ON THE ACQUISITION OF ORDINAL NUMBERS IN GERMAN

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1. Introduction

Studies on the acquisition of ordinal number words in phrases like *the third car* are relatively scarce (Beilin 1975, Colomé & Noël 2012, Fischer & Beckey 1990, Fuson & Hall 1983, Miller, Major, Shu & Zhang 2000). This gap strongly contrasts with the body of knowledge on the cognitive development of number perception in infants (e.g., Butterworth 2005; Coubart et al. 2013; Piazza & Izard 2009), on the acquisition of cardinal numbers and the counting sequence in language acquisition, and the development of mathematical skills (e.g., Fuson, Richards & Briars 1982; Gelman & Gallistel 1978; Wynn, 1992).

Ordinal number acquisition is a research area at the interface of cognitive, mathematical, and linguistic development. The concept of ordinality is often used in a more general way to refer to the *greater than* and *less than* relation, which is a possible prerequisite for the acquisition of ordinal numbers (e.g., Brannon 2002; Kingma & Koops 1981). Brannon (2002) found that the ability to discriminate between increasing and descending sequences of numerosities develops already between 9 and 11 months of age. How children learn to map these order relations to linguistic expressions in terms of ordinal number words remains an open question.

Like order relations and size comparisons, ordinal number words refer to sequences of objects. In contrast to the latter, more general concepts of comparisons, ordinal number words refer to a specific position of an element within a sequence and thereby rely on knowledge about the specific succession of natural numbers.

The few existing studies, which compared small numbers up to *fourth* and larger numbers such as *sixth* and *seventh*, indicate a stepwise acquisition of ordinal numbers (Colomé & Noël 2012). It is still open whether young

children acquire small ordinal numbers also in a stepwise fashion. Stepwise acquisition may indicate that children are not yet able to use the information encoded in the ordinal suffix productively. Instead they may acquire each ordinal number as an independent lexical item.

To fill this gap, our study investigated the acquisition of the small ordinal numbers 2nd and 3rd in German-speaking children in more detail.

The paper is structured as follows: Section 2 gives some background on the relation between cardinal and ordinal numbers. Section 3 summarizes previous results on ordinal number acquisition. In section 4 we present our own study with monolingual German-speaking children aged 4 to 6. The results are discussed in section 5.

2. On the relation of cardinal and ordinal numbers

In many languages such as English, German, French, or Chinese ordinal number words are morphologically derived from cardinal number words by adding an affix (Miller et al. 2000, Wiese 2003). Dependent on the specific language, sometimes suppletive forms as *first, second* or *third* in English are used that reduce the transparency of the morphological composition.

In German, ordinal numbers are derived from cardinal numbers by adding the suffix *–te*[2]. The morphological derivation of *zweite* (*'second'*) from the cardinal number word *zwei* in German is fully transparent, *dritte* (*'third'*) is derived from *drei via* a vowel change. Like adjectives, ordinal numbers are marked for case and gender. They usually occur as part of definite noun phrases, and precede other kinds of modifiers (Wiese 2003). Examples are given in (1) and (2).

(1) Der zweite schwarze Pullover ist schön.
The$_{NOM}$ second black sweater is nice.

(2) Ich nehme den dritten schwarzen Pullover.
I take the$_{AKK}$ third$_{AKK}$ black$_{AKK}$ sweater.

Ordinal numbers such as *first, third*, or *sixteenth* express one of the central properties of natural numbers: the well-defined and fixed order of elements. Due to the stable order of number words we can describe the position of an object within a sequence by using the respective ordinal number word that is associated with the rank of the object in the sequence. In contrast to ordinal numbers, cardinal numbers like *two* or *thirteen* use the property of the stable order of number words to denote the number of

elements in a set or sequence. Thus, cardinal and ordinal numbers both refer to the countably infinite set of natural numbers but use its properties to denote different aspects.

In addition to the list of cardinal and ordinal words, children have to learn abstract underlying principles for the use of cardinal and ordinal numbers. Already in 1978, Gelman and Gallistel posited five counting principles for cardinal numbers. In 2003, Wiese formulated analogous principles for the assignment of ordinal numbers. Both ways of counting have to obey the *One-to-One Principle,* which stipulates that each element of a set or sequence must correspond exactly to one number word. In addition, the *Stable-Order Principle*, requiring that number words have to be used in a fixed order, holds for cardinal and ordinal use as well as the *Abstraction Principle*, which holds that any set or sequence can be counted. For determining the cardinality of a set the order of counting is irrelevant. Thus, the objects in a set can be counted from left to right, from right to left, from bottom to top, or in any other order. This principal does not hold for ordinal numbers. They have to be assigned in exactly the order of the sequence (*Order-Relevance Principle*). Cardinal and ordinal numbers also differ in that for ordinal numbers each number word directly identifies the rank of the item in the sequence instead of referring to the cardinality of the set, as cardinal numbers do. Wiese summarizes this crucial property as the *Ordinality Principle*.

In addition to these conceptual similarities and differences, children have to learn that cardinal and ordinal numbers are implemented in natural languages as belonging to different word classes. Whereas cardinal numbers pattern with quantifiers like *few* and *many* in many languages, ordinal numbers are similar to superlative forms of adjectives or adjectives in general (Wiese 2003).

3. Previous research on the acquisition of ordinal numbers

According to Fuson and Hall (1983), the acquisition of ordinal numbers relies on the knowledge of cardinal numbers. Previous studies on the acquisition of cardinal numbers indicated that cardinal numbers are acquired step by step starting from age two and developing until age eight for addition and multiplication operations (e.g., Butterworth 2005; Coubart et al. 2013; Fuson, Richards & Briars 1982; Fuson & Hall 1983; Gelman & Gallistel 1978; Piazza & Izard 2009; Wynn 1992). Infants can already distinguish between sets including up to three or four elements on the

basis of different perceptual properties (Butterworth 2005, Coubart et al. 2013). Around age 2 children start to learn the number word list (Fuson & Hall 1983) and one year later children can count small sets of objects (Wynn 1992). In general, children show a better performance for counting small numbers up to three or four than for bigger ones, with performance improving with age (Fuson & Hall 1983). General better performance for small numbers, also in adults, is often explained by subitizing, i.e. the ability to grasp the exact number of objects without explicit counting (Kaufmann et al. 1949; Piazza & Izard 2009). With regard to the acquisition of cardinal numbers Gelman and Gallistel (1978), among others, doubt that subitizing is present before the ability to count small sets. The underlying counting principles are acquired, also in stepwise fashion, one by one during pre-school years (e.g., Gelman & Gallistel 1978; Fuson & Hall 1983).

As for ordinal numbers, few studies have investigated their acquisition as well as the relation to cardinal number development (Beilin 1975, Colomé & Noël 2012, Fischer & Beckey 1990, Fuson & Hall 1983, Miller et al. 2000). As reported by Fuson and Hall (1983) children between age 3 and 6 often use their known list of counting words and translate the selected cardinal number word to the appropriate ordinal word (e.g., "*One, two, three, four. Fourth. This one is the fourth*." p. 89). In general, previous results suggest a delayed acquisition of ordinal numbers compared to the acquisition of cardinal numbers.

Investigating the ordinal number word list, Beilin (1975) reports that none of the 3-year-olds, only 2% of the 5-year-olds and 10% of the 6-year olds in his study could count to 23rd in a rote counting task for ordinal numbers. In addition, none of the 3-year old children could label a stick at second or third position in a row of differently coloured sticks. At age 5, 33% of children could label the 2nd but only 8% could label the 3rd position. At age 6, children's performance increased to 63% for 2nd and 33% for 3rd. These results demonstrate a stepwise acquisition of the number system; the ordinal number 2nd is produced correctly more frequently than 3rd (about +30%) in all age groups. However, note that Beilin (1975) used only one item each to investigate the ordinal numbers 2nd and 3rd in the respective tasks.

Fischer and Beckey (1990) studied ordinal numbers in 97 5-year-old English-speaking children. They investigated the interpretation of the ordinal 3rd and the production of the ordinal number 5th with one item each in a toy selection task. Results show that 31% of the 5-year-old children picked the third toy correctly, and 25% named correctly the fifth toy.

Colomé and Noël's (2012) study is based on the design of Fischer and Beckey (1990). The authors compared cardinal and ordinal number acquisition of small and larger numbers (3, 4 vs. 6, 7) in comprehension and production and used 4 test items each in well-controlled conditions. In the "tell me" task 48 3- to 5-year-old French-speaking participants were asked in which position a yellow car was located in a queue in front of a traffic light. The "give me" task investigated the interpretation of cardinal and ordinal numbers. For ordinal numbers, the participants had to pick the n^{th} car out of a queue and put it in a garage. Each task comprised 4 items for ordinal numbers, using the small numbers 3 and 4, as well as 4 items for the larger numbers 6 and 7.

The results of Colomé and Noël (2012) are consistent with the previous findings. Though children's performance increased with age, performance for ordinal numbers was significantly below that of cardinal numbers both in production and comprehension. In the production task, 3-year-olds could name the 3^{rd} or 4^{th} position in only 13%, and the 6^{th} and 7^{th} position in only 6% of items. At age 5, performance on ordinal number production was between 86% and 82%. In the comprehension task only 25% of the 3-year-olds picked the correct car at 3^{rd} or 4^{th} position and none of the children in this age group selected the 6^{th} or 7^{th} car in a queue correctly. At age 5 children picked the n^{th} car correctly in 67% of items for small numbers and in 59% of items for larger numbers. These findings provided first evidence that target-like interpretation of ordinal number words is mastered later than correct production.

In a cross-linguistic study on number concepts Miller et al. (2000) tested English- and Chinese-speaking school-age children between 6 and 10 years on ordinal number acquisition. Rote counting of ordinal numbers showed language specific differences due to the morphologically transparent number system in Chinese and the less systematic formation of English number words. More than 90% of the Chinese-speaking children at age six could count to 45^{th}, whereas only 50% of the English children could count to 20^{th} and 19% to 45^{th}. All Chinese-speaking children performed at ceiling in a task in which they had to pick the n^{th} car in a sequence out of seven cars, whereas English-speaking six-year-olds interpreted 66% of the cases correctly. Miller et al. (2000) do not discuss whether performance differed between small and larger numbers for the six-year-olds and how differences in the education system may have contributed to the observed cross-linguistic differences.

The above studies suggest that small ordinal numbers like 1^{st}, 2^{nd}, and 3^{rd} are acquired before larger ones such as 6^{th} and 7^{th} and that target-like performance is reached at school age (Colomé & Noël 2012, Miller et al.

2010). Apart from the pilot work by Beilin (1975), it is still unclear whether mastery of small ordinal numbers is achieved in a stepwise manner as well is. Alternatively, as small cardinal number words, which ordinal numbers are derived from, are acquired very early, it may be that small ordinal numbers are acquired in an all or nothing fashion.

4. Our Study

In our study we investigate the acquisition of small ordinal numbers in German-speaking children. We focus on the interpretation of ordinal numbers only, since the study of Colomé and Noël (2012) showed that target-like interpretation of number words is mastered later than correct production. Our study addressed the following questions:

(Q1) At which age do children interpret small ordinal numbers (2nd and 3rd) target-like?

(Q2) Does the acquisition of the ordinal number 2nd precede the acquisition of 3rd?

4.1. Participants

We tested 81 typically developing monolingual German-speaking children in three age groups. Table 1 summarizes the details about the participants for the 4-, 5- and 6-year-olds. In addition, 20 adults were tested as a control group. According to the information from a parental questionnaire, no child showed signs of language impairment, language delay, or hearing problems.

	Age 4	**Age 5**	**Age 6**	**Adults**
Number of participants	n=37 21 girls, 16 boys	n=36 18 girls, 18 boys	n=8 3 girls, 5 boys	n=20 11 women, 9 men
Age range	4;0 to 4;11	5;0 to 5;11	6;0 to 6;10	18;9 to 40;9
Mean age	4;5 SD = 3.7 months	5;5 SD = 3.1 months	6;4 SD = 3.3 months	26;9 SD = 71.5 months

Table 1: Description of participants

4.2. Method and Design

To investigate the interpretation of the ordinal numbers 2nd and 3rd , we developed a computerized picture selection task, similar to the design by Colomé and Noël (2012) . Four items assessed the core meaning of ordinal numbers in German-speaking children: two items investigated the interpretation of 2nd (*zweite/n*) and two items 3rd (*dritte/n*) in object

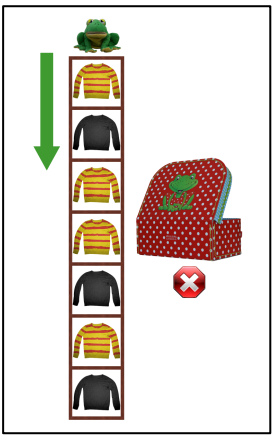

Figure 1: Example test item

position. The gender of the noun phrase and therefore the inflection of the ordinal number varied across the items. In addition, two warm-up items familiarized the participants with the experimental procedure. An example test item is given in (3).

(3) Puppet:
"Nimm den dritten Pullover und leg ihn in den Koffer."
Take the third sweater and put it in the suitcase.

In each test picture seven daily-life objects were displayed in a cupboard from top to bottom on the computer screen. A puppet was depicted on top of the cupboard and – via a prerecorded voice – asked the child for help to pack its suitcase. This way, counting from top to bottom was invited; in addition, an arrow indicated the direction of counting (cf. Figure 1). Results indicated no problem with the direction of counting. The participants had to click on the puppet to hear which object he wanted the child to select. All test sentences spoken by the puppet were pre-recorded and checked for prosodic contours.

Children were tested individually in a quiet room in their day-care facilities; no response-contingent feedback was given to the participants. All test sessions were video-recorded for later data analyses.

4.3. Results

Figure 2 depicts the group means for each age group across all items. Children at age 4 selected the correct 2nd or 3rd object in only 56% of items. Children's performance increased with age: At age 5 children selected the correct object in 89% of items and at age 6 in 94% of items. As expected, adults performed at ceiling.

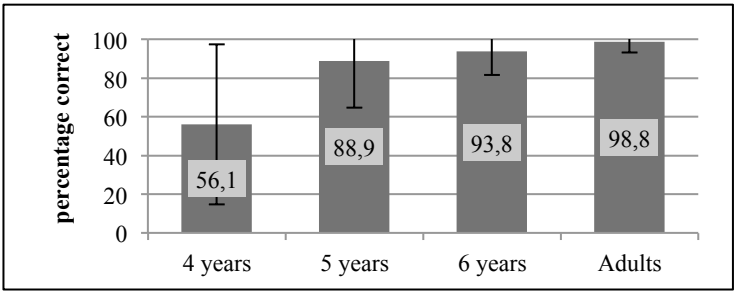

Figure 2: Mean percentage correct for ordinal number selection per group

To answer research question Q1, statistical group comparisons were performed. The analysis revealed significant differences between the age groups (Kruskal-Wallis for independent samples: $H(2)=16.28$, $p<.001$). Pairwise comparisons showed that 4- and 5-year-olds' performance differs significantly (Mann-Whitney-U, $U=969.50$, $p<.001$). Comprehension rates of 5- and 6-year olds were not significantly different (Mann-Whitney-U, $U=145.0$, $p=1.0$). In addition, only the 4-year-olds differ significantly from the adult control group (Mann-Whitney-U, $U=591.0$, $p<.001$), the performance of children at age 5 is statistically not distinguishable from the adult control group (Mann-Whitney-U, $U=424.50$, $p=.084$).

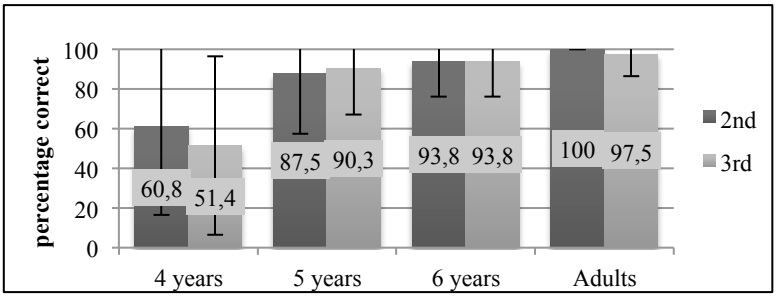

Figure 3: Mean percentage correct with SD per condition and group

To answer research question Q2, responses to 2nd and 3rd were analyzed separately. Figure 3 shows the mean percentages of correct interpretations broken down for the ordinals 2nd and 3rd by age group. Only 4-year-olds differed in their comprehension rates for *second* (60.8%) and *third* (51.4%). This is in line with previous studies that found children at age 4 to interpret the smaller ordinal number 2nd more often correctly than 3rd. However, in our sample, this difference did not reach significance (Wilcoxon, Z=-1.62, *p*=.106). Children at age 5 and 6, as well as adults do not differ with respect to the investigated ordinal numbers.

To investigate whether in German children master 2nd before 3rd, we classified the 4- to 6-year-old children according to their individual performance in the two conditions. The contingency table (cf. Table 2) illustrates how many children correctly interpret the two ordinal number words.

		3rd	
		0 or 1 correct	**2/2 correct**
2nd	**0 or 1 correct**	21	4
	2/2 correct	8	48

Table 2: Individual performances for 2nd and 3rd across all children

21 children failed in both 2nd and 3rd. 48 children interpreted both ordinals target-like. 8 children mastered the ordinal 2nd but not 3rd. However, 4 children showed the opposite pattern, with better performance on 3rd then on 2nd. Counting backwards, wrongly selecting the 3rd for the 2nd or vice versa, or selecting randomly were not frequently observed error patterns. The predominant error pattern was children's strategy to form subsets of objects and, e.g. count only the striped sweaters (cf. Figure 1).

5. Discussion

In this study we investigated the acquisition of the small ordinal numbers *second* and *third* in German. Previous research on the acquisition of cardinal numbers indicates that counting words are acquired stepwise and that small numbers up to *three* or *four* are acquired before larger numbers. Acquisition findings regarding ordinal number words mirror these data. Colomé and Noël (2012) report that small ordinal numbers like 3rd and 4th are produced and comprehended earlier than larger ones such as 6th and 7th. Previous research left open the question if mastery of small ordinal numbers proceeds stepwise as well or in a uniform fashion. Therefore, we investigated the interpretation of 2nd and 3rd in 4- to 6-year-old children. Extending previous studies with French, English- and Chinese-speaking children, our results point to a high increase in correct interpretations between ages 4 and 5. Regarding Q1, our data shows adult-like performance for small ordinal numbers in German starting at age 5. Target-like performance around this age is also reported by Colomé and Noël (2012) for small ordinal numbers in French-speaking children.

Addressing Q2, children at age 4 interpret the ordinal number 2nd more often correctly than the ordinal 3rd; but this difference does not reach statistical significance, and is smaller than previously reported (cf. Beilin 1975). From age 5 onwards performance on 2nd and 3rd is the same and adult-like.

An analysis of children's individual performance revealed that most of the children either had already mastered both small ordinal numbers 2nd and 3rd or had not yet mastered either. Eight of the 81 children tested mastered 2nd but not 3rd. Taken together with the descriptively better performance on 2nd than on 3rd at age 4, this may indicate a stepwise acquisition of small ordinal numbers at least for some learners. Four children showed the inverse pattern, i.e. target-like interpretation of 3rd but not of 2nd. Therefore, our results are also compatible with the assumption that small ordinal numbers are acquired uniformly. Parallel acquisition of small ordinal numbers may in fact be a side-effect of the very early acquisition of the respective cardinal number words.

In summary, our data provides further evidence that small ordinal numbers are already acquired at age 5. In addition, our data demonstrates that for 4-year-olds acquisition of ordinal numbers is a gradual process. Whether small ordinal numbers are acquired at the same time or one by one cannot be yet answered in detail. To investigate the early development of these small ordinal numbers in more detail, future research should test even younger children. In addition, it would be interesting to shed light on

the role of transparency in the morphological derivation of ordinal numbers. Therefore the ordinal number *fourth* should be studied, which unlike *third* has a transparent derivation in English and German[3]. Moreover, investigating the acquisition of specific semantic properties of ordinal numbers such as intersectivity and subsectivity (Heim & Kratzer 1998) and their interpretation in double modifier constructions (cf. Matthei 1983, Marcilese et al. 2013, Miller et al 2010) might be an interesting elaboration in the study of ordinal numbers.

Notes

[1] This study was part of a larger testing battery on the acquisition of nominal modification and relative clauses within the project "The Acquisition of (non-)restrictive relative clauses in German". This project (SCHU 1983/1-1) is part of the DFG-Research Group 1783, funded by the German Science Foundation (DFG).
[2] For number words between 19 and 99 the suffix to derive an ordinal number word is *-st*, as in *zwanzigste* (20th).
[3] Thank you to an anonymous reviewer for this advice.

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