Consciousness and Cognition 40 (2016) 45–53

Contents lists available at ScienceDirect

Consciousness and Cognition

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

Finger counting habit and spatial–numerical association in children and adults

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ARTICLE INFO

Article history:
Received 1 July 2015
Revised 14 December 2015
Accepted 27 December 2015
Available online 31 December 2015

Keywords:
Finger counting
Spatial–numerical association
Number-to-position task
Number bisection task
Embodied cognition

ABSTRACT

Sensory-motor experiences are known to build up concrete and abstract concepts during the lifespan. The present study aimed to test how finger counting habits (right-hand vs. left-hand starters) could influence the spatial–numerical representation in number-to-position (explicit) and digit-string bisection (implicit) tasks. The subjects were Italian primary school children ($N = 184$, from the first to the fifth year) and adults ($N = 42$). No general preference for right- or left-starting in the finger counting was found. In the explicit task, right- or left-starting did not affect performance. In the implicit task, the right-hand starters shifted from the left to the right space when bisecting small and large numbers respectively, while the left-hand starters shifted from the right to the left space with higher leftward bias for large numbers. The finger configuration in Italian children and adults influences the spatial–numerical representation, but only when implicit number processing is required by the task.

1. Introduction

Embodied and grounded cognition theories (e.g., Barsalou, 1999; Barsalou, 2008; Wilson, 2002) state that human knowledge is grounded into perception–action systems through which sensory-motor experiences build up concrete and abstract concepts during the lifespan. Recently, an embodied nature of numbers has also been proposed for numerical cognition (Di Luca & Pesenti, 2011; Fischer & Brugger, 2011; Moeller et al., 2012). Across different cultures and ages, numbers are represented using body parts, such as hands and fingers (Butterworth, 2005). For instance, children use their fingers when they learn to count and calculate (Fuson & Kwon, 1992). From a developmental point of view, fingers are used not only to represent numerosities but also to establish the one-to-one correspondence principle (e.g., Gallistel & Gelman, 1992). In 4-year old children, Alibali and DiRusso (1999) showed that not only was finger counting helpful to keep track of the counted objects, but it also increased the coordination between number words and objects. Moreover, as we have 10 fingers, bimanual finger counting is probably useful to sustain the comprehension of the 10-base numerical system as well as the realization of basic arithmetic operations. Consequently, it has been observed that children with difficulties in learning arithmetic use finger counting as a classical resource for solving arithmetic problems (Butterworth, 1999). Even if children frequently use finger counting to grasp numerical knowledge, little attention has been directed to the study of the relationship between finger counting and the spatial nature of number representation.

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http://dx.doi.org/10.1016/j.concog.2015.12.012
1053-8100/

Concerning finger counting, Lindemann, Alipour, and Fischer (2011) reported cultural differences in finger counting habits. In other words, Western (European and American) individuals preferred to start counting with their left hand, while Middle Eastern individuals preferred to start counting with their right hand. This finding seems to suggest that the cultural finger counting mapping is related to the direction of spatial–numerical association. Nevertheless, Lindemann et al. (2011) also observed that within Western culture there were some differences in the hand used to start counting the numbers. Indeed, Italian, Belgian and French participants showed more of a right-starting preference than a left-starting preference. Specifically, in Italian culture, the right-starting preference is considered a prototypical finger counting habit (Di Luca, Grana, Semenza, Seron, & Pesenti, 2006; Fabbri, 2013; Sato, Cattaneo, Rizzolatti, & Gallese, 2007).

Spatial number representation has been described by many studies on adults with particular attention to the *Spatial–Numerical Association of Response Codes* (or SNARC) effect discovered by Dehaene, Bossini, and Giraux (1993; for a review see, Wood, Nuerk, Willmes, & Fischer, 2008). Briefly, in a parity task, the SNARC effect indicates that small numbers (e.g., 1) are associated with the left space, while large numbers (e.g., 9) are associated with the right space. This spatial–numerical association reflects the idea that numbers are represented using the metaphor of a left-to-right mental line. The SNARC effect is culturally mediated: in Western culture, numbers are represented from left to right along the mental line, while in Middle-Eastern culture, the SNARC effect is reversed, suggesting a right-to-left mental number line (e.g., Zebian, 2005; for a review see, Göbel, Shaki, & Fischer, 2011). Reviewing the developmental studies on the SNARC effect, the onset of the SNARC effect is not clear (Patro & Haman, 2012). For instance, Berch, Foley, Hill, and Ryan (1999) showed that the SNARC effect did not emerge until third grade (about 9 years, in the American system). Differences in the emergence of the SNARC effect were described in function of explicit and implicit processing. In fact, a SNARC effect was described in 7-year old children when explicit processing of numerical magnitude was required (in a magnitude comparison task) and in 8–9-year old children when the numerical information was not explicitly processed (see also, Imbo, Brauwer, Fias, & Gevers, 2012, for Belgium children; Schweiter, Weinhold Zulauf, & von Aster, 2005, for Swiss children; van Galen & Reitsma, 2008, for Dutch children). However, Patro and Haman (2012) found that young preschoolers exhibited a spatial–numerical congruity effect during a nonsymbolic numerosity comparison, and thus, the preschoolers were faster to compare between stimuli sets when the small set appeared on the left side and the large set on the right side. This result probably reduces the cultural influence on spatial representation of numbers, but it remains that some cultural factors, like finger counting, may influence the numerical representation, even in preschoolers, as Patro and Haman (2012) suggested.

The relationship between finger counting and the SNARC effect has been explored by few studies in the past 10 years, with more attention to adults than to children. Fischer (2008) observed that Scottish left-hand starters (those who counted numbers 1–5 using the fingers on their left hand, while the fingers on the right hand were used to count numbers 6–10) showed a stronger SNARC effect than right-hand starters (those who counted numbers 1–5 with their right hand). By contrast, Fabbri (2013) showed a stronger SNARC effect for Italian right-starting than left-starting adults. This result was in line with the findings reported by Di Luca et al. (2006), who showed that Italian adults with a right-starting preference classified a single digit on the screen faster when the numbers from 1 to 10 were assigned to the fingers they normally used during finger counting. The comparison between Fischer's (2008) and Fabbri's (2013) studies suggested that the most often-reported finger counting mapping in a particular culture may play a role in the spatial–numerical association. In other words, the individuals with the preferred finger counting mapping exhibited a stronger SNARC effect. According to this account, Di Luca and Pesenti (2008, 2010) showed that adult subjects were faster in naming numerical finger configurations when they conformed to their own preferred finger counting habits than when they did not. Thus, the idea could be advanced that left- and right-starting preferences influence spatial–numerical association, contributing in a different way. For instance, Tscherntscher, Hauk, Fischer, and Pulvermüller (2012) presented Arabic digits (ranging from 1 to 9) and the corresponding number words to adults with left- and right-starting preferences in finger counting. The hemisphere that was contralateral to the hand used for counting small numbers was activated when small numbers were presented, supporting the idea that the finger counting habit has an influence on numerical processing. To our knowledge, few studies have investigated this issue in children. For example, Knudsen, Fischer, and Aschersleben (in press), recently, reported the directional preferences in finger counting, object counting, and picture naming for German children from 3- to 6-year-olds and for adults. In all children groups, an higher frequency of right-starting preferences was found (see also Sato & Lalain, 2008 for similar results with French children), with a left-side preference for counting objects and naming pictures, especially at the 6 years of age. However, the study did not clearly test the relationship between finger counting preference and spatial–numerical representation. The present study aimed to investigate finger counting habits in Italian children and adults and the relationships between these and numerical representation.

In the present study, we first compared the finger counting habits of Italian school children (from first- to fifth-grade) and adults, and then tested whether the left- and right-starting preferences influenced spatial biases in two tasks where the spatial–numerical association was measured. The tasks used were the number-to-position (NP) and the manual digit-string (DS) tasks. The choice of these tasks was based on the assumption that both tasks required an involvement of the spatial–numerical representation, with the difference that in the NP task an explicit spatial–numerical association was required, while in the DS task the spatial–numerical involvement was implicit.

In the NP task (for a review see, Siegler, Thompson, & Opfer, 2009) a horizontal bounded number line with labeled endpoints (0–10, 0–100, or 0–1000) and a target number were administered. In each trial, the participants were asked to indicate the position that the target number would occupy on the number line (Siegler & Opfer, 2003). Even if several theoretical models can account for the estimation performance of children and adults in the NP task (e.g., Barth & Paladino, 2011),