# Situated counting

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We present a model of how counting is learned from the perspective of situated cognition, focusing on the cognitive structures that are involved. As an epistemological basis we present the three knowledge components that are involved. In order to be able to count, one needs to:
(1) know that numerosity is a property of collections.
(2) be able to recite a list of numerals (up to a certain level).
(3) be able to create one-to-one mappings from one collection of items to another collection.

We argue that these components develop independently and then get conceptually linked. The component (1) involves the knowledge that the answer to the question "How many?" refers to a collection and that the answer is independent of the spatial locations of the objects in the collection, and is also independent of other features of collections, such as the total surface occupied by the collection, and of the features of the objects in collections, such as their shape or colour. The component (2) typically consists in the ability to recite names for numerals learned by heart. A child may have this knowledge, but not be able to fulfil (3). On the other hand, a child can know how to create a one-to-one mapping, that is (3), without knowing or understanding the words for the numerals. This shows that the abilities (2) and (3) are independent.

Our main focus in this talk is on the development of the ability to form one-to-one correspondence. Following the approach of situated cognition, we show that this ability in many ways depends on the character of the items that are involved in this process.

In the literature, much attention has been devoted to the so-called cardinality principle, which says that the last numeral used in a count represents the cardinality of the items counted (Sarnecka and Carey 2008, Carey 2009). Our analysis of the situation from the perspective of situated cognition leads us to arguing that this principle is not sufficient to determine when children are able to count (see also Davidson et al. 2012).

In order to understand better which cognitive structures are involved in the one-to-one correspondence performance the second part of the paper is devoted to the analysis of counting as a sequence of six tasks: (i) identify the collection to be counted; (ii) select an uncounted item; (iii) increment the count; (iv) mark the counted item; (v) stop when all items are counted; and (vi) identify the cardinality of the collection with the last numeral. Only the last task is applying the cardinality principle. The tasks cannot be performed without building on the three knowledge components.

Some of these tasks may be supported by the external organization of the counting situation. Using the methods of situated cognition (Zhang and Norman 1994), we separate internal representations (in the mind) from external representations (in the world). We analyse how the balance between external and internal representations will imply different loads on the working memory and attention of the counting individual. In relation to the task of counting, the main question concerns to what extent the tasks (i) – (vi) involve a load on working memory and attention. The more that is required, the greater is the risk that the counter makes an error in some of the tasks.

To some extent following Fuson (1988), we analyse a number of cases of counting situations, where reciting numerals is coordinated with the elements of a collection. These cases involve establishing a one-to-one mapping between the *temporal* domain of the recital and the *spatial* domain of the collection. We show that various one-to-one correspondences and counting routines depend on the amount of external cognitive support that is provided. For example, if the items to be counted are linearly ordered, then step (ii) (selecting an uncounted item) is easy to fulfil, while if the items are unordered, then keeping track of which item are not counted involves a high load on the working memory of the counter. However, if the items of an unordered set can be moved (by the finger of the counter, for example), then it is visually easy to determine which items have been counted and thereby to select an uncounted item. Moving the objects also makes it easy to fulfil step (v) (stop when all items are counted.

Our analysis shows that even if the counter applies the cardinality principle – what is called a CP-knower (Sarnecka and Carey 2008), the other tasks of the counting procedure will be more or less difficult depending on which kind of collection is to be counted. Being a CP-knower is therefore not sufficient to be able to count

An important aspect that has been neglected in earlier literature on counting is that the elements that are counted typically have a distribution in *space*, for example, the cookies to be counted are located on a plate, while the recital of numerals and the pointing to the objects is a process in *time*. This means that standard counting involves a mapping from the *time* domain to the *space* domain (Gärdenfors 2000). If the numerals are instead externally presented in a linear spatial layout, then the working memory involved in reciting the numerals in the correct order (task (iii)) can be offloaded. We show that this setup makes counting cognitively easier.

Our aim has not been to propose specific protocols of experiments. Instead, our purpose has been to motivate philosophically the need for experiments studying the impact of situated cognition and the ability to create one-to-one correspondences on how counting is learned. We believe that our theoretical investigations into temporal and spatial aspects of counting will be valuable for experimental research in numerical cognition.

## References

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