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A 3-year longitudinal study of children's comprehension of counting: Do they recognize the optional nature of nonessential counting features?☆

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ABSTRACT

This 3-year longitudinal study examines developmental changes in children's ability to differentiate essential from nonessential counting features. Kindergarteners watched a computer-presented detection task which included three kinds of counts: correct conventional, erroneous and pseudoerrors (with and without statements of cardinal values for the sets). Children had to judge the correctness of those counts and justify their responses. Our data showed that children's explanations provided additional information and thus increased reliability of the assessment. Children were better at detecting erroneous counts than pseudoerrors and at detecting pseudoerrors with cardinal value than pseudoerrors without it. Group analysis showed that children's performance improved with age but analysis of individual differences qualified this result by identifying individual differences in developmental patterns. This study thus provides a more detailed picture of the developmental trajectories of children's comprehension of essential and nonessential counting aspects.

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Understanding how children develop the ability to count is crucial not only from a psychological perspective but also because of its educational importance. After decades of research, recent studies suggest that it is necessary to consider children's comprehension of the essential and nonessential aspects involved in counting (Briars & Siegler, 1984; Escudero, 2012; Kamawar et al., 2010; Laupa & Becker, 2004; LeFevre et al., 2006; Rodríguez, Lago, Enesco, & Guerrero, 2013).

Essential aspects, also known as *logical*[1] *rules*, are indispensable for counting correctly and are defined by the five principles described by Gelman and Gallistel (1978): (a) one-to-one correspondence: assigning a unique tag to each element; (b) stable order: the tags used must be unique, and their order must be the same in successive counts; (c) cardinality: the final tag used has a special significance, as it provides a cardinal value to the set; (d) abstraction: the three previous principles may be applied to any collection of objects; and (e) order irrelevance: the order in which elements are counted does not affect the cardinal value of the set. The first three principles are known as *how-to-count principles* because they define the conceptual structure of counting, and the last two principles are known as *permissibility principles* because they expand and give flexibility to the range of conditions under which the first three may be applied.

Nonessential aspects, or *conventional rules*, depend on the context or common practices. Nonessential aspects regularly appear in the procedures witnessed by children although they are not necessary for correct counting. For example, in Western culture, a common practice consists of counting rows of objects from left to right consecutively, but violating this conventional rule does not lead to incorrect answers as long as the counting principles are correctly applied.

Although Gelman and Gallistel (1978) stated that many counting behaviors are arbitrary, Briars and Siegler (1984) were the first to define four nonessential characteristics: (a) pointing to each object once, (b) starting from one end, (c) counting from left to right, and (d) counting all objects consecutively (adjacency). Recently, Rodríguez et al. (2013) also identified two types of adjacency using explanations offered by children: spatial, which coincides with the type described by Briars and Siegler (1984), and temporal, which involves emitting all of the numerical tags without skipping forwards or backwards, pausing, or iterating.

Children's comprehension of the essential and nonessential aspects of counting has been studied using detection tasks in which the child must observe how a character (e.g., an adult, doll, or puppet) counts and then judge whether the counting has been performed correctly or incorrectly. In some cases, the character counts correctly according to the usual mode (correct conventional counts). In other cases, the character fails to comply with a specific logical rule (erroneous counts), for example by assigning the same numerical tag to two different elements. Finally, at other times, the character counts correctly in a nonconventional mode (nonconventional counts or pseudoerrors), for example beginning to count at an element located in the middle of the row.

Because of inconsistent results from the pioneering studies of Gelman and Meck (1983), Gelman and Meck (1986) and Briars and Siegler (1984), in which the results of the former study revealed the capacity of 3–5-year-olds to correctly detect pseudoerrors or nonconventional counts, while the latter findings revealed the poor performance of children of the same age with similar counts, recent research has expanded the age range to include primary school children (Escudero, 2012; Kamawar et al., 2010; LeFevre et al., 2006; Rodríguez et al., 2013). These investigations corroborate the proposal by Briars and Siegler (1984), which states that the differentiation of the essential and nonessential aspects of counting is not complete at 5 years of age. In general, the findings also agree in demonstrating that children judge both erroneous counts (transgressing logical rules) and unusual counts or pseudoerrors (transgressing conventional rules) as incorrect.

Finally, several studies have shown that children with and without learning disabilities have difficulties in distinguishing between logical and conventional counting rules (Geary, Bow-Thomas, & Yao, 1992; Geary, Hamson, & Hoard, 2000; Geary, Hoard, Byrd-Craven, & DeSoto, 2004). For example, Geary et al. (2004) found that it is necessary for children without learning disabilities to reach 8–9

[1] The term "logical" refers to the conceptual knowledge involved in the counting principles, not to the Piagetian notion of logical development.