2014

Improving Preschoolers' Mathematical Performance: The Nature of Spatial Input by Early Childhood Educators

Joanna Zambrzycka
Wilfrid Laurier University, zamb1650@mylaurier.ca

Recommended Citation

Zambrzycka, Joanna, "Improving Preschoolers' Mathematical Performance: The Nature of Spatial Input by Early Childhood Educators" (2014). *Theses and Dissertations (Comprehensive)*. 1656.
http://scholars.wlu.ca/etd/1656

Improving preschoolers' mathematical competence:
The nature of spatial input by early childhood educators

by

Joanna Zambrzycka

Bachelor of Arts, Psychology, Wilfrid Laurier University, 2012

THESIS

Submitted to the Department of Psychology

in partial fulfillment of the requirements for

Master of Arts

Wilfrid Laurier University

2014

Abstract

Early spatial abilities are related to a number of positive academic outcomes such as success in geometry and chemistry domains in later adulthood (Delgado & Prieto, 2004; Stieff, 2007). Further, more advanced spatial abilities in early adolescence predicts engagement and success in science, technology, engineering, and mathematics (STEM) occupations in later adulthood (Shea, Lubinski, & Benbow, 2001). There is a wealth of research that links spatial abilities to overall mathematics achievement in both adults (e.g., Casey, Nuttall, Pezaris, & Benbow, 1995) and children (e.g., Holmes, Adams, & Hamilton, 2008).

Adult input positively impacts children's subsequent spatial and mathematical development. Parental use of spatial language when children are 14-46 months old predicts children's own use of spatial language, which, in turn, leads to better performance on spatial tasks (Pruden, Levine, & Huttenlocher, 2011).

Currently, research has focused on young children's spatial input and their mathematical development in home or lab settings. Few studies have explored the spatial input children receive at child care centres, despite evidence that this type of care in Canada is increasing (Bushnik, 2006). This is especially important, given evidence that suggests spatial input in the home is limited, particularly for children from low socioeconomic status (SES) families (e.g., Verdine et al., 2013).

The objectives of the present study were (i) to examine the types and frequency of spatial language that early childhood educators (ECEs) naturally engage in during circle times, (ii) to investigate whether spatial language input predicts children's mathematical knowledge, and (iii) to evaluate the differences in spatial language input between ECEs from child care centres serving low and high SES families (as measured by highest maternal educational level). Twelve ECEs participated in the study. Seventy 3- and 4-year-old children's mathematical abilities were pre- and post-tested with: The Test of Early Mathematics Ability (Ginsburg & Baroody, 2003) and the Give-N-Task (Lee & Sarnecka, 2011). The circle times in six classrooms were video recorded over an eight-week period and were transcribed and coded for the frequency and types of categories of spatial talk in which the ECEs typically engaged. Results revealed that ECEs did not spend a substantial portion of time engaging in spatial input, and as such, the amount of spatial input by ECEs was minimally related to preschooler's mathematical competence. Furthermore, the ECEs serving high and low SES families did not differ in the amount or types of spatial language in which they engaged. The present study sheds insight on the amount of spatial input children are receiving in childcare and has implications for educational practices.

Keywords: spatial language, spatial input, early childhood education, early spatial development, early mathematics development

Acknowledgements

First, I would like to express my sincere gratitude to my advisor, Dr. Joanne Lee, who has helped foster my growth as a researcher over the last four years and who has supported and guided me throughout this thesis process. Dr. Lee’s guidance has immensely shaped me and prepared me for my next academic journey.

I am also truly appreciative for my thesis committee members, Dr. Donna Kotsopoulos and Dr. Eileen Wood, and for my external examiner, Dr. Danielle Law, for their invaluable insight and feedback on my thesis document. I was so lucky to have such brilliant and supportive committee members and mentors.

I am incredibly thankful for Samantha Makosz, my partner in countless hours of data collection. Your friendship has meant more to me than you know. Thanks for letting me lean on you throughout this process and for all of the tea and cupcakes. Our most significant friendships really are formed in the unlikeliest of places.

I would also like to thank my amazing lab mates and fellow students. Thanks to Ariel Ho, for your kindness and friendship, as well as for always having a smile on your face to brighten my day. I can always count on you for a good laugh. A huge thanks to Sonia Sengsavang for your numerous hours of help with my results section, your encouragement when I needed it most, and for talking through my frustrations with me. I will always be grateful for that Seattle trip for bringing us together. Thanks to Alexandra Markou and Carissa Heinbuck for checking over my transcripts and secondary coding- it was a pleasure getting to know you both this year. Last but not least, thanks to Katty Wu for assisting in preparing my transcripts for coding and always lending a helping hand.

Table of Contents

List of Tables

List of Figures

List of Appendices

Improving preschoolers’ mathematical competence:
The nature of spatial input by early childhood educators

Early mathematical experiences are important for mathematical development. Formal numeracy practices (i.e., teaching arithmetic) engaged in by parents, before their children start kindergarten, lead to better understanding of symbolic numeracy one year later (i.e., number identification; Skwarchuk, Sowinski, & LeFevre, 2014). Moreover, informal practices by parents (i.e., playing numerical board games) subsequently lead to increases in their children’s non-symbolic arithmetic knowledge (i.e., addition using manipulatives; Skwarchuk et al., 2014). Thus, purposefully teaching mathematical content and providing young children with an enriched informal mathematical environment leads to cognitive benefits and is essential for their future mathematical development.

Socioeconomic status (SES) and gender have also been found to contribute to mathematical development. By the age of four, children from different SES backgrounds (based on family income) already exhibit differences in their mathematical competencies in that children from low SES families underperform on standardized mathematics assessments as compared to their peers from middle and high SES families; however, no difference is found between children from middle and high SES households (Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006). Children between four- and six-years-old also demonstrate gender spatial ability differences as boys perform better on spatial transformation tasks (Levine, Huttenlocher, Taylor, & Langrock, 1999).

Given that mathematical knowledge in the preschool years predict mathematical performance throughout elementary school and adulthood (Aunola, Leskinen, Lerkkanen,

& Nurmi, 2004; Claessens, Duncan, & Engel, 2009; Duncan et al., 2007; Jordan, Kaplan, Locuniak, & Ramineni, 2007; Shea, Lubinski, & Benbow, 2001), these findings support the importance of early mathematical experiences and underscore the concern that some children may be at a significant disadvantage from other peers at the start of kindergarten. These early differences may persist throughout their formal mathematical education. One critical consideration that follows from these findings is the importance of identifying the types of environments (e.g., home or preschool setting) and the kinds of adult input that can help children to be better prepared for early academic success in mathematics.

One domain of mathematics that is particularly important is geometry and spatial sense, the focused strand of the present research. Geometric knowledge and spatial abilities (such as mental rotation skill) are related to a number of academic outcomes, such as the ability to solve geometric problems in high school (Delgado & Prieto, 2004) and solving chemistry problems in post-secondary school (Stieff, 2007). In fact, Smith (1964) suggested that spatial abilities are only partially distinct from general intelligence, and not an entirely separate construct. Using hierarchal factor analyses, evidence has indeed found that spatial ability loads highly on measures of IQ (Miyake, Friedman, Rettinger, Shah, & Hegarty, 2001) and also strongly correlates with fluid ability (Colom, Contreras, Botella, & Santacreu, 2002), sharing a large portion of common factor variance. The importance of geometry and spatial abilities is further evident in that these abilities provide the foundational skills required for a number of future occupations. More advanced spatial abilities in young adulthood predict engagement and success in science, technology, engineering, and mathematics (STEM) occupations in later adulthood (Shea et al., 2001). Thus, fostering these abilities at a young age can have important implications for one’s future in a variety of ways.

Early experiences such as block play for 4-6-year-olds (Casey, Andrews, et al., 2008), puzzle play for 2-4-year-olds, (Levine, Ratliff, Huttenlocher, & Cannon, 2012), utilizing gestures during spatial tasks (Ehrlich, Levine, & Goldin-Meadow, 2006), and parental use of spatial language when children are 14-46 months old (Pruden, Levine, & Huttenlocher, 2011), have all been found to lead to children’s subsequent spatial abilities. However, research in this area has largely focused on the spatial input children receive in their home environment by their parents.

Thus far, no study has explored the spatial input children receive at child care centres. In 2002 it was reported that 54% of Canadian children, prior to formal schooling age, were attending some sort of care outside of the home. Of these children, 28% were enrolled in child care centres, and the majority (68%) spent approximately 30 hours per week at the centre (Bushnik, 2006). One study, which did examine the amount of mathematics instruction in 103 Ontario child care centres, only coded for measurement, counting, relational thinking, the use of mathematical language, and patterns (Perlman & Zhang, 2010). However, the mathematical language coded for in this study did not include a comprehensive list of spatial language. It is, therefore, hard to determine if spatially relevant language was used, and in what frequency if it did occur. In another study, the complexity of preschool children’s independent play using shapes and spatial relations in child care contexts was reported to be very low (Seo & Ginsburg, 2004). Young children, therefore, may not be getting the rich experience with spatial activities and input that they need. This underscores the importance of investigating whether, and how much, spatial input children receive in an environment where many spend most of their wakeful hours during the work week, as well as what academic benefits this input yields, if any.

The present research had three objectives. First, the study investigated the nature of spatial talk in terms of the types/frequency that early childhood educators (ECEs) produced during circle times to 3- and 4-year-old children at child care centres. Given that previous research has found a causal connection between children's spatial learning and other domains of mathematics such as arithmetic (Cheng & Mix, 2014), the second objective of the present study was to investigate the relationship between ECEs' spatial talk and children's overall mathematical abilities. Third, this study sought to investigate whether ECEs serving families from differing SES groups would differentiate in the amount of spatial input. Three-year-old children from lower SES families receive less spatial language input at home compared to their peers from high SES families (Verdine et al., 2013). Further, first-grade girls from low SES families (measured by family income) participate in less spatial activities at home (e.g., drawing maps) compared to girls from higher SES families (Dearing et al., 2012). Thus, it is important to investigate whether children from lower SES backgrounds are receiving spatial input in child care centres.

Defining Terms

The term spatial ability is frequently interchanged with spatial skills, spatial thinking, spatial cognition, spatial reasoning, spatial understanding, and spatial sense. The term spatial sense refers to the overall mathematical subject/domain and is comprised of two abilities: spatial visualization and spatial orientation. Spatial visualization refers to being able to mentally visualize, manipulate, rotate, and transform 2- and 3-D shapes, figures, and other objects (Casey, Andrews, et al., 2008; Clements, 2004b, p. 42). Spatial orientation refers to understanding one's location in space, and being able to navigate the world (Clements, 2004b, p. 42). For the purpose of the present study, the term spatial ability is used as a broad term to refer to the "non-linguistic ability to evaluate relationships within or between objects, and the mental manipulation of objects" (Tepylo, 2014).

Another important term that is pertinent to the present study is the term geometry, which is used to indicate the study of shapes (i.e., categories and characteristics of shapes) and their relation to space, such as transformations ("flips", "turns"; Clements, 1999, p. 77).

Further, the term child care is used as a noun in the present study, though there are variations between childcare, daycare centres, early education centres, and early learning centres within the literature. The term childcare is used when referring to an adjective.

Lastly, when describing socioeconomic status (SES), it is important to note that there are numerous ways to measure this demographic variable. The SES that a child comes from can be determined by their parents' highest education level, income, or occupation (Ensminger & Fothergill, 2012). Using only mother's highest education level is also common, and is found to be a good proxy for SES (Catts, Fey, Zhang, & Tomblin, 2001). Some studies have used census data, race and/or ethnicity information, and neighbourhood and/or school data (Ensminger & Fothergill, 2012). The present study measured SES using mother's highest education level attained.

Importance of Geometry and Spatial Abilities

Geometric knowledge and spatial abilities have many practical implications for a variety of tasks in daily life. Children use their spatial abilities to tie their shoelaces, put puzzles together, and build castles using blocks. The importance of these abilities, however, strengthens throughout development and these abilities have strong influences on children's academic achievement, their career choice, and their success within these careers. Currently, it is unclear what the typical developmental trajectory is for mastering spatial visualization and spatial orientation, though there is evidence that infants as young as five-months-old are able to mentally rotate objects (Moore & Johnson, 2008), and children as young as four-years-old can be proficient in map-reading (Blades et al., 1998).

School Achievement. The importance of geometry and spatial sense is that these abilities provide a foundation for many academic subjects, even ones that do not appear to be outwardly spatial such as in art (Pollman, 2010). Further, spatial abilities are particularly related to achievement in overall mathematics (e.g., Casey, Nuttall, Pezaris, & Benbow, 1995), as well as specific mathematical domains such as numeracy (e.g., Gunderson, Ramirez, Beilock, & Levine, 2012). There is also evidence to suggest that spatial intelligence is strongly correlated with general intelligence (e.g., Miyake et al., 2001). Thus, to score high in spatial intelligence suggests high achievement in other areas as well.

Pollman (2010) introduces many ways in which geometry and spatial abilities can be used to enhance teaching and learning in various academic subjects. For example, in terms of the arts and literature, the geometric concept of the line can be introduced. Lines can be made with a variety of tools and materials in art, and represent a variety of expressions; vertical lines express height and power, horizontal ones a feeling of peace such as within a sunset, diagonal lines represent speed, and curved lines represent softness such as in the petal of a flower (Pollman, 2010). Further, different types of lines are necessary to create shapes, and shapes can be found in nature, such as in the different faces of the moon, the shape of mountains, shark teeth, and in the eyes of fish. Spatial abilities and art making are related because both activities require hand-eye coordination and visually attending to patterns and details, which may account for the fact that preschoolers who engage in art more often perform better on visual-spatial tasks (Caldera et al., 1999).

Interestingly, engagement in block play, a spatial activity, fosters children’s reading abilities as well. Preschoolers who engaged in more complex block building exhibited higher scores on the Test of Early Reading Ability (TERA; Reid, Hresko, & Hammill, 1989), and a faster rate of growth in these abilities, each year up to eight years old (Hanline, Milton, & Phelps, 2010). Similarly, when parents of 18- to 30-month-old children documented how often their children played with blocks over a six-month period, it was found that those who played with blocks more frequently had significantly higher language scores on the MacArthur-Bates Communicative Development Inventories (MCDI; Christakis, Zimmerman, & Garrison, 2007). This is perhaps due to the language and communication opportunities that come along with such constructional play.

Geometry and spatial abilities are also necessary tools for learning in social studies. According to the Roper 2002 Global Geographic Literacy Survey conducted by the National Geographic Education Foundation (NGEF; 2002) on 18-24-year-old young adults, Canada consistently ranked third last (after Mexico and the U.S.A.) on a variety of tests such as locating world countries on a map, world issues and events, and map-reading skills. Although there is evidence that young children can read maps without specific instruction or training (e.g., Shusterman, Lee, & Spelke, 2008), the Roper 2002 results reveal that specific instruction plays a fundamental part in later understanding.

When Blades and colleagues (1998) showed four-year-old children from a variety of countries (e.g., South Africa, England, Iran, and the U.S.A.) an aerial photo of their region, without any training, many were able to correctly indicate that the photo was a map, that certain features/symbols represented buildings in the real-world, and when asked to indicate how they would get from point A to point B, over half of the children in each country were able to correctly navigate using streets shown on the map versus drawing a straight line over trees and other obstacles. The Ontario Social Studies (Grade 1-6) curriculum stipulates that children should successfully be taught how to use maps by reading, drawing, and labeling them, as well as to locate world countries on them (Ontario Ministry of Education, 2004).

The Roper 2002 Global Geographic Literacy Survey results on Canadian young adults (NGEF, 2002) reveals an inconsistency between what children are being taught in school and the expectation set out in the curriculum, given that Canada ranked poorly on map reading and locating world countries. This finding is not likely due to forgetting the spatial abilities that are taught at a young age, as a meta-analysis of studies on spatial ability training found that spatial abilities are long-lasting despite time delays (Uttal et al., 2013). Pollman (2010) indicates that in order to build upon children's spatial representational abilities, training and instruction in child care centres and schools is necessary. Thus, social studies teaching should be introduced even earlier than grade one with activities such as making a map of the child's environment and incorporating all of the centres dispersed throughout the room (i.e., dramatic centre, block centre), as well as adding symbols for an exit or bathroom. These experiences help children transfer understanding from a 2-D label on a map onto an object or area in the real world (Pollman, 2010).

Geometry and spatial abilities also lay a foundation for learning in science domains. Activities such as block play teach children about gravity, balance, and how positioning and moving objects cause changes to systems and constructions; such understanding is needed in the area of physics and engineering (Shea et al., 2001). Further, the introduction of shapes leads to more advanced scientific learning such as the shapes of constellations in astronomy (Pollman, 2010). Mental rotation skills have also been found to be vital to understanding molecular structures in chemistry (Stieff, 2007), and are correlated with university students' scores on anatomy examinations (Guillot, Champely, Batier, Thiriet, & Collet, 2007).

It is evident that geometric knowledge and spatial abilities are essential in numerous areas. These abilities are vital because being able to mentally visualize, understand, and dissect complex relationships is a necessary component of higher education. Further, these abilities are transferable to different areas because spatial abilities can provide an alternate route to solving problems when logical/deductive solutions are unsatisfactory, or can complement them (Casey, Andrews, et al., 2008).

Occupations. The importance of fostering children's geometric and spatial abilities is evident in the benefits it has for their future endeavors and success. It has been found that spatial abilities assessed during the adolescent years largely predict one's post-secondary major and future occupation over and above their mathematical and verbal abilities, even twenty years later (Shea et al., 2001; Wai, Lubinski, & Benbow, 2009). For example, Shea and colleagues (2001) measured spatial abilities in 13-year-old adolescents and then longitudinally assessed their least and most favourite undergraduate class, their undergraduate and graduate degree majors, and then their occupation at 33 years of age. The findings revealed that adolescents with greater spatial abilities were more likely to choose and excel in majors and occupations in engineering, mathematics, and computer science domains. Further, evidence suggests that spatial abilities can predict performance in other, more specific occupations such as dental (Hegarty, Keehner, Khooshabeh, & Montello, 2009), surgical (Keehner, Lippa, Montello, Tendick, & Hegarty, 2006), and aviation (de Kock, & Schlechter, 2009) occupations.

In line with these findings, the widely acknowledged gender difference in spatial ability (e.g., Levine et al., 1999; Linn & Peterson, 1985; Voyer, Voyer, & Bryden, 1995) may partially account for the underrepresentation of women in STEM related programs and occupations. In 2011, Statistics Canada reported that although the majority (66%) of all university graduates were female, they only represented 39% of all STEM graduates aged 25-34. Further, the unemployment rate for women with STEM degrees was 7.0% as compared to 4.7% for men with the same degree (Hango, 2013). This underrepresentation may perhaps be explained by the male advantage in spatial abilities, and may not necessarily be due to gender stereotypes. One meta-analysis suggests that the largest discrepancy between male and female spatial abilities is found on measures of mental rotation (standard deviations range from .25 to 1.00), and is smaller on other spatial abilities, such as spatial perception (standard deviations range from 0.33 to 0.67; Linn & Peterson, 1985). This gender difference in mental rotation ability is found as young as four months of age (Quinn & Liben, 2008) and remains consistent throughout the life-course (Linn & Peterson, 1985). The question still remains as to why these differences exist, not only in North American populations, but also across other cultures such as in Japanese students (Mann, Sasanuma, Sakuma, & Masaki, 1990).

Gender Differences. Attempts to explain the sex difference in spatial abilities have looked at both biological approaches and the differing environment boys and girls experience. Even as early as the preschool years, three-year-old boys exhibit higher spatial abilities in simple mental rotation tasks (Ehrlich et al., 2006; Levine et al., 1999), and an advantage in building three-dimensional constructions compared to girls (McGuinness & Morley, 1991). More recently, researchers have even found a difference in mental rotation ability in children as young as three to five months old (Moore & Johnson, 2008; Quinn & Liben, 2008). Moore and Johnson (2008) habituated five-month-old infants to a 3-D object rotating at a 240° angle. The infants were then preference-tested by being shown either the habituation object, but rotated at a 120° angle this time, or its mirror image, also rotated at a 120° angle. The male infants preferred to look at the mirrored version of the object, indicating that they recognized the habituation object even from a new angle. The female infants, however, did not show a looking preference for the habituation object or its mirror version, indicating that they did not recognize either rotating object as being the one to which they were habituated. The authors suggested that the male infants were able to mentally rotate the two objects, which allowed them to recognize the habituated object even from a new perspective.

Though such an early gender difference appears to support a biological explanation for spatial sex differences, studies that have aimed to find a biological hormonal cause (i.e., testosterone levels) for spatial ability have been inconsistent. One study found that testosterone fluctuations for women during their menstrual cycle could predict spatial task performance (Hausmann, Slabbekoorn, Van Goozen, Cohen-Kettenis, & Güntürkün, 2000) but the same was not found for male testosterone fluctuations, which naturally occur throughout the day (Silverman, Kastuk, Choi, & Phillips, 1999). Other studies have not been able to find a relationship between hormones other than testosterone and spatial ability either (Halari et al., 2005).

It is unknown what specific factors contribute to mental rotation skill differences in infants, but it is most likely that biological influences interacting with environmental inputs allow this difference to remain constant throughout adolescence and adulthood. Especially because there are inconsistencies in the hormone literature, there is merit to examining the differing experiences and environments toddlers are exposed to in order to perhaps explain differences in spatial ability throughout development.

One influence of environment is socioeconomic status. A study conducted by Levine, Vasilyeva, Lourenco, Newcombe, and Huttenlocher (2005) followed a group of second and third grade students longitudinally for two years and assessed their spatial abilities, and found that boys from high and middle SES families (as determined by household income) outperformed girls from the same background on a mental rotation and aerial-mapping test, even after controlling for overall cognitive intelligence. Boys from a low SES background, however, did not differ in spatial ability when compared to girls from low SES households. These results suggest that boys from high SES backgrounds may have greater access to toys, games, and activities that facilitate spatial development. For example, boys have been found to play action-type video games more often than girls. These games foster mental rotation abilities (Quaiser-Pohl, Geiser, & Lehmann, 2006), however they are also costly forms of entertainment. Further, boys as young as one-, three-, and five-years-old already show a preference for construction-type toys such as blocks and LEGO® (Desouza, & Czerniak, 2002; Servin, Bohlin, & Berlin, 1999) which also foster spatial development (e.g., Casey, Andrews, et al., 2008) and may be more prevalent in high SES households. Though girls from high SES families do engage in more spatial activities than those from low SES families (Dearing et al., 2012), the difference in engagement may be even higher for young boys.

In support of the environmental input argument is the finding that although preschool-aged boys prefer to play with blocks more often than girls, girls and boys do not necessarily show a difference in the complexity of their block constructions (Kersh, Casey, & Young, 2008). This indicates that the amount of time spent in constructional play may be an important factor in the development of the male spatial advantage, versus inherited spatial and complex block building competencies. Consistent with this, Casey, Andrews, and colleagues (2008) found that 5- and 6-year-old boys showed an advantage in a 3-D mental rotation task, but not in block play complexity when they provided boys and girls with the same instructions and time period for a block building task. Whether the reason for the male preference for construction-like and spatial-fostering toys is innate, due to parental modeling, and/or gender stereotypes requires further investigation.

Fostering Children's Spatial Abilities

Given the importance of spatial abilities in school achievement, along with evidence that indicates that environment plays a crucial role in spatial development, it is vital to investigate what specific daily activities or toys can best help foster children's spatial abilities and understanding. For example, children experience a decline in spatial abilities over the summer from kindergarten to first grade (Huttenlocher, Levine, & Vevea, 1998) indicating the importance of adult spatial input.

Adult input is especially important because The National Council of Teachers of Mathematics (NCTM; 2000; 2006) standards for prekindergarten children include a number of expectations and focal points when it comes to geometry and spatial ability, such as the ability to sort, classify, order objects, predict object transformations, and describe spatial relationships. These standards are strongly recommended to ensure that children enter formal school with the geometric and spatial knowledge that is crucial for higher grade levels; however, it appears that elementary school students in North America are lagging behind compared to their international peers in the area of geometry (Battista, 1999; TIMSS, 2011). Specifically, the Program for International Student Assessment (PISA) 2012 results indicate that 64% of Canadian 15-year-old adolescents are scoring below or at level three, out of six levels, on the shapes and space subtest compared to 40% in Hong Kong, 40% in Korea, and 38% in Singapore. Thus, the teaching practices must vary considerably in Canada compared to other countries. So, how can children's spatial abilities be fostered?

Spatial Language. Exposure to mathematical language at a young age is a critical component of children's overall mathematical learning (Klibanoff et al., 2006; Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010). This area of research indicates that not only does exposure to variations in general vocabulary affect children's language production overall (e.g., Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991), but that language heard in a specific domain leads to increased knowledge, better abilities, and promotes thinking in that field.

It is an ongoing debate as to what mechanisms account for the relationship between language exposure and cognitive development. One position, the Whorfian perspective, posits that language leads to thought and so different types of language or input affect thought in different ways, such that different languages lead to differences in how one views the world ("Linguistic Relativity"; Whorf, 1956). For example, some languages differentiate broad categories more than others (which results in more words). Among most North Americans, the same word is used, "snow", to specify all kinds of snow: falling snow, snow on the ground, and slushy snow. However, Inuit cultures[1] have a different word for each type of snow and their perception of snow is much different. All of these types are inherently different and knowing the type of snow can impact on decisions and thus, they use different words for each type to express this important information (Carroll, 2008).

Another perspective proposes that people are born with universal cognitive concepts and that language merely shifts the way in which people think about those concepts. With this perspective, all people are born with the ability to perceive different forms of snow as operationally different from one another, but language provides the labels for only some of these existing concepts and determines their boundaries.

---

[1] The original source used the word "Eskimo" but was changed to Inuit to adhere to current terminology.

The last view looks at language as a tool that enhances and guides the cognitive categories that children possess, but does not replace other methods of cognitive thinking, representation, or reasoning. For example, hearing spatial language is a tool which enhances one's concept of relational representations, however, maps and puzzle play may lead to cognitive representations of relational information in other ways (Gentner & Goldin-Meadow, 2003 as cited in Loewenstein & Gentner, 2005). This suggests that hearing language that is specific to a certain domain, such as spatial language, allows one to acquire unique information that could otherwise not be learned.

Adult spatial language input has been found to foster the development of the mental processing involved in completing spatial tasks in young children, such as in the relational understanding between objects in one's surrounding (Dessalegn & Landau, 2008; Loewenstein & Gentner, 2005). For instance, when a group of three and four year olds watched a researcher hide an object and use relational language such as, "I am putting the card on top/in the middle/under the box" versus another group who heard, "I am putting the card here," they were better able to find the card subsequently. This held true even when the researchers replicated the study using the same relational language but in a separate, unrelated task prior to the hiding game. For example, children in the relational language condition first played a game where they were asked to place a toy either *on, in,* or *under* a box for fun, and the non-relational language condition was asked to place the toy *right here*. Later, both groups were introduced to the target hiding game where both the language and the non-language condition heard, "I am putting the card here." Children in the relational language condition were better able to find the card, even though they had only heard relational language in a separate task prior to the hiding game. Further, the benefits of hearing the relational language remained when children came back to the lab two days later and participated in the same relational mapping task without hearing any sort of relational language during the second follow-up session (Loewenstein & Gentner, 2005).

Children also perform better on spatial tasks after hearing relational language even if they do not necessarily know what the words mean. Children who heard, “The red side is to the left of the green side” versus “The red is touching the green” when presented with a target image, were better able to remember what they had seen subsequently. This was true even though the children performed poorly on tests of left/right production and comprehension accuracy, indicating that the children did not necessarily know what these relational words meant. The authors suggest that hearing these relational words acted as a tool to help the children map which direction was left and right and encode the target image better, even if only temporarily (Dessalegn & Landau, 2008), though, older children who produce “left” and “right” correctly perform better on more difficult spatial reorientation tasks (Hermer-Vazquez, Moffet, & Munkholm, 2001). Thus, simply hearing spatial language may be a powerful tool in helping one recall spatial details, such as the location of an object or the location of details on an image.

Less is known about the long-term effects of such interventions; perhaps hearing spatial language only temporarily helps children recall spatial information. Though interventions using block play (Casey, Andrews, et al., 2008) and puzzles (Casey, Erkut, Ceder, & Young, 2008) have been found to increase children’s spatial abilities over time, it is unclear whether it is the activity that promotes this learning, the spatial language that is naturally elicited with such activities (e.g., Ferrara, Hirsh-Pasek, Newcombe, Golinkoff, & Lam, 2011), or a combination of both. Thus, more research is required to tease apart the relative contribution of spatial language and activities.

Children's language production is also related to their geometric and spatial performance. Native English speakers as well as English Language Learners (ELL) with overall higher language abilities in the first grade show predictive improvements in areas of geometry and data analysis/probability up until the fourth grade after controlling for general intelligence and visual-spatial working memory; but this is not true for the areas of arithmetic or algebra (Vukovic & Lesaux, 2013). Given that the tests on data analysis involved interpreting charts and tables, and the geometry tests involved analyzing, comparing, and mentally manipulating 2- and 3-D objects, overall language acquisition must be connected to spatial processing in a way that is not required for the cognitive processing of numbers. This is further supported by a case study by Hyde and colleagues (2011) of a 13-year-old boy with a hearing impairment named IC who had limited language input throughout childhood. IC performed at his age level on numerical tests, but did very poorly on a spatial test that required the use of processing geometrical and landmark information. IC was also able to produce number words accurately, but showed deficits in his spatial language production. Based on these findings, there may be shared underlying processes in language acquisition that specifically aid in spatial cognition and mental representations of space.

What could account for these findings? Gentner's (1988) relational shift hypothesis posits that very young children only focus on objects as whole, and it is not until later that they start to recognize the spatial relationships between objects. Spatial language can aid in children's shifts from focusing on objects to focusing on relations among objects by providing them with the tools required to describe such spatial relations, which makes these features more salient and allows for more advanced encoding of such information. In other words, by providing children with labels for spatial relationships, they are better able to store, retain, and then retrieve that information. However, the studies mentioned thus far have only focused on improving children's spatial performance through exposure in a lab setting in the short-term, or examined children's overall language abilities without a focus on their spatial language abilities specifically.

The first study to longitudinally evaluate children's spatial language input and its effect on their own spatial language production and abilities was conducted by Pruden and colleagues (2011). Children and their parents were videotaped at home, performing their natural everyday activities, every four months when children were 14 months old until they reached 46 months. Parents and children's spatial utterances about shapes, spatially descriptive words (e.g., long, small), and words that describe the properties of 2- and 3-D objects (e.g., edge, corner) were coded. There was considerable variability in the number of spatial words (in a spatial context) that were uttered; parents ranged from 5-525 words, and children 4-191 over the nine 90-minute sessions. However, the most vital finding was that the amount of words parents uttered was positively related to children's spatial word production, even after controlling for other non-spatial talk. Further, children's spatial language production significantly predicted subsequent performance on a spatial transformation task and a spatial analogies task at 54 months of age.

The importance of Pruden and colleagues' (2011) study was that it was the first to not encourage an adult to use specific spatial language related to the task that the children would be tested on, and measured children's spatial abilities eight months after the last video session, instead of immediately after hearing spatial language. Thus, uttering spatial language does not have to be a planned or formal activity, but focusing on engaging in informal activities that naturally elicit spatial talk, such as block play (e.g., Ferrara et al., 2011), could have important and long-lasting effects. Further, it emphasizes the importance of introducing children to a spatially-rich home environment, especially given that children from low SES families hear less spatial talk, and perform worse on spatial tasks as a result, than their peers from high SES families - this is seen as young as three years of age (Dearing et al., 2012; Verdine et al., 2013). These new findings lend support to Gentner's (1988) hypothesis that introducing children to spatial language gives them a platform for being able to name and recognize spatial relationships and thus, encode and recognize these relationships to a greater extent than children who are not exposed to such language. In addition to spatial language, there are a few other ways that adults can foster children's spatial abilities.

Gestures. People use gestures most when describing spatial words (i.e., "under"), versus non-spatial words (Kraus, 1998) and portray a significant decrease in rate of speech when prevented from using gestures during spatial-related talk, but not when talking about other content (Rauscher, Krauss, & Chen, 1996). This research provides evidence that there is a connection between gestures and spatial thought, perhaps because the use of gestures can convey meaning beyond that of just using spatial language alone. This may especially be important in early spatial learning, when children need a salient, visual representation (such as a gesture) of new words in order to better understand and encode their meanings. For instance, parents may spread their arms out to represent the word “long” and cup their hands together to indicate that something is “small” or “flat” in order to foster spatial learning.

Ehrlich and colleagues (2006) were one of the first to investigate whether the use of gestures is related to spatial abilities in young children. The researchers pre- and post-tested five-year-old children on a spatial transformation task. The task involved showing pictures of symmetrical objects separated and translated at the line of symmetry and asking children to choose which shape the objects would make if translated back together from four possible choices. Children were assigned to different intervention conditions after the pre-test session to examine whether certain training instructions could improve spatial ability. In the “imagine movement” condition, children were instructed to move the pieces together in their minds, in the “observe movement” condition they watched the experimenter put the pieces together, and in the “practice” condition they were only told that if you put the pieces together they make a shape- the same instructions given during the pre- and post-tests. After the post-test session, the children were asked to describe how they came to their answers; their verbal explanations and gestures were coded. The researchers found that although the children’s spatial abilities did not improve significantly across conditions, children who used gestures more frequently to express their strategy in figuring out the answer on the spatial tasks (e.g., demonstrating with their hands to show how to slide the pieces together) outperformed those who only used verbal explanations. Further, boys used gestures more often than girls and performed better on the spatial tasks overall, emphasizing the relation between gesture use and spatial abilities.

In addition to children's use of gestures, there has been more recent interest in experimentally investigating whether gestures modeled by a more capable "other" could improve children's spatial development as a means of intervention. Cartmill, Young, Levine, and Goldin-Meadow (2013) assessed children's improvements in putting a puzzle together after being assigned to one of four training conditions. Children were asked to build a puzzle with an experimenter who either a) used spatial language and gestures b) used spatial language with no gestures c) used gestures with no spatial language or d) did not use spatial language or gestures while assembling the puzzle. It was found that children's ability to put together a puzzle on a post-test improved significantly if they were assigned to either one of the gesture conditions, irrespective of whether spatial language was used. Thus, adults' use of gesture, such as making an "L" shape with the hand when talking about a corner piece during spatial activities, facilitates children's performance on those activities even after one week. The benefits of using gestures are even evident in natural, everyday settings, when gestures are not purposefully being modeled. Children who observe their parents using gestures naturally during spatial related talk produce more spatial language subsequently (Cartmill, Pruden, Levine, Goldin-Meadow, & Center, 2010). Thus, the use of gestures encodes spatial information that is unique to other means of spatial learning, perhaps by acting as a tool to help map spatial concepts to their meaning.

Puzzles. Puzzles are a beneficial spatial activity because they require the use of both mental and physical transformations and allow for immediate feedback as to whether the transformations are correct or not. Further, puzzles are a common activity that are available to both boys and girls in a variety of child-friendly contexts such as at home, in child care centres, and community centres, and are considered to be a gender-neutral toy (Caldera, Huston, & O'Brien, 1989).

Research has found that puzzles are valuable intervention tools for improving young children's geometry and spatial abilities. For example, Casey, Erkut, and colleagues (2008) introduced part-whole relation puzzles to a kindergarten classroom over a one-month period. Part-whole puzzles require that two or more pieces make up a shape (i.e., two small triangles make up one big triangle). Use of the puzzles led to improvements in the children's post-test scores on a parts-whole spatial task as compared to a control classroom, especially for the girls. This is not surprising, given the strong correlations found between puzzle performance and various spatial abilities such as mental rotation and visualization (Verdine, Troseth, Hodapp, & Dykens, 2008).

Though the introduction and specific instruction of part-whole puzzles (which are similar to tangrams) may not be available to all children, naturally playing with typical commercially-available puzzles at home can also have beneficial effects. One longitudinal study videotaped a group of children six times when they were between 26 and 46 months old for 90 minutes per observation (Levine et al., 2012). The parents were asked to act as naturally as possible and engage in their daily routine. What was found was that the children whose parent-child dyads exhibited playing with puzzles more frequently over the 20-month period performed better on a spatial task (involving choosing which shape two pieces separated at the line of symmetry would make if mentally translated together) at 54 months of age, even after controlling for SES and parental language input. Interestingly, even though boys exhibited a higher quality of puzzle play (as measured by puzzle difficulty, parent-child engagement, and use of spatial words), only the quality of girls' puzzle play predicted their spatial scores (Levine et al., 2012). Thus, it appears that girls can especially benefit from engaging in puzzle-like activities. This recent study highlights the spatial benefits of puzzle play using typical, every day puzzles that are widely used and accessible such as pegboards and jigsaw puzzles. This underscores the simplicity of fostering spatial development in young children with the use of traditional activities.

Block Play. According to Piaget (1977), block play from infancy may lead to the development of the skills required in subsequent advanced mathematics. During infancy, block play enhances cognitive development because the motor and reflex skills acquired through such play are the basis for learning during the sensorimotor years. Later on, when a child reaches the pre-operational stage (around 18 to 24 months old), blocks serve as concrete, physical symbols that represent features of a child's environment and allow them to physically witness spatial relationships. Thus, once children reach the operational stage of thinking (around 7 to 12 years old), play with blocks has provided the foundation needed for abstract thinking without the use of concrete objects (such as is needed in mental rotation). Thus, early block play may prepare one for the cognitive mechanisms required for higher mathematical learning. For example, being able to mentally visualize spatial relationships may benefit one in a calculus course or to interpret diagrams in statistics.

Engagement with blocks and other toys used in constructional play (i.e., LEGO®, Lincoln Logs) at preschool age are considered to be mathematically enriching because of their relation to mathematics scores, even ten years later (Stannard, Wolfgang, Jones, & Phelps, 2001; Wolfgang, Stannard, & Jones, 2001; 2003). Specifically, block play may contribute to mathematics development because of its specific ability in enhancing spatial abilities and geometric thinking. Park, Chae, and Boyd (2008) demonstrated that engagement in block play allows six- and seven-year-old children to learn about various geometric skills such as measurement, angles, area, orientations, and part-whole relations. For instance, in order to complete a task where children were required to fill in outlines of a house and car using blocks, the children realized that putting two triangles together can make a square. Furthermore, the complexity of block play, as measured by the dimensionality and hierarchy of block constructions, engaged in by parents with their preschoolers has also been found to be a predictor of early numeracy competence one year later (Lee, Zambrzycka, & Kotsopoulos, under review). Studies have also found a direct relationship between block play and spatial abilities. For example, children who are more accurately able to recreate complex block structures score higher on standardized tests that require visual-spatial abilities (Caldera et al., 1999). Moreover, spatial ability is the strongest predictor of successful recreation of complex LEGO® constructions (Brosnan, 1998).

Thus far, studies have investigated the correlational relationship between block play and spatial abilities; however a causal link between block play and spatial abilities has been made. Casey, Andrews, and colleagues (2008) investigated the benefits of block play on spatial abilities using an intervention methodology. The researchers introduced a teacher-guided block-building program into two separate kindergarten classrooms and had one control classroom. One of the intervention classrooms implemented just the block building activities, while the other intervention classroom implemented the block building activities in addition to integrating a story-telling context with the activities. For example, the first classroom looked at posters to recreate block structures of increasing difficulty over 6-8 weeks, while the second classroom had to build these constructions to help “Sneeze”, a dragon who accidentally knocked down structures in her castle and needed help rebuilding them. In previous studies, using a story-telling context has been found to be an effective intervention tool above and beyond implementing an activity on its own (Casey, Erkut, et al., 2008). The control classroom did not engage in any specific activities but went on with their usual routines.

The children were pre- and post-tested on the Block Design subtest of the Wechsler Intelligence Scale for Children- Fourth Edition (WISC-IV) to measure spatial visualization, as well as a block-building task where they were asked to build a “school” with various features (e.g., a roof). Both of the intervention classrooms performed significantly better on the Block Design test as compared to the control classroom, irrespective of a storytelling context. Further, children in the intervention classrooms exhibited more complex block building in terms of dimensionality and hierarchal integration when building a “school”. Thus, block play does not only have long-term benefits on children’s mathematical achievement, but the short-term benefits of block play on spatial abilities has important implications for children who are soon entering the formal school system.

There are also indirect benefits to block play that aid in spatial development. One study analyzed the transcripts of parent-child dyads engaging in everyday activities such as during lunch time, drawing, and playing dress-up, and compared the amount of spatial talk uttered in these contexts to the amount of spatial talk engaged in when parents and children were playing with blocks (Ferrara et al., 2011). The authors found that the spatial words uttered by both parents and children during everyday activities was significantly lower than the spatial talk produced in any of the three block play conditions (free play, guided play, and preassembled play). Further, parents and children engaged in the most spatial talk in the guided block play condition, where their task was to follow instructions in order to build a block construction (Ferrara et al., 2011). Thus, block play contributes to the development of spatial abilities both directly and indirectly, as parents who produce more spatial talk increase their children's subsequent spatial word production who, in turn, perform better on future spatial tasks (Pruden et al., 2011). Further, Ferrara and colleagues' (2011) study suggests that parents lack spatial input in their every day activities in comparison to activities that are spatial in nature.

Currently, it is unclear whether specific activities largely contribute to children's spatial development or whether the benefits are mostly due to the spatial language that naturally accompanies such activities (e.g., Ferrara et al., 2011). The present study focuses on the benefits of spatial language input, and not the other activities outlined in the above section, as there is evidence suggesting that spatial language input is limited (e.g., Graham, Nash, & Paul, 1997; Seo & Ginsburg, 2004). Given that no study has examined spatial input in a child care setting, the current study serves as an exploratory step in determining the nature of such input by early childhood educators (ECEs).

Spatial Abilities and Mathematics

Children's mathematical input prior to formal schooling has important benefits to their future success. Research has shown that mathematics comprehension in the preschool years remains highly stable until at least the second grade, and that those with a high level of competence experience a faster rate of growth in their mathematical development than those that enter school with limited mathematical understanding (Aunola et al., 2004; Jordan et al., 2007). Further, mathematical competence in the early years has been found to be the strongest predictor of reading abilities across elementary school samples in both American (Duncan et al., 2007) and Canadian (Romano, Babchishin, Pagani, & Kohen, 2010) contexts.

Why focus on spatial development then? Mix and Cheng (2012, p.198) state that the relation between spatial abilities and mathematics is one of the best established in cognitive psychology. There is a wealth of research that links spatial abilities to overall mathematics achievement in both adults (e.g., Casey et al., 1995; Weckbacher & Okamoto, 2014) and children (e.g., Holmes, Adams, & Hamilton, 2008), especially with regards to numeracy and arithmetic (Geary, Saults, Liu, & Hoard, 2000; Gunderson et al., 2012; Kyttälä, Aunio, Lehto, Van Luit, & Hautamaki, 2003; Laski et al., 2013; Rasmussen & Bisanz, 2005; Robinson, Abbott, Berninger, & Busse, 1996; Thompson, Nuerk, Moeller, & Kadosh, 2013).

Recently, there has been evidence to suggest that the underlying mechanism – the internal number line – accounts for the relation between spatial abilities and mathematics (Gunderson et al., 2012). A number line usually portrays a scale with one number shown on the left end (i.e., the number one), and another on the right end (i.e., the number ten or beyond). In order for an individual to indicate where the number "eight" would approximately fall on this line, he or she must be able to mentally visualize the distance between each number and comprehend that the line symbolically represents increasing values. Gunderson and colleagues (2012) found that mental transformation ability at five years old predicted accuracy on a linear number line task at age six, and linear number line comprehension at age six mediated the children's performance on a symbolic calculation task at age eight, but not on a non-symbolic calculation task. The authors suggested that because the linear number line helps to represent numbers in a spatial nature and thus leads one to excel in numeracy tasks, the number line is the underlying mechanism for the space-math connection. This hypothesis is further supported by findings suggesting that individuals who experience damage to their parietal cortex exhibit disruptions in both spatial orientation abilities and their ability to produce and make use of an internal number line (Zorzi, Priftis, & Umiltà, 2002), as well as other findings indicating that the parietal cortex is activated by both numerical and spatial processing (Hubbard, Piazza, Pinel, & Dehaene, 2005).

Mathematics performance can even be improved by using spatial training. A meta-analysis which looked at 217 spatial training studies concluded that spatial abilities are malleable, training effects are long-lasting, and that the effects are transferable to performance on overall mathematics tasks (Uttal et al., 2013). Uttal and colleagues (2013) identified every study over the past 25 years that examined the effects of training spatial abilities. The researchers grouped the studies into three categories: children (younger than 13-years-old), adolescents (13- to 18-years-old), and adults (older than 18-years-old). The overall effect size for each study was determined by calculating the difference in spatial ability improvement between the treatment and control groups, or improvements from the pre-test to the post-test if a control group was not included. Further, the researchers compared spatial ability improvements in studies where the post-tests were administered immediately after training to studies where they were administered after a delay, as well as the transferability of such training to other areas of mathematics. The authors found the following: spatial training leads to significant improvements in spatial and mathematics abilities, the training remains durable over extended time periods, and that this effect is present regardless of age group. Thus, mathematics development can be positively influenced through spatial practice and training in the early years.

Cheng and Mix (2014) specifically demonstrated how mathematics performance can be improved through spatial training. Six- to eight-year-old children improved on adding and subtracting assessments (a non-spatial task) even with just 40 minutes of mental rotation training (a non-quantitative task). Four- and five-year-olds have also been found to improve on a variety of mathematical tasks, such as magnitude comparison, after playing linear board games for only one hour versus circular shaped numerical board games, again indicating the effect of the linear number line (Siegler & Ramani, 2009). Even as young as three years old, spatial ability independently accounts for the variation in mathematical comprehension (Verdine et al., 2013). Predictively, spatial ability in kindergarten accounts for 12% of the variance in achievement on the Test of Early Mathematics Ability-2 in third grade (Lachance & Mazzocoo, 2006), and 64% of the variance on the mathematics component of the Scholastic Aptitude Test (SAT) in young adolescence- even more than mathematics anxiety or beliefs about mathematical abilities (Casey et al., 1995; Casey, Nutall, & Pezaris, 1997).

Spatial abilities are also evident in the mathematical strategies that children utilize, such as subitizing (being able to non-verbally use one-to-one correspondence to quickly and accurately determine the number of objects in a small set; Silverman & Rose, 1980), and use of the Spatial Numerical Association of Response Code (SNARC; being able to identify smaller numbers faster on the left hand than the right, and larger numbers on the right hand than the left; van Galen & Reitsma, 2008), suggesting that young children already perceive numerical quantities and magnitudes in terms of space.

It has yet to be determined exactly which components of spatial ability relate to which mathematical domains (Mix & Cheng, 2012), especially given that there is no agreement for a classification system for spatial abilities. Some researchers believe spatial ability is composed of three main components (i.e., spatial perception, mental rotation, and spatial visualization), whereas others believe that there are more (Uttal et al., 2013). Currently, the most important point is to recognize that such a relation exists and that being exposed to spatial input and geometry is vital to the development of the main content areas of mathematics from preschool to at least grade two. Specifically, geometry learning is a precedent to understanding number operations and models, such as the multiplication table, and is the primary tool used for learning about and teaching concepts related to measurement (Clements, 2004b, p. 16). Thus, fostering spatial abilities in the early years is vital for mathematics development and achievement throughout one's education. However, though the importance of spatial abilities is known, there is a dearth of research on how these abilities can be fostered at home prior to formal schooling, and even less research on how they can be fostered in child care settings. The NCTM (2000; 2006) outlines specific standards as to what children should know in terms of geometry and spatial abilities even before attending kindergarten. Thus, it is important to examine the nature of input children receive in the environments – home and child care centres – in which they spend a significant amount of time.

Why Child Care Settings?

Researchers have taken an increasing interest in the long-term effects of placing children in out-of-home childcare over the past decade. The child care environment and its relation to children's social, emotional, and academic development have especially become areas of particular interest due to the steadily increasing rates of women entering the workforce before their child is old enough to attend formal schooling (e.g., National Institute of Child Health and Human Development, 2005; Peisner-Feinberg et al., 2001). Women, who are more likely than their male spouses to take maternity leave (Statistics Canada, 2006), have increasingly been entering the workforce before their child is old enough to be sent to school, and thus, have had to find alternate means of childcare, often outside of the home. In 1976, the employment rate of women whose youngest child was three years old was 27.6%, which by 2009, was more than double that rate at 64.4% (Statistics Canada, 2013). It is no wonder that parents, scholars, policymakers, and educators have thus taken an interest in how factors such as overall childcare quality, ECE characteristics, and the child care environment/exposure, have an effect on a child's development.

The importance of the benefits or detrimental effects of early childcare for parents and educators is not surprising, but why would this industry be of interest to policymakers? A special report conducted by TD Economics reveals that the childcare industry in Canada yields the largest monetary return; for every dollar that is invested in child care, results in a $1.50 - $3.00 return for the economy in the future (Alexander &

Ignjatovic, 2012). This is because child care settings prepare children for subsequent academic success by providing the skills and knowledge required at a critical time period. These foundational skills are precursors to those that will impact the workforce later on in life, thus reducing unemployment and poverty rates and increasing profits. Further, high quality childcare is associated with higher completion rates for primary, secondary, and post-secondary schooling and a subsequent decreased likelihood of smoking, doing drugs, and abusing alcohol (e.g., Campbell, Ramey, Pungello, Sparling, & Miller-Johnson, 2002). These factors lead to an increase in overall health for the population and results in the government having to spend less on healthcare per person. Research on the effects of childcare has important implications and applications in a variety of areas. Unfortunately, a recent *Globe and Mail* article indicated that Canada actually spends the least amount of money when it comes to early childhood education as compared to a number of other countries (“Canada ranks poorly”, 2014). This highlights that more needs to be invested in children’s early childhood education.

In 2002 and 2003, over half (54%) of Canadian children between the ages of six months to five years old attended care outside of the home. Of this number, 28% of children were enrolled in child care centres, and most (68%) attended this type of care on a full-time basis (Bushnik, 2006). The number of children attending child care centres may keep increasing, and the cognitive development that is promoted in this environment is integral to a child’s future academic success. Due to the importance of spatial and geometric knowledge to future STEM achievement (e.g., Shea et al., 2001), there is a need to investigate the types and frequency of spatial input children are receiving in child care settings, especially given that this childcare arrangement is on the rise.

Child Care and Early Spatial Education

The NCTM (2000; 2006) includes prekindergarten in their report on the mathematical standards that children should meet at various developmental levels. These standards identify the foundational skills preschool children need in order to continue advancing in their mathematical understanding. The Geometry Standards for prekindergarten to the second grade indicate that children should be able to recognize and identify spatial relationships (i.e., using spatial talk such as "on top"), mentally rotate and manipulate objects, recognize 2- and 3-D shapes and be able to identify their characteristics, and to be able to spatially visualize the separating and putting together of shapes (NCTM, 2000; 2006). Given the number of children who attend formal child care (Bushnik, 2006), it is important to consider what kind of spatial and geometrical input ECEs are providing to their preschoolers in order to prepare them for these standards.

Brown's (2005) observations indicate that early childhood educators tend to rate mathematics on the lower end as a vital area of early education, and that their teaching practices reflect this. Even ECEs who believe that mathematics teaching is important and have indicated that they engage in this type of teaching often, when observed, they actually do not take opportunities to teach mathematics (Graham et al., 1997). Given that spatial ability is not considered to be a subject area on its own and is expected to be integrated into the mathematics curriculum, the fact that mathematics teaching is not frequently engaged in child care centres suggests that spatial teaching and practice may occur even less often.

Perhaps early childhood educators shy away from mathematics teaching, at least in Ontario, because of their lack of mathematical training. In the current Ontario curriculum for colleges, out of 24 early childhood education programs, none offer a separate course on mathematical instruction though each one offers at least one on literacy (Perlman & Zhang, 2010). It is unlikely that any of these programs explicitly address the development of spatial abilities, or the importance of having advanced spatial abilities, in a significant manner. Given that an ECE's education accounts for 90% of the variance in time spent engaging in mathematical teaching (i.e., the higher level of education an ECE has, the more likely they are to teach mathematical content; Perlman & Zhang, 2010), ECEs may not feel comfortable introducing preschoolers to spatial concepts or may not be aware of the type of spatial input and activities that are appropriate for preschoolers. This is in line with research that has found that students studying to become early childhood educators rate primary operations (e.g., addition, subtraction) as more "mathematical" than relational terms, which also fall under spatial language (e.g., more, less, greater; Moseley, 2005). This evidence suggests that ECEs may not be fully aware of the broad scope of what the domain of mathematics entails, and especially may not view spatial input as mathematical.

It does indeed appear that teachers of young children also lack geometric and spatial knowledge. Kindergarten teachers assessed on their mathematical pedagogical content knowledge scored lowest in the areas of shapes, comparison, and spatial sense, but highest in number sense, patterning, and ordering (Lee, 2010). Though preschool-aged children may enter child care with preliminary knowledge about shapes, ECEs may not be building upon this knowledge. Kindergarten teachers tend to verify that children know their shapes, but do not go beyond this understanding by introducing children to shapes outside of typical prototypes, which leads to a rigid view of shapes and geometry

(Clements, 2004a, p. 268). For instance, children between the ages of three and six tend to believe that when a square is turned, it is not a square anymore but is now a diamond (Clements, Swaminathan, Hannibal, & Sarama, 1999), however, no study thus far has specifically examined what kind of spatial input ECEs provide. The National Research Council (2006) in the United States released a report, *Learning to Think Spatially,* which confirmed that unfortunately, spatial education is not emphasized at any grade level, despite its importance.

A lack of education on early spatial development may lead ECEs to have “spatial anxiety”, which can impact children’s learning. It has been found that first and second grade teachers who have high spatial anxiety have students who score low on spatial abilities at the end of the school year, even after controlling for their spatial abilities at the beginning of the year (Gunderson, Ramirez, Beilock, & Levine, 2013). This is significant because many of the academic beliefs and fears children possess are learned from parents and educators. Children as young as five years old already report having spatial anxiety, which predicts their performance on spatial tasks (Ramirez, Gunderson, Levine, & Beilock, 2012). Thus, spatial and geometric teaching from early on already have an impact on children’s beliefs and performance, which may carry through to formal schooling.

Children also need competent adults to scaffold and challenge their abilities. Even in terms of block play, which fosters spatial abilities (Park et al., 2008), an adult’s engagement is necessary so that children can receive the full benefits of such play. For instance, Gregory, Kim, and Whiren (2003) asked students majoring in child development to use verbal scaffolding to encourage children to build block structures of high complexity, in terms of hierarchy and dimensionality, over a period of three weeks without any form of physical assistance. As compared to a control condition where the students were simply encouraging the children to play with the blocks in any way they desired, those children in the scaffolding condition demonstrated an increase in the complexity of their block play constructions, a practice which increases spatial abilities (e.g., Caldera et al., 1999). This study once again highlights the benefits of an adult engaging in purposeful spatial language, however, it did not examine this input from an ECE. High quality interactions between early childhood educators and children are important because the child care environment can act as a buffer against poor cognitive outcomes if there is a lack of high quality input in the child's home. For example, when the complexity and diversity of verbal input by mothers in the home environment is low, positive verbal input provided by ECEs acts as a buffer for those children who are at risk for poor language development (Vernon-Feagans & Bratsch-Hines, 2013). Nevertheless, there is currently a lack of knowledge on the spatial language input early childhood educators provide even though formal childcare is on the rise. Children require a more skilled and competent adult to guide them in their spatial education in all of their lived environments, especially if they are not receiving the rich input they require at home.

There is very limited research that investigates ECE instruction in general, let alone spatial input specifically. Perlman and Zhang (2010) found that 6% of instruction by ECEs in Ontario is mathematical in nature, and that most of this instruction has to do with relational thinking, counting, and using mathematical language. However, the study did not investigate instruction on spatial relations and did not use a comprehensive coding scheme to include all mathematical language (i.e., spatial). The one code that may have been most spatial in nature was that to do with pattern, which was removed from the analysis because of its low occurrence. Another study conducted in the United States found similar results, that preschoolers in child care centres engage in mathematical-related content for 6% of the day (Winton & Buysse, 2005). These are the only studies that have assessed mathematical instruction in a child care setting, though none looked at spatial or geometric teaching. Thus, there is a need to investigate spatial input in child care centres.

Present Study

Evidence of the malleability and durability of spatial abilities (Uttal et al., 2013) indicates that adult input has a strong developmental influence throughout the early years. Research has mainly focused on parental spatial input (e.g., Pruden et al., 2011). There is a dearth of research on the benefits of spatial engagement in child care centres. Though it appears that early childhood educators do not place a strong emphasis on spatial input, research investigating this has largely been conducted on U.S. samples (e.g., Lee, 2010). Further, no study has yet to examine exactly how much and what type of spatial input ECEs provide, and the cognitive impact that this has on their preschoolers. Research has shown that parents engaging in activities such as block and puzzle play increase children's spatial abilities (e.g., Levine et al., 2012; Park et al., 2008), as well as children's numeracy abilities (Lee et al., under review). However, it remains unclear whether it is the activity specifically, the spatial language that accompanies such play, or a mixture of both that is responsible for this increase. As previously mentioned, using specific spatial labels, even during non-spatial tasks, benefits children's understanding of spatial concepts and abilities (Loewenstein & Gentner, 2005).

The present study was one of the first to explore early childhood educators' spatial language input during circle times and its effects on preschoolers' early numeracy competence in Ontario child care centres. The circle times were chosen for analysis because they are a period of the day in which ECEs purposefully engage in activities and/or teaching with their preschoolers. Thus, these segments were used as a beginning step to evaluating such input. Spatial language exposure was assessed during a typical, daily circle time. The type and frequency of spatial language that ECEs engaged in during their circle time was coded for in contexts such as during puppet play, reading a picture book, or telling a story. Based on previous research (Clements, 2004a, p.285; Perlman & Zhang, 2010), it was expected that ECEs would engage in more spatial talk with regards to categories about shapes and spatial dimensions (e.g., “big”, “small”), and less in the categories of spatial features and properties (e.g., describing that all squares have four sides) and talk about patterning. Overall, however, it was expected that spatial language input would be limited given that ECEs and kindergarten teachers score lowest on pedagogical knowledge of spatial sense (Lee, 2010), and believe mathematics is not an important subject to teach preschoolers (Brown, 2005).

Secondly, the present study investigated whether such spatial talk was related to children's mathematical comprehension and numeracy skills. The effect of ECEs spatial input on three and four year olds' overall mathematical knowledge was assessed through The Test of Early Mathematics Abilities Version 3 (TEMA-3), a standardized mathematical assessment for children three years of age and older (Ginsburg & Baroody, 2003) and the Give-N-Task (Wynn, 1992; Lee & Sarnecka, 2011), a task that measures children's cardinality knowledge. Cardinality refers to the understanding that the last number counted in a set of objects represents the total number of items in that set (Fluck, Linnell & Holgate, 2005). Both tasks were administered to each child at the beginning and end of the eight-week study period. Given the strong relation between children's spatial abilities and numerical understanding (e.g., Gunderson et al., 2012), and the fact that spatial training increases mathematics performance (Cheng & Mix, 2014), it was expected that after controlling for children's pre-test scores, a higher frequency of spatial words uttered by ECEs would predict higher mathematical and numeracy comprehension for their preschoolers. This was based on Gentner's (1988) relational shift hypothesis that spatial language helps children map and encode spatial words onto their meanings and thus, aids in spatial and mathematical thinking. This is essential as children who enter kindergarten with an advanced understanding of numbers continue to thrive in their mathematics courses (e.g., Duncan et al., 2007).

The third objective of the present study was to examine whether ECEs differentiate in their spatial input as a function of the SES of the children at their centres, as determined by children's mother's education level. For example, children from low SES families score poorer on spatial tasks (Levine et al., 2005) than their high SES peers, possibly due to receiving less spatial language input at home (e.g., Verdine et al., 2013). Thus, it is important to determine whether children from low SES families receive spatial input at child care due to a lack of enriched home input, especially since input by ECEs in child care settings can act as a buffer for poor developmental outcomes (Dearing, McCartney, & Taylor, 2009). To explore whether there were fundamental differences in the language and mathematical environments between centres serving high and low SES families, a classroom environment checklist collected throughout the eight-week period was also utilized.

Fostering children’s spatial abilities is vital considering that they are a strong predictor of one’s likelihood to pursue and succeed in STEM-related occupations (e.g., Wai et al., 2009). Thus, the current study has both theoretical and practical implications for children’s early mathematical development and education.

Method

Data Source

The present study was part of a cross-sectional research project evaluating the effectiveness of an early numeracy program on children’s mathematical development in a child care setting. Four child care centres were recruited for the study. As part of the larger study, one centre received two professional development workshops based on the early numeracy program throughout the eight-week research project. The other three centres received the professional development workshop once data collection was completed. The professional development workshop did not have a spatial focus, therefore it was not expected that the numeracy workshop for ECEs would influence the results of the present study on spatial input. An analysis was conducted to confirm this and there were no differences found between the centre that received the workshop throughout the study and those that received the workshop at the end of the study in terms of engagement in spatial talk (see the Results section).

The data collected consisted of a total of 32 videotapes taken during the circle times in each classroom. There was one ECE per circle time that was videotaped. These videotapes were used to examine the types and frequency of spatial talk that ECEs engage in to their 3- and 4-year-old preschoolers. The ECEs were asked to deliver their typical planned circle time activities. As such, no time constraint was imposed. Each videotape was transcribed and coded using the Observer XT version 8.0 program (The Observer XT 8.0, 2008). Out of the 32 observations, 37% (12 observations) were coded for inter-coder reliability, with Cohen's Kappa = 0.92 and the population coefficient, Rho = 0.99.

Participants

Six classrooms from four child care centres from the Waterloo, Ontario region participated in the study. Eighty children were recruited, however the final dataset consisted of seventy (39 boys and 31 girls) children (M_{age} = 47.49, *SD* = 7.84; *Range* = 34 months to 70 months) due to the following reasons: seven children did not attend the child care at the time of post-testing, two children were formally diagnosed with autism, and one child was non-verbal during the pre-test. Out of the remaining 70 children, one child refused to participate in one (out of two) of the mathematical assessments at the pre-test, thus, the child was not post-tested on this measure. However, pre- and post-test data for the second mathematical assessment for this child was included in the analysis. Approximately 81% (n=57) of the children were Caucasian. The primary language spoken at home was as follows: 61% (n=43) of children spoke English, 9% spoke another language (n=6), and 30% (n=21) of parents did not complete the demographics questionnaire.

A total of twelve female early childhood educators from the six classrooms were also recruited for the study (see Figure 1 for a visual depiction of the participating centres, classrooms, ECEs, and children). All of the early child educators were

Caucasian. The ECEs were not asked to complete a demographic questionnaire, therefore, no additional demographic information is available.

The mother's highest education level was used as a proxy for SES (Catts et al., 2001). The highest education level attained by mothers was as follows: 21% of mother's completed highschool, 13% had a college education, 26% had a university degree, and 40% had graduate/professional training (see Table 1 for a list of mother's highest education level attained). Also, the average of mother's education level was used to determine the SES of the families that each centre serves. It is common practice to aggregate an individual-level data into a higher-order variable (e.g., Paccagnella, 2006). Education level was coded as the following: 1 = *highschool*, 2 = *college/trade*, 3 = *university* and 4 = *graduate/professional education*. Two centres were serving families from a low SES and the other two centres were serving families from a high SES.

Consent forms for each child within the age range were sent home, along with a demographic questionnaire for the parents to complete (See Appendix A for the questionnaire). The participating ECEs also signed a consent form. The centres were compensated with a complimentary mathematics-focused development workshop for the ECEs once the study was complete. One centre received $1.00 for every child who participated in the study, due to an ongoing agreement between the centre and WLU.

Materials

The Test of Early Mathematics Ability- Version 3 (TEMA-3). The TEMA-3 (Ginsburg & Baroody, 2003) is a standardized, one-on-one test which assesses children's overall mathematical understanding. It has been normed for children between the ages of three-years and eight-years and eleven months old. The test consists of 72 questions that are orally administered and assess informal (i.e., comparing number magnitudes, word problem calculations) as well as formal (i.e., written addition/subtraction calculations, writing numbers) mathematical concepts.

Testing usually takes around 30-45 minutes for the youngest age group, though the assessment is not timed. The questions increase in difficulty and are categorized into different entry points depending on the child's age. For instance, a three-year-old would start testing at question number one, whereas a four-year-old would start at number seven. Once a child answers five incorrect questions in a row, they have reached a ceiling and testing stops. The exception to this is if the child has not yet correctly answered five questions in a row, in which case the examiner must go back and start asking questions from the entry point below where the child started. This is to ensure that the child receives a basal as well as a ceiling for his/her assessment. However, if the child is three-years-old and has not reached a basal, it is not possible to ask questions from the previous entry point so in this case, testing stops.

To score the TEMA-3, each correct answer is given one point and summed to determine the child's raw score, which also determines the age and grade equivalents. Then, using Table A in Appendix C of the examiner's manual, the Math Ability Score (a standard score with a mean of 100 and standard deviation of 15), the percentile rank, and the standard error of mean can be calculated.

The TEMA-3 has a coefficient's alpha reliability score of 94% and a test-retest reliability of 82%. It is also a test that is considered to have good content-description validity as it accurately measures what it is intended to measure: overall mathematical ability. The test is also deemed to have good criterion-predictive validity as it can predict children’s mathematics performance on other mathematical activities and tests.

The TEMA-3 consists of two forms: Form A and Form B to avoid practice effects for pre- and post-test purposes. The forms are parallel to each other, meaning that each question assesses the same construct as the other form and with the same level of difficulty, but asks for different answers. For instance, on Form A the child is asked to count two, one, and three cats, but on Form B, the child is asked to count one, two, and four cats (Ginsburg & Baroody, 2003).

Give-N-Task. The Give-N-Task was created by Wynn (1992), however, the version used for the current study was adopted from Lee and Sarnecka (2011) who utilized a more conservative scoring system in order to better determine each child’s numerical understanding. The task assesses children’s understanding of numbers through their performance on a cardinality task. Specifically, it determines the highest number (up to ten) that a child fully understands, and has not just memorized in a rote fashion. Children were asked to give a dog puppet each trial of one, two, three, four, five, eight, and ten balls. There were three blocks in total, with each block asking for each of the trials once, but in a random order. Thus, each trial (each number) was asked a total of three times, for a total of 21 trials.

For this task, the examiner used a dog puppet, three sets of 15 balls each (an orange set, red set, and green set), a bowl, and a plate. The examiner wore the puppet and placed one set of balls (in the bowl) and the plate in front of the child. The researcher explained and demonstrated to the child, “We are going to play with a puppy and he wants you to give him some balls! The puppy will ask you to give him a certain number of balls, and then you will put them on this plate and slide it over to the puppy". The testing began once the researcher asked for the first trial in the first block, "Can you give the puppy *x* balls?". Once the child was finished putting balls on the plate, the researcher confirmed, "Is that *x*?" to ensure that the child understood how many balls s/he gave. If the child responded with "Yes", regardless if s/he was correct or not, the next trial would begin. However, if the child responded with "No", the examiner repeated the trial, but only once more.

On trials asking for five, eight, and ten balls, the child was also asked, "Can you count them?" after the researcher asked the confirming question. If the child counted correctly, the next trial began. If the child counted incorrectly, however, s/he was asked, "Can you fix it so that it's *x*?" in which case their second response was recorded and the next trial began.

Scoring for this task is based on a classification system of the highest number for which the child can successfully demonstrate full cardinal understanding. Children were given labels of either a *one-, two-, three-, four-, five-, eight*-, or *ten-knower*. In order to receive a label, the child had to have provided the correct number of balls for at least two out of the three blocks. Further, the child could not incorrectly provide that number of balls on a trial asking for a different number more than once. For example, a child who was classified as a *three-knower* could incorrectly provide three balls on a trial asking for eight balls, but if s/he incorrectly provided three balls on one more trial, that child would not be considered a *three-knower* anymore. Further, on trials asking for five, eight, and ten balls, the child must have correctly counted to receive that label. If a child was unable to meet any of these scoring criteria, they were classified as a *pre-numeral-knower*.

Early Childhood Environment Rating Scale - Revised (ECERS-R) and Early Childhood Environment Rating Scale - Extension (ECERS-E). ; The ECERS-R (Harms, Clifford & Cryer, 2004) and ECERS-E (Sylva, Siraj-Blatchford, & Taggart, 2010) assess the overall quality of the early childhood classroom environment to promote literacy and mathematics learning. The scales are based on the materials in the classroom, as well as the instructions provided by the ECE.

The “Language-Reasoning” subscale from the ECERS-R and the “Mathematics” subscale from the ECERS-E were utilized. The “Language-Reasoning” subscale has three sections: Books and Pictures (11 items; e.g., “Books organized in a reading centre”), Encouraging Children to Communicate (9 items; e.g., “Some materials accessible to encourage children to communicate”), and Using Language to Develop Reasoning Skills (8 items; e.g., “Concepts are introduced in response to children’s interests or needs to solve problems”). Each item is presented as a statement and then is scored with “Yes” or “No”. The items are categorized along a seven-point Likert scale (1 = *Inadequate*, 3 = *Minimal*, 5 = *Good*, 7 = *Excellent*). For instance, for the Books and Pictures section, the item “Staff rarely read books to children” is under “Inadequate”, but the item “Books and language materials are rotated to maintain interest” is located under “Excellent”. The language subscale has an internal consistency of .83. It is also considered to have good predictive validity; the language subscale predicts children’s language and literary performance (Clifford, Reszka, & Rossbach, 2010).

The “Mathematics” subscale was two sections: Counting and Application of Counting (12 items; e.g., “Numbers are named as part of daily routines”), and Reading and Representing Simple Numbers (9 items; e.g., “Children are regularly encouraged to read and/or represent simple numbers”). Using this checklist is the same as the ECERS-R. The mathematics subscale has a concurrent validity of .78 with the ECERS-R. It is also considered to have good predictive validity of early number concepts (Brenneman, 2011).

To score the ECERS-R and ECERS-E, the number of items scored under each Likert-point was considered. For instance, if any item under *Inadequate* (point number “one”) was scored as “yes”, the entire section would be given a score of “one”, regardless of whether there were items scored as “yes” under the higher points. A section could only get the highest score of seven if all of the items under *Excellent* were given a “yes”. Each section was given a score out of seven, and the scores were then averaged for an overall “Language and Reasoning” score and an overall “Mathematics” score.

Procedure

The current study was conducted over an eight-week period. The children whose parents signed and returned the consent form participated in the study. The ECEs who signed the consent form and agreed to be videotaped participated. The first two weeks of the study consisted of pre-testing the children on their mathematical abilities (TEMA-3) and numeracy competence (Give-N-Task). The pre-test consisted of two sessions on two separate days in a quiet room/area that was outside of the child’s classroom. There were two female researchers who conducted all of the testing. The author always administered the first session, assessing children’s mathematical abilities using *The Test of Early Mathematics-Version 3*: Form A (Ginsburg & Baroody, 2003) which took around 30-45 minutes. On a separate day, the second researcher assessed the children’s numeracy understanding using the *Give-N-Task* (Lee & Sarnecka, 2011; Wynn, 1992), which took around 20 minutes. Each child was asked to provide oral assent to complete the tasks with the researchers.

The classrooms' circle times were videotaped over the next six weeks once the pre-tests were completed. As part of the larger study, the ECEs from one centre received two mathematics workshops throughout these six weeks. The number of video recordings depended on the number of participating ECEs in each classroom. During the taped circle times, children whose parents did not return a consent form engaged in a separate activity other than the circle time (i.e., played outside, played a game in a separate part of the room), with another ECE. This was to ensure that children whose parents did not consent to the study would not be recorded (i.e., voice heard, hand raised), though the primary focus of the recordings was on the ECE and the camera was positioned to achieve this. The ECEs were asked to act as naturally as possible as if it was any other given day, though they were aware that the study had a general numeracy focus.

In order to determine the quality of the environment in the child care centres, the classrooms were also observed and rated using the *Early Childhood Environment Rating Scale – Revised Edition* (ECERS−R) (Harms et al., 2004) and the *Early Childhood Environment Rating Scale Extension* (ECERS-E) (Sylva et al., 2010) throughout these six weeks. Each classroom was observed four times using these checklists for 30-minutes each observation. The author, who completed the language checklist, and another researcher, who completed the mathematics checklist, scored these checklists during the observations. After the observations, the researchers discussed each other's scoring and any discrepancies were evaluated and resolved.

Once the video tapings were completed, the children were post-tested on the same measures utilized during the pre-test with the same examiners and procedures. The only difference is that for the TEMA-3, a second, parallel from (Form B) was used in order to avoid practice effects. The ECEs from the three centres that did not receive the mathematics workshop during the study attended this workshop once post-testing was completed.

Transcribing and Coding

Each circle time was recorded using the Noldus Observer XT 8.0 technology (The Observer XT 8.0, 2008). The Observer XT 8.0 recording system consists of a camera with a portable remote control that can control the zoom functions for best visibility. The ECEs were asked to wear a wireless microphone for audio recording.

Spatial Talk. The video recordings were transcribed in order to examine the total talk per circle time in which the ECEs engaged. Using the Noldus Observer XT 8.0 software (The Observer XT 8.0, 2008), the transcriptions were used to code for the ECEs' spatial language uttered. The coding scheme was adopted from Cannon, Levine, and Huttenlocher's (2007) *A System for Analyzing Children and Caregiver's Language about Space in Structured and Unstructured Contexts* (with permission from the authors; See Appendix B for the complete coding scheme). Other coding schemes were explored (e.g., Internicola & Weist, 2003), however, none were as comprehensive as this system, or the spatial words in other coding schemes were already present in Cannon's and colleagues' (2007) system. This system categorizes spatial words into eight categories:

i. *Spatial Dimensions* refers to words that describe the size of physical objects, people, and spaces (i.e., big, little, small). An example would be, "We have different sized frogs- some *small*, some *big,* and some medium";

ii. *Shapes* refers to any 2- or 3- dimensional object or space (i.e., circle, triangle, rectangle). An example would be, "Okay everyone, let's make a big, big *circle* so that everyone can see the book";

iii. *Locations and Directions* indicates words that describe the whereabouts of objects, people, and spaces (i.e., left, under, above, between). An example would be, "I'm just going to remind everyone to stick your hands *behind* your back";

iv. *Orientations and Transformations* refers to an object's or person's orientation or transformation (i.e., turn, flip, rotate). An example would be, "Let's *turn* this chalkboard *upside down* now, and see what the picture looks like from this view";

v. *Continuous Amount* indicates words that refer to the amount of continuous quantities such as objects, liquids, and spaces (i.e., half, whole, piece, more). An example would be, "See *all* of these cans? I'm going to take *half* of them and put them in the shopping cart. That's *a lot* of cans!";

vi. *Deictics* refers to words that are place deictics/ pro-forms and rely on the context of which they are used to determine whether they are used spatially (i.e., here, there, somewhere). An example would be, "I will put the frogs right *here,* and the butterflies over *there* by the door";

vii. *Spatial Features and Properties* indicates words that describe 2- and 3-dimensional objects, people, and spaces (i.e., straight, curvy, round). An example would be, “A square has four *straight sides*, and four right *angles*”;

viii. *Pattern* refers to spatial words that are used in a spatial pattern (i.e., next, first, repeat). Also, a sentence such as, “*First,* we will put a small square, *then* a big square, and *then* another small square” would be coded as a spatial pattern.

The current study used a “word-type level analysis” (Cannon et al., 2007) in which spatial words in the transcripts, from the coding scheme, were identified. Then, each word was considered in the context it was used in and whether it was spatial or not. If the word was indeed used in a spatial context, it was coded based on the associated spatial category it fell under. Spatial words used in a non-spatial context were coded as “non-spatial”. Examples of when spatial words were not used in a spatial context include: “That is *right*, Paul”, “Can you *close* the drawer?”, “She is my *little* sister”, and “It will not take a *long* time”. These instances are further discussed in Appendix B. The total frequency of spatial words uttered for each classroom were summed and divided by the total time of video recording gathered for that classroom, as the tapings were of different lengths. This allows for a spatial talk per minute score for each classroom.

Results

Mathematical assessment data was collected for 70 children. One child, however, did not provide oral assent to participate in the Give-N-Task during the pre-test. Thus, this child was not post-tested on this measure. For the post-test, data was collected on 44 children for the Give-N-Task with the remaining 25 children being excluded due to reaching a ceiling effect in the pre-test (they were classified as the highest level knower, *ten-knowers*).

Analysis revealed that there was no significant difference in terms of individual SES between children who reached the ceiling during pre-test on the Give-N-Task (M = 3.16, SD = 0.99) and children who did not reach the ceiling (M = 2.64, SD = 1.24), $t(67)$ = 1.81, p = 0.08. Further analysis revealed that children who reached the ceiling during pre-test on the Give-N-Task were significantly older (M = 53.88 months, SD = 6.33) than children who did not reach the ceiling (M = 43.61 months, SD = 5.88), $t(67)$ = 6.78, $p <$ .001. This indicates that older children are more likely to have a better understanding of the number ten, and are more likely to count to ten successfully as compared to younger children.

Objective One

The first objective of the present study was to explore the types and frequency of spatial talk that ECEs naturally engage in, without the use of prompts or encouraging engagement in specific spatial activities. The total frequency of spatial talk from each video was summed and divided by the total time of the video observation in order to obtain a spatial talk per minute score.

The total time of all 32 observations was 606 minutes, or 10.1 hours (M = 18.93 minutes, SD = 6.14, *Range* = 7 to 38 minutes). The ECEs produced a total of 3,675 spatial words across the 32 observations, with substantial variability between videos (M = 114.84, SD = 51.01, *Range* = 36 to 209 spatial words). On average, they produced 6.02 spatial words per minute (SD = 1.80, *Range* = 3.05 to 9.67 words per minute). The most frequent types of spatial talk were Location and Direction (58%), followed by Spatial

Dimensions (15%), Continuous Amount (12%), and Deictics (10%). The least frequent types were Shapes (1%), Orientation and Transformation (1%), and Pattern (less than 1%). Frequencies and proportions of the types of spatial talk ECEs engaged in are shown in Table 2, as well as the number of videos that used each type of spatial talk.

Analysis revealed a number of correlations between the four most common types of spatial talk (see Table 3 for correlations between all spatial talk categories). Talk about Spatial Dimensions was positively correlated with Continuous Amount ($r = 0.51$, $p = 0.003$), Deictics ($r = 0.40$, $p = 0.02$), and Location and Direction ($r = 0.41$, $p = 0.02$). Talk about Deictics was positively correlated with Location and Direction ($r = 0.51$, $p = 0.003$) and Continuous Amount ($r = 0.42$, $p = 0.02$).

The early childhood educators produced a total of 69,319 non-spatial words (*Range* = 700 to 4,016 non-spatial words). On average, they produced 114.40 non-spatial words per minute (*SD* = 15.19, *Range* = 81.56 to 152.69 non-spatial words). ECEs who produced a lot of “other” talk were more likely to produce a lot of spatial talk, $r = 0.38$, $p = 0.03$. Overall, ECEs engaged in spatial talk approximately 5% of the time throughout the circle time activities (6.02 spatial words per minute / 114.40 non-spatial words per minute).

Objective Two

The second objective was to determine whether the amount of spatial talk engaged in by ECEs predicted children’s mathematical and numeracy knowledge. Recall that the present study is a part of a study on the effects of a numeracy intervention in child care centres. The ECEs at one centre received a mathematics workshop throughout the study period whereas the other three centres received this workshop at its completion.

An independent samples t-test was performed in order to ensure that the mathematics workshop did not affect the amount of spatial talk engaged in at this one centre. The t-test revealed that the numeracy intervention centre (*M* = 6.23, *SD* = 1.95) did not significantly differ from the other centres (*M* = 5.81, *SD* = 1.67) in terms of spatial talk per minute, $t(30) = 0.65$, $p = 0.52$. Further, there was no significant difference between the numeracy intervention centre (*M* = 5.14, *SD* = 2.61) and the other centres (*M* = 5.83, *SD* = 2.39) in terms of other mathematical talk (i.e., counting, calculations), $t(30) = -0.63$, $p = 0.53$.

Due to the clustered structure of the data (i.e., children were nested within child care classrooms), the current analysis used two separate multilevel models for each mathematical assessment (i.e., TEMA-3 and Give-N-Task) to investigate how the amount of spatial talk in each classroom influenced the children's mathematical and numeracy knowledge. For the present study, an MLM approach is needed as the unit of analysis is based on a nested structure of the data that violates the independence assumption required for other statistical analyses such as ANOVAs and regressions (e.g., Bickel, 2007; Musca et al., 2011). Thus, performing other statistical analyses that do not account for the nested structure would increase the likelihood of Type 1 error (Musca et al., 2011).

An unconditional intraclass correlation (ICC) was computed in order to determine the proportion of total variance within the sample that is due to nesting. This is similar to the R^2 effect size in a regression (Peugh, 2010). The calculation for this is:

r = between-group variability / (between-group variability + within-group variability), also known as r = intercept / (intercept + residual).

For TEMA-3, the ICC was = 96.527 / (96.527 + 191.635); $r = 0.3349$. Thus, 33.49% of the variability in TEMA-3 occurs between classrooms, with the other 66.51%

occurring among students. For the Give-N-Task, the ICC was 4.504 / (4.504 + 10.374); *r* = 0.3027. Thus, 30.27% of the variability in the Give-N-Task occurs between classrooms, with the other 69.73% occurring among students. Evidently, the data is inherently nested and an MLM approach is needed for analyses.

A series of correlations were first conducted in order to determine which variables should be controlled for in the MLM analyses. The TEMA-3 standard score from the post-test was significantly, positively correlated with SES ($r = 0.40$, $p = 0.001$) and the TEMA-3 standard score from the pre-test ($r = 0.84$, $p < .001$). However, it was not correlated with gender ($r = -0.15$, $p = 0.22$). Similarly, the Give-N-Task post-test was significantly, positively correlated with SES ($r = 0.344$, $p = 0.003$) and the Give-N-Task pre-test ($r = 0.83$, $p < .001$), but not with gender ($r = -0.23$, $p = 0.14$). Though boys had higher TEMA-3 scores at post-test ($M = 110.97$, $SD = 17.32$) compared to girls ($M = 106.23$, $SD = 13.52$), this difference was not statistically significant, $t(68) = 1.25$, $p = 0.22$. Similarly, though boys had a higher Give-N-Task score at post-test ($M = 4.83$, $SD = 4.00$) compared to girls ($M = 3.20$, $SD = 2.97$), this difference was also not significant, $t(42) = 1.51$, $p = 0.14$. Thus, only SES and the children's pre-test scores were used as covariates in both the TEMA-3 and Give-N-Task MLM analyses.

The level one model with the children's individual-level variables is:

$$Y_{ij} = \beta_{0j} + \beta_{1j}(SES_{ij}) + \beta_{2j}(Pretest_{ij}) + \varepsilon_{ij}$$

Where *i* refers to the individual student in the *j*th classroom. At the second level, the group variable of average spatial talk per minute for each classroom was entered. Spatial talk per minute was grand-mean centered in which the grand mean of the spatial talk per minute variable across all classrooms was subtracted from each classroom's individual spatial score. The benefits of centering a variable is that it creates a true zero and reduces the Y-intercept to the sample mean for the dependent variable, as well as makes interpretation simpler (e.g., Bickel, 2007). The level two model is:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(SPATIAL_j) + \mu_{0j}$$
$$\beta_{1j} = \gamma_{10}$$
$$\beta_{2j} = \gamma_{20}$$

The full model is:

$Y_{ij} = \gamma_{00} + \gamma_{01}(SPATIAL_j) + \gamma_{10}(SES_{ij}) + \gamma_{20}(Pretest_{ij}) + \mu_{0j} + \varepsilon_{ij}$

Where γ_{00} is the true score intercept (or approximate average) across all SES and the pre-test scores for each assessment (TEMA-3 and Give-N-Task), γ_{01} is the effect of spatial talk across all levels of SES and the pretest scores, γ_{10} is the intercept of the slope or average rate of change as a function of SES (a covariate), and γ_{20} is the intercept of the slope or average rate of change as a function of the pretest scores (a covariate). Further, μ_{0j} is the random intercept or unique error of individual (j) on the intercept, and ε_{ij} is the residual error or unique error associated with the individual variables or within-group variance.

The first MLM analysis revealed that spatial talk was not a significant predictor of the variability in TEMA-3 post-test standard score ($\gamma_{01} = 1.96$, $SE = 1.04$, $p = 0.06$), though this analysis was approaching significance. SES was also not a significant predictor of TEMA-3 post-test standard score ($\gamma_{10SES1} = -2.65$, $SE = 2.90$, $p = 0.37$; $\gamma_{10SES3} = 2.27$, $SE = 2.51$, $p = 0.37$), except for at the college level ($\gamma_{10SES2} = -6.84$, $SE = 3.19$, $p = 0.04$), though this relationship was negative. This indicates that children whose mother's completed college did not perform as well on TEMA-3 than those who completed higher education (undergraduate and graduate/professional school). As expected, TEMA-3 pre-test scores significantly predicted TEMA-3 post-test scores (γ_{20} = 0.73, *SE* = 0.07, *p* < .001). See Table 4 for the complete coefficients table.

In the second MLM analysis, spatial talk was not a significant predictor of the variability in the Give-N-Task scores (γ_{01} = 0.31, *SE* = 0.15, *p* = 0.51). Similarly, SES was also not a significant predictor of the Give-N-Task (γ_{10SES1} = -0.65, *SE* = 1.02, *p* = 0.53; γ_{10SES2} = -0.44, *SE* = 0.89, *p* = 0.63), except for at the university level (γ_{10SES3} = -1.78, *SE* = 0.85, *p* = 0.04), though this relationship was negative. This indicates that children whose mother's completed an undergraduate degree did not perform as well on the Give-N-Task than those who completed higher education (graduate/professional school). Finally, as expected, the Give-N-Task pre-test scores did significantly predict Give-N-Task post-test scores (γ_{20} = 1.32, *SE* = 0.15, *p* < .001). See Table 5 for the complete coefficients table.

Objective Three

The third objective was to examine the differences in spatial input between centres serving low and high SES families, as well as the differences in the quality of the language and mathematics environments. Mother's education level of children enrolled at each centre was averaged and used as a proxy for child care SES. This procedure is common where individual-level data is used to compute a group-level variable (Paccagnella, 2006). Centres with an average SES of 2.5 or lower were determined to serve families from a low SES, whereas those with an average of 2.6 to 4.0 were determined to serve families from a high SES. Two centres were serving families from a low SES (*M* = 1.45, *SD* = 0.69; *M* = 2.06, *SD* = 1.12) and the other two centres were serving families from a high SES (*M* = 3.54, *SD* = 0.77; *M* = 3.17, *SD* = 0.41).

There were a total of 14 circle time videotapes from the centres serving low SES families and 18 videotapes from centres serving high SES families. An ANOVA was conducted with SES group (high vs. low) as the independent variable and spatial talk per minute as the dependent variable. The ANOVA revealed no significant difference in spatial talk during circle time between the high SES (M = 6.27, SD = 1.88, *Range* = 3.05 to 9.67 words per minute) and low SES (M = 5.68, SD = 1.70, *Range* = 3.50 to 9.09 words per minute) child care centres, $F(1, 30) = 0.83$, $p = 0$ .37, $\eta^2 = 0.03$.

A MANOVA was also conducted with the eight spatial talk categories as the dependent variables, and group SES (high vs. low) as the independent variable to determine whether types of spatial talk differed between centres (see Table 6 for frequencies and proportions of spatial talk categories engaged in at each SES centre). The overall model for the MANOVA was not significant, $F(8,23) = 0.96$, $p = 0.49$. None of the variables within the model were found to be significant (see Table 7 for the coefficients table).

Besides spatial talk during circle time, each classroom was observed and scored four times using the mathematics subscale from the ECERS-E and the language subscale from the ECERS-R. Thus, there are a total of 12 checklists from the low SES group and 12 from the high SES group. An ANOVA was conducted with SES group (high vs. low) as the independent variable and the ECERS-E mathematics score as the dependent variable. The ANOVA revealed no significant difference between the high SES (M = 5.29, SD = 1.62) and low SES (M = 6.29, SD = 0.62) child care centres, $F(1, 22) = 4.01$, $p = 0.06$, $\eta^2 = 0.15$, though this analysis was approaching significance.

Another ANOVA was conducted with the ECERS-R language score as the dependent variable and with SES group (high vs. low) as the independent variable. The ANOVA showed no significant difference on the language scores between the high SES ($M = 6.10$, $SD = 0.42$) and low SES ($M = 5.97$, $SD = 0.64$) child care centres, $F(1, 22) = 0.32$, $p = 0.58$, $\eta^2 = 0.01$.

In addition to examining the centres at the SES level, further analysis was conducted to compare the children's mathematics scores and their individual SES. An ANOVA with children's individual SES as the independent variable and TEMA-3 standard score at post-test as the dependent variable revealed that the model was significant, $F(3,66) = 7.51$, $p < .001$, $\eta^2 = 0.25$. Post-hoc analysis revealed that children from low SES families whose mothers completed high school ($M = 95.92$, $SE = 3.79$) and college ($M = 99.75$, $SE = 4.97$) scored significantly lower than children from high SES families whose mothers completed an undergraduate degree ($M = 107.13$, $SE = 4.75$) and graduate/professional school ($M = 106.81$, $SE = 4.01$). This suggests that children who are from low SES families perform less well on the TEMA-3 than those who are from high SES families.

A second ANOVA with children's individual SES as the independent variable and Give-N-Task score at post-test as the dependent variable revealed that the model was significant, $F(3,40) = 3.92$, $p = 0.02$, $\eta^2 = 0.23$. Post-hoc analysis revealed that this difference occurred between children whose mother's highest education level was high school ($M = 1.58$, $SE = 0.42$) and children whose mothers completed graduate/professional school ($M = 5.88$, $SE = 0.86$), thus indicating that children from a low SES background scored the lowest on the Give-N-Task as compared to those children from a high SES background.

Discussion

The objectives of the present study were: (i) to examine the types and frequency of spatial language that ECEs naturally engage in during circle times, (ii) to investigate whether spatial language input predicts children's mathematical (TEMA-3) and numeracy (Give-N-Task) knowledge, and (iii) to evaluate the differences in spatial language input between ECEs, as well as the quality of the language (ECERS-R) and mathematical (ECERS-E) environment of child care centres serving high and low SES families.

Our findings based on the three objectives reveal that ECEs spent about 5% of circle time engaging in spatial talk and mostly discussed the location and direction, spatial dimension, and continuous amount of objects, people, and/or spaces. The least amount of talk occurred in the areas of shapes, orientations and transformations, and spatial patterns. Moreover, the amount of spatial input by ECEs was not related to preschooler's mathematical and numeracy competence, though for the mathematical assessment (TEMA-3), the relation was approaching significance. Further, ECEs serving high and low SES families did not differ in the amount or types of spatial language in which they engaged. Finally, the quality of the different SES centres' language and mathematical environments as determined by a classroom checklist did not differ, though a difference was approaching significance for the mathematics subscale.

These findings reveal important information on the nature of spatial talk in child care centres, especially since no study thus far has specifically investigated this type of mathematical input in this setting. The present study suggests that 3- and 4-year-old children's spatial development, and in turn, their mathematical development, may not be adequately supported prior to formal schooling in child care centres.

Spatial Input in Early Childhood Education

Hypothesis one predicted that the early childhood educators would engage most in spatial talk with regards to categories about shapes and spatial dimensions (e.g., "big", "small"), and less in the categories of spatial features and properties (e.g., describing that all squares have four sides) and talk about patterning. The ECEs demonstrated engagement in certain spatial categories that were partially consistent with the first hypothesis. For example, ECEs did not talk about shapes as much as was expected, though they did engage in talk about spatial dimensions. As expected, there was minimal talk about spatial patterns, and spatial features and properties. Though it was assumed that ECEs would talk about shapes most often (i.e., Clements, 2004a, p.285), especially given the popularity of shapes in children's early environments (i.e., toys), this category of spatial talk was actually one of the least demonstrated.

Clements (2004a, p. 285) acknowledges that the American early childhood curriculum includes teaching children about the prototypes of the four most popular shape categories: circle, rectangle, square, and triangle. Most children are aware of these prototypes before they even attend preschool. However, the ECEs in the present study did not tend to build upon this knowledge and as a result, children did not get opportunities to be exposed to atypical shapes (e.g., an isosceles triangle as compared to an equilateral triangle). By the age of five, children are already rigid in their thinking that a square is not a rectangle (Hannibal, 1999). ECEs should be describing and exploring the characteristics of shapes so that children's concepts of shapes and their categories remain flexible, such as describing that "triangles have three sides", so that even if a child encounters a non-equilateral triangle, they are still able to determine that the shape is indeed a triangle (Clements, 2004a, p. 285). The findings of the present study reveal that ECEs do not teach children about the characteristics of shapes, as talk about spatial properties and features only occurred about 2% of the time out of all the spatial categories, with talk about shapes occurring even less often. Since children's concepts of shapes stabilize around six years of age (Hannibal, 1999), it is important that children are introduced to various examples of shapes, atypical prototypes, and they should be able to classify shapes based on their attributes prior to this age or risk confusion in later geometrical instruction.

Lee, Lee, and Collins (2009) found that when teaching about shape properties and features does occur at the early and elementary school level, ECEs tend to focus on definitions and naming attributes in a way that leads to fact memorizing, but ensuring whether children are fully understanding these terms is overlooked. The NCTM (2000) even emphasizes that early mathematics and spatial education should not just focus on memorizing terminology and definitions, but on exploring these features by using manipulatives.

The finding that pattern was the least type of spatial talk engaged in by ECEs is consistent with prior research investigating the types of mathematical instruction that children receive in Ontario child care centres (Perlman & Zhang, 2010). In fact, pattern talk only occurred once in one video recording out of the 32 videotapes. Our finding is similar to Perlman and Zhang's (2010) finding; the instance of pattern was so low in their study that the variable was dropped from their analysis. This is contrary to the finding that kindergarten teachers score highest on pedagogical knowledge of pattern, right after number sense (Lee, 2010). However, Lee (2010) did not specify whether “pattern” included content pertaining to spatial patterns or whether it also included patterns related to numbers and operations, which is more common in preschool settings (Klibanoff et al., 2006).

Overall, it was expected that spatial language input would be limited. Engagement in spatial talk by the early childhood educators was calculated to be an average of 6.02 words per minute. It is difficult to determine whether this average constitutes a high or low level of engagement, given that the present study was of an exploratory nature and comparison with other studies is not possible. Though six words per minute appears to indicate a lot of spatial talk, many spatial words uttered by the ECEs were not explicitly uttered with the purpose of engaging in spatial teaching. For example, if an ECE said, “Can you get me the book over there on the shelf, underneath the clock?”, the words “there”, “on”, and “underneath” are used in a spatial context, but are not necessarily used for pedagogical purposes . It would be worthwhile to pursue research in this area by conducting a thematic analysis on ECEs’ explicit and implicit engagement of spatial talk.

The observation that overall spatial talk – 5% of the total circle times – by the early childhood educators was low may be due to a lack of training in mathematical instruction. Given that kindergarten teachers who have bachelor degrees score lowest on their pedagogical knowledge in spatial sense (Lee, 2010), it is likely that the ECEs in the current study would score similarly in their knowledge on spatial sense in early childhood education. Though the ECEs did not fill out a demographics questionnaire, through informal interviews with our participating early childhood educators, all but one had indicated that they did not receive any training on early mathematical teaching. This is likely due to the fact that early childhood education college programs in Ontario do not offer courses on mathematical instruction (Perlman & Zhang, 2010). Only one ECE mentioned that she had taken a mathematics teaching course, and that was because she was enrolled in a four-year bachelor's degree program. Early childhood education accounts for 90% of the variance in time spent engaging in mathematical teaching - the higher level of education an ECE has, the more likely they are to teach mathematical content (Perlman & Zhang, 2010). Additionally, ECEs rate mathematics on the lower end of important things to teach children (Brown, 2005). Thus, our current findings provide further evidence that early childhood educators may not engage in mathematical, and specifically spatial, teaching due to a lack of knowledge on children's early mathematical development and the importance of mathematics on subsequent academic competence, such as in literacy (Duncan et al., 2007).

Besides the scarcity of spatial input by early childhood educators during circle time, we noted the large variability in spatial talk observed by the ECEs. For example, over a period of eight weeks, the ECEs produced a minimum of 3.05 spatial words per minute to 9.67. This variability is also comparable to that of parental engagement in spatial talk at home. Pruden and colleagues (2011) found that parents produced as low as 5 spatial words to as high as 525 spatial words in a 90-minute natural observation over three years. We also noted in our study that in terms of SES, there was a large variability for the centres serving families from a high SES (minimum of 3.05 to maximum of 9.67 spatial words per minute) and for those serving families from a low SES (minimum of

3.50 to maximum of 9.09 spatial words per minute). The present findings, together with Pruden and colleagues' (2011) findings, indicate that children's spatial input varies considerably across home and ECE environments. Thus, it would be beneficial for parents and ECEs to purposefully engage in spatial activities that naturally elicit spatial language, considering this type of talk tends to not occur with other, every day activities and routines (Ferrara et al., 2011). Our observation of the circle time videos revealed that ECEs did not introduce children to spatial activities such as puzzles, blocks, or even shape manipulatives. Instead, there appeared to be a routine the ECEs followed which consisted of some songs, at least one story reading, and an activity such as drawing on a chalkboard.

Although there was large variability in the amount of spatial input that the ECEs in each classroom engaged in, there was still a low portion of spatial talk engaged in overall. As such, it is unsurprising that our second hypothesis – the amount of ECE's spatial input would be related to preschoolers' mathematical and numeracy knowledge – was not supported. However, it is possible that differences in children's mathematical and numeracy abilities are due to other factors in the environment and not just the amount of spatial talk. This is evident by the intraclass correlation calculations (ICC), which revealed a large portion of the variance in the children's mathematics scores was due to differences between classrooms.

Additionally, the present study included seventy participants (but only forty-two for the Give-N-Task due to a ceiling effect at pre-test) at the first, individual level. Despite the acceptable number of participants at the first level, the number of classrooms at the second level was six. Though there is no "rule" as to how large of a sample size is needed at the highest level in a nested model, it is always recommended to have as many units as possible in order for the true effect to emerge (Snijders, 2005). Thus, with more classrooms and hence more participants, we hypothesize that a significant positive relation between spatial input and children's mathematical competence would be found, especially given that spatial talk was marginally predictive of TEMA-3 scores. However, we were unable to increase the number of classrooms to run a powerful nested model due to unforeseen circumstances and the time constraint of the participant recruitment process of the present study. Evaluating the variability in spatial talk of more classrooms may have allowed for the true effect that spatial talk has on children's mathematics knowledge to be present, given its consistent relationship in the previous literature (e.g., Geary et al., 2000; Gunderson et al., 2012; Holmes et al., 2008; Kyttälä et al., 2003; Laski et al., 2013; Rasmussen & Bisanz, 2005; Robinson et al., 1996; Thompson et al., 2013).

The finding that spatial talk did not predict children's mathematical abilities is contrary to what Pruden and colleagues (2011) found when evaluating the mathematical and spatial gains children demonstrated when hearing spatial language in the home, even though both studies had many similarities. Both studies were one of the first to examine spatial language input in a natural versus a lab setting, to not provide spatial talk specific to the assessment that the children were tested on, and to not test the children right after hearing spatial language, but after a delay. One explanation for this could be due to the fact that the present study ran over the span of eight weeks versus Pruden and colleagues' (2011) study that ran over a period of three years, allowing for a broader collection of data.

Another explanation for the differences in findings could be because the spatial words uttered by ECEs were not made salient enough for the children to pay attention and encode them whereas in a home setting, it is much easier for parents to focus a child's attention and maintain it. Gentner's (1988) relational shift hypothesis suggests that spatial language helps children shift their focus from objects as a whole (e.g., what shape they are) to the relations between objects. Spatial language provides children with the saliency required to notice such relational features, pay attention to them, and encode them. Thus, the hypothesis suggests that during spatial and mathematical tasks, children with a higher understanding and vocabulary of spatial terms are better able to retrieve such information, which leads to a reduction in their cognitive load and makes it easier to focus on the solution at hand. Thus, to be able to encode such information, the spatial language children hear must be made salient to them.

Spatial talk was coded regardless of what activity the ECEs were engaging in, for example, if an ECE reading a book said, "The frog jumped into the box", the word *into* would be coded as a location/direction word. However, even if there was a picture depicting this spatial relation, it may not have been as salient as if the ECE would have demonstrated putting something *into* the boundaries of a volume with the use of props. Observation of the circle time videotapes indicated that using physical materials with spatial talk rarely occurred. This suggests that perhaps spatial language alone does not increase children's spatial abilities, but requires the accompaniment of spatial activities such as block play (Casey, Andrews, et al., 2008), puzzle play (Levine et al., 2012), and/or the use of gestures (Ehrlich et al., 2006). Thus, an explanation for the different findings between the present and Pruden and colleagues' (2011) study could be because it is easier to engage in activities such as block and puzzle play in a dyadic interaction versus a group setting. Perhaps parents in Pruden and colleagues' (2011) study participated in such activities more frequently, though this information was not reported. Further, spatial language heard in the home during other every day activities may be more salient because of the one-on-one interaction involved, which gives children more opportunity to pay attention to such language, adopt it into their own vocabulary, and thus, perform better on spatial tasks. It is possible that such one-on-one interactions between ECEs and children occur outside of circle time. Future research is needed to explore the spatial input that takes place throughout the day at child care centres.

Child Care and Socioeconomic Status

It has been found that there is a lack of spatial input that children from a lower SES receive at home (e.g., Dearing et al., 2012; Verdine et al., 2013). For example, parents of preschoolers and first grade children from low income households report that they use less spatial words with their children and that their daughters engage in less spatial activities compared to parents from high income households (Dearing et al., 2012; Verdine et al., 2013). In line with existing research, our findings show that children from lower SES backgrounds performed less well on both the TEMA-3 and Give-N-Task compared to children from a high SES background. Thus, children from a low SES background are most likely not getting as much mathematical input or resources at home compared to children from high SES households. This is consistent with other research findings that children as young as four years of age from different backgrounds exhibit differences in mathematical achievement (e.g., Duncan et al., 2007; Klibanoff et al., 2006).

Our findings underscore the fact that children from low SES families especially need mathematical input in their child care environments to buffer the negative outcomes that are often associated with low SES. Yet, our findings reveal that these children receive the same amount of spatial input at child care, regardless of the SES of the families that the centres serve. It has been found that the more enriched experiences children between 6 and 54 months old from low income families receive from high quality child care protect them from having poor mathematics outcomes (Dearing et al., 2009). In fact, some children between 6 and 54 months from low income families who attend such centres achieve equivalent academic competence in middle childhood as their affluent peers (Dearing et al., 2009). Due to low SES families lacking the materials, psychosocial resources, and support children require for high cognitive and social development (Dearing & Taylor, 2007), high quality child care can make up for these inadequacies. Children from a low SES background who hear less spatial talk at home (Verdine et al., 2013) and engage in less spatial activities (Dearing et al., 2012) especially require such input in child care settings in order to offset the negative outcomes, such as poor spatial abilities, associated from a lack of enriched stimulation (Verdine et al., 2013).

A possible explanation for the nonsignificant difference found in spatial engagement between centres serving families of different SES backgrounds could be due to a lack of difference found in the mathematics and language environments between these centres. The mathematics subtest was approaching significance, with centres serving low SES families scoring higher on the mathematics checklist. However, given that the checklists are heavily based on the materials in the classroom, many child care classrooms score highly on the subtests overall (Frede, Jung, Barnett, Lamy, & Figueras, 2007). Thus, the checklists are a good measure for analyzing the general environment of a classroom, but may not necessarily provide insight into how the materials within a classroom are being used between ECEs and children.

Limitations

The present study had a few limitations. The first is that the ECEs did not complete a demographics questionnaire, which prevented us from collecting information about their specific level or type of educational training, and specifically, their level of mathematical training. Given that early childhood educators' education level (Perlman & Zhang, 2010), their belief in the importance of mathematics (Brown, 2005), and their own mathematical knowledge (Moseley, 2005) largely influence the frequency and amount of time ECEs spend in mathematics teaching, this information could have been helpful to the current study's objectives. However, given the time commitment the ECEs had to give to the present study, it was not feasible to add a demographic questionnaire. We tried to overcome this limitation by informally asking the ECEs about their backgrounds, and they provided sufficient information to gain a general understanding of their mathematics training.

The other limitation was that the length of each circle time was different, making it more difficult for interpretation of the frequency of spatial talk in each video. That being said, to circumvent this limitation, we used words per minute to account for the different lengths of the circle times. Further, the purpose of the present study was to ascertain the types and frequency of spatial talk engaged in by ECEs during a typical circle time in a natural setting. If ECEs had been given a time constraint for the circle times, it may have compromised the integrity of the data as some ECEs may have felt too rushed, while others may have been searching for more activities to do to fill the time. Thus, the varying circle time lengths may actually be deemed to be a strength of the present study.

The last limitation is that the present study only analyzed the spatial talk engaged in during circle times, which is a small portion of the day. As previously mentioned, there may be episodes of one-on-one engagement between ECEs and children in specific spatial activities outside of circle time due to the difficulty of engaging in such activities with a group of children, such as working on a puzzle. Nevertheless, given that the present study was the first to explore spatial input specifically in a child care setting, circle time was deemed to be a practical period to investigate because of the purposeful teaching that ECEs engage in during this time. Thus, analyzing the circle times allowed for a general idea of the amount of spatial input that occurs throughout the day.

Future Research

The findings of the present study provide insight into the future research that should be conducted in the field. Given the overall low engagement of spatial talk that occurred during circle times, it would be beneficial to explore the spatial language input that occurs throughout other periods during the day. Children spend most of their time in free play and in the activity centres at child care (Winton & Buysse, 2005). Since activities such as block play elicit more spatial language than regular activities (Ferrara et al., 2011), it would be important to compare the differences in spatial talk engagement by ECEs during circle times and typical spatial activities in order to gain a better understanding of the spatial input children are receiving at child care.

Further, our study provided the foundation required to evaluate spatial language using an experimental approach. Such an approach would compliment the present study by examining the influence of spatial language alone on mathematics abilities. Research has shown there are other ways to foster children's spatial development, such as the use of gestures (e.g., Cartmill et al., 2013). Children could be assigned into various conditions during a non-spatial activity with an adult (such as reading a book)- a spatial language condition, a gesture condition, a spatial language and gesture condition, and neither spatial language nor gesture, while engaging in the activity. This methodology would allow for teasing apart the exact influence of spatial language on mathematical thinking by isolating spatial language from other factors that are related to increased mathematical and spatial understanding.

Future research could also introduce a spatial program to centers by educating ECEs on the benefits of such engagement and how to foster spatial development, while measuring children's mathematical and spatial gains over the course of the school year and comparing them to centres that did not receive such a program. This could provide insight into the importance of providing spatial input to children at childcare, particularly for those from low income families.

Lastly, future research on the nature of spatial input in child care centres should also measure children's own spatial language production. Past research indicates that the amount of spatial language parents use at home increases children's own use of spatial language, which in turn increases their subsequent spatial abilities (Pruden et al., 2011). Thus, children's own use and comprehension of spatial language could mediate the relationship between ECE's spatial language input and children's mathematical comprehension.

Conclusion

The importance of having spatial abilities is evident, given that spatial abilities provide the necessary tools required for success in STEM related occupations (Shea et al., 2001) and in mathematical achievement (e.g., Cheng & Mix, 2014). Further, the finding that spatial abilities are malleable, and that the effects of spatial training are long-lasting (Uttal et al., 2013) indicates the importance of adult spatial input. Though gender spatial ability differences suggest that spatial abilities are innate (e.g., Linn & Peterson, 1985), research indicates that this difference can be eliminated through training and practice (e.g., Feng, Spence, & Pratt, 2007). Research indicating that the amount of spatial language and activities young children engage in mediates the relationship between SES and spatial ability (Verdine et al., 2013), as well as that children's spatial abilities decline over the summer from kindergarten to first grade (Huttenlocher et al., 1998), point to the fact that the development of young children's spatial abilities strongly depends on adult input. With an appropriate enriched environment, the mastery of spatial abilities is possible to achieve.

The present study was one of the first to investigate the nature of spatial input in a child care setting, particularly in a Canadian context. Results indicate that overall, ECEs engaged in a low amount of spatial language input during circle times- a period of purposeful teaching. The early childhood educators also did not differentiate the amount of spatial talk that they engaged in, regardless of the socioeconomic income status of the families in which they were serving. This is critical given that children from low SES households receive minimal spatial input (e.g., Verdine et al., 2013) and high quality input at child care could potentially buffer the negative mathematical outcomes of such limited input (e.g., Dearing et al., 2009).

The present study was also was one of the few to investigate the benefits of spatial input on 3- and 4-year-old children's mathematical abilities outside of a laboratory setting. Our results are promising given that the relationship between the amount of spatial input by ECEs and children's overall mathematics abilities was approaching significance. This finding highlights that spatial input in preschool should be an important subject to focus on, along with other areas such as literacy and numeracy, as the mathematical knowledge children acquire prior to entering formal schooling have a critical effect on their mathematical achievement throughout elementary school (Duncan et al., 2007). Thus, fostering their development as early as possible is essential. The findings from the present study shed light on the spatial input ECEs are providing to preschoolers, and the practical importance of further studying children's early environments in home and child care settings. Further, it is vital to understand how children's early environments can facilitate the acquisition of their spatial and mathematical knowledge so that they are better prepared for educational outcomes.

References

Alexander, C., & Ignjatovic, D. (2012). Early childhood education has widespread and long lasting benefits (Special Report). Retrieved from TD Economics website: http://www.td.com/document/PDF/economics/special/di1112_EarlyChildhoodEducation.pdf

Aunola, K., Leskinen, E., Lerkkanen, M., & Nurmi, J. (2004). Developmental dynamics of math performance from preschool to grade 2. *Journal of Educational Psychology, 96*(4), 699-713. doi:10.1037/0022-0663.96.4.699

Battista, M. T. (1999). Geometry results from the Third International Mathematics and Science Study (geometry and geometric thinking). *Teaching Children Mathematics, 5,* 367-374.

Bickel, R. (2007). *Multilevel analysis for applied research: It's just regression!* New York: Guilford.

Blades, M., Blaut, J. M., Darvizeh, Z., Elguea, S., Sowden, S., Soni, D., …. Uttal, D. (1998). A cross-cultural study of young children's mapping abilities. *Transactions of the Institute of British Geographers, 23*(2), 269-277. doi:10.1111/j.0020-2754.1998.00269.x

Brenneman, K. (2011). Assessment for preschool science learning and learning environments. *Early Childhood Research and Practice, 13*(1), 1-9. Retrieved from http://files.eric.ed.gov/fulltext/EJ931225.pdf

Brosnan, M. J. (1998). Spatial ability in children's play with LEGO blocks. *Perceptual and Motor Skills, 87*(1), 19-28.

Brown, E. T. (2005). The influence of teachers' efficacy and beliefs regarding mathematics instruction in the early childhood classroom. *Journal of Early Childhood Teacher Education, 26*(3), 239-25. doi:10.1080/10901020500369811

Bushnik, T. (2006). *Child care in Canada (Children and youth research paper series)*. Retrieved from the Statistics Canada website http://www.statcan.gc.ca/pub/89-599-m/89-599-m2006003-eng.pdf

Caldera, Y. M., Culp, A. M., O'Brien, M., Truglio, R. T., Alvarez, M., & Huston, A. C. (1999). Children's play preferences, construction play with blocks, and visual-spatial skills: Are they related? *International Journal of Behavioral Development, 23*(4), 855-872. doi:10.1080/016502599383577

Caldera, Y. M., Huston, A. C., & O'Brien, M. (1989). Social interactions and play patterns of parents and toddlers with feminine, masculine, and neutral toys. *Child Development, 60*(1), 70-76.

Campbell, F. A., Ramey, C. T., Pungello, E., Sparling, J., & Miller-Johnson, S. (2002). Early childhood education: Young adult outcomes from the Abecedarian Project. *Applied Developmental Science, 6*(1), 42-57. doi:http://dx.doi.org/10.1207/S1532480XADS0601_05

Canada ranks poorly in spending on early childhood education. (2014, February 09). *The Globe and Mail.* Retrieved from http://m.theglobeandmail.com/news/national/canada-ranks-poorly-in-spending-on-early-childhood-education/article16771470/?service=mobile&cmpid=rss1&click=dlvr.it

Cannon, J., Levine, S., & Huttenlocher, J. (2007). *A system for analyzing children and caregivers' language about space in structured and unstructured contexts*. Spatial

Intelligence and Learning Center (SILC) technical report.

Carroll, D. W. (2008). *Psychology of Language.* Belmont, CA: Thomson Wadsworth.

Cartmill, E., Pruden, S. M., Levine, S. C., Goldin-Meadow, S., & Center, S. I. L. (2010). The role of parent gesture in children's spatial language development. In Proceedings of the 34th Annual Boston University Conference on Language Development (pp. 70–77). Retrieved from http://mail.spatiallearning.org/publications_pdfs/Cartmill%20Pruden%20Levine%20%20Goldin-Meadow%20(in%20press).pdf

Cartmill, E., Young, J. M., Levine, S., & Goldin-Meadow, S. (2013). *Improving young children's jigsaw puzzle skills: The role of spatial gestures.* Retrieved from http://www.spatiallearning.org/index.php/showcase/175-showcase-february-2013-gesture-but-not-speech-input-improves-children-s-performance-on-puzzle-assembly

Casey, B. M., Andrews, N., Schindler, H., Kersh, J. E., Samper, A., & Copley, J. (2008). The development of spatial skills through interventions involving block building activities. *Cognition and Instruction, 26*(3), 269–309. doi: 10.1080/07370000802177177

Casey, B. M., Erkut, S., Ceder, I., & Young, J. M. (2008). Use of storytelling context to improve girls' and boys' geometry skills in kindergarten. *Journal of Applied Developmental Psychology, 29*(1), 29–48. doi:10.1016/j.appdev.2007.10.005

Casey, B. M., Nuttall, R., & Pezaris, E., (1997). Mediators of gender differences in mathematics college entrance test scores: A comparison of spatial skills with internalized beliefs and anxieties. *Developmental Psychology, 33*(4), 669-680. doi: 0.1037/0012-1649.33.4.669

Casey, B. M., Nuttall, R., Pezaris, E., & Benbow, C. P. (1995). The influence of spatial ability on gender differences in mathematics college entrance test scores across diverse samples. *Developmental Psychology, 31*(4), 697-705. doi:10.1037/0012-1649.31.4.697

Catts, H. W., Fey, M. E., Zhang, X., & Tomblin, J. B. (2001). Estimating the risk of future reading difficulties in kindergarten children: A research-based model and its clinical implementation. Language*, Speech, and Hearing Services in Schools, 32*(1), 38-50. doi:10.1044/0161-1461(2001/004

Cheng, Y. L., & Mix, K. S. (2014). Spatial training improves children's mathematics ability. *Journal of Cognition and Development*, *15*(1), 2-11. doi:10.1080/ 15248372.2012.725186

Christakis, D. A., Zimmerman, F. J., Garrison, M. M. (2007). Effect of block play on language acquisition and attention in toddlers. *Archives of Pediatrics and Adolescent Medicine, 161*(10), 967-971. doi:10.1001/archpedi.161.10.967

Claessens, A., Duncan, G., & Engel, M. (2009). Kindergarten skills and fifth-grade achievement: Evidence from the ECLS-K. *Economics of Education Review, 28*(4), 415-427. doi:10.1016/j.econedurev.2008.09.003

Clements, D. H. (1999). Geometric and spatial thinking in young children. In J. Copley (Ed.), *Mathematics in the early years* (pp. 66-79). Reston, VA: The National Council of Teachers of Mathematics.

Clements, D. H. (2004a). Geometric and spatial thinking in early childhood education. In D. H. Clements, J. Sarama, & A. DiBiase (Eds.), *Engaging young children in mathematics: Standards for early childhood mathematics education* (pp. 267-297). Mahwah, NJ: Lawrence Erlbaum Associates.

Clements, D. H. (2004b). Major themes and recommendations. In D. H. Clements, J. Sarama, & A. DiBiase (Eds.), *Engaging young children in mathematics: Standards for early childhood mathematics education* (pp. 7-72). Mahwah, NJ: Lawrence Erlbaum Associates.

Clements, D. H., Swaminathan, S., Hannibal, M. A. Z., & Sarama, J. (1999). Young children's concepts of shape. *Journal for Research in Mathematics Education, 30(2),*192-212.

Clifford, R. M., Reszka, S. S., & Rossbach, H.-G. (2010). Reliability and validity of the Early Childhood Environment Rating Scale. Unpublished Working paper. FPG Child Development Institute, University of North Carolina. Retrieved from http://ers.fpg.unc.edu/sites/ers.fpg.unc.edu/files/ReliabilityEcers.pdf

Colom, R., Contreras, M. J., Botella, J., & Santacreu, J. (2002). Vehicles of spatial ability. *Personality and Individual Differences, 32*(5), 903-912. doi:http://dx.doi.org/10.1016/S0191-8869(01)00095-2

de Kock, F., & Schlechter, A. (2009). Fluid intelligence and spatial reasoning as predictors of pilot training performance in the South African Air Force (SAAF). *SA Journal of Industrial Psychology, 35*(1), 31-38. doi:10.4102/sajip.v35i1.753

Dearing, E., Casey, B. M., Ganley, C. M., Tillinger, M., Laski, E., & Montecillo, C.

(2012). Young girls' arithmetic and spatial skills: The distal and proximal roles of family socioeconomics and home learning experiences. *Early Childhood Research Quarterly, 27*(3), 458-470. doi:10.1016/j.ecresq.2012.01.002

Dearing, E., McCartney, K., & Taylor, B. A. (2009). Does higher quality early child care promote low-income children's math and reading achievement in middle childhood? *Child Development, 80*(5)*,* 1329-1349. doi:http://dx.doi.org/10.1111/j.1467-8624.2009.01336.x

Dearing, E., & Taylor, B. A. (2007). Home improvements: Within-family associations between income and the quality of children's home environments. *Journal of Applied Developmental Psychology, 28*(5-6), 427-444. doi:http://dx.doi.org/10.1016/j.appdev.2007.06.008

Delgado, A. R., & Prieto, G. (2004). Cognitive mediators and sex related differences in mathematics. *Intelligence, 32*(1), 25–32. doi:10.1016/S0160-2896(03)00061-8

Desouza, J. M., & Czerniak, C. (2002). Social behaviors and gender differences among preschoolers: Implications for science acitivites. *Journal of Research in Childhood Education, 16*(2), 175-188. doi:http://dx.doi.org/10.1080/02568540209594983

Dessalegn, B., & Landau, B. (2008). The role of language in binding and maintaining feature conjunctions. *Psychological Science, 19*(2), 189-195. doi: 10.1111/j.1467-9280.2008.02066.x

Duncan, G., Dowsett, C., Claessens, A., Magnuson, K., Huston, A., Klebanov, P., … Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428-1446. doi:10.1037/0012-1649.43.6.1428

Ehrlich, S., Levine, S., & Goldin-Meadow, S. (2006). The importance of gestures in children's spatial reasoning. *Developmental Psychology, 42*(6), 1259 –1268. doi: 10.1037/0012-1649.42.6.1259

Ensminger, M. E., & Fothergill, K. E. (2012). A decade of measuring SES: What it tells us and where to go from here. In M. H. Bornstein & R. H. Bradley (Eds.), *Socioeconomic status, parenting, and child development* (pp. 13-28). New York, NY: Routledge.

Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological Science, 18*(10), 850-855. doi: 10.1111/j.1467-9280.2007.01990.x

Ferrara, K., Hirsh-Pasek, K., Newcombe, N. S., Golinkoff, R. M., & Lam, W. S. (2011). Block talk: Spatial language during block play. *Mind, Brain, and Education, 5*(3), 143-151. doi:http://dx.doi.org/10.1111/j.1751-228X.2011.01122.x

Fluck, M., Linnell, M., & Holgate, M. (2005). Does counting count for 3- to 4-year-olds? Parental assumptions about preschool children's understanding of counting and cardinality. *Social Development*, *14*(3), 496–513. doi:10.1111/j.1467-9507.2005.00313.x

Frede, E., Jung, K., Barnett, W. S., Lamy, C. E., & Figueras, A. (2007). *The Abbott preschool program longitudinal effects study (APPLES)*. Rutgers, NJ: National Institute for Early Education Research.

Geary, D. C., Saults, S. J., Liu, F., Hoard, M. K. (2000). Sex differences in spatial cognition, computational fluency, and arithmetical reasoning. *Journal of Experimental Psychology, 77*(4), 337-353. doi:10.1006/jecp.2000.2594

Gentner, D. (1988). Metaphor as structure mapping: the relational shift. *Child Development, 59*(1), 47–59. doi:10.2307/1130388

Gentner, D., & Goldin-Meadow, S. (Eds.). (2003). *Language in mind: Advances in the study of language and thought* (pp. 195–235). Cambridge, MA: MIT Press.

Ginsburg, H. P., & Baroody, A. (2003). *Test of early mathematics ability-third edition*. Austin, TX: Pro-Ed

Graham, T. A., Nash, C., & Paul, K. (1997). Young children's exposure to mathematics: The child care context. *Early Childhood Education Journal*, *25*(1), 31–38.

Gregory, K. M., Kim, A. S., & Whiren, A. (2003). The effect of verbal scaffolding on the complexity of preschool children's block constructions. In D. E. Lytle (Ed.), *Play and Educational Theory and Practice: Play and Culture Studies, Vol. 5* (pp. 117–133). Westport, CT: Praeger.

Guillot, A., Champely, S., Batier, C., Thiriet, P., & Collet, C. (2007). Relationship between spatial abilities, mental rotation, and functional anatomy learning. *Advances in Health Sciences and Education, 12*(4), 491-507. doi:10.1007/s10459-006-9021-7

Gunderson, E. A., Ramirez, G., Beilock, S. L., & Levine, S. C. (2012). The relation between spatial skill and early number knowledge: The role of the linear number line. *Developmental Psychology, 48*(5), 1229–1241. doi:10.1037/a0027433

Gunderson, E. A., Ramirez, G., Beilock, S. L., & Levine, S. C. (2013). Teachers' spatial anxiety relates to 1st- and 2nd- graders' spatial learning. *Mind, Brain, and Education, 7*(3), 196-199. doi:10.1111/mbe.12027

Halari, R., Hines, M., Kumari, V., Mehrotra, R., Wheeler, M., Ng, V., & Sharma, T. (2005). Sex differences and individual differences in cognitive performance and their relationship to endogenous gonadal hormones and gonadotropins. *Behavioral Neuroscience, 119*(1), 104-117. doi:10.1037/0735-7044.119.1.104

Hango, D. (2013). *Gender differences in science, technology, engineering, mathematics, and computer science (STEM) programs at university.* (Catalogue number 75-006-X). Retrieved from the Statistics Canada website http://www.statcan.gc.ca/pub/75-006-x/2013001/article/11874-eng.pdf

Hanline, M. F., Milton, S., & Phelps, P. C. (2010). The relationship between preschool block play and reading and maths abilities in early elementary school: A longitudinal study of children with and without disabilities. *Early Child Development and Care, 180*(8), 1005-1017. doi:10.1080/03004430802671171

Hannibal, M. A. (1999). Young children's developing understanding of geometric shapes. *Teaching Children Mathematics*, *5*(6), 353- 357.

Harms, T., Clifford, R. M. & Cryer, D. (2004). *Early Childhood Environment Rating Scale – Revised Edition*. New York, NY: Teachers College Press.

Hausmann, M., Slabbekoorn, D., Van Goozen, S. H., Cohen-Kettenis, P. T., & Güntürkün, O. (2000). Sex hormones affect spatial abilities during the menstrual cycle. *Behavioural Neuroscience, 114*(6), 1245-1250. doi:10.1037/0735-7044.114.6.1245

Hegarty, M., Keehner, M., Khooshabeh, P., & Montello, D. R. (2009). How spatial abilities enhance, and are enhanced by, dental education. *Learning and Individual Differences, 19*(1), 61-70. doi:10.1016/j.lindif.2008.04.006

Hermer-Vazquez, L., Moffet, A., & Munkholm, P. (2001). Language, space, and the development of cognitive flexibility in humans: The case of two spatial memory tasks. *Cognition, 79*(3), 263-299. doi:10.1016/S0010-0277(00)00120-7

Holmes, J., Adams, J. W., & Hamilton, C. J. (2008). The relationship between visuospatial sketchpad capacity and children's mathematical skills. *European Journal of Cognitive Psychology, 20*(2), 272-289. doi:10.1080/09541440701612702

Hubbard, E. M., Piazza, M., Pinel, P., & Dehaene, S. (2005) Interactions between number and space in parietal cortex. *Nature Reviews Neuroscience, 6*(6), 435 448. doi:10.1038/nrn1684

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., & Lyons, T. (1991). Early vocabulary growth: Relation to language input and gender. *Developmental Psychology, 27*(2), 236–248. doi:10.1037/0012-1649.27.2.236

Huttenlocher, J., Levine, S., & Vevea, J. (1998). Environmental input and cognitive growth: A study using time-period comparisons. *Child Development, 69*(4), 1012-1029. doi:10.2307/1132360

Hyde, D. C., Winkler-Rhoades, N., Lee, S-A., Izard, V., Shapiro, K. A., & Spelke, E. S. (2011). Spatial and numerical abilities without a complete natural language. *Neuropsychologia, 49*(5), 924-936. doi:10.1016/j.neuropsychologia.2010.12.017

Internicola, R. W., & Weist, R. M. (2003). The acquisition of simple and complex spatial locatives in English: A longitudinal investigation. *First Language, 23*(68), 239-248. doi:10.1177/01427237030232005

Jordan, N. C., Kaplan, D., Locuniak, M. N., & Ramineni, C. (2007). Predicting first-grade math achievement from developmental number sense trajectories. *Learning Disabilities Research & Practice, 22*(1), 36-46. doi:10.1111/j.1540-5826.2007.00229.x

Keehner, M., Lippa, Y., Montello, D. R., Tendick, F., & Hegarty, M. (2006). Learning spatial skill for surgery: How the contributions of abilities change with practice. *Applied Psychology, 20*(4), 487-503. doi:10.1002/acp.1198

Kersh, J., Casey, B., & Young, J. M. (2008). Research on spatial skills and block building in girls and boys: The relationship to later mathematics learning. In B. Spodak & O. Saracho (Eds.), *Contemporary perspectives on mathematics in early childhood education* (pp. 233–253). Charlotte, NC: Information Age Publishing.

Klibanoff, R. S., Levine, S. C., Huttenlocher , J., Vasilyeva, M., & Hedges, L. V. (2006). Preschool children's mathematical knowledge: The effect of teacher "math talk". *Developmental Psychology, 42*(1), 59-69. doi:10.1037/0012-1649.42.1.59

Krauss, R. M. (1998). Why do we gesture when we speak? *Current Directions in Psychological Science, 7*(2), 54-60. doi:10.1111/1467-8721.ep13175642

Kyttälä, M., Aunio, P., Lehto, J. E., Van Luit, J., & Hautamaki, J. (2003). Visuospatial working memory and early numeracy. *Educational and Child Psychology, 20*(3), 65–76.

Lachance, J. A., & Mazzocco, M. M. (2006). A longitudinal analysis of sex differences in math and spatial skill in primary school age children. *Learning and Individual Differences, 16*(3), 195-216. doi:10.1016/j.lindif.2005.12.001

Laski, E. V., Casey, B. M., Yu, Q., Dulaney, A., Heyman, M., & Dearing, E. (2013).

Spatial skills as a predictor of first grade girls' use of higher level arithmetic strategies. *Learning and Individual Differences, 23,* 123-130. doi: 10.1016/j.lindif.2012.08.001

Lee, J. (2010). Exploring kindergarten teachers' pedagogical content knowledge of mathematics. *International Journal of Early Childhood, 42*(1), 27-41. doi: 10.1007/s13158-010-0003-9

Lee, J., Lee, J. O., & Collins, D. (2009). Enhancing children's spatial sense using tangrams. *Childhood Education, 86*(2), 92-94. doi:10.1080/00094056.2010.10523120

Lee, M. D., & Sarnecka, B. W. (2011). Number-knower levels in young children: Insights from bayesian modeling. *Cognition, 120*(3), 391-402. doi: 10.1016/j.cognition.2010.10.003

Lee, J., Zambrzycka, J., & Kotosopoulos, D. (under review). Block play: A predictor of preschoolers' numeracy competence. *Journal of Experimental Child Psychology.*

Levine, S. C., Huttenlocher, J., Taylor, A., & Langrock, A. (1999). Early sex differences in spatial skill. *Developmental Psychology, 35*(4), 940–949. doi:10.1037/0012-1649.35.4.940

Levine, S. C., Ratliff, K. R., Huttenlocher, J., & Cannon, J. (2012). Early puzzle play: A predictor of preschoolers' spatial transformation skill. *Developmental Psychology, 48*(2), 530-542. doi:10.1037/a0025913

Levine S. C., Suriyakham, L. W., Rowe, M. L., Huttenlocher, J., & Gunderson, E. A. (2010). What counts in the development of young children's number knowledge? *Developmental Psychology, 46*(5), 1309-1319. doi:10.1037/a0019671

Levine, S. C., Vasilyeva, M., Lourenco, S. F., Newcombe, N. S., & Huttenlocher, J. (2005). Socioeconomic status modifies the sex difference in spatial skill. *Psychological Science, 16*(11), 841-845. doi:10.1111/j.1467-9280.2005.01623.x

Linn, M. C., & Peterson, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Development, 56*(6), 1479-1498. doi: 10.2307/1130467

Loewenstein, J., & Gentner, D. (2005). Relational language and the development of relational mapping. *Cognitive Psychology, 50*(4), 315-353. doi:10.1016/j.cogpsych.2004.09.004

Mann, V. A., Sasanuma, S., Sakuma, N., & Masaki, S. (1990). Sex differences in cognitive abilities: A cross-cultural perspective. *Neuropsychologia, 28*(10), 1063-1077. doi: /10.1016/0028-3932(90)90141-A

McGuinness, D., & Morley, C. (1991). Sex differences in the development of visuo-spatial ability in pre-school children. *Journal of Mental Imagery, 15*(3-4), 143-150.

Mix, K. S., & Cheng, Y. L. (2012). The relation between space and math: Developmental and educational implications. In Janette B. Benson (Ed.), *Advances in child development and behavior* (Vol. 42, pp. 197–243). Burlington: Academic Press.

Miyake, A., Friedman, N. P., Rettinger, D. A., Shah, P., & Hegarty, M. (2001). How are visuospatial working memory, executive functioning, and spatial abilities related? A latent-variable analysis. *Journal of Experimental Psychology, 130*(4), 621-640. doi:10.1037/0096-3445.130.4.621

Moore, D. S., & Johnson, S. P. (2008). Mental rotation in human infants: A sex difference. *Psychological Science, 19*(11), 1063-1066. doi:10.1111/j.1467-9280.2008.02200.x

Moseley, B. (2005). Pre-service early childhood educators' perceptions of math-mediated language. *Early Education and Development, 16*(3), 385-396. doi: 10.1207/s15566935eed1603_5

Musca, S. C., Kamiejski, R., Nugier, A., Méot, A., Er-Rafiy, A., Brauer, M. (2011). Data with hierarchical structure: Impact of intraclass correlation and sample size on Type-1 Error. *Frontier in Psychology, 2*(74). Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3110485/

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics. (2006). *Curriculum focal points: A quest for coherence.* Reston, VA: National Council of Teachers of Mathematics.

National Geographic Education Foundation. (2002). *Roper 2002 global literacy survey: 16.* Retrieved March 17, 2014, from http://www.nationalgeographic.com/geosurvey2002/download/RoperSurvey.pdf

National Research Council. (2006). *Learning to think spatially.* Washington, DC: National Research Council, National Academic Press.

The National Institute of Child Health and Human Development Early Child Care Research Network (Eds.). (2005). *Child care and child development.* New York, NY: The Guilford Press.

The Observer XT 8.0. (2008) [Computer Software]. Netherlands: Noldus Information

Technology

Ontario Ministry of Education. (2004). *The Ontario curriculum: Social studies, grade 1 to 6; History and geography, grades 7 and 8.* Retrieved from http://www.edu.gov.on.ca/eng/curriculum/elementary/sstudies18curr.pdf

Paccagnella, O. (2006). Centering or not centering in multilevel models? The role of the group mean and the assessment group effects. *Evaluation Review, 30*(1)*,* 66-85. doi:10.1177/0193841X05275649

Park, B., Chae, J. L., & Boyd, F. (2008). Young children's block play and mathematical learning. *Journal of Research in Childhood Education, 23*(2)*,* 157-162.

Peisner-Feinberg, E. S., Burchinal, M. R., Clifford, R. M., Culkin, M. L., Howes, C., Kagan, S. L., & Yazejian, N. (2001). The relation of preschool child-care quality to children's cognitive and social developmental trajectories through second grade. *Child Development, 72*(5)*,* 1534-1553. doi:10.1111/1467-8624.00364

Perlman, M., Zhang, J. (2010). Math instruction in child-care centres: Prevalence and predictors of early mathematics instruction in child care settings. *Canadian Council on Learning.* Retrieved from http://www.ccl-cca.ca/pdfs/FundedResearch/201009PerlmanZhangMathInstructionFullReport.pdf

Peugh, J. L. (2010). A practical guide to multilevel modeling. *Journal of School Psychology, 48*(1)*,* 85-112. doi:http://dx.doi.org/10.1016/j.jsp.2009.09.002

Piaget, J. (1977) Problems in equilibration. In M. Appel & L. Goldberg (Eds.), *Topics in cognitive development: Vol. 1. Equilibrations: Theory, research and application* (pp. 3–13). New York: Plenum.

Pollman, M.J. (2010). *Blocks and beyond*. Baltimore, MD: Paul H. Brookes Publishing Co.

Program for International Student Assessment (PISA). (2012). Washington, DC: Institute of Education Sciences.

Pruden, S. M., Levine, S. C., & Huttenlocher, J. (2011). Children's spatial thinking: does talk about the spatial world matter? *Develomental Science, 14*(6)*,* 1417-1430. doi:10.1111/j.1467-7687.2011.01088.x

Quaiser-Pohl, C., Geiser, C., & Lehmann, W. (2006). The relationship between computer-game preference, gender, and mental-rotation ability. *Personality and Individual Differences, 40*(3)*,* 609-619. doi:http://dx.doi.org/10.1016/ j.paid.2005.07.015

Quinn, P. C., & Liben, L. S. (2008). A sex difference in mental rotation in young infants. *Psychological Science, 19*(11)*,* 1067-1070. doi:http://dx.doi.org/10.1111/j.1467-9280.2008.02201.x

Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2012). Spatial anxiety relates to spatial abilities as a function of working memory in children. *The Quarterly Journal of Experimental Psychology, 65*(3)*,* 474-487. doi: http://dx.doi.org/10.1080/17470218.2011.616214

Rasmussen, C., & Bisanz, J. (2005). Representation and working memory in early arithmetic. *Journal of Experimental Child Psychology, 91*(2), 137–157. doi:10.1016/j.jecp.2005.01.004

Rauscher, F. H., Krauss, R. M., & Chen, Y. (1996). Gesture, speech, and lexical access: The role of lexical movements in speech production. *Psychological Science, 7*(4)*,* 226–231.

Reid, D.K., Hresko, W.P., & Hammill, D.D. (1989). *Test of early reading ability (TERA-2)*. Austin, TX: Pro-Ed.

Robinson, N. M., Abbott, R. D., Berninger, V. W., & Busse, J. (1996). Structure of abilities in math-precocious children: Gender similarities and differences. *Journal of Educational Psychology, 88*(2)*,* 341-352. doi:10.1037/ 0022-0663.88.2.341

Romano, E., Babchishin, L., Pagani, L. S., & Kohen, D., (2010). School readiness and later achievement: Replication and extension using a nationwide Canadian survey. *Developmental Psychology, 46*(5)*,* 995-1007. doi:http://dx.doi.org/ 10.1037/a0018880

Servin, A., Bohlin, G., & Berlin, L. (1999). Sex differences in 1-, 3-, and 5-year-olds' toy-choice in a structured play-session. *Scandinavian Journal of Psychology, 40*(1)*,* 43-48. DOI: 10.1111/1467-9450.00096

Seo, K.-H., & Ginsburg, H. P. (2004), What is developmentally appropriate in early childhood mathematics education? Lessons from new research. In D. H. Clements, J. Sarama & A.-M. DiBiase (Eds.), *Engaging young children in mathematics: Standards for early childhood mathematics education* (pp. 91-104). Hillsdale, NJ: Erlbaum.

Shea, D. L., Lubinski, D., & Benbow, C. (2001). Importance of assessing spatial ability in intellectually talented young adolescents: A 20-year longitudinal study. *Journal of Educational Psychology, 93*(3)*,* 604-614. doi:http://dx.doi.org/10.1037/0022-0663.93.3.604

Shusterman, A., Lee, S. A., & Spelke, E. S. (2008). Young children's spontaneous use of geometry in maps. *Developmental Science, 11*(2)*,* F1–F7. doi: 10.1111/j.1467-7687.2007.00670.x

Siegler, R. S., & Ramani, G. B. (2009). Playing linear number board games- but not circular ones- improves low-income preschoolers' numerical understanding. *Journal of Educational Psychology, 101*(3)*,* 545-560. doi:http://dx.doi.org/10.1037/a0014239

Silverman, I., Kastuk, D., Choi, J., & Phillips, K. (1999). Testosterone levels and spatial ability in men. *Psychoneuroendocrinology, 24*(8)*,* 813-822.

Silverman, I. W., & Rose, A. P. (1980). Subitizing and counting skills in 3-year-olds. *Developmental Psychology, 16*(5), 539-540. doi: 0012-1649.16.5.539

Skwarchuk, S-L., Sowinski, C., & LeFevre, J-A. (2014). Formal and informal home learning activities in relation to children's early numeracy and literacy skills: The development of a home numeracy model. *Journal of Experimental Child Psychology, 121,* 63-84. doi:http://dx.doi.org/10.1016/j.jecp.2013.11.006

Smith, I. M. (1964). *Spatial ability: Its educational and social significance*. San Diego: Knapp.

Snijders, T. A. B. (2005). Power and sample size in multilevel linear models. In B. S. Everitt & D. C. Howell (Eds.), *Encyclopedia of statistics in behavioral science (Vol. 3)* (pp. 1570-1573). Chisester, England: Wiley.

Stannard, L., Wolfgang, C. H., Jones, I., & Phelps, P. (2001). A longitudinal study of the predictive relations about construction play and mathematical achievement. *Early Childhood Development and Care, 167,* 115-125.

Statistics Canada. (2006). *Parental leave practices- General social survey.* Retrieved from the Statistics Canada website http://www.statcan.gc.ca/pub/89-625-x/2007002/c-g/4054999-eng.htm

Statistics Canada. (2013). *Employment rate of women with children by age of youngest child- Labour force survey.* Retrieved from the Statistics Canada website http://www.statcan.gc.ca/pub/89-503-x/2010001/article/11387/tbl/tbl005-eng.htm

Stieff, M. (2007). Mental rotation and diagrammatic reasoning in science. *Learning and Instruction, 17*(2)*,* 219–234. doi:10.1016/j.learninstruc.2007.01.012

Sylva, K., Siraj-Blatchford, I., & Taggart, B. (2010). *ECERS-E The Four Curricular Subscales Extension to the ECERS-R: 4th Edition*. New York, NY: Teachers College Press.

Tepylo, D. (2014). *Spatial reasoning and mathematics education: A review of the literature* (Doctoral dissertation, University of Toronto). Retrieved from http://www.researchgate.net/profile/Diane_Tepylo

Thompson, J. M., Nuerk, H-C., Moeller, K., & Kadosh, R. C. (2013). The link between mental rotation ability and basic numerical representations. *Acta Psychologica, 144*(2)*,* 324-331. doi:http://dx.doi.org/10.1016/j.actpsy.2013.05.009

Trends in International Mathematics and Science Study (TIMSS). (2011). Chestnut Hill, Mass.: Boston College.

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: A meta-analysis of training studies. *Psychological Bulletin, 139*(2)*,* 352–402. doi:10.1037/a0028446

van Galen, M. S., & Reitsma, P. (2008). Developing access to number magnitude: A study of the SNARC effect in 7- to 9-year-olds. *Journal of Experimental Child Psychology, 101*(2), 99–113. doi:10.1016/j.jecp.2008.05.001

Verdine, B. N., Golinkoff, R. M., Hirsh-Pasek, K., Newcombe, N. S., Filipowicz, A. T., & Chang, A. (2013). Deconstructing building blocks: Preschoolers' spatial assembly performance relates to early mathematics skills. *Child Development, 85*(3), 1062-1076. doi:10.1111/cdev.12165

Verdine, B. N., Troseth, G. L., Hodapp, R. M., & Dykens, E. M. (2008). Strategies and correlates of jigsaw puzzle and visuospatial performance by persons with prader-willi syndrome. *American Journal on Mental Retardation, 113*(5), 343-355. doi:10.1352/2008.113:342-35

Vernon-Feagans, L., & Bratsch-Hines, M. E. (2013). Caregiver-child verbal interactions in child care: A buffer against poor language outcomes when maternal language input is less. *Early Childhood Research Quarterly, 28*(4*),* 858-873. doi:http://dx.doi.org/10.1016/j.ecresq.2013.08.002

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin, 117*(2)*,* 250-270. doi:http://dx.doi.org/10.1037/0033-2909.117.2.250

Vukovic, R. K., & Lesaux, N. K. (2013). The language of mathematics: Investigating the ways language counts for children's mathematical development. *Journal of Experimental Child Psychology, 115*(2)*,* 227-244. doi:http://dx.doi.org/10.1016/j.jecp.2013.02.002

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology, 101*(4)*,* 817-835. doi:http://dx.doi.org/10.1037/a0016127

Weckbacher, L. M., & Okamoto, Y. (2014). Mental rotation ability in relation to self-perceptions of high school geometry. *Learning and Individual Differences, 30,* 58-63. doi:http://dx.doi.org/10.1016/j.lindif.2013.10.007

Whorf, B. (1956). *Language, thought and reality.* Cambridge, MA: MIT Press.

Winton, P., & Buysse, V. (Eds.). (2005). *Early Developments (Vol. 9).* Chapel Hill, NC*:* FPG Child Development Institute, The University of North Carolina at Chapel Hill.

Wolfgang, C. H., Stannard, L. L., & Jones, I. (2001). Block play performance among preschoolers as a predictor of later school achievement in mathematics. *Journal of Research in Childhood Education, 15*(2)*,* 173-180. Retrieved from http://search.proquest.com/docview/62260636?accountid=15090

Wolfgang, C., Stannard, L., & Jones, I. (2003). Advanced constructional play with LEGOs among preschoolers as a predictor of later school achievement in mathematics. *Early Child Development and Care, 173*(5)*,* 467-475. doi:http://dx.doi.org/10.1080/0300443032000088212

Wynn, K. (1992). Children's acquisition of number words and the counting system. *Cognitive Psychology, 24*(2)*,* 220–251.

Zorzi, M., Priftis, K., & Umiltà, C. (2002). Brain damage: Neglect disrupts the mental number line. *Nature, 417*(6885)*,* 138-139.

Table 1

Total frequencies and proportions of mother's highest education level

Education	Total Number	Proportion of Total
High School	15	0.21
College/Trade	9	0.13
University	18	0.26
Graduate/Professional	28	0.40

Table 2

Total frequencies, proportions, and number of videos using each spatial category produced by ECEs

Type of Spatial Category	Total Instances Across Videos	Proportion	Number of Videos Using This Type (N=32)
Spatial Dimensions	553	0.15	32
Shapes	54	0.01	13
Locations and Directions	2147	0.58	32
Orientations and Transformations	35	0.01	14
Continuous Amount	428	0.12	32
Deictics	381	0.10	32
Spatial Features and Properties	76	0.02	17
Pattern	1	< 0.01	1

Table 3

Correlations between spatial categories engaged in by ECEs

Type of Spatial Category	1	2	3	4	5	6	7	8
1. Spatial Dimensions	-	-.02	.42*	.16	.51**	.40*	.18	-.14
2. Shapes	-	-	-.20	-.08	.26	-.09	.03	.26
3. Locations and Directions	-	-	-	-.04	.28	.51**	.31	-.11
4. Orientations and Transformations	-	-	-	-	-.06	-.05	.26	-.01
5. Continuous Amount	-	-	-	-	-	.42*	.31	.09
6. Deictics	-	-	-	-	-	-	.28	-.03
7. Spatial Features and Properties	-	-	-	-	-	-	-	-.02
8. Pattern	-	-	-	-	-	-	-	-

Note. * * *p*<.01, * *p*<.05

Table 4

Results of the multilevel model analysis with TEMA-3 post-test

						95% confidence interval	
Variable	Coefficient	SE	*t*	*df*	*p*	Lower	Upper
Intercept	34.04	7.20	4.73	5	.00	19.64	48.43
SES=1	-2.65	2.90	-0.91	3	.37	-8.45	3.15
SES=2	-6.84	3.19	-2.15	3	.04	-13.20	-0.47
SES=3	2.27	2.51	0.90	3	.37	-2.75	7.29
TEMA pre-test	0.73	0.07	11.04	1	.00	0.60	0.86
Spatial talk per minute	1.96	1.04	1.88	1	.06	-0.13	4.04

Table 5

Results of the multilevel model analysis with Give-N-Task post-test

Variable	Coefficient	SE	*t*	*df*	*p*	95% confidence interval	
						Lower	Upper
Intercept	0.76	0.90	0.85	5	.40	-1.06	2.59
SES=1	-0.65	1.02	-0.64	3	.53	-2.71	1.41
SES=2	-0.44	0.89	-0.49	3	.63	-2.25	1.37
SES=3	-1.80	0.85	-2.12	3	.04	-3.51	-0.08
Give-N-Task pre-test	1.32	0.15	8.68	1	.00	1.01	1.63
Spatial talk per minute	0.31	0.47	0.67	1	.51	-0.63	1.25

Table 6

Total frequencies and proportions of spatial talk categories engaged in at each SES centre

	High SES		Low SES	
Type of Spatial Category	Total	Proportion	Total	Proportion
Spatial Dimensions	284	0.13	269	0.18
Shapes	31	0.01	23	0.02
Locations and Directions	1302	0.60	845	0.56
Orientations and Transformations	25	0.01	10	0.01
Continuous Amount	246	0.11	182	0.12
Deictics	236	0.11	145	0.10
Spatial Features and Properties	39	0.02	37	0.02
Pattern	1	0.00	0	0.00

Note. SES of child care centre was determined by average of maternal highest education level attained of the children attending each centre

Table 7

MANOVA summary with SES as the predictor variable and spatial talk categories as the dependent variables

Variables	*F*	*df*	Error *df*	*p*
Spatial Dimensions	0.28	1	30	.60
Shapes	0.04	1	30	.84
Locations and Directions	1.64	1	30	.21
Orientations and Transformations	0.83	1	30	.37
Continuous Amount	0.04	1	30	.84
Deictics	2.34	1	30	.14
Spatial Features and Properties	0.24	1	30	.63
Pattern	0.77	1	30	.39

Participant Diagram

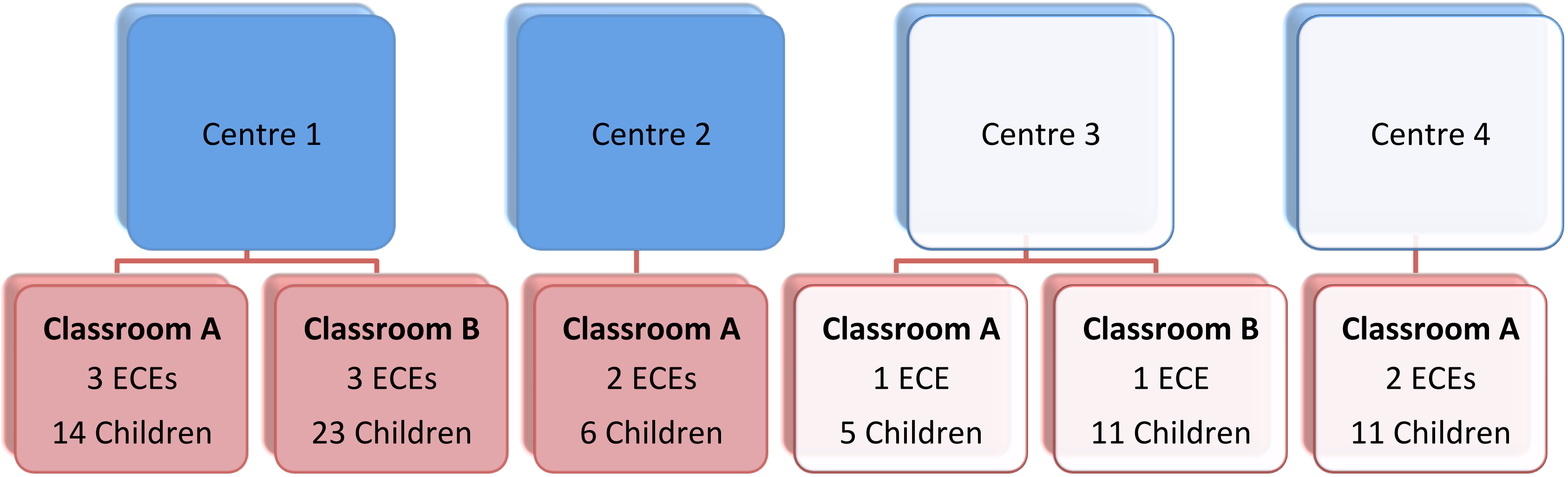

Figure 1. Number of classrooms, child, and ECE participants across each child care centre. Darker shades indicate centres serving high SES families and lighter shades represent centres serving low SES families

Appendix A

Demographic Questionnaire

Child's Date of Birth _ _/_ _/_ _ (MM/DD/YY)

Child Gender (circle one) Male / Female

Please indicate: the primary language your child speaks at home ;
the first language your child learned to speak .

Number of Siblings ___ Age of Siblings ___________

Mother's Highest Education (please circle):
High School
College/Trade
University
Graduate/Professional

Father's Highest Education (please circle):
High School
College / Trade
University
Graduate/Professional

Appendix B

Spatial Coding Scheme

(Cannon, Levine, & Huttenlocher, 2007)

- Only talk by the ECE running the circle time to be coded
- There are eight spatial domains and sub-categories under each domain. You may have to refer to the context of a certain spatial word to determine if it is spatial or non-spatial, as well as what domain it falls under

Summary of Spatial Domains:

A. **Spatial Dimensions:** words that describe the size of objects, people and spaces (not including weight or density because these do not have a tangible presence in the 2D/3D world).
B. **Shapes:** Words that describe the standard or universally recognized form of enclosed two- and three- dimensional objects and spaces (does not include ice cream *cone* or ice *cube* because they are not always the standard form of these shapes- e.g., an ice cube is still an ice cube even if it looks distorted or is melting).
C. **Locations and Directions:** Words that describe the relative position of objects, people, and points in space (Similar words are found in Category G: Spatial Features and Properties- must refer to context).
D. **Orientations and Transformations:** Words that describe the relative orientation or transformation of objects and people in space.
E. **Continuous Amount:** Words that describe amount (including relative amount) of continuous quantities (including extent of an object, space, liquid, etc.). The word "some" is not included here because it is a discrete quantity. Also, quantities that do not have a spatial dimension (time, temperature, weight, money, etc.) are not included.
F. **Deictics:** Words that are place deictics/pro-forms (i.e., these words rely on context to understand their referent)
G. **Spatial Features and Properties:** Words that describe the features and properties of 2D and 3D objects, spaces, people, and the properties of their features. Words are coded in this category if they refer solely to the features/properties of a single shape or space. If the context is referring to the relation between two or more objects, spaces, or people, then they are coded in category C.
H. **Pattern:** Words that *indicate* a person may be talking about a spatial pattern (e.g., big, little, big, little, etc. or small circle, bigger circle, even bigger circle, etc.). No number patterns (1,3,1,3) or non-spatial dimensions (red, blue, red, blue) are coded here.

Examples of non-spatial usages:

	Examples
1. Homonyms or Endearments ▪ Spatial words that can also have	▪ I *left* my sweater on the bus ▪ You got that answer *right*

non-spatial meanings, as well as words used to denote affection	▪ It is your *turn* ▪ *Close* the drawer ▪ You are my *little* angel
2. Metaphors/Abstract Phenomena ▪ Anything that has to do with relating to, dimensions, and movements of objects that do not exist in the 2D or 3D world	▪ You have a *big* heart ▪ That is a *little* problem ▪ That took a *long* time ▪ The *back* of my mind ▪ He is *out of* his mind
3. Spatially Ambiguous ▪ Usages where it is difficult to tell whether the speaker is referring to objects that are real in 2D or 3D, or abstract phenomena	▪ It will only be a *short* walk ▪ That was a *big* meal ▪ He’s your *little* brother ▪ I’m *full* because I ate too much
4. Nominatives ▪ Spatial words that are used as part of a name or a body part. Also, spatial prepositions preceding verbs, adverbs, or conjunctions	▪ *Big* Bird ▪ *Little* Drummer Boy ▪ My *back* hurts ▪ Sit on your *bottom/behind* ▪ Don’t go *up*stairs
5. Other ▪ Ambiguous phrases	▪ *Turn* on the light/television ▪ Let’s play/eat *together* ▪ He was *on/in* the bus ▪ I like the boy *in* the book ▪ Go *away* ▪ Look *into/at* my eyes ▪ I want to eat it *with* milk
Non-Spatial Usages for Prepositions	
6. Verb particles ▪ Prepositions that function as part of a phrase/verb or a common expression (e.g., “*look up* something in the dictionary” together means to investigate, but the words cannot be broken down into a separate verb and preposition)	▪ I ran *into* a friend ▪ Turn *on/off* the light ▪ Get *over* it ▪ Oh, come *on* ▪ Fold *up* the letter ▪ Let’s get *out of doors* today ▪ Did you go *into hiding?* ▪ Did he get *on board* ▪ Do it *by yourself*
7. Non-spatial Prepositional Relations ▪ Prepositions used to convey relationships between an object and the rest of the sentence	▪ We are meeting them *between* 5 and 6 o’clock ▪ The movie has to be returned The movie has to be returned *by* Friday ▪ I am leaving *in* five minutes ▪ Your appointment is *on* Tuesday ▪ Eat *with* your fork ▪ Play *with* me ▪ He is *in* one of those moods ▪ He went *by* train

	▪ I’ll wear it *with* pride ▪ I’m bad *at* math ▪ The book is *on/about* colours ▪ I was hit *by* a ball ▪ I came *on* foot ▪ Talk *on* the phone ▪ I moved it *to* make some room ▪ The book was written *by* Dr. Seuss ▪ Get the truck *from* the toy store

Spatial Domains

A. SPATIAL DIMENSIONS	
Modifiers	**Words**
Unconstrained Spatial Dimensions	Big (Bigger, Biggest) Little (Littler, Littlest) Small (Smaller, Smallest) Large (Larger, Largest) Tiny (Tinier, Tiniest) Enormous Huge Gigantic Teeny Itsy-bitsy Itty-bitty
Horizontal/Vertical Dimensions	Long (Longer, Longest) Short
Only Vertical	Tall (Taller, Tallest)
Only Horizontal	Wide (Wider, Widest) Narrow (Narrower, Narrowest) Thick (Thicker, Thickest) Thin (Thinner, Thinnest) Skinny (Skinnier, Skinniest) Fat (Fatter, Fattest)
Horizontal/ Vertical Dimensions in 3D	Deep (Deeper, Deepest) Shallow (Shallower, Shallowest)
Enclosed 3D Object	Full (Fuller, Fullest) Empty (Emptier, Emptiest)
Overall Spatial Words	Size Length Height Width Depth Volume Capacity Area (as in of a square)

	Measure (Measurement)
B. SHAPES	
Modifiers	**Words**
2D Shapes Without Sides	Circle Oval Ellipse Semicircle
2D Shapes	Triangle Square Rectangle Diamond Pentagon Hexagon Octagon Parallelogram Quadrilateral Rhombus Polygon
3D Shapes	Sphere Globe Cone Cylinder Pyramid Cube Rectangular Prism
Overall Shape Words	Shape
C. LOCATION AND DIRECTION	
Modifiers	**Words**
Terms that Follow Nouns	At To Toward From (as in moving *away* from something)
Resting Along A Surface	On Onto Upon Off
Within/Outside Boundaries of a Volume	In Into Inside Within Out Out of Outside
Along a Vertical Axis	Under Underneath

	Beneath Below Over Above Up Upper Upward Down Downer Downward (On) top Bottom High (Higher, Highest) Low (Lower, Lowest) Column Vertical Vertically
Along a Horizontal Axis	Left Leftward Right Rightward Front In front Back In back Ahead Behind Sideways Row Horizontal Horizontally
Proximal to Another Point	By Near (Nearer, Nearest) Nearby Close (Closer, Closest) Next to With Beside Far (Farther, Farthest) Away Beyond Further Past Against Together Separate

	Separated Join Joined Apart
Relationship Between Two Other Points (at least)	Between Among
Equal Distance from Something	Middle Center
In Broad Vicinity of Another Point	About Around Throughout
Length of Object/Person/Point	Along Lengthwise
Cardinal Direction	North (Northern) South (Southern) East (Eastern) West (Western)
One Side to Another Side of Object/Person/Point	Around Through
Other Side of Object/Person/Point	Across Over Opposite Aside Reverse
Direction of Orientation of Object/Person/Point/Plane	Around Reverse Reversed Back (verb) Backward Forward Parallel Perpendicular Diagonal Down (as in “down the street”) Up (as in “up the street”)
Overall Location and Direction Words	Location Position Direction Route Path Head Headed Heading Place Distance
D. ORIENTATION AND TRANSFORMATION	

Modifier	Words
Orientation of Object/Person	Upside down Right side up Upright
Transformation Around Axis	Turn (Turned, Turning) Flip (Flipped, Flipping) Rotate (Rotated, Rotating)
Overall Orientation/Transformation Words	Orientation Rotation
E. CONTINTUOUS AMOUNT	
Modifier	**Words**
Entire Amount	Whole All
Inexact Part of Continuous Object	Part Piece Section Bit Segment Portion Fragment Fraction Some A lot A little Much Enough
Exact Part of Continuous Object	Half Third Quarter Fifth Sixth Seventh Eight Ninth Tenth Etc.
Absence of Continuous Amount	None
Comparison Between Continuous Amounts	More Less Same Equal
Standard Measurement Units	Inch Foot Mile Centimeter Meter

	Etc.
Overall Continuous Amount Words	Amount Room Space Area (as in "space")
F. DEITICS	
Modifier	**Words**
Location of Speaker	Here
Location of Other	There
Question to Identify Location	Where
No, Any, Some, or All Locations	Anywhere Somewhere Nowhere Everywhere Wherever
G. SPATIAL FEATURES AND PROPERTIES	
Modifier	**Words**
Flat Surfaces	Side Sided Edge Edged Border Bordered Line
Curvature of Object	Round (Rounder, Roundest, Rounded) Curve (Curved, Curvy) Bump (Bumped, Bumpy) Bent (Bend, Bended, Bendy) Wave Wavy Lump Lumpy Arc Sector
Lack of Curvature	Straight (Straighter, Straightest) Flat (Flatter, Flattest)
Two Sides Meeting	Angle Corner Point (Pointed, Pointy)
Surface of 3D Object	Plane Surface Face
Standard Shapes	Circular Rectangular Triangular Conical

	Spheric Spherical Elliptical Cylindric Cylindrical Shaped (e.g., heart-shaped)
Orientation of 2D or 3D Shape or Space	Horizontal Vertical Diagonal Axis
Relation Between Elements	Parallel Perpendicular Symmetry Symmetric Symmetrical
H. PATTERN	
Modifier	**Words**
Consistent Organization	Pattern Design Sequence Order
Relative Location in Pattern	Next First Last Before After
Type of Organization of Pattern	Repeat (repetition) (Repeated, Repeating) Increase (Increased, Increasing) Decrease (Decreased, Decreasing)
Overall Pattern Words	Pattern Design Sequence Order