# Toddlers learning the meaning of counting words as increase in discerned aspects of number

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The focus of this paper is on toddlers (1-3-year-olds) learning the meaning of counting words while participating in a three semester preschool intervention. This was investigated with task-based interviews analysed through the lens of variation theory of learning which implies observing the aspects of numbers discerned by the toddlers. In general, the toddlers learned to use counting words purposively. Discerning represen­tations as an aspect of counting words was shown to be central, but cardinal and ordinal meaning of counting words liberate a more advanced understanding of representations. Further, the study shows that the development of toddlers’ knowledge is diverse as there are quite different learning trajectories among the toddlers in the study.

## Introduction

Observations of young children’s engagement in preschool activities was the starting point for implementing designed numeracy education with 27 toddlers (1-3 years) during three semesters in Swedish preschools. The goal of the intervention was to make possible for toddlers to explore the meaning of numbers, particularly ordinality, cardinality, part-whole relations and representations, as these have been found to be necessary to discern in order to develop a powerful basic number knowledge (Björklund et al., 2021). The aim of this paper is to describe development in these toddlers’ ways of using and understanding counting words, as one representation of numbers, while participating in these interventions. Task-based interviews were conducted on five occasions; before, during and after the intervention. These provided an overview of the development of number knowledge among the toddlers. In this paper we specifically focus on the toddlers’ learning of the the meaning of counting words. The research question we aim to answer is: How can toddlers’ learning of counting words be described in terms of increase in discerned aspects of numbers?

## Knowledge of numbers and counting words

A large body of research has given us a good understanding of children’s general development of number knowledge within which ordinality, cardinality, part–whole relations, and representations have been shown to be essential aspects (Baroody & Purpura, 2017; Björklund et al., 2021; Fuson, 1992). There are however few studies involving toddlers as most tools for investigating numbers are based on children having knowledge of the spoken number system.

Counting words include several significant aspects necessary to discern for making use of them, and their meaning is also connected to the context in which they are used (Fuson, 1992). The meaning of ordinality implies that every object or counting word has an exclusive position in a sequence and relates to the others in the same sequence (Fuson, 1992). Cardinality then implies knowing that counting words may represent a set or composed unit of items (Baroody & Purpura, 2017). Cardinality is by Sarnecka and Carey (2008, p. 665) described as a ‘principle stating that a numeral’s cardinal meaning is determined by its ordinal position in the [counting] list’. This knowledge has been shown among most four-year-olds, and is a fundamental insight if one is to be able to make use of counting words and handle numbers in problem solving involving quantities. Cardinality is often observed in counting acts in which the last uttered counting word includes all the counted items (Gelman & Gallistel, 1978). Nuñes and Bryant (1996) do however raise some concerns regarding this interpretation of the cardinality principle, since it may reflect a learnt procedure rather than numerical understanding. Cardinality is furthermore a prerequisite for understanding numbers’ part-whole relations*,* which allows children to compare sets, add, subtract and in different ways operate with numbers to solve numerical problems (Venkat et al., 2019).

Because of the abstract nature of numbers, they are only accessible through representations like spoken language, symbols and images (Duval, 2006). According to Lesh et al. (1987), learning is reflected in the ability to make connections *between* and *within* the representation used. A study by Gibson et al. (2019) has shown that children who use several representations, whether or not they are used in correct correspondence with a number of objects, more easily learn the cardinal meaning of numbers. In many situations, at least two representations are explicitly or implicitly used, depending on the mathematical activity (Duval, 2006), with pictures, verbal and written symbols, manipulatives, and real-world situations being representations that are often elaborated on in early mathematics education (see Lesh et al., 1987). Learning about numbers thus implies discerning their meaning (including ordinality, cardinality, and part–whole relations) mediated through different representations. This discernment does not appear on its own, but through communication with others (van Oers, 2010). Using several modes of representation in this communication is not enough either; the representations must be pointed out and demonstrated to the child, as neither representations themselves nor connections between and within them are automatically realized by children (Björklund & Palmér, 2022, 2023; Palmér & Björklund, 2023). Learning to use counting words is thereby a complex endeavor that goes beyond reciting the counting sequence, but should be possible to promote in early years because of the frequent use of counting words in daily communication and education.

## Theoretical framework

The theoretical framework for this study is Variation theory of learning as this framework directs attention to how a learner experiences the meaning of a phenomenon (Marton, 2015). How a person experiences the meaning of numbers entails both a holistic experience (experiencing numbers “as” something), and a complex experience, in which discerned aspects of the phenomenon together constitute the meaning that the child attributes to it (Gibson & Gibson, 1955; Marton & Pong, 2005). This means, the child always has some way of experiencing numbers, based on previous and similar experiences. When the toddler discerns aspects of the phenomenon that he or she has not previously discerned, it changes the meaning for that toddler, leading him or her to a new way of understanding (experiencing) numbers. Through using variation theory it is possible to design an intervention offering children to experience necessary aspects of numbers through carefully selected patterns of variation and invariance (see Marton, 2015 and Björklund et al. 2021 for further details) and to make a detailed interpretation of what it means to learn something and by analysing learning outcomes in terms of changed ways of experiencing a phenomenon (see Björklund & Runesson Kempe, 2019). In every situation, several aspects of a phenomenon can be discerned, and those that are discerned are decisive for how the phenomenon is experienced. For example, if a child has not yet discerned the cardinal meaning of numbers, counting words are reduced to having the meaning similar to a nursery rhyme (the order of the words are stabile but bear no meaning of ‘numerical sets’). Learning then occurs when the learner discerns new and necessary aspects of that phenomenon, which in this study means a focus on those aspects that children have and have not yet discerned of counting words. Thus, the approach does not limit the analysis to ‘knowing or not knowing’, but instead makes it possible to analyse *different ways of knowing*.

**Method**

The focus of this paper is on toddlers’ knowledge of counting words. For three semesters, two researchers and three preschool teachers from three preschools in two Swedish municipalities collaborated. Activities focused on numbers were implemented in the preschools during these three semesters. The activities in the intervention were adapted to toddlers and differed in nature, for example, book reading, memory games, as well as dance and motoric play (se e.g., Björklund & Palmér, 2021; Palmér & Björklund, 2023). At the start of the study, the 27 children participating in the intervention were 12–27 months old. The children’s guardians agreed to the participation of their children. The tools and methods of the study have been approved by the Swedish Ethical Review Authority (Dnr: 2019-01037). To investigate the advancement of toddlers’ number knowledge, task-based interviews were conducted on five occasions: before, three times during and then after the intervention (Björklund & Palmér, 2021). In the first interview the mean age of the children were 1 year 5 months, in the second 1 year 9 months, in the third 2 years 1 month, in the forth 2 years 7 months and finally in the last interview, 3 years 1 month.

To overcome the challenge of toddlers’ often non-verbal communication, the task-based interview was play-oriented, not depending on verbal responses (Björklund & Palmér, 2021). The interview consisted of seven tasks, framed in a narrative familiar to the children (i.e., a birthday party), with numerical aspects available to be discerned and reasoned about by the toddlers in different ways, for example by using words, gestures, and other actions. Each task included five levels of advancement, to offer the children opportunities to show their individual potential regardless of their biological age and to be used for longitudinal analyses of advancement. All interviews were conducted by the preschool teachers, who were trained in conducting research interviews with young children (Palmér & Björklund, 2022).

### Analysis

The analysis is based on 60 hours of video-documented interviews, coded in NVivo. In this paper, the focus in on toddlers’ use of counting words which was observed in tasks where the toddlers are enumerating or reasoning about “how many” questions. In accordance with variation theory (Marton, 2015), how the toddlers acted (made use of counting words) was considered to be a function of how he or she experienced the meaning of the counting words. Discerned and undiscerned aspects were central in the analysis because what is discerned constitutes the meaning the phenomenon has for the toddler in a particular situation.

First, the toddlers’ ways of using counting words in the different tasks were categorized. These ways were, in line with variation theory, interpreted in terms of discerned aspects. This first part of the analysis ended up in a qualitative description (six categories) of the toddlers’ knowledge of counting words. Second, we sorted the observed instances of the qualitative categories covering all the five interview occasions for all of the participating children. Through this procedure, four distinct learning trajectories emerged from the data set. In the results, examples from four toddlers illustrate these learning trajectories.

**Results**

The results are presented in two parts: First the six qualitative different categories of ways the toddlers use counting words are presented, second four tables that illustrate the learning trajectories found among the toddlers in the study.

The qualitative different ways of using counting words are below described based on what aspects are discerned and not yet discerned.

#### A. Repeating words in a systematic chanting manner

Example: Pointing at each cookie while saying ”di, di, di”

When toddlers repeat words in a systematic chanting manner, they discern objects as differentiated units constituting a collection that can be demarcated with verbal and gestural actions. This is a pre-requisite for experiencing a set as partitioned and as a composite whole at the same time. However, the toddler has not yet discerned cardinality or ordinality of numbers. The way the toddler demarcates one word for each item in a collection indicates, however, some sense that words or certain utterances spoken in a rhythmic way may represent the items in the collection.

#### B. Random counting word

Example: Answering “three” to every task regardless of the number of objects

The use of random counting words means that the toddlers discern counting words as a special kind of words that are to be used in certain situations, such as when asked “how many”. Counting words are in this sense experienced as a representation for quantities. The use of random (or one and the same) counting word seems on the other hand to lack connection to the set of objects and thereby lack the meaning of cardinality or ordinality or any relations between numbers.

#### C. Reciting the counting rhyme unsystematically

Example: Answering “one, two, five, eight” when asked to determine the number of three objects

Toddlers in the study sometimes recite the counting rhyme unsystematically, which is interpreted as they are discerning counting words as a collection of words with several differentiated examples (different words). The words do have some kind of representational meaning, because the words are used in a certain setting and in a certain way to answer the question “how many”. However, the toddler does not yet discern ordinality because the string of words are random and the words do not seem to be related to one another other than as parts of a similar category of words. Neither have the words the meaning of cardinality because one single counting word is not used to determine the quantity of a collection of objects.

#### D. Reciting the counting rhyme in correct order, not connected to the set of objects

Example: Counting out loud, sometimes pointing with index finger at objects but does not stop counting when reaching the last object.

The toddlers may recite the counting rhyme in correct order but not connect the words to a set of objects, which means they discern ordinality in the sense that the counting words are ordered in a sequence, starting from “one”. There is however no cardinality meaning discerned because the counting action does not end up in a collection answered by a single counting word. Likewise, toddlers who name each item (in the correct order) but are not flexble in their use (that “number two” can be any object depending on where you start the counting act) have not discerned the cardinality of the counting words either. Similar as in the previous category, the words have a representational meaning, because the words are used in a certain setting and in a certain way as a “string of words”.

#### E. Reciting the counting rhyme in correct order, stops at last counted object

Toddlers who recite the counting rhyme in the correct order often accompany this with pointing actions and conducts the counting in one-to-one correspondence. Ordinality can thereby be interpreted as discerned, especially if the toddler reacts to someone else’s incorrect counting and/or pointing. If the child stops his or her counting action (words and gestures) on the last object, coordinating the reciting and pointing, this may indicate that cardinality is discerned. The counting words have a representational meaning in that they are coordinated with objects that are pointed at and uttered in a stable order, thereby representing a sequence and the ordinality of the counting words are foregrounded.

#### F. Correct counting word for a set of objects

Example: “Soon there will be five”, the toddler is building a tower of bricks one at a time, stops and points and counts when there are five bricks in the tower.

Some toddlers use (correct) counting words for sets of objects. Cardinality is then discerned as an aspect of number. Some are also able to make judgements of whether there are too many or too few objects to make a specific quantity that is asked for (with a counting word). Thus, among these toddlers, ordinality is also discerned. Representations of numbers expressed in the counting words also have a distinct meaning related to the cardinality and ordinality, to the toddlers.

### Overview of discerned aspects

The above fine-grained analysis of the toddlers’ way of using counting words provides a complementary view on number knowledge. This is shown for example when it comes to discerning the meaning of representations. Representations appear as a foundational aspect that foregrounds ordinal and cardinal aspects, which in turn are decisive for experiencing a numerical meaning of counting words (and thereby making possible to use counting words to enumerate and determine a quantity). The analysis further shows that representation in itself constitutes several aspects that determine its meaning, and use. Counting words seen as a representation of numbers can mean a certain kind of words to be used in certain kinds of situations. That is, a general idea of what the counting words are meant to be used for. When toddlers use counting words as a sequence (either random or in a stable order) they have differentiated the words from each other as examples of the same kind of representation. To understand representations in even more advanced ways, other aspects such as ordinality and cardinality are necessary to discern as well, in order for counting words to represent a numerical meaning.

### Progress in development of counting word knowledge

Taking starting point in the above described categories of different ways of knowing and using counting words, we can conclude that there is a distinct difference in *how* but also *when* the toddlers make use of counting words. To further answer the research question, four types of learning trajectories were identified. The numbers in tables 1-4 indicate the number of observations in respective interview.

#### Linear progression in discerning necessary aspects

A typical progression is linear, which means that a toddler in the early interviews use counting words in ways that are interpreted as expressions of not discerning cardinality or ordinality. The toddler rather use counting words and rhythmic chanting as certain kinds of actions and words to be used in certain situations. In the later interviews more necessary aspects are discerned, which is indicated by an increase of reciting of the counting sequence is in correct order and also connected to the set of objects to be counted (see Table 1).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Ways of using counting words** | int 1 | int 2 | int 3 | int 4 | int 5 |
| A. Repeating words in a systematic chanting manner | 0 | 3 | 7 | 1 | 1 |
| B. Random counting word | 0 | 0 | 3 | 8 | 1 |
| C. Reciting the counting rhyme unsystematically | 0 | 0 | 0 | 5 | 0 |
| D. Reciting the counting rhyme, correct order, not connected to se | 0 | 0 | 0 | 2 | 7 |
| E. Reciting the counting rhyme in correct order | 0 | 0 | 0 | 2 | 15 |
| F. Correct counting word for a set of objects | 0 | 0 | 0 | 12 | 10 |

Table 1. Example of linear progression in discerning necessary aspects

#### “Ketchup effect”

Some of the toddlers do not verbally express any discerned aspects of counting words in the first interviews. In the later interviews, however, they suddenly make use of counting words in ways that indicate their discerning all necessary aspects of counting words. Interestingly, for these toddlers all categories usually appear in parallell which may indicate some uncertainty about how to use counting words in different tasks (see Table 2).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Ways of using counting words** | int 1 | int 2 | int 3 | int 4 | int 5 |
| A. Repeating words in a systematic chanting manner | 0 | 0 | 0 | 0 | 1 |
| B. Random counting word | 0 | 0 | 0 | 4 | 6 |
| C. Reciting the counting rhyme unsystematically | 0 | 0 | 0 | 1 | 2 |
| D. Reciting the counting rhyme, correct order, not connected to se | 0 | 0 | 0 | 4 | 5 |
| E. Reciting the counting rhyme in correct order | 0 | 0 | 0 | 5 | 8 |
| F. Correct counting word for a set of objects | 0 | 0 | 0 | 3 | 16 |

Table 2. Example of “ketchup effect” in the discernment of necessary aspects

#### Even progress in discerning necessary aspects

A third observed learning trajectory shows an even progress in discerned aspects, where some actions in the early interviews indicate an awareness of ordinality and cardinality. However, the number of observations indicating this awareness increase, showing an even spread across the categories with tendencies to make use of counting words in a numerical manner more often in later interviews, which indicates their discerning both ordinality and cardinality in addition to representations (see Table 3).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Ways of using counting words** | int 1 | int 2 | int 3 | int 4 | int 5 |
| A. Repeating words in a systematic chanting manner | 0 | 0 | 0 | 0 | 0 |
| B. Random counting word | 0 | 4 | 3 | 2 | 4 |
| C. Reciting the counting rhyme unsystematically | 0 | 2 | 1 | 1 | 0 |
| D. Reciting the counting rhyme, correct order, not connected to se | 1 | 1 | 3 | 1 | 3 |
| E. Reciting the counting rhyme in correct order | 2 | 0 | 7 | 12 | 12 |
| F. Correct counting word for a set of objects | 0 | 3 | 9 | 8 | 15 |

Table 3. Example of even progress in discerning necessary aspects

#### No or limited discernment of necessary aspects

In a few cases, we observed a very limited use of counting words across all interviews indicating that the toddlers were not (yet) discerning any of the necessary aspects of counting words to make use of them in the numerical tasks (see Table 4). Because no later interviews were conducted, it is not possible to draw any conclusions whether they are extreme examples of “ketchup effect” or if there might be other reasons for the toddlers not making use of counting words.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Ways of using counting words** | int 1 | int 2 | int 3 | int 4 | int 5 |
| A. Repeating words in a systematic chanting manner | 0 | 0 | 0 | 0 | 0 |
| B. Random counting word | 0 | 0 | 0 | 0 | 0 |
| C. Reciting the counting rhyme unsystematically | 0 | 0 | 0 | 1 | 0 |
| D. Reciting the counting rhyme, correct order, not connected to se | 0 | 0 | 0 | 0 | 0 |
| E. Reciting the counting rhyme in correct order | 0 | 0 | 0 | 0 | 0 |
| F. Correct counting word for a set of objects | 0 | 0 | 0 | 0 | 0 |

Table 4. Example of no or limited discernment of necessary aspects

The observed progress in development of counting word knowledge among the toddlers in the study shows four typical learning trajectories. These are different regarding at what time some of the necessary aspects of counting words are discerned for the first time, however, most of the toddlers (regardless of learning trajectory) show their discerning all necessary aspects in the fourth interview (as approximately 2.5 year-olds) and even more so in the last interview (with the exception of the fourth trajectory where no or very limited use of counting words have been observed). What the first three learning trajectories seem to have in common, is that all ways of using counting words, even those that do not indicate discerning ordinality or cardinality, are observed also in the later interviews. This might be due to the tasks used in the interviews, which the current analysis has not taken into account.

## Discussion

The results show a frequent use of counting words among the toddlers but also a distinct difference in *how* toddlers make use of counting words. Studying this in terms of discerned aspects of counting words is an approach that complements most earlier research on young children’s number knowledge, where focus often is set on the skills to solve a numerical problem that the children express when encountering numerical tasks (for example if they are able to produce a specific number of items when asked “can you give me n”, see e.g., Sarnecka & Carey, 2008).

First, one result is that to learn the meaning of counting words is a very complex endeavor why what it means to “know” numbers should be given more attention. For example, our study unfolds that to discern the meaning of number representations it is necessary to discern cardinality and ordinality meaning of counting words, while discernment of these latter aspects liberates a more advanced understanding of representations. This might add an explanation to Gibson et al.’s (2019) study showing that children who use several representations, correct or incorrect in numerical sense, more easily learn the cardinal meaning of numbers. Thus, representations are themselves a complex learning object, closely related to other aspects of numbers. More studies, both theoretical and empirical, are needed to distinguish what constitutes this relationship between and within aspects of counting words.

Second, when taking a longitudinal perspective on the discernment of necessary aspects, we conclude that there are quite different learning trajectories among the toddlers. This is an important finding, because the toddlers have participated in the same interventions during a considerably long time period (three semesters). This finding has significant impact on our understanding of how to assess the outcome of interventions implemented in authentic preschool practices, but also on the theoretical understanding of children’s numerical development. This study is however small scale and the participating children are not (yet) followed up in later ages; issues that should be considered and investigated further in future studies.

Third, at the same time as this study shows that it is possible to make fine-grained analyses of toddlers’ actions as expressions of different ways of understanding counting words, the analysis reveals the necessity to include several tasks when drawing conclusions about discerned aspects. Otherwise observations of children counting in a one-to-one correspondence, item-to-counting word, stopping at the last counted item, may be falsely interpreted as the child understanding the cardinality meaning of counting words (see Gelman & Gallistel, 1978; Nuñes & Bryant, 1996).

## References

Baroody, A., & Purpura, D. (2017). Early number and operations: Whole numbers. In J. Cai (Ed.), *Compendium for research in mathematics education* (pp. 308–354). National Council of Teachers of Mathematics.

Björklund, C., Ekdahl, A-L., & Runesson Kempe, U. (2021). Implementing a structural approach in preschool number activities. Principles of an intervention program reflected in learning. *Mathematical Thinking and Learning, 23*(1), 72–94. https://doi.org/10.1080/10986065.2020.1756027

Björklund, C., Marton, F., & Kullberg, A. (2021). What is to be learnt? Critical aspects of elementary arithmetic skills. *Educational Studies in Mathematics, 107*(2), 261–284. https://doi.org/10.1007/s10649-021-10045-0

Björklund, C., & Palmér, H. (2021). Designing a tool for exploring toddlers’ number knowledge in preschool. In Y. Liljekvist, L. Björklund Boistrup, J. Häggström, L. Mattsson, O. Olande, & H. Palmér (Eds.), *Sustainable mathematics education in a digitalized world.* Proceedings of MADIF 12 The twelfth research seminar of the Swedish Society for Research in Mathematics Education, Växjö, 2020 (pp. 1–10). SMDF.

Björklund, C., & Palmér, H. (2022). Teaching toddlers the meaning of numbers: Connecting modes of mathematical representations in book reading. *Educational Studies in Mathematics, 110*, 525–544. <https://doi.org/10.1007/s10649-022-10147-3>

Björklund, C., & Palmér, H. (2023). Enhancing Swedish toddlers’ learning opportunities through interactions with pictures and narrative designed for numerical learning purposes. *Early Childhood Education Journal*. Advance online publication. https://doi.org/10.1007/s10643-023-01556-x

Björklund, C., & Runesson Kempe, U. (2019). Framework for analysing children’s ways of experiencing numbers. In U. T. Jankvist, M. Van den Heuvel-Panhuizen, & M. Veldhuis, (Eds.), *Proceedings of the Eleventh Congress of the European Society for Research in Mathematics Education* (CERME11, February 6 – 10, 2019). Utrecht, the Netherlands: Freudenthal Group & Freudenthal Institute, Utrecht University and ERME.

Duval, R. (2006). A cognitive analysis of problems of comprehension in a learning of mathematics. *Educational Studies in Mathematics, 61*(1), 103–131.

Fuson, K. (1992). Research on whole number addition and subtraction. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 243–275). Macmillan.

Gelman, R., & Gallistel, C. (1978). *The child’s understanding of number*. Harvard University Press.

Gibson, D., Gunderson, E., Spaepen, E., Levine, S., & Goldin-Meadow, S. (2019). Number gestures predict learning of number words. *Developmental Science, 22:e12791*, 1–14. https://doi.org/10.1111/desc.12791

Lesh, R., Post, T. R., & Behr, M. (1987). Representations and translations among representations in mathematics learning and problem solving. In C. Janvier (Ed.), *Problems of representation in the teaching and learning of mathematics* (pp. 33-40)*.* Lawrence Erlbaum Associates.

Marton, F. (2015). *Necessary conditions of learning*. Routledge.

Nuñes, T. & Bryant, P. (1996). *Children doing mathematics*. Blackwell Publishers.

Palmér, H., & Björklund, C. (2022). Divergence in interviews with children: Improving research quality. *Designs for learning, 14*(1), 52–57. http://doi.org/10.16993/dfl.187

Palmér, H., & Björklund, C. (2023). The teaching of numbers in common preschool activities: A delicate balancing act. *Early Childhood Education Journal, 51*, 971–980. https://doi.org/10.1007/s10643-022-01354-x

Sarnecka, B., & Carey, S. (2008). How counting represents number: What children must learn and when they learn it. *Cognition, 108*(3), 662–674.

Van Oers, B. (2010). Emergent mathematical thinking in the context of play. *Educational Studies in Mathematics, 74*, 23–37.

Venkat, H., Askew, M., Watson, A., & Mason, J. (2019). Architecture of mathematical structure. *For the Learning of Mathematics, 39*(1), 13–17.