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Competing features influence children's attention to number

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ABSTRACT

Spontaneous focus on numerosity (SFON), an attentional process that some consider distinct from number knowledge, predicts later mathematical skills. Here we assessed the "spontaneity" and malleability of SFON using a picture-matching task. We asked children to view a target picture and to choose which of four other pictures matched the target. We tested whether attention to number (defined as number-based matches) was affected by (a) age, (b) the presence of very noticeable (or salient) features among alternative match choices, and (c) the examiner's use of motor actions to emphasize numerosity. Although adults attended to number more frequently than did preschoolers, the salience of competing features affected responses to number in both age groups. Specifically, number-based matches were more likely when alternative choices matched the target on features of low versus high salience (e.g., the relative location within a picture frame vs. color). In addition, adults' attention to number was more frequent if their first exposure to number-based matches occurred with alternative choices that matched the target on low salience features. This order by salience interaction was not observed among children. Simply observing motor actions that emphasized number (i.e., tapping stimuli) did not enhance children's attention to number. The results extend previous findings on SFON and provide evidence for the contextual influences on, and malleability of, attention to number.

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Introduction

Early numerical skills are paramount to later mathematics achievement. Among the earliest observed numerical skills are those that involve attending to numerical features in daily environments. That children attend to numerical details is supported by evidence that children can differentiate among small sets of 1–4 objects and can even differentiate large sets provided that the sets differ by a detectable ratio. The ability to discriminate among large approximate quantities is a skill that develops early and quickly, improves gradually until early adulthood, and is subject to large individual differences that are correlated with mathematics achievement throughout development (Halberda, Mazzocco, & Feigenson, 2008; Libertus, Feigenson, & Halberda, 2013; Starr, Libertus, & Brannon, 2013). In contrast, the ability to identify small exact numbers of individual objects (3 or 4) emerges and plateaus early in development and is subject to minimal individual variation (Antell & Keating, 1983; Revkin, Piazza, Izard, Cohen, & Dehaene, 2008; Starkey & Cooper, 1995).

To recognize and compare numerosities of any size, a person must attend to the numerical aspect of a set, an aspect that nearly always co-occurs amid other features. Hannula-Sormunen and colleagues propose that attention to numerical aspects of objects or events supports identifying exact number, which in turn facilitates number word learning. They define spontaneous focus on numerosity (SFON) as the tendency to focus on numerical features across contexts and *without prompting*, and they argue that SFON is distinct from, and predictive of, formal number knowledge (Hannula & Lehtinen, 2005; Hannula-Sormunen, 2015; Railo, Koivisto, Revonsuo, & Hannula, 2008). Baroody and colleagues propose a related but distinct construct, spontaneous attention to number (SAN), which they define as an attentional process that supports recognition and differentiation of small exact numbers. They argue that learning number words directs children's attention to exact numerosities of known numbers (Baroody & Li, 2016; Baroody, Li, & Lai, 2008; Li & Baroody, 2014). The distinction between SFON and SAN constructs remains a topic of ongoing debate (Baroody & Li, 2016; Hannula-Sormunen, McMullen, Räsänen, Lepola, & Lehtinen, 2016), but both approaches concern children's attending to number and view attention to number as spontaneous. Here we proposed that this attention is contextually bounded and might not be entirely spontaneous.

In our study, we examined whether the presence of competing non-numeric features in a matching task detracts participants from the relative salience of number as a potential basis for matching pictures. We use the term "salience" to refer specifically to the measurable frequency with which a given feature of a stimulus (e.g., its color, shape, orientation, or quantity) is selected as a basis for a match with another target stimulus. In this way, we measure the malleability of SFON behavior and, thus, challenge the notion of spontaneity.

SFON and SAN tasks often involve asking children to imitate an examiner's actions such as individually feeding berries to a toy parrot (Hannula & Lehtinen, 2005) and observing whether children reproduce the correct number of action-linked behaviors. More recently, however, Batchelor and colleagues designed an SFON task that involves no actions and instead requires describing pictures (Batchelor, Inglis, & Gilmore, 2015). A feature shared across all SFON and SAN tasks is that the examiner refrains from explicitly drawing children's attention to number so as to afford children's *self-initiated* focus on numerosity. In the current study, we proposed that number may be implicated in other ways even if unintentionally. We tested this notion by manipulating whether an examiner's motion can increase the salience of numerical features during a matching task.

Are SFON and SAN spontaneous?

It is possible that SFON and SAN tasks capture the unfiltered prominence of *number* as a feature or that they instead reflect contextual influences on number's *salience*. In previous SFON and SAN studies, it was unclear whether contexts such as motor actions and visual features enhanced the salience of, and thus children's attention to, number. There is evidence that attention to number occurs independently of attention to other features such as spatial location (e.g., Hannula, Lepola, & Lehtinen, 2010). But if attention to number and attention to other features are examined separately, it is unclear whether attention to other features affects attention to number. Baroody and colleagues (2008) examined effects of co-occurring features, systematically varying set size (from 2 to 4) and set com-