Journal of Experimental Child Psychology 131 (2015) 19–37

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

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

Set size and culture influence children's attention to number

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ARTICLE INFO

Article history:
Received 16 April 2014
Revised 25 October 2014
Available online 29 November 2014

Keywords:
Cross-culture
Number
Quantity
Attention
Vision
Holistic
Perception

ABSTRACT

Much research evidences a system in adults and young children for approximately representing quantity. Here we provide evidence that the bias to attend to discrete quantity versus other dimensions may be mediated by set size and culture. Preschool-age English-speaking children in the United States and Japanese-speaking children in Japan were tested in a match-to-sample task where number was pitted against cumulative surface area in both large and small numerical set comparisons. Results showed that children from both cultures were biased to attend to the number of items for small sets. Large set responses also showed a general attention to number when ratio difficulty was easy. However, relative to the responses for small sets, attention to number decreased for both groups; moreover, both U.S. and Japanese children showed a significant bias to attend to *total amount* for difficult numerical ratio distances, although Japanese children shifted attention to total area at relatively smaller set sizes than U.S. children. These results add to our growing understanding of how quantity is represented and how such representation is influenced by context—both cultural and perceptual.

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http://dx.doi.org/10.1016/j.jecp.2014.10.010
0022-0965/

Introduction

A large body of research shows that human adults and young children—without counting—approximately represent the number of items in a set through a noisy cognitive system frequently called the approximate number system (ANS) (Dehaene, 1997; Feigenson, Dehaene, & Spelke, 2004; Kaufman, Lord, Reese, & Volkmann, 1949; Whalen, Gallistel, & Gelman, 1999; Xu & Spelke, 2000). The ability has been associated with two main ideas. First, representation in the system has been argued by some researchers to be biased to number (e.g., Cantlon, Safford, & Brannon, 2010; Cordes & Brannon, 2008; Odic, Libertus, Feigenson, & Halberda, 2013). That is, although the congruency of number and other quantity dimensions such as total amount, density, and item size boosts accuracy in numerical decisions, when number is pitted against these other dimensions—that is, when participants are presented with sets of items and their memory is later tested for which of two dimensions was most robustly stored (e.g., number *or* total amount)—number often wins out, suggesting that number not only is salient but also may be most relevant in decisions about quantity (Brannon, Abbott, & Lutz, 2004; Cantlon & Brannon, 2007; Cantlon et al., 2010; Cordes & Brannon, 2008; Odic et al., 2013). Second, accuracy in quantity judgments, within the current understanding of the ANS, are dependent on the ratio of difference in the numerical value of two sets, and this is presumably true for all set sizes (although there is some debate for small sets; e.g., Whalen et al., 1999; Cantlon et al., 2010; see Feigenson et al., 2004, for a review). This means that, all other factors being equal, the ease of discriminating and comparing 8 and 12 (sets that present a 2:3 ratio of difference) should be the same as the ease of discriminating and comparing 12 and 18, 20 and 30, or relatively larger sets of 40 and 60 items.

Here we present data suggesting that attention to other dimensions of quantity may be more salient in certain contexts and that comparison of two numerical sets is not determined solely by ratio dependency. Specifically, the data we present demonstrate that attention to number versus total amount depends on the set size in which items are presented and the cultural and linguistic history of the viewer. We suggest that our findings are—as researchers have previously suggested—the result of a quantity system that represents multiple dimensions (e.g., Abreu-Mendoza, Soto-Alba, & Arias-Trejo, 2013; Cantlon, Platt, & Brannon, 2009; Gebuis & Reynvoet, 2012a; Lourenco & Longo, 2011; Rousselle, Palmers, & Noël, 2004; Walsh, 2003); however, we suggest that—novel to the literature—the degree to which a dimension or combination of dimensions is stored in the representation *varies and shifts* as a function of these contextual factors. We first briefly review relevant literature that led to the hypothesis that culture and set size should affect attention to number versus total amount and then turn to the details of the main experiments.

Set size effects on attention to numerosity?

The number of items in a set influences how children and adults think and speak about those items. Items in small sets are frequently described as collections of *individual things,* with noun labels taking the plural (e.g., some cows, four birds, a few grains); large sets are frequently described as collective wholes or aggregated amounts (e.g., a herd, a flock, sand) (see Middleton, Wisniewski, Trindel, & Imai, 2004, and Wisniewski, 2009). Recent findings from a study investigating how children and adults categorize items provides supporting evidence (Cantrell & Smith, 2013b): items in small sets were attended to, represented, and categorized as discrete individuals (being categorized by their individual shapes), whereas items in large sets were not. Cantrell and Smith (2013b) noted that the relation between the number of items in a set and the types of nouns we use to talk about those sets could be related to perceptual processes of discrete object representation—processes that are known to be limited by item density and the proximity of elements to each other (Dukette & Stiles, 1996; Hyde & Wood, 2011; Pelli, Palomares, & Majaj, 2004). As the items in an array become more numerous, they are likely be more visually crowded—a stimulus property that limits the identification of individual items—and studies of visual processing show that there is a limit at which crowded arrays are not perceived as independent elements but the whole is perceived as a texture (Morgan, Raphael, Tibber, & Dakin, 2014; Parkes, Lund, Angelucci, Solomon, & Morgan, 2001; see also Robitaille & Harris, 2011). Although many sets can be seen and construed in both ways (as a set of individuals units