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# Geometric toys in the attic? A corpus analysis of early exposure to geometric shapes

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ABSTRACT

Preschoolers' experiences with shapes are important because geometry is foundational to aspects of mathematics and it is now part of the Common Core for school-readiness. Exposure to shapes also provides experiences that are key to developing spatial thinking more broadly. Yet achieving a strong conceptual understanding of geometric categories can extend well into elementary school (Satlow and Newcombe, 1998) despite a general sense that many kindergarten children "know their shapes." The extended time period may be partially a product of the nature of the spatial input to which children are exposed. This study characterizes the geometric input preschoolers receive from three sources: shape books, sorters, and interactive digital content. These shape materials were examined for the types of shapes they include. Shapes were further classified as canonical (e.g., equilateral triangles) vs. non-canonical (e.g., isosceles or scalene), and whether the shape was presented as a geometric form vs. everyday object and in isolation vs. embedded in a scene. The quantity of shape terms was documented for each shape material. The level of sophistication of associated shape language was assessed by tracking the presence of geometric adjectives and explicit definitions. Findings suggest that children are exposed to a limited number of shape categories and very few non-typical variants within those categories. Shapes were typically labeled with only a single generic identifier (e.g., *triangle*) and few of the materials provided explicit definitions, geometric adjectives (e.g., *scalene*), or identified similarities and differences across shapes. Findings suggest a need for more thoughtful design of shape learning materials to provide variety and evoke discussion of their defining properties.



## 1. Introduction

Identifying, visualizing, and manipulating geometric forms (i.e., shapes) builds a foundation for understanding a wide range of mathematical concepts, including measurement, part-whole relations, cardinal knowledge, composition, decomposition, and the number line (Cross, Woods, & Schweingruber, 2009; Casey, Nuttall, Pezaris, & Benbow, 1995; Sarama & Clements, 2004; Gunderson, Ramirez, Beilock, & Levine, 2012). Exposure to shapes has been identified as a particularly valuable opportunity for children to practice the mental manipulation of spatial information (Cross et al., 2009). Spatial thinking in childhood, in turn, is predictive of science, technology, engineering, and mathematic (STEM) achievement (Kyttälä & Lehto, 2008; Mix & Cheng, 2012; Newcombe, Levine, & Mix, 2015; Wai, Lubinski, & Benbow, 2009), a link that is observed as early as preschool and kindergarten (Grissmer et al., 2013; Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2014; Verdine, Lucca, Golinkoff, Newcombe, & Hirsh-Pasek, in press). Preschool and kindergarten mathematics standards now emphasize early geometry knowledge and understanding of related spatial terminology (National Governors Association Center for Best Practices, 2010; Office of Head Start, 2011). For example, the Common Core Standards state that children should be able to: 1) "describe objects in the environment using names of shapes"; 2) "correctly name shapes regardless of their orientations or overall size"; and 3) "analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts..." Thus, shape knowledge is vital for school readiness.

Yet children can have difficulty learning geometric forms well into elementary school (Satlow & Newcombe, 1998). It is not clear how children eventually induce the key properties that define geometric forms from their experiences interacting with shapes.

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Language corpora exist for the study of language input, but no studies have systematically explored the nature of the shape exposure children receive. Given that parents' spatial language (including shape terms) is uniquely predictive of children's spatial ability (Pruden, Levine, & Huttenlocher, 2011), one potential source of shape input is parents' and possibly teachers' spatial and shape language. Unfortunately, parents and early childhood teachers infrequently use geometric terms. For example, geometric terms (e.g., *triangle*, *circle*) comprised only 0.11% of all words produced by parents in everyday speech with children aged 20–27 months (Verdine et al., in press). However, exposure to shape input is likely important in shape learning at even earlier ages; children already can discriminate between shapes by two and half months (Schwartz, Day, & Cohen, 1979). Further, only 1.2% of the mathematics-related words used by teachers with children ranging from birth to five years of age are about geometric forms (Rudd, Lambert, Satterwhite, & Zaier, 2008). The minimal time teachers do spend on geometry is focused on identification of shapes and not on the core or defining properties of shape categories (Sarama & Clements, 2004). Children are typically asked to identify a shape (e.g., a triangle) but no further explanation of shape properties is provided (e.g., a triangle has three sides and three angles). As children learn through play – especially in these preschool years (Hirsh-Pasek & Golinkoff, 2008) – promising sources of geometric input include books and play materials, such as toys and interactive digital content. Shape sorters and books have traditionally been used for learning about shapes. More recently, a new educational medium has become prevalent: touchscreen applications or "apps" (Hirsh-Pasek, Zosh et al., 2015).

The aim of this study is to characterize preschool children's exposure to geometric form input. Given that parents and teachers rarely talk about shapes (Rudd et al., 2008; Verdine et al., in press), we have identified an alternative source of geometric input: shape learning materials in the form of books, sorters, and apps. To characterize the shape input children receive from these sources we ask three related questions: (1) what shapes are presented; (2) how are these shapes depicted; and (3) what (if any) additional information is provided regarding the shapes that might help children learn them? The examination of shape input is analogous to the characterization of language input. Without knowing how children are exposed to shapes (or to language) we cannot know how the environment supports young children's inductions about shapes or about the language(s) they are learning (Gathercole & Hoff, 2008).

It is important to note that there may be factors other than input that may also contribute to shape learning, which are not assessed in the current study. For example, perceptual features of the shapes, such as the relative length of sides or the orientation in which they are presented, may make the shapes more difficult to discriminate. When an equilateral triangle, for instance, is presented on its side, instead of with the point at the top, identifying it may be challenging (Wohlwill & Wiener, 1964). Additionally, cognitive processes such as executive function may also play a role in shape learning in that, for example, failing to inhibit an incorrect response to a rectangle may make it harder for children to learn its true name. However, if the properties of shape materials observed in this analysis align with reported shape learning difficulties, it suggests that these shape learning materials play an important role in shape understanding. For example, while 3-to-6-year-olds are fairly accurate in identifying circles (96% accuracy, Clements, Swaminathan, Zeitler Hannibal, & Sarama, 1999), they are far less accurate with other shapes (e.g., 54% accuracy in identifying rectangles; Clements et al., 1999). Is it the case that shape books and toys do not typically include *rectangles* and often include *circles*?

### 1.1. What types of geometric forms are included in shape materials?

A wide variety of classic geometric shapes (e.g., triangle, square) and iconic shapes (e.g., star, cross) can be presented in children's shape materials, and these shapes can be canonical or non-canonical variants. Canonical shapes are the "standard" or "archetype" version of that shape, typically possessing equilateral properties. Non-canonical shapes, then, are unusual shape variants, typically with sides and angles of varying sizes. For example, an equilateral triangle or a square would both be considered canonical variants of their shape categories (triangle and quadrilateral, respectively), whereas any other triangle (e.g., scalene triangles: triangles with three sides of different lengths) and any other quadrilateral (e.g., trapezoids: quadrilaterals with sides of different lengths) would both be considered non-canonical. These distinctions are informative because accurate classification of non-canonical shapes is difficult for young children by comparison to canonical versions (Clements et al., 1999; Verdine et al., in press). For example, while equilateral triangles are identified by children as *triangles*, scalene triangles are often not (Satlow & Newcombe, 1998; Fisher, Hirsh-Pasek, Golinkoff, Singer, & Berk, 2011).

Given how long it takes children to appreciate the properties of geometric forms (Satlow & Newcombe, 1998), it may be the case that young children are not exposed to a diverse set of shapes within a superordinate shape category. Research indicates that exposure to varied instances of a category helps children appreciate the parameters of that category (Gentner & Namy, 1999; Goldenberg & Sandhofer, 2013; Tversky, 1977). Thus, seeing ten equilateral triangles is likely not as valuable for learning that triangles have three sides, as it would be to see ten triangles of varying types (e.g. *scalene*, *isosceles*, *right*). The properties of equilateral triangles – such as sides of equal length – do not define all *triangles*, and may unintentionally mislead. Inducing shape properties based on exposure to canonical instances alone is akin to learning the term *dog* exclusively from pictures of Chihuahuas; the learner might focus on common properties of Chihuahuas (e.g., small size) that do not define all dogs. Subsequently, the learner may have trouble understanding, for example, that Great Danes are also in the *dog* category and that small house cats are not. In both learning animals and shapes, inducing properties from a limited number of similar instances increases the chance of making induction-based errors.

### 1.2. How are the shapes depicted?

Shapes can be presented as geometric forms (e.g., a line drawing of a rectangle) or as everyday objects (e.g., a door as a rectangle), either in isolation (e.g., an image of just a door) or embedded in a scene (e.g., a front door of a house). Identifying shapes from within a complex scene, however, can be difficult for young children (Coates, 1972; Karl & Konstadt, 1971; for review see Busch, Watson, Brinkley, Howard, & Nelson, 1993), a finding that is used as the basis for the Embedded Figures test (Goodenough & Eagle, 1963). Verdine et al. (in press) also found that 30-month-olds had more difficulty identifying shapes presented as isolated everyday objects compared to isolated geometric forms.

Identifying shapes instantiated in everyday objects may be made more difficult for children due to mutual exclusivity, an assumption children make when learning words that a given object can only have one label (Markman, 1989). Mutual exclusivity makes it likely that children will resist new shape labels (e.g., *rectangle*) for common objects in their environment for which they already have a name (e.g., a door). Young children have also not yet mastered dual representation (DeLoache, 2000), which is required to understand that an object can simultaneously be an object itself *and* a symbol