Cognitive Development 48 (2018) 235–243

Contents lists available at ScienceDirect

Cognitive Development

journal homepage: www.elsevier.com/locate/cogdev

Symbolic representations and cardinal knowledge in 3- and 4-year-old children

Jimena Rodríguez[a], Eduardo Martí[b], Analía Salsa[a,*]

[a] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina
[b] Universidad de Barcelona, Spain

ARTICLE INFO

Keywords:
Cardinal knowledge
Symbolic representation
Iconicity
Number words

ABSTRACT

This study analyzes the impact of iconic representations of quantity (objects and images) and arbitrary representations (spoken number words) on the performance of 3-, 3.5- and 4-year-old children when building collections of 1–6 items. We used an adaptation of the Give-N task in which children had to use the information about quantity transmitted by collections of bottle caps, round dots on cards and number words. The results show that iconic representations helped children produce sets which cardinal values were larger than their known number words. This pattern of results was found in a transitional stage to learning that a given number word picks out an exact cardinal value, for set sizes 3 and 4 among children in all three age groups. These findings suggest that children would be in different (but proximal) levels of cardinal competency according to the symbolic modality employed to present the quantitative information.

1. Introduction

Children's understanding of cardinality and the mechanisms underlying the acquisition of this knowledge are at the centre of current debates in developmental literature. A large body of research has examined how young children begin to understand the cardinal meanings of the first number words, an acquisition that occurs slowly and in order. There is approximately an 18 month lapse, between 2 and 4 years of age, from the moment in which children are able to produce and label collections of 1 item until the time they can do so with collections of 4 or more items, when children typically learn that the last number word reached when counting a set represents the size of the whole set (cardinal principle) (Condry & Spelke, 2008; Gelman & Gallistel, 1978; Huang, Spelke, & Snedeker, 2010; Sarnecka & Carey, 2008; Sarnecka & Lee, 2009; Wagner & Johnson, 2011; Wynn, 1990, 1992).

At these ages, the development of cardinal knowledge has been investigated by using a variety of experimental tasks such as asking children to state the number of items that are displayed on a card, or picking up a given number of elements from a larger set. From the knower-levels account (Baillargeon & Carey, 2012; Sarnecka, 2015; Wynn, 1992) the expressions "one-knowers", "two-knowers", and "three-knowers" are used to refer to children who succeed in these tasks with the quantities of 1, 2 and 3, respectively. Similarly, the expression "pre-number knowers" is used to refer to children who do not coherently relate number words with cardinal values. Thus, early cardinal knowledge seems to be associated with the ability to use and understand the unique and exact cardinal meaning of the first number words.

However, spoken number words (referred to simply as "number words" in subsequent mentions) are only one way to represent quantity. From early on in life, children interact in their sociocultural environments with other symbolic representations of quantity

* Corresponding author at: Instituto Rosario de Investigaciones en Ciencias de la Educación – IRICE (CONICET), Bv. 27 de Febrero 210 bis, 2000, Rosario, Argentina.
E-mail address: salsa@irice-conicet.gov.ar (A. Salsa).

https://doi.org/10.1016/j.cogdev.2018.09.004
Received 27 March 2017; Received in revised form 11 June 2018; Accepted 26 September 2018

(i.e. objects, images, number gestures, written number words or numerical notations such as Arabic numerals used to indicate quantity in a set) that pose a gradient of cognitive and symbolic challenges for young children. The present study compares the effects of three symbolic representations of quantity, namely, objects, images and number words, on 3-, 3.5- and 4-year-old children's ability to construct collections of different cardinal values. Until now, developmental research has not paid enough attention to symbolic components of number and the role that they play in the first steps of its acquisition (Martí & Scheuer, 2015; Sfard & Lavie, 2005; Sfard, 2000; Walkerdine, 1988).

1.1. Symbolic representations of quantity

Symbolic representations of quantity differ from each other on various levels. Number words and gestures (finger patterns to represent a set size) are ephemeral representations in the sense that they unfold over time and therefore do not have a materiality. In contrast, numerical notations, images (drawings or graphic marks on a card) and collections of objects are permanent representations; they are displayed in space and have a concrete reality which facilitates their handling and preservation (Martí, 2003; Tolchinsky, 2003). Given the role of executive functions in number knowledge (Cragg & Gilmore, 2014; Cragg, Keeble, Richardson, Roome, & Gilmore, 2017), differences in working memory demands may be related to the ephemeral or permanent nature of representations. For example, when children have to produce sets of elements corresponding to the number words provided by an adult, they need to hold the requested quantity in memory and compare it to the number of items produced because the number words vanish as soon as they are spoken.

Another aspect in which symbolic representations of quantity vary is how they represent their numerical referents (Martí, 2003; Tolchinsky, 2003; Wiese, 2003). Iconic representations, number gestures, drawings or objects, are item-based representations because there is a one-to-one correspondence between their elements and the elements of the represented collection. Instead, number words and Arabic numerals establish an arbitrary relation to what they represent: their forms do not map transparently to the number of items in a set.

In addition, symbolic objects and images have a "dual reality" (Gibson, 1979; Ittelson, 1996) in the sense that they have both a physical and representative nature. DeLoache (1995, 2002) has shown that, to symbolically use an object or a picture, one must mentally represent both facets of their dual reality; that is, one must represent the concrete entity itself and simultaneously its relation to its referent (dual representation). Numerous studies have demonstrated that young children comprehend and use the symbolic function of pictures before objects (DeLoache, 1987, 1991; Marzolf & DeLoache, 1994). Although images are physical objects, their conventional function is to be a symbolic representation (as opposed to the three-dimensional objects that may have other instrumental functions), so they present less of a challenge with respect to dual representation. An object (or a set of objects in the case of representing the number of objects in another collection) has salient characteristics that may draw children's attention to its physical and instrumental characteristics, hindering the possibilities of interpreting its representational status (McNeil, Uttal, Jarvin, & Sternberg, 2009; Uttal et al., 2013).

Objects and images also allow for the realization of different activities. For instance, a collection of objects can be manipulated: children can separate the items, form smaller collections, and bring them back together to again form a global collection. Images do not have this flexibility, the drawings or marks depicted in a picture cannot be manipulated individually; they have to be observed as a whole. In the current study, we wondered if the differential properties between two- and three-dimensional representations that introduce a clear impact on the symbolic domain may be relevant to emerging cardinal knowledge.

1.2. Iconic and arbitrary representations in cardinal knowledge

A few studies have investigated how different symbolic representations of quantity affect the onset of cardinal knowledge. Bialystok and Cood (1996) asked children of 3, 4 and 5 years of age to produce (by writing or drawing on a blank card) or to select (from a set of printed cards) a representation and then use it to recall the number of items contained in a closed box; the cards depicted Arabic numerals or arrays of dots. In general, results showed that Arabic numerals responses increased with age in both tasks, and that they were more reliable than dots as an indication of quantities less than 10 for children in all age groups.

In a more recent study, Nicoladis, Pika and Marentette (2010) tested 2- to 5-year-old children in the Give-a-Number ("Give-N") and the How Many tasks (Wynn, 1990, 1992) using number words and gestures. For the Give-N task, the experimenter gave 16 toys to the children and asked them to put in a box the quantity of toys corresponding to either the number word she said or the number gesture she made (from 1 to 10). For the How Many task, the experimenter presented the children with a collection of toys and asked them to either say orally how many toys there were or to show the correct number of fingers to represent the quantity of toys. The results indicated that children were more accurate with number words than with number gestures on both tasks, particularly the older children (4- to 5-year-olds) with set sizes 6, 7, 8 and 9.

Taken together, the aforementioned studies suggest a facilitative effect of arbitrary representations (Arabic numerals and number words) in comparison to the iconic ones (arrays of dots and number gestures) for some cardinal values. Recent work shows that 3- and 4-year-olds may first map Arabic numerals to number words (two arbitrary representations of number) and only through this mapping are numerals subsequently tied to the quantities they represent (Hurst, Anderson, & Cordes, 2017).

With regard to iconic representations, only two studies that we are aware of have experimentally investigated how objects and images affect children's understanding of quantity. Petersen et al. (2014) compared the effects of counting practice with picture books versus physical objects on 3.5-year-old children's counting skill and understanding of cardinality. Children who practiced counting with images improved their performance on the Give-N task (numbers 1–6), but children who practiced counting with three-