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# Maternal support of young children's planning and spatial concept learning as predictors of later math (and reading) achievement

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ABSTRACT

The goal of this study was to examine maternal support of spatial concept learning and planning at 36 months as predictors of children's math achievement at 4 ½ years and first grade. Observational measures of videotaped mother-child interactions from the Boston site of the NICHD Study of Early Child Care and Youth Development (*N* = *140*) were used to examine the effectiveness of support for spatial concept learning and planning during a block building play activity. Trained observers rated maternal support of children's learning of spatial concepts through spatial language and gestures, with higher ratings involving explanations and encouragement of children's use of spatial concepts. This measure was predictive of math achievement at 4 ½ years when controlling for length of the parent-child observation, child gender, ethnicity, and IQ at 2 years, as well as maternal years of education, verbal intelligence, income-to-needs averaged from 1 to 36 months, parenting stress, general cognitive stimulation, and maternal support of numerical concepts during the same observation. Maternal support of children's planning skills, also rated by trained observers during the block building activity, involved identifying incremental steps to reach the block building goal, with higher ratings given for encouraging planning on the part of the child. This measure was predictive of math achievement at 4 ½ years, as well as reading achievement at both 4 ½ years and first grade, suggesting that maternal planning support has associations with the two key measures of school readiness, while maternal spatial support may be specific to mathematics.

## 1. Introduction

Children's early math skills are important indicators of their readiness for school and later academic achievement (Currie & Duncan, 2000; Duncan et al., 2007; Feinstein & Bynner, 2004; Shonkoff & Phillips, 2000). Given how early these individual differences in math skills have been found, parent support for math learning likely plays an important role. Although the study of parental support of early math learning remains a relatively small field, a growing body of evidence indicates that both the quantity and quality of parental support for learning numerical skills are predictive of child math achievement (Casey et al., 2016; Gunderson & Levine, 2011; Ramani, Rowe, Eason, & Leech, 2015). The goal of the current study was to expand this research to examine the role of two other types of early parental support (spatial concept and planning support) that may be valuable for children's later math school readiness, and to determine whether this support extends to children's later reading school readiness as well.

Approaches for analyzing parental support during joint activities are generally based on Vygotsky's (1978) widely influential socio-cultural concept of the "Zone of Proximal Development" (i.e., the conceptual learning space where the child is unable to solve a problem independently and requires the guidance of an adult to succeed) and the related concept of "scaffolding" introduced by Wood, Bruner, and Ross (1976). There is extensive evidence showing that children's learning is influenced by the ways that parents and children jointly participate in activities (Carr & Pike, 2012; Wood et al., 1976). As a result, the analysis of parent-child interactions has become a very useful paradigm for studying parental support and assistance during learning tasks (Casey, Dearing, Dulaney, Heyman, & Springer, 2014). Of particular note, a number of measures of maternal support have been linked with children's later academic achievement using the same data as is used for the current study, the NICHD Study of Early Child Care and Youth Development (SECCYD), including measures of maternal cognitive stimulation (Crosnoe, Leventhal, Wirth, Pierce, & Pianta, 2010; NICHD Early Child Care Research Network, 2002; Raviv, Kessenich, & Morrison, 2004), autonomy support (Bindman, Pomerantz, & Roisman, 2015),

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sensitivity (Friedman et al., 2014; NICHD Early Child Care Research Network, 2002; Raviv et al., 2004), and numerical support (Casey et al., 2016).

While there is extensive evidence that sensitive, supportive and cognitively stimulating interactions between parents and children during early childhood are important contributors to children's cognitive development, there is less understanding of the specific types of parental learning support that predict math achievement. Because spatial skills and planning have proven important for children's math reasoning (Friedman et al., 2014; Mix & Cheng, 2012; Naglieri & Das, 1987; Zhang & Lin, 2017), the current study examined links between maternal support of spatial concept learning and planning and children's math achievement before and after entry into school. We also examined whether these associations with later achievement were specific to later math skills or extended more broadly to reading skills. First, we describe existing research that provides the foundation for examining maternal support of spatial concept learning and planning during early childhood as predictors of children's school readiness.

### 1.1. The importance of spatial skills for early math achievement

Spatial skills involving mental representations of images and the maintenance of spatial information in working memory, as well as those involving the transformation, manipulation, and rotation of mental images, have been found to be associated with math skills (Gunderson & Levine, 2011; Mix & Cheng, 2012; Mix et al., 2016; Zhang & Lin, 2017). Spatial skills have been shown to be foundational for mathematical learning across ages (Mix & Cheng, 2012; Wai, Lubinski, & Benbow, 2009), with associations between spatial skills and math achievement evident as early as preschool and early elementary school (Assel, Landry, Swank, Smith, & Steelman, 2003; Casey et al., 2014; LeFevre et al., 2013; Levine, Ratliff, Huttenlocher, & Cannon, 2012; Li & Geary, 2013; Mix et al., 2016; Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2017; Zhang & Lin, 2017). Some early childhood activities that tap into these spatial skills include block building, puzzles, origami, and tangrams – each of which involves a series of multi-step spatial problems, drawing on image generation, retention, and mental transformations.

Recent research suggests that early spatial ability may be related to the math readiness via multiple pathways, involving both early number line and calculation skills (Gunderson, Ramirez, Beilock, & Levine, 2012; LeFevre et al., 2013; Mix et al., 2016; Zhang & Lin, 2017). The ability to visualize the relation between numbers along a mental number line is an important element of early numerical skills and may be a key mechanism by which early spatial skills are beneficial to the learning of early number concepts (Gunderson & Levine, 2011).

The present study focuses on maternal support during block building. Block building interventions have been found to improve block building performance as well as showing transfer to a measure of spatial visualization, the Block Design Subtest of the Wechsler Intelligence Scale for Children (WISC; Casey et al., 2008). Further, block building skills have been found to predict math skills for both younger and older children (Nath & Szücs, 2014; Verdine, Golinkoff et al., 2014; Verdine et al., 2017; Wolfgang, Stannard, & Jones, 2001). In fact, studies have found that block building skills in 3-year-olds uniquely predict about one-quarter of the variability in mathematics at age 4 and more than one-third of the variability in mathematics at age 5 (Verdine, Golinkoff et al., 2014; Verdine et al., 2017).

#### 1.1.1. Parental support of early spatial skills

General quality of parent learning stimulation during early childhood has been examined using parent-child spatial problem solving tasks (including joint block building, puzzle tasks, or origami activities), with evidence that better general learning support during these spatial activities is predictive of later math and overall school achievement (e.g., Casey et al., 2014; Mulvaney, McCartney, Bub, & Marshall, 2006; Pianta & Harbers, 1996). For example, one study found that general maternal cognitive stimulation on an origami task at first grade predicted mental rotation and spatial visualization skills, which, in turn, predicted arithmetic performance at the same age (Casey et al., 2014).

However, to our knowledge, only a few studies have conducted research focused on the spatial nature of maternal support (Ferrara, Hirsh-Pasek, Newcombe, Golinkoff, & Lam, 2011; Levine et al., 2012; Pruden, Levine, & Huttenlocher, 2011). During a puzzle task with toddlers, Levine and her associates examined the frequency of parental use of spatial language (such as spatial features and properties of objects), and found that frequency of parental use of spatial language predicted the use of these terms by their children during the task and, in turn, children's later spatial visualization and transformation skills at 4 years of age (Levine et al., 2012; Pruden et al., 2011). Another study with a guided block play condition found that both parents and children produced more spatial language than those in a free play and a pre-assembled play condition (Ferrara et al., 2011).

It is useful to point out that these prior researchers examined the relation between spatial support and later *spatial* skills (rather than math skills). We are aware of no research that has specifically examined how early parental support of spatial concept learning might be predictive of children's later school entry math skills. That was one of the goals of the current study, addressed through the medium of maternal support of spatial concept learning on a Duplos block building activity at 36 months. In order to separate out maternal support that was *specific* to spatial skills, an additional control variable, assessing maternal support of *general* cognitive stimulation at the same age was included in the study.

It was proposed that maternal support specific to spatial skills would involve spatial explanations and encouragement of children's use of their spatial visualization skills during block building and other spatial activities. This type of high quality spatial support should assist children in developing their image generation, retention, and mental transformations skills, which, in turn, should transfer to the ability to spatially represent the concept of quantity and the relation of numbers to one another along a continuum.

### 1.2. Planning skills associated with achievement

Interestingly, most research on young children's planning has also been conducted within the context of spatial tasks, including construction and puzzle tasks (Bronson, 1981; Clark, Pritchard, & Woodward, 2010; de la Ossa & Gauvain, 2001) as well as route-planning using a model or maze (Carlson et al., 2004; Fabricius, 1988; Gauvain, 1992a, 1992b; McColgan & McCormack, 2008; Sandberg & Huttenlocher, 2001). Planning skills are defined as the formulation and enactment of future-directed behaviors (Friedman, Scholnick, & Cocking, 1987; Unterrainer & Owen, 2006), and planning has been identified as a unique construct that is linked with children's future thinking, executive functions, and classroom readiness (Casey et al., 1991; Friedman et al., 2014; Meltzer, 2007; Naglieri & Das, 1987). Planning skills are considered a critical contributor to problem solving (Das, Naglieri, & Kirby, 1994), because planning requires goal directedness, sub-goal decomposition, and sequencing of actions toward a goal (Anderson, 2000). Though measured with different types of tasks and tools, there is evidence that children's planning generalizes across tasks (Casey et al., 1991).

Children's planning abilities go through tremendous growth during early childhood. Previous research has identified that while planning is challenging for most toddlers (Bauer, Schwade, Wewerka, & Delaney, 1999), between the ages of 3 and 5, children's ability to set goals and identify the incremental steps needed to reach these goals goes through a dramatic change (for a full review, see McCormack & Atance, 2011). And, during this period of time − starting around age 3–large individual differences in children's ability to plan and execute goals