the indefinite determiner *a* (for exceptions see Goldberg & Michaelis, 2017). This distinction may continuously serve as a means to emphasize the cardinal, upper bounded properties of *one*. Based on this opposition, *one* is interpreted as unambiguously referring to exactly one (not more), even by young children learning English. In German, on the other hand, *eine* can be ambiguous and even adults sometimes interpret the term in a vague way. However, crucially, the ambiguity of *eine* seems to be resolved differently by German-speaking children and adults. That is, whereas the majority of adults arrives at an exact interpretation of *eine*, children predominantly interpret *eine* in a non-exact way. German-speaking children thus differ from both German adults and English-speaking children in their default interpretation of *eine*. These findings demonstrate that subtle cross-linguistic differences may lead to different interpretations of the number *one*, adding to the growing body of evidence that properties of language can affect numerical cognition.

Notes

i) Since the German numeral/determiner has to be congruent with the grammatical gender of the noun that it modifies (i.e. by using *ein* for nouns of masculine and neuter gender and *eine* for feminine nouns), we allude to this fact by writing *ein/e*.

ii) It should be noted that–despite a similar age-range–the cohort of German-speaking children was older than the cohort of English-speaking children. However, since German-speaking children were indeed less prone to opt for an upper bounded interpretation of ein/e than the younger group of English-speaking children, this provides even stronger evidence for cross-linguistic effects on number interpretation.

iii) Like Barner and colleagues, we also asked children for other quantifiers like *alle* ('all'). However since the purpose of the present study was to examine children's comprehension of the term *ein/e*, we will focus on those results that are directly relevant in this context (the same holds true for the results reported in Barner et al., 2009).

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Competing Interests

All authors declare that they have no competing interests.

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Data Availability

For this study, a dataset is freely available (see the Supplementary Materials section).

Supplementary Materials

The supplementary material contains the data file of the German-speaking participants tested in our study (i.e. data of the German-speaking children and adults tested in Experiment 1 as well as the data of the German-speaking children tested in Experiment 2). (for access, see Index of Supplementary Materials below).

Index of Supplementary Materials

Dolscheid, S., Schleussinger, F., & Penke, M. (2019). *Supplementary materials to "When "one" can be "two": Cross-linguistic differences affect children's interpretation of the numeral one".* PsychOpen. https://doi.org/10.23668/psycharchives.2663

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