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In any way, shape, or form? Toddlers' understanding of shapes

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ABSTRACT

Using the intermodal preferential looking paradigm, two-year-old children's ability to discriminate valid (typical and atypical) squares, rectangles, triangles, and circles from invalid distractors was examined. The cognitive and environmental factors that might predict this ability were also investigated. Two-year-old children ($N = 33$) were able to discriminate squares, triangles, and circles, but not rectangles. No significant cognitive or environmental predictors of this ability were found. The results suggest that the ability to shape discriminate at age two is under considerable development and that other factors may be responsible for children's ability to discriminate shapes.

1. Introduction

The National Council of Teachers of Mathematics (NCTM) geometry standards state that prekindergarten children should be able to discriminate between basic two- and three-dimensional shapes and to identify their characteristics in order to be best prepared for subsequent geometric and spatial thinking when entering formal school (2000, 2006). There is indeed evidence to suggest that some shape discrimination ability is present prior to kindergarten and may be innate. For example, newborns have exhibited the ability to discriminate between classes of shapes, as well as between different forms of shapes within the same class (Quinn, Slater, Brown, & Hayes, 2001). By six months of age, they are able to discriminate contours of shapes – particularly circles and squares (Baker, Tse, Gerhardstein, & Adler, 2008). Further, research has found that by 4 and 12 months of age, infants respond to and prefer vertically symmetrical objects over horizontal and assymetrical ones (Bornstein, Ferdinandsen, & Gross, 1981).

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Despite the early evidence of shape discrimination ability, adult input may be necessary for learning the categories and properties of various shapes. Young children up until at least age six tend to make classification errors of atypical and invalid shapes by determining if they are visually similar to standard prototypes and not based on their properties (Aslan & Arnas, 2007; Clements, Swaminathan, Hannibal, & Sarama, 1999; Fisher, Hirsh-Pasek, Newcombe, & Golinkoff, 2013; Hannibal, 1999; Kalenine, Pinet, & Gentaz, 2011). Thus far, research has mostly investigated the ability to discriminate shapes of children aged three and older who have developed language capabilities, as well as the conditions under which they best learn about shapes. One recent study by Verdine, Lucca, Golinkoff, Hirsh-Pasek, and Newcombe (2015), however, investigated this ability in younger children, aged 25 and 30 months old, using a pointing version of the intermodal preferential looking paradigm (IPLP). The IPLP method uses two images simultaneously presented to a child who also hears a verbal prompt. The traditional IPLP method posits that if a child looks at the image that matches the verbal prompt for a significant period of time, it is determined that they comprehended the verbal stimulus. Pointing versions of this task require children to point to one of the two screens. IPLP methods have been found to be a valid and sensitive method of measuring children's language comprehension (Golinkoff, Ma, Song, & Hirsh-Pasek, 2013).

In their study, Verdine et al. (2015) found that the 25-month-old children showed a limited amount of knowledge about typical, atypical, and embedded shapes (shapes embedded within objects such as a starfish as a star, and a door as a rectangle), but were fairly accurate with discriminating circles. The 30-month-olds exhibited much more knowledge of typical shapes (i.e., star, circle, triangle, square, pentagon), but had difficulty with some of the atypical and embedded shapes. In this research, children's language production was not correlated to the 25-month-old children's shape discrimination ability, but was for the 30-month-old children. The study did not investigate other cognitive or environmental factors related to children's shape discrimination ability.

The present study investigated a similar age group but employed the traditional IPLP method using looking gazes. An advantage of using the traditional method is that it does not require children to perform an action and it derives a continuous value for the dependent variable (Golinkoff et al., 2013). Thus, we used the traditional IPLP method to better adhere to the potential limitations of pointing versus looking for our sample demographic.

Thus, the purpose of the present research was to confirm whether children at age two, with underdeveloped expressive language abilities, are able to discriminate typical and atypical shapes from invalid distractors, and to examine the possible contributing cognitive and environmental factors. Cognitive and environmental factors such as socioeconomic status (SES), the home play environment, parental spatial ability, children's language production, children's visual-spatial ability, children's number knowledge, and children's general intelligence, were investigated.

Given that the NCTM (2000, 2006) recommends that children be exposed to various categories and examples of shapes prior to entering formal school, and that experience with shapes is most likely children's first opportunity to engage in geometric and spatial thinking, it is important to determine what children know about shapes at this early age. Knowledge of shapes is believed to underscore many aspects of spatial reasoning and consequently, spatial ability. The relationship between shape understanding and spatial ability can be understood through Uttal et al.'s (2013) four different types of spatial reasoning which contribute to enhanced visual-spatial ability. A task analysis of each of the four types of spatial reasoning, described below, shows that shape recognition is often a component.

The first type of spatial reasoning is intrinsic-static, which is the ability to perceive an object within another object (Okamoto, Kotsopoulos, McGarvey, & Hallowell, 2015; Uttal et al., 2013). Common tests of intrinsic-static spatial reasoning, such as the Embedded Figures Test (Witkin, Oltman, Raskin, & Karp, 1971) and the Hidden Figures Test (Ekstrom, French, Harman, & Derman, 1976) involve the identification of both typical and atypical shapes. Specifically, children are asked to identify basic shapes that are within a more complex shape or figure.

The second type, extrinsic-static spatial reasoning, is the ability "to code an object's location in relation to a reference system against a distracting field change" (Okamoto et al., 2015, p. 19). Understanding maps and surveys is an example of extrinsic-static spatial reasoning. Young children, around three years of age, tend to use and rely on explicit geometric cues (i.e., defined typical and atypical shapes) to determine the location of an object using 2D maps. It is not until children are older that they are able to use partially constructed shapes or geometric objects to locate objects on maps (Vasilyeva & Bowers, 2006).

Intrinsic-dynamic, the third type of spatial reasoning, is the ability to mentally transform an object (Okamoto et al., 2015). A variety of spatial ability measures that utilize shapes explore this ability, including block design measures and paper folding (Okamoto et al., 2015; Uttal et al., 2013). Included in intrinsic-dynamic spatial reasoning is also shape composition and decomposition. This involves the ability to imagine the shape/image created when other shapes are combined (e.g., you can create a "house" using a square and a triangle), and this ability improves with age (Clements, Wilson, & Sarama, 2004). Young children have difficulty at first, but as they get older, they are able to use shape features to create the composite shape that they are working towards. In the final stage of shape composition development, children are able to use their knowledge of the properties of shapes, as well their mental imagery abilities, to successfully create shape compositions (Clements et al., 2004).

The last type, extrinsic-dynamic spatial reasoning, is the ability to recognize "the dynamic or changing spatial relations among two or more objects or between one's own moving body and objects or landmarks in the environment" (Okamoto et al., 2015, p. 24). An example of this type of spatial reasoning involves having children search for hidden objects using their knowledge of spatial relations, the direction and distance of other landmarks in relation to the object, and knowledge