Spatial Language Development in Preterm and Full-Term Infants: The Role of Object Exploration and Parents' Spatial Input

By

Mert Kobaş

A thesis submitted to the Graduate School of Social Sciences and Humanities in Partial

Fulfillment of the Requirements for the Degree of

Master of Arts

in

Psychology

KOÇ ÜNİVERSİTESİ

August 2021

Spatial Language Development in Preterm and Full-Term Infants: The Role of Object Exploration and Parents' Spatial Input

Koç University

Graduate School of Social Sciences and Humanities

This is to certify that I have examined this copy of a master's thesis by

Mert Kobaş

and have found that it is complete and satisfactory in all respects, and that any and all revisions required by the final examining committee have been made.

Committee Members:

____

Assoc. Prof. Tilbe Göksun

____

Prof. Aylin Küntay

____

Assist. Prof. Ece Demir-Lira

Date: ______________________________

STATEMENT OF AUTHORSHIP

This thesis contains no material which has been accepted for any award or any other degree or diploma in any university or other institution. It is affirmed by the candidate that, to the best of her knowledge, the thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signed Mert Kobaş

ABSTRACT

Spatial Language Development in Preterm and Full-Term Infants: The Role of Object Exploration and Parents' Spatial Input

Mert Kobaş

Master of Arts in Psychology

August 2021

Through object exploration, infants learn features about objects, which is related to children's language learning. Object exploration and parents' verbal spatial input may lead to cascades for the development of spatial language that can differ for preterm infants and full-term infants. This longitudinal study examined whether object exploration at 14 months and parents' spatial input at 14 (Time 1) and 19 (Time 2) months were related to spatial language in preterm (Mean gestational age = 30 weeks) and full-term infants (Mean gestational age = 38.9 weeks) at 26 months. The object exploration at Time 1 and parents' spatial input at Times 1 & 2 were coded from the free play sessions. We expected that preterm infants would receive less spatial input from their parents compared to full-term infants and they would explore the objects less than full-term infants. Additionally, object exploration was associated with parents' spatial input and together they predicted children's spatial language, providing developmental cascades. Our results showed that there was no difference for object exploration and parents' spatial input based on neonatal condition. Object exploration was not uniquely associated with parents' spatial input, controlling for age and neonatal condition. However, we found that the interaction between object exploration and parents' spatial input at 14 months predicted spatial language at 26 months, regardless of neonatal status. These findings suggest that object exploration and parents' spatial input lead to a cascading effect on the development of spatial language at younger ages for preterm and full-term children.

Keywords: object exploration, spatial language, parental input, preterm infants

ÖZETÇE

Preterm ve Full-Term Bebeklerde Uzamsal Dil Gelişimi: Obje Keşfinin ve Ebeveynin Uzamsal Kelime Kullanımının Rolü

Mert Kobaş

Psikoloji Bölümü, Yüksek Lisans

Ağustos, 2021

Bebekler objeleri keşfederek objelerin özelliklerini öğrenebilir. Ayrıca obje keşfi dil gelişimi ile de yakından alakalıdır. Obje keşfi ve ebeveynlerin uzamsal kelime kullanımı, zamanından önce doğan (preterm) ve zamanında doğan (full-term) bebeklerde gelişimsel kaskadlar yaratarak, uzamsal dil gelişimine katkıda bulunabilir. Bu boylamsal çalışma zamanından önce doğan (preterm, ortalama doğum haftası = 30 hafta) ve zamanında doğan bebeklerde (full-term, ortalama doğum haftası= 38,9 hafta),14.aydaki (1.zaman dilimi) obje keşfinin ve 14. (1. zaman dilimi) ve 20. (2. zaman dilimi) aylardaki ebeveynlerin uzamsal kelime kullanımlarının, 26. (3. zaman dilimi) aydaki çocukların uzamsal dil gelişimi ile ilişkisini incelemiştir. 1. zaman dilimindeki obje keşfi ve 1. ve 2. zaman dilimindeki ebeveynlerin uzamsal kelime kullanımları serbest oyun oturumlarından kodlanmıştır. Bu çalışmada, preterm bebeklerin, full-term bebeklere göre ebeveynlerinden daha az uzamsal kelime duyması ve daha az obje keşfi yapmaları beklenmekteydi. Ek olarak, obje keşfinin ebeveynlerin uzamsal kelime kullanımları ile ilişkili olması ve obje keşfi ile ebeveynlerin uzamsal kelime kullanımlarının etkileşiminin çocukların uzamsal kelime bilgisini yormadası beklenmekteydi. Sonuçlarımız obje keşfi ve ebeveynlerin uzamsal kelime kullanımı açısından preterm ve full-term bebekler arasında bir fark olmadığını gösterdi. Obje keşfinin, yaş ve yenidoğan durumu kontrol edildiğinde, ebeveynlerin uzamsal dil kullanımı ile arasında anlamlı bir ilişki bulunmamaktadır. 14. aydaki obje keşfi ve ebeveynlerin uzamsal dil kullanımı arasındaki etkileşim değişkeni, yenidoğan durumu farketmeksizin, 26. aydaki uzamsal kelime sayısını yordamaktadır. Bu sonuçlar, obje keşfi ve ebeveynlerin uzamsal kelime kullanımının bir kaskad etkisi yaratarak, full-term ve preterm bebeklerdeki uzamsal dil gelişimine katkıda bulunduğunu göstermektedir.

Anahtar kelimeler: obje keşfi, uzamsal dil, ebeveynlerin kelime kullanımları, preterm bebekler

ACKNOWLEDGEMENTS

This research was supported by the award from James S. McDonnell Foundation (Grant/Award Number: 220020510) to Tilbe Göksun.

Being a grad student is like being an infant. The environment and their bodies challenge infants to learn basic and advanced things. In my master's period, I learned many things, from basics to more advanced skills, just like an infant. I had challenges that are the must for development, but I also had (and still have) great supporters, who are my friends, my family, and my advisor. They are always there when I fall, when I stand; when I fail and when I succeed.

To start with, I would like to thank my advisor, Tilbe Göksun. She was not only my mentor but also like an academic mother to me. She always pushed her limits whenever I needed help to develop my research skills and academic thinking. She introduced me with the area where development and cognition overlap. Every "thanks" in the world is not enough to describe my gratefulness to her. In my life, my biggest turning point was the moment when I took her course and I met her. I'll try harder to make her proud in my later academic life.

I would also like my committee members, Aylin Küntay and Ece Demir-Lira, to spend their time reviewing my thesis. They gave valuable feedback for my proposal. I improved this research thanks to them. I also want to thank Karen Adolph and Infant Action Lab members. I learned many things from their lab meetings in my last year, which contribute to my research.

My friends in the Language and Cognition Lab also deserve a big thanks. I learned many things from every single lab member within the lab's collaborative and supportive working environment. In particular, I want to thank Aslı Aktan Erciyes for contributing my research skills and supporting my research. Her guidance was invaluable. Thanks to my dear

colleagues, Eylül and Erim. I learned many things from them, and we did fantastic jobs. I also want to thank one of my best friends, Emir, for supporting me in my academic life and good humor. Thanks to the rest of the preterm team, Işıl and Salih, we helped each other for the project whenever one of us needed. I would like to thank Demet, she was very helpful and kind from the beginning of my lab days. I would like to thank other Language and Cognition lab members, Burcu, Feyza, Gülten and Esma, for their invaluable friendship. Finally, I thank to Elif, Taygun and İlke for their help in the project.

Lastly, I want to thank my mother and my father to believe in me always. We had rises and falls, but I knew that they are proud of me and show respect to my choices. They always try to protect me and they always walk with me, whenever I need.

"So long and thanks for all the fish!"

TABLE OF CONTENTS

LIST OF TABLES

Chapter 1:
INTRODUCTION

Infants' actions broaden their learning opportunities, and consequently cognitive skills, such that exploration of objects or spatial area contributes to the development of language skills. Previous studies have examined the relation between infants' exploratory actions and their cognitive skills, investigating the real-time interactions and cascading effect of motor behaviors on cognitive development (Adolph & Hoch, 2019; Iverson, 2010; Smith & Gasser, 2005). Object exploration provides information about objects with real-time behaviors (Jarvis, West & Iverson, 2020). Children having differential developmental trajectories are behind typically developed children in these skills. For instance, preterm infants, who are born before 37 weeks of gestational age, have been reported as having developmental delays in motor skills and object exploration (Ruff et al., 1984; Benassi et al., 2016; Zuccarini et al., 2018). These problems in exploration may lead to a cascading effect on later language development in preterm infants. Rather than the direct relation between exploration and overall language development, exploration may support specific linguistic units in language development such as spatial language or object names (Smith, 2013; Oudgenoeg-Paz, Leseman & Volman, 2015). However, exploration may become impactful for language development with support of social interactions. For example, parental verbal input plays a great role in infants' cognitive achievements (Golinkoff et al., 2019; Masek et al., 2021). Quality and quantity of parental input are related to children's language development (e.g., Anderson et al., 2021; Huttenlocher et al., 2007). More importantly, specific types of linguistic input such as spatial input referring to object sizes, features, rotations, locations or directions are related to development in specific domains such as spatial cognition and spatial language (Pruden, Levine & Huttenlocher, 2011; Kısa et al., 2019), and learning object names (Kobaş, Aktan-Erciyes & Göksun, 2021). Building on these earlier findings, this study investigates (1) the relation between object exploration and spatial language input of parents in preterm and full-term infants, and (2) the role of object exploration and parents' spatial input on later spatial language of preterm and full-term infants.

1.1 Spatial Language

Spatial words describe actions, features of objects, and relations between objects. For example, we use adjectives to describe spatial features of objects like small, tiny, or big. We also use prepositions to express the spatial relations between a figure object and a reference object (Talmy, 1983; Munnich & Landau, 2010). As an example, in the sentence "I put the book *on* the shelf," "on" connects the figure object (the book) to the reference object (the shelf). In that sense, prepositions are the expressions of regions or positions based on the reference object (Munnich & Landau, 2010) as well as the expressions of containment and support (Parish-Morris, 2011). Containment is the description of whether an object covers or includes another object fully or partially, like milk *in* a bowl. Support describes whether an object is placed on top of the other object, such as a computer *on* the desk. Although infants categorize these relations from very early on, comprehension and production of the words that describe these relations can be challenging (Casasola, 2008; Casasola, 2018).

Infants need to understand spatial categories to map the labels onto these spatial relations (Gentner & Boroditsky, 2001). However, this process is difficult due to the relational nature of spatial words (Gentner, 2016). The first spatial words that can be comprehended and produced by infants are "in," "on" and "under" in different languages such as English, Turkish, or Hebrew (Bowerman, 1996). Even infants at 15 months can comprehend these words if the events are familiar (Hoff & Shatz, 2009). From 18 months on, infants extend this comprehension towards unfamiliar events or situations (Meints et al., 2002). Children who learn English, Italian or Turkish can comprehend the terms for "near" around 2;5 years old and express it at around 3 years old (Johnston, 1988). The terms for "between" is comprehended and expressed between 3 and 4 years in these languages. "Right" and "left" are the last ones that children can comprehend and produce by 4-5 years (e.g., Scott & Sera, 2018; Turan, Kobaş & Göksun, 2021).

There is a great diversity in the age of acquisition of spatial labels and categories. Importantly, spatial language is also closely related to later spatial development. Besides communicative functions, spatial language augments children's spatial skills because spatial language highlights spatial information, supports learning of spatial relations, and allocates attention to task-specific information. For example, Loewenstein and Gentner (2005) found that prompting children with spatial language such as "on, in, under" increased their performance on a spatial mapping task. Following this, Simms and Gentner (2019) used a spatial task that requires finding a hidden object in the middle of other objects. They found that 4 years-olds would be more successful in this task, if they knew the words "middle" and "between." Recently, Turan and colleagues (2021) showed that comprehension and production of postpositions in Turkish were related to preschool-aged children's mental rotation abilities. Therefore, the development of spatial skills is intertwined with the development of spatial language. However, both the acquisition of spatial language and its relation to spatial skills in children under the risk of developmental delays such as preterm infants are understudied.

Preterm infants are born before 37 weeks of gestational age. Based on gestational age, preterm infants are mostly divided into 3 groups: Extremely preterm infants are born before 28 weeks, very preterm infants are born between 29 and 32 weeks, and moderately preterm infants are born between 33 and 37 weeks (Quinn et al., 2016). Preterm birth brings cognitive and physical problems such as language delays or motor problems (Sansavini, Guarini & Caselli, 2011). Even preterm infants who follow typical developmental pathways were reported as having lower scores on visuospatial performance and spatial working memory than full-term infants at ages 3-4 (Vicari et al., 2004). Preterm infants also show delays in both receptive and expressive language development (e.g., Caravale et al., 2005; Foster-Cohen et al., 2007; Sansavini et al., 2011). Studies on early spatial language development in preterms are very rare and blended with general language development analyses. A meta-analysis study by van Noort-van der Spek and colleagues (2012) covered 7 studies with preterm infants and showed that preterm infants between 3 and 12 years are behind full-term infants for complex language functions (i.e., the complete assessment of preposition knowledge, verb knowledge, grammar competence and linguistic complexity). A recent study (Clingan-Siverly et al., 2021) found that there was no difference in spatial language in a puzzle playing task between preterm and full-term preschoolers.

Overall, these variations in the age of acquisition for spatial language and spatial categories point out different developmental pathways (i.e., cascades) for spatial language development in both full-term and preterm infants.

1.2 Developmental Cascades

The development of cognitive and motor skills consists of multiple pathways in multiple timelines with complex interactions among different domains, structures, and functions, which are called developmental cascades (Oakes & Rakison, 2019). The developmental cascades approach implies that an early achievement in the developmental system, such as reaching the sitting milestone, leads to possible pathways (e.g., object exploration) to help develop later cognitive or motor skills (e.g., object knowledge). This approach argues that earlier experiences on different skills, interactions, or maturational attainments enable some pathways for the development of certain skills. However, this does not imply that earlier experiences that enable these pathways must be causes of developmental milestones (Adolph, 2019). Indeed, different pathways combine and lead to development of a cognitive skill.

Cumulative and enabling effects of earlier experiences improve developmental system in multiple ways. Every new achievement starts a new pathway that enables the acquisition of different skills. For example, infants can utter their first words at around their first birthdays. They need to map words onto objects or concepts to produce their first words, but this is not enough for word learning. Infants also need to perceive the related words among the speech stream with their statistical learning abilities for mapping process (Saffran, 2003). The statistical learning related experiences is not a cause for uttering “ball” as a first word, as infants perceive many words in the speech stream, but it enables a developmental pathway for the first word expressions through mapping referents to concepts with other possible pathways (e.g., Smith, 2013). Developmental cascades reflect individual variabilities in early development and delays in cognitive and motor skills of infants as a result of these cumulative effects (Iverson, 2021).

Spatial language development can also be investigated within the developmental cascade perspective. For the development of spatial language in infants, object exploration and parents’ spatial input can lead to a cascading effect on later spatial language. Following this, we first reviewed the literature on object exploration and parents’ spatial input in full-term and preterm infants. Then, we explained how these factors enable cascades for spatial language development.

1.3 Object Exploration

Examining or manipulating objects and space is a way to interact with the world. When children interact with their environment, perceptual and motor skills allow searching for spatial clues. These skills enable manual actions for real-time interactions. Manual actions can be diverged from rhythmic movements towards goal-directed movements such as reaching. Object exploration as a discovery process of objects’ physical properties is a big part of the manual actions. Hence, the development of fine motor skills that enrich manual actions also supports object exploration. For example, neuromuscular growth of hand skills (e.g., bimanual coordination) and increase in body-related grasping-reaching size (i.e., increase in the distance of reaching an object or grasping a big size object in time) promote object exploration (Oudgenoeg-Paz et al., 2015). Infants have sophisticated object exploration skills at around 6 months (Lobo et al., 2015). They demonstrate more complex behaviors such as turning and looking by 6 months. Hence, these complex behaviors provide a broad scale of information about objects when combined with manual and visual exploration.

Object exploration is mainly investigated on the basis of 6 different behaviors. These are holding, mouthing, transferring, banging, shaking, and fingering (Ruff, 1984; Jarvis et al., 2020). *Holding* is grasping an object by applying a force with hands. *Mouthing* is taking an object into the mouth. *Transferring* is changing an object between two hands. *Banging* is hitting an object onto a place or another object. *Shaking* is moving the object forward and backward. *Fingering* is touching the surface of an object gently.

Object exploration enables different developmental pathways for language and other cognitive skills. In a study of Needham (2000), infants between 3 and 4 months can start to learn object features to segregate objects with exploration. Following this, Wilcox and colleagues (2007) found that object exploration improves individuation of objects through acquiring color information at around 9 months. Object exploration promotes problem solving skills (Caruso, 1993; Lobo & Galloway, 2008), causal understanding (Rakison & Krogh, 2011), and understanding object similarities (Woods & Wilcox, 2013). Object exploration also facilitates infants' social understanding through recognition of other people's goal-directed actions at 3 months (Sommerville et al., 2005).

Spatial skills are closely related to object exploration. Slone and colleagues (2018) investigated mental rotation skills of 4-month-olds. Infants worn Velcro mittens gloves and explored the 3-D objects similar to the ones in the Shepard-Metzler mental rotation task. Their mental rotation performance was measured with simplified version of Shepard-Metzler in a visual habituation task. Results showed that object exploration promotes mental rotation skills at 4 months. Similarly, infants at 6 months would have been better in a different mental rotation task, if they manually had explored the objects rather than only looking at them (Möhring & Frick, 2013). In a similar mental rotation task of Slone et al. (2018), Schwarzer and colleagues (2013) found that infants who explored five different toys freely looked at mirror images of objects longer than the control group at 9 months. The increasing performance of infants in mental rotation task can be related to the effect of object exploration on learning object shapes. For example, infants can learn 3-D visual representations with the rotation behavior in object exploration (Soska, Adolph & Johnson, 2010). Following this finding, Schröder and colleagues (2020) found that object exploration intervention facilitates visual form perception such as shapes at 8 months. These studies highlight that object exploration is associated with spatial skills, starting very early on and in a comprehensive way.

Language development is also predicted by early object exploration in full-term infants, infants having risks of autism, and preterm infants within 24 months of age (e.g., Hellendoorn et al., 2015; Oudgenoeg-Paz, Volman & Leseman, 2016; Zuccarini et al., 2017; Zuccarini et al., 2018). Object exploration may enable cascades for specific linguistic units such as object words or spatial language. For the object words, Smith (2013) proposed a possible cascade starting from sitting onset. Sitting frees hands that make object exploration possible. Object exploration promotes visual representation of objects because when infants hold an object, that object can be attended better than other objects in the visual field. Infants' object manipulation such as rotating them or fingering them provides broad multimodal information about object. Overall, mapping words onto visual representations of objects becomes easier with object exploration, providing information about object features and object locations that consist of visual representations of objects (Samuelson, 2021).

Object exploration may play a specific role in the development of spatial language besides its relations with spatial skills. For example, Oudgenoeg-Paz and colleagues (2015) found that exploration at 20 months mediated the relation between sitting onset and spatial language at 36 months. In a further study, exploration at 20 months mediated the relation between walking onset and spatial language at 43 months (Oudgenoeg-Paz et al., 2016). These studies involve both object exploration (i.e., fine motor toys such as blocks or cups) and spatial exploration (i.e., gross motor toys such as tunnel or hoops) and revealed roles of object exploration in spatial language development. A possible mechanism behind this may be related to manipulating the location and position of objects during object exploration. This manipulation may trigger parents' spatial input, which facilitates mapping process of spatial language.

Infants who follow different developmental trajectories explore objects and spatial area later than typically developing children. Jarvis and colleagues (2020), for example, found that the delay in sitting onset was associated with delays in object exploration in children with a high risk of autism. Since the changes or transitions in the motor skills influence changes in object exploration, these infants may benefit from exploration later than infants following typical trajectories.

For the preterm infants, only a few studies have examined the connection between object exploration and cognitive skills. For example, Ruff and colleagues (1984) investigated the relation between early object exploration on later cognitive development with 30 typical and atypical preterm and 20 healthy full-term infants. Atypical preterm infants have unilateral or bilateral neurological damage due to preterm birth. In this study, Ruff and colleagues (1984) classified atypical infants as high-risk group based on their risk for the brain potential, the duration of living in an incubator and neurobehavioral test scores. The cognitive skills, which was measured by Bayley's MDI at 24 months in this study, were eye-hand coordination, imitation and comprehension, and social/active vocabulary. They found that object exploration at 9 months predicted children's cognitive skills at 24 months. Zuccarini and colleagues (2017) also found that object exploration of extremely preterm infants at 6 and 9 months predicted language and cognitive skills measured with General Development Quotient at 24 months. Therefore, object exploration may play a role in later cognitive and language development in preterm infants.

As preterm infants follow different developmental pathways, the developmental cascades for spatial language may vary for preterm infants. Previous studies reported that preterm infants are under risk of delays in motor skills (Sansavini et al., 2011). These delays may be an obstacle for preterm infants to explore objects and elicit parental input. For example, the frequency of object exploration for preterm children is less than full-term peers at around 6 months (Lobo et al., 2015; Zuccarini et al., 2016). Due to delays in their motor development, preterm infants cannot explore objects like full-term infants. Therefore, the developmental trajectories of spatial language for preterm infants may be different than full-term infants. Problems with object exploration may lead to cascading effect on delays in language development in preterm infants (e.g., Zuccarini et al., 2018).

1.4 Parents' Spatial Input

Parents' language input is one of the primary factors for language development in infants (Huttenlocher et al., 2007). Both quantity and quality of parental input play a role in language development (Anderson et al., 2021). Joint attention and children's real-time behaviors shape parents' language input that facilitates not only infants' language development but also their cognitive skills through child language (Golinkoff et al., 2019). Parents' spatial input is a good example for this link. Pruden and colleagues (2011) found that parents' spatial input from 14 months towards 46 months predicts children's spatial skills at 54 months. Furthermore, this relation is mediated by the spatial word knowledge of children.

Parents' spatial input contains words that describe size, shape, features, and orientation of objects, deictics such as here or there, location words such as prepositions, or amount words (Cannon, Levine & Huttenlocher, 2007; Kısa et al., 2019). Space is continuous, but spatial words help form category boundaries in space, highlighting spatial relations for children so that they can use their spatial skills more efficiently. For example, using the word "on" helps 18-month-old infants learn the spatial concept of support (Casasola, 2005).

Spatial language development needs parents' spatial input within social interactions. Polinsky and colleagues (2017) evaluated parents' spatial input from 3-min conversations in a museum. In the experimental group, parents were prompted for spatial talk with flashcards and in the control group, parents were not prompted to use any specific words. Parents' spatial input facilitates children's talk about spatial features and relations. In a puzzle play setting, parents talking about space between 2 and 4 years predicted spatial language development of girls at around 4 years (Levine et al., 2012). Following this, Kısa and colleagues (2019) found that parents' spatial input increased by age, controlling sex and spatial word knowledge of infants. These studies indicate that parents' spatial input in infancy facilitate spatial language development and its effect increases by age. Parents' spatial input may also be related to earlier experiences such as exploring objects with their features, sizes, shapes or locations and location changes.

Parental verbal input is also effective on language and cognitive development of preterm infants (Adams et al., 2018). A few earlier studies showed that preterm and full-term infants are similar in the amount of parental input (Salerni et al., 2007; Adams et al., 2018). These advantages of parental input seem to be independent from birth status or health history.

Talking about objects, actions, relations, and concepts enriches learning opportunities for language and cognitive skills of preterm infants from low SES families (Smith et al., 2000). In a recent study, Clingan-Siverly and colleagues (2021) found that there was no difference both for verbal and gestural spatial language between 3- to 5-year-old preterm and full-term children. Furthermore, regardless of neonatal condition, parents' spatial input in both modalities was related to children's mental transformation scores through children's use of spatial language. However, none of these studies has investigated the role of manual experiences together with parents' spatial input on preterm infants' spatial language development.

1.5 Developmental Cascades for Spatial Language in Preterm & Full-Term Infants

Developmental cascades allow changing physical and social interactions with the accessible environment. For example, when infants reach to sitting milestone, they can reach and hold the objects easier than before. Infants, then, can turn the objects and examine their spatial features after they hold the objects. Therefore, interactions with objects provide new information about object features, spatial interactions, or social interactions. In line with these arguments, infants' spatial language learning may emerge through real-time interactions in the environment. Real-time interactions such as object exploration are executed by motor behaviors, thus, the development of motor behaviors play a role in exploration (Soska et al., 2010). Interacting with the environment contributes to children's understanding of spatial and action-based relations and learning their names.

Object exploration can lead to the cascading effect on spatial language development, but parents' spatial input can have a role in this relation. When infants explore the environment, they use perceptual skills to learn affordances, locations, and spatial features of objects such as their size or shape. Object knowledge, which can be considered an early basis of language development, is constructed with visual and manual exploration in the first years of life (Oakes & Rakison, 2019). Exploration of objects requires perceptual skills such as eye-hand coordination. Infants explore the features and shapes of objects to recognize and label them (Smith, 2009). Beyond that, object information is related to learning the perceptual concepts behind the spatial language. For example, the exploration of objects brings location information (e.g., putting a toy on a table). Furthermore, exploration of locations (e.g., searching a toy in a toy box) also leads to object exploration (Landau & Stecker, 1990). However, children are not passive learners in the environment. Their exploration of objects triggers and shapes parental input (Tamis LeMonda et al., 2013). Parents' spatial input (i.e., talking about spatial features, locations, and orientations of objects) is related to children's spatial language development (e.g., Pruden et al., 2011). Therefore, object exploration and parents' spatial input can be two factors behind the development of spatial language in preterm and full-term infants. The delay or decrease in one of them may be related to the delay in spatial language, especially for preterm infants.

Infants can explore objects and spatial area alone, but they can also interact with their parents during exploration episodes. At 4 months, infants usually focus on a single object that is held by their mothers or themselves (de Barbaro et al., 2016). However, they can distribute their attention between their mothers and the objects that they interact at around 12 months. Therefore, parental engagements may be more effective at around 12 months. Parental engagements can be defined as verbal or non-verbal efforts to shape the interaction with objects, places, or people of infants. For example, when an infant holds an object, parents may offer a box to put that object in.

Parental engagement in exploring objects is one of the factors that shape children's learning episodes (Tamis-LeMonda et al., 2013). Parents canalize their infants' exploration efforts to more effective learning processes. McQuillan and colleagues (2019) found that these engagements during object exploration increase learning opportunities of object features visually. Object exploration such as holding or turning objects provides informative moments for the visual system. Furthermore, visual representations based on object shapes are key factors in mapping processes for language development (Yu & Smith, 2012). Therefore, parents continue to label relations or objects, but they also verbally and manually contribute to exploration episodes.

Parents give feedback with spatial words to their children when they explore objects in free play episodes. Object exploration is not only manipulating one object, but infants can “put” an object “on” a table, “throw” an object “in” a box. That is, object exploration may trigger parents’ spatial input use in real-time or in developmental time. Parents give feedback for the within and between object relations with verbs and prepositions beyond only descriptive sentences such as “look, this is a ball.”.

No previous research has examined whether parents of preterm infants adjust their input based on responses they receive within infants’ object explorations. Although preterm infants benefit from parental input like full-term infants, their delays in object exploration may lead to receiving less spatial input over time. This in turn may negatively relate to preterm infants’ spatial language development.

1.6 The Current Study

This study investigates the relation among object exploration at 14 months, parents’ spatial input at 14 and 20 months, and spatial language of infants at 26 months in preterm and full-term infants. We have three main questions: (1) Do preterm and full-term infants differ in object exploration and receiving parents’ spatial input? (2) Is object exploration associated with parents’ spatial input for both groups? (3) Are object exploration and parents’ spatial input related to later spatial language of infants interactively or separately?

Object exploration of infants was coded in a dyadic free play setting with caregivers at Time 1 when children were 14 months. We also coded parents’ spatial input in play sessions at two time points when children were 14 and 20 months. Children's spatial language is assessed through parental reports at 26 months.

We expect that preterm and full-term groups will differ in object exploration and the amount of parental spatial input they receive. Previous studies (Ruff et al., 1984; Lobo et al., 2015; Zuccarini et al., 2016) found that preterm infants explored objects less than full-term infants at 6 and 9 months (but also see Zuccarini et al., 2018). Following these results, we expect that preterm infants will significantly explore objects less than full-term infants. Although a previous study (Clingan-Silverly et al., 2021) found no difference between preterm and full-term preschoolers in receiving parental spatial input, we still do not know whether preterm infants hear fewer spatial words from their parents than full-term infants in the first two years.

If object exploration triggers parental input (e.g., Tamis-LeMonda et al., 2013; Iverson, 2021), parents' spatial input may also be less for preterm infants than full-term infants related to a decrease in object exploration. We also hypothesize that object exploration is related to parents' spatial input. Previous studies showed that object exploration shapes parental input, which leads to cognitive changes in infants (e.g., Tamis-LeMonda et al., 2013; McQuillan et al., 2019). However, how object exploration is related to specific units of parental input such as spatial input has not been studied. We expect that object exploration will be positively related to parents' spatial input. When infants explore more, they hear more about objects' spatial features such as size, location or deictic information. This relation may be different for preterm infants as their delays in object exploration can lead to delays in parents' spatial input.

For the third question, we hypothesize that object exploration at Time 1 and parents' spatial input at Times 1 and 2 will predict infants' spatial language at 26 months, controlling for children's age, and overall vocabulary comprehension. In this question, we used object exploration in the analysis to see how infants' own efforts lead the developmental pathway for spatial language. Preterm infants can follow a different developmental pathway, thus, there may be a difference between preterm infants and full-term infants for these relations. We also hypothesized that the interaction between object exploration and parents' spatial input will predict infants' spatial language at Time 3. Infants who explore objects more may hear more spatial input from their parents. We predict that beyond their unique predictions to spatial language development, the interaction between object exploration and parents' spatial input will predict spatial language of preterm and full-term infants.

Chapter 2:
METHOD

2.1 Participants

The data for this study came from a longitudinal study that investigates preterm and full-term infants' cognitive and language skills. We focus on three time points (Time 1, Time 2, and Time 3) in this study. Seventy-eight infants (34 girls, 44 boys, *M*age = 13.7, *SD* =1.40, range=10-18 months) participated in the study in Time 1. The preterm group in this sample consisted of 42 infants and the full-term group consisted of 36 infants. At Time 2, there were 65 infants in total (29 girls, 36 boys, *M*age = 20.1, *SD* =1.33 range=18-24 months). The preterm group in this sample consisted of 31 infants and the full-term group consisted of 34 infants. At Time 3, there were 48 infants (20 girls, 28 boys, *M*age = 26, *SD* =1.21, range=24-29 months). The preterm group in this sample consisted of 21 infants and the full-term group consisted of 27 infants (for all demographic information see Table 1). We used corrected ages for the preterm infants. Based on cranial ultrasound, 16 preterm children (for Time 1, *M*age=13.7 months, SD=1.68; for Time 2, *M*age=20.4 months, SD=1.75; for Time 3, *M*age=26.3 months, SD=1.17) were reported as having minor medical complications. None of these infants have retinopathy due to prematurity. We merged the entire preterm group checking whether significant difference between these infants and the rest of the preterm group. The results demonstrated that preterm infants with medical complications were not different from other preterm infants for object exploration, parents' spatial input, and word comprehension at Time 1 (all *p*s>.05).

Parents of infants gave informed consent and Koç University's Institutional Review Board approved the study (Project name: A longitudinal study of examining preterm and full-term children's early language and cognitive development-Protocol no: 2018.118.IRB3.083).

Table 1. Demographic information of children born full-term and preterm

	Preterm		Full-Term		X^2 or t	*p*	d
Time 1	Mean or %	SD	Mean or %	SD			
% Girl	41		47		0.36	*0.55*	-
GA (weeks)	30	3.17	39	1.40	-15.5	*<.001*	-3.51
Birth Weight (g)	1506	533	3297	400	-16.6	*<.001*	-*3.76*
Maternal Education (years)	15	2.01	16	2.06	-2.44	*0.017*	-0.56
Time 2							
% Girl	39		50		0.84	*0.36*	-
GA (weeks)	30	3.25	39	1.43	-14	*<.001*	-3.48
Birth Weight (g)	1501	532	3311	402	-15.6	*<.001*	-3.86
Maternal Education (years)	15	1.73	16	2.12	-2.06	*0.044*	-0.51
Time 3							
% Girl	33		48		1.07	*0.30*	-
GA (weeks)	29	3.15	39	1.44	-14.3	*<.001*	-4.16
Birth Weight (g)	1369	482	3329	440	-14.7	*<.001*	-4.27
Maternal Education (years)	15	1.83	16	1.96	-1.54	*0.131*	-0.45

2.2 Measures

2.2.1 Time 1 Measures

TCDI-1. Parents completed Turkish Communication Development Inventory-1 (TCDI-1) to assess their infants' language development between 8-16 months. As the Turkish adaptation of MacArthur-Bates CDI, the focus of TCDI-1 is receptive language, expressive language, and early communicative behavior (Aksu-Koç et al., 2019). TCDI questionnaires were used to administered to both full-term and preterm infants (e.g., Kısa et al., 2019; Aktan-Erciyes & Göksun, 2019; Kobaş, Aktan-Erciyes, & Göksun, 2021; Kobaş et al., under review).

Vocabulary Checklist that is the first part of TCDI-1 consists of 418 items. Parents are expected to assess word comprehension and word production in this checklist. We used word comprehension subscale as a control variable of early language development in this study. Aksu-Koç and colleagues (2019) found high internal consistency (*Cronbach's α* =.99) for word comprehension subscale.

Free Play Session. Infants and their caregivers play with toys together in play sessions. These sessions are a good way to obtain semi-naturalistic observations of infants' and caregivers' behaviors. The play sessions were used to measure object exploration and parents' spatial input.

In this session, first, infants and parents were welcomed into a silent room with toys and a carpet. They were asked to play with the given toys (1 abacus, 4 cubes, 1 ball, 2 plush toys, and 1 book) for 10 minutes. The instruction of the experimenter was, "Here, we want you to play with your child as you play at home." These play sessions were recorded with a camera that was placed at a corner of the room.

2.2.2 Time 2 Measure

Free Play Session. The same session was applied with the same play setting of Time 1. The same toys were used. We coded parents' spatial input from these sessions at Time 2.

2.2.3 Time 3 Measures

TCDI-2. Parents were asked to fill Turkish Communication Development Inventory 2 (TCDI-2). TCDI-2, which is the Turkish adaptation of MacArthur-Bates CDI, has been administered to examine infants' communicative and language skills (Aksu-Koç et al., 2019). TCDI-2 can be used for infants between 16 and 36 months of age. TCDI-2 includes two parts. The first part is the Words, including 711 items. The items in the Words part are used to measure expressive language of infants (Aksu-Koç et al., 2019). For this study, we considered verbs and prepositions as spatial language at 2 years. Therefore, we summed prepositions and verbs from TCDI-2 to measure spatial language. For our study, we did not use the second part, which was the Sentences Section.

2.3 Procedure

Infants were tested at Koç University or in Cerebral Palsy Turkey Metin Sabancı Center. Free play sessions at two time points were recorded by a video camera. The duration of free play sessions was 10 minutes. These sessions were the last part of a series of studies that took approximately 75 minutes in total. TCDIs were completed by parents during their participation or via internet. Coding and data entry were completed later. Infants received a book as a gift and parents were compensated for transportation expenses.

2.4 Coding

2.4.1 Object Exploration

Object exploration behaviors of infants were coded from 5 minutes of play session videos out of 10 minutes at Time 1 using ELAN software (Lausberg & Sloetjes, 2009). We used only Time 1 for this coding because infants show object exploration behaviors with fine motor toys less, whereas they start to engage in gross motor toys and spatial (or locomotor) exploration after the first year (e.g., Oudgenoeg-Paz et al., 2015, Oudgenoeg-Paz et al., 2016; Hoch, Rachwani & Adolph, 2020). Time sensitive coding was done, and coders were trained before to agree on at least 80% of the behaviors. We used object exploration and caregiver's object manipulation categories in this study. We measured the duration and frequency (i.e., how much they performed) of object exploration episodes.

Infants' intentional engagement with objects were coded as object exploration. Following Jarvis et al. (2020), these behaviors were classified into 4 subcategories: holding, inspective actions, rhythmic actions, and mouthing. *Holding* is any kind of engagement that includes grasping with a whole hand (i.e., palmar grasp) or fingers (i.e., pincer grasp). *Inspective actions* include turning, fingering, and transferring behaviors. Turning is manipulating spatial orientation of objects to examine them or place them better. Transferring is changing an object between hands, and fingering is gentle finger movements on the surface of objects. *Rhythmic actions* include shaking and banging. Shaking is moving the object from forward to backward or other directions repeatedly. Banging is throwing or hitting objects to another one or a place like a wall or floor. *Mouthing* is bringing objects into the mouth to lick, bite or hold them.

Parental object manipulation is any kind of action with objects that is executed in line with infants' exploration. Rolling balls, placing cubes into their places, or counting with the abacus are the examples of this behavioral category. If caregivers engage with objects for other purposes such as tidying up the objects, we did not consider them as parental object manipulation.

The intraclass correlation (ICC) analyses showed a high degree of reliability between the two coders for the total duration of object exploration (ICC was .98 with a 95% confidence interval from .960 to .996, $F(13, 13)=84.737$, $p<.001$), total duration of caregivers' object manipulation (ICC was .99 with a 95% confidence interval from .988 to .999, $F(13, 13)=280.083$, $p<.001$), total frequency of object exploration (ICC was .82 with a 95% confidence interval from .474 to .942, $F(13, 13)=6.031$, $p<.001$), and total frequency of parents' object manipulation (ICC was .96 with a 95% confidence interval from .879 to .987, $F(13, 13)=27.173$, $p<.001$).

2.4.2 Parents' Spatial Input

Parents' spatial input was coded from play sessions at Time 1 and Time 2. The coding schema has been adapted from Cannon et al. (2007). We followed the Turkish version of coding schema that was used in Kısa et al. (2019). The verbal transcriptions of play sessions were done by blind assistants. The transcriptions were then coded for spatial words or phrases of parents. For *what* part of spatial input, words related to size, shape, feature, and orientation of object were coded such as "big" (*büyük* in Turkish), "square" (*kare* in Turkish), "front side" (*ön yüzü* in Turkish), "turning" (*çevirmek* in Turkish). For the *where* part, words related to deictic, amount, and location/direction of objects will be coded such as "here," "all," "on." We coded only the total number of spatial feature words (token) because the token of parental input is a better indicator for the contribution of parents on language development than type around 2 years old (Anderson et al., 2021). Additionally, parental spatial input token is also correlated with parental spatial input type (Kobaş et al., 2021). We summed all the spatial words of parents and divided them to video durations separately in every time points and we used them in our regression analyses.

The intraclass correlation (ICC) analyses indicated a high degree of reliability between the two coders for the total spatial input of parents at Time 1 (ICC was .97 with a 95% confidence interval from .550 to .992, $F(19, 19)=74.725$, $p<.001$) and Time 2 (ICC was .941 with a 95% confidence interval from .852 to .977, $F(19, 19)=17.086$, $p<.001$).

Chapter 3:

RESULTS

Descriptive data for object exploration coding can be found in Table 2. The Bonferroni correction was applied in the comparisons ($p < .006$). Preterm infants were not different than full-term infants for holding, inspective actions, rhythmic actions, and mouthing behaviors for both duration and frequency, *p*s> .006 (Table 2).

Table 2. Descriptive data for duration and frequency of sub-categories in object exploration and group differences: Sample Sizes (n), Adjusted Means, Adjusted SDs, ranges, F, p, and partial eta-squared (ηp^2) values for ANCOVAs for preterm and term infants controlling related ages.

	Preterm (n=33)			Term (n=36)			ANCOVA		
(duration)	Mean	(SD)	Range	Mean	(SD)	Range	F	*p*	ηp^2
Holding	106	46.6	21-189	90.2	37.3	10-154	0.90	0.35	0.01
Inspective Actions	55.3	41.4	5-192	58.3	34.7	2-165	0.007	0.94	0
Rhythmic Actions	16.5	14.7	0-65	11.1	12.5	0-40	0.86	0.36	0.01
Mouthing	5.24	11.3	0-62	2.94	7.84	0-43	0.14	0.71	0
(frequency)									
Holding	0.05	0.02	0.01-0.09	0.05	0.02	0.01-0.1	0.07	0.80	0.001
Inspective Actions	0.04	0.02	0.003-0.08	0.04	0.02	0.004-0.09	0.19	0.67	0.003
Rhythmic Actions	0.02	0.02	0-0.06	0.01	0.01	0-0.04	3.42	0.07	0.05
Mouthing	0.004	0.006	0-0.03	0.003	0.007	0-0.03	0.19	0.66	0.003

Descriptive information and age-adjusted comparisons of the key variables for each group are presented in Table 3. The Bonferroni correction was applied in the comparisons (*p* < .006). Parents' spatial input did not differ to preterm and full-term infants at 14 months and at 20 months. Parental object manipulation was also similar between the two groups at 14 months. Preterm infants were similar to full-term infants for word comprehension, and object exploration at 14 months, and spatial language at 26 months (Table 3).

Table 3. Group Differences: Sample Sizes (n), Adjusted Means, Adjusted SDs, ranges, F, p, and partial eta-squared (ηp^2) values for ANCOVAs for preterm and term infants controlling related ages. The Bonferroni correction was applied in the comparisons (p < .006).

	Preterm				Term				ANCOVA		
	n	Mean	(SD)	Range	n	Mean	(SD)	Range	F	*p*	ηp^2
Time 1 Word Comprehension	39	91.7	89.4	0-343	36	138	78.7	17-317	0.69	0.41	0.01
Object Exploration (duration)	33	183	46	89-259	36	162	49.6	62-237	1.25	0.27	0.02
Object Exploration (episode)	33	0.11	0.03	0.06-0.16	36	0.10	0.04	0.04-0.21	0.50	0.48	0.01
Parents' Object Manipulation (duration)	33	152	34.3	109-243	36	149	40.9	66-255	0.03	0.86	0.00
Parents' Object Manipulation (frequency)	33	0.07	0.02	0.03-0.13	36	0.07	0.02	0.03-0.12	0.12	0.74	0.00
Parents' Spatial Input at Time 1	41	0.07	0.03	0.02-0.14	36	0.09	0.04	0.04-0.16	6.68	0.01	0.08
Parents' Spatial Input at Time 2	29	0.07	0.03	0.01-0.13	34	0.08	0.03	0.04-0.16	3.05	0.09	0.05
Cumulative Parents' Spatial Input	29	0.14	0.06	0.02-0.24	34	0.17	0.06	0.08-0.30	3.00	0.09	0.05
Time 3 Spatial language	20	73.3	69.1	0-167	27	95.3	67.7	0-223	0.90	0.35	0.02

Table 4. Correlations between different measures.

	Age at Time 1	Age at Time 2	Age at Time 3	Word Comprehension at Time 1	Object Exploration (duration)	Object Exploration (frequency)	Parents' Object Manipulation (duration)	Parents' Object Manipulation (frequency)	Parents' Spatial Input at Time 1	Parents' Spatial Input at Time 2	Cumulative Parents' Spatial Input	Spatial language at Time 3
Age at Time 1	1											
Age at Time 2	0.55***	1										
Age at Time 3	0.48***	0.58***	1									
Word Comprehension at Time 1	0.49***	0.18	0.26	1								
Object Exploration (duration)	-0.26*	-0.25	-0.07	-0.31*	1							
Object Exploration (frequency)	-0.19	-0.23	-0.12	-0.15	0.46***	1						
Parents' Object Manipulation (duration)	-0.17	-0.01	-0.27	-0.33**	0.20	0.06	1					
Parents' Object Manipulation (frequency)	-0.20	.0.02	-0.23	-0.19	.0.24	0.42***	0.51***	1				
Parents' Spatial Input at Time 1	0.21	0.10	0.09	0.36**	-0.24*	-0.18	0.06	-10	1			
Parents' Spatial Input at Time 2	0.07	0.24	0.22	0.09	-0.22	-0.08	0.13	0.16	0.57***	1		
Cumulative Parents' Spatial Input	0.20	0.17	0.17	0.24	-0.27*	-0.15	0.13	0.08	0.91***	0.86***	1	
Spatial language at Time 3	0.35*	0.19	0.15	0.41**	-0.18	-0.15	-0.22	-0.07	0.17	0.05	0.14	1

Note. * *p* < .05, ** *p* < .01, *** *p* < .001.

Table 4 showed the correlation matrix among different measures. Only age and word comprehension at Time 1 were related to spatial language at Time 3. Therefore, we decided to put these variables as a control variable in the regression analyses. As the frequency and duration of object exploration correlated (r=0.46, p<.001), we used only duration of object exploration in our analyses following previous studies (e.g., Jarvis et al., 2020).

We used Jamovi stats software to conduct a mixed ANOVA to test the relation between object exploration and parents' spatial input in preterm and full-term infants (R Core Team, 2020; The Jamovi project, 2020). Object exploration and age were control variables, neonatal condition was the between-subject variable, and time points were the within-subject variables. The results showed that parents' spatial input was similar across two time points, $F(1, 55) = 1.02$, $p = .317$. There was not a statistically significant difference in parents' spatial input based on the interaction between time and neonatal condition, controlling for age at Time 1 and duration of object exploration, $F(1, 55) = 0.11$, $p = 0.74$. The interaction between time and object exploration duration was not significantly related to parents' spatial input, controlling for age at Time 1 and neonatal condition, $F(1, 55) = 0.13$, $p = 0.72$. There was no significant main effects of neonatal condition, $F(1, 55) = 1.81$, $p = 0.18$, and object exploration, $F(1,55) = 2.37$, p=0.13.

We used hierarchical linear regression analyses to examine the predictors of spatial language at Time 3. In our first model, the first step included neonatal condition (i.e., being preterm or not), infants' age, and word comprehension at Time 1. In the second step, the duration of object exploration at Time 1 and parents' spatial input at Time 1 were introduced. The third step included the interaction term. This interaction term between object exploration and parents' spatial input was the cross product of related mean-centered terms. For Model 2, neonatal condition, age at Time 1, and word comprehension at Time 1 were entered to step 1. The second step included the duration of object exploration at Time 1 and parents' spatial input at Time 2. The third step included the interaction term of the duration of object exploration at Time 1 and parents' spatial input at Time 2 (see Appendix A for other models with frequency of object exploration, cumulative spatial input, and caregivers' object manipulation).

Table 5. Regression analyses of Model 1, spatial language of infants at 26 months as the outcome variable.

		Outcome: Spatial language at 26 months				
Step	Predictors	ΔR^2	F-change	β	*t*	*p*
1		0.16	2.59			
	Neonatal Condition			0.01	0.02	0.99
	Age at Time 1			0.16	0.94	0.35
	Word Comprehension at 14 months			0.29	1.74	0.09
2		0.01	0.14			
	Neonatal Condition			-0.002	-0.01	0.996
	Age at Time 1			0.16	0.92	0.36
	Word Comprehension at Time 1			0.27	1.50	0.14
	Object Exploration at Time 1			-0.08	-0.52	0.61
	Parents' Spatial Input at Time 1			-0.01	-0.06	0.95
3		0.13	6.73			
	Neonatal Condition			-0.11	-0.37	0.71
	Age at Time 1			0.35	1.94	0.06
	Word Comprehension at Time 1			0.24	1.41	0.17
	Object Exploration at Time 1			-0.16	-1.07	0.29
	Parents' Spatial Input at Time 1			-0.10	-0.66	0.51
	Object Exploration x Spatial Input			0.40	2.60	0.01*

Note. * $p < .05$

The first model was significant and accounted for 30% of the variance (see Table 5), $F(6,38)=2.60$, $p=0.033$. Neonatal condition, age at Time 1, and word comprehension were not significant predictors at step 1. Object exploration and parents' spatial input were not significant predictors at step 2. In the third step the interaction between object exploration and parents' spatial input at Time 1 was the only significant predictor, *β* =0.40, *p* = .01. The third step was accounting for an additional 13% variance. When we use the frequency of object exploration instead of duration, we had similar results (see Appendix A Model 1). We also had similar results, using caregivers' object manipulation as a control variable, but the model was not significant (see Appendix A Model 2).

Table 6. Regression analyses of Model 2, spatial language of infants at 26 months as the outcome variable.

		Outcome: Spatial language at 26 months				
Step	Predictors	ΔR^2	F-change	β	*t*	*p*
1		0.16	2.59			
	Neonatal Condition			0.01	0.02	0.99
	Age at Time 1			0.16	0.94	0.35
	Word Comprehension at 14 months			0.29	1.74	0.09
2		0.01	0.13			
	Neonatal Condition			-0.003	-0.01	0.99
	Age at Time 1			0.16	0.92	0.36
	Word Comprehension at Time 1			0.27	1.52	0.14
	Object Exploration at Time 1			-0.08	-0.50	0.62
	Parents' Spatial Input at Time 2			-0.001	-0.005	0.99
3		0.06	2.95			
	Neonatal Condition			-0.09	-0.30	0.77
	Age at Time 1			0.22	1.25	0.22
	Word Comprehension at Time 1			0.22	1.28	0.21
	Object Exploration at Time 1			-0.11	-0.73	0.47
	Parents' Spatial Input at Time 2			-0.02	-0.11	0.92
	Object Exploration x Spatial Input at Time 2			0.25	1.72	0.09

Note. * $p < .05$

The second model was not significant (see Table 6), F (6,38) = 1.84, p =0.117. There was no significant predictor in any steps. When we use the frequency of object exploration instead of duration, we had similar results (see Appendix Model 3). Likewise, adding caregivers' object manipulation as a control variable yielded similar results (see Appendix Model 4). Last, when we used the cumulative score of parents' spatial input from Time 1 and Time 2, instead of only one time point, the results were similar to the one we obtained with Time 1 parents' spatial input (see Appendix A Model 5).

Chapter 4:
DISCUSSION

This study examined the relations among object exploration, parents' spatial input, and spatial language development in preterm and full-term infants. We investigated three questions. For the first question, we examined whether there was a difference between preterm and full-term infants for object exploration and parents' spatial input. Our assumptions were not in line with our results as we did not find any difference between the groups in these variables. For the second question, we predicted that there was a relation between parents' spatial input and object exploration. On the contrary to our hypothesis, we found that object exploration was not related to parents' spatial input at 14 months and at 20 months. For our last question we found that the interaction between parents' spatial input and object exploration at 14 months predicted spatial language at 26 months, rather than spatial input and object exploration uniquely predicting spatial language.

Our results showed that there was no difference for object exploration between preterm and full-term infants. Preterm infants were found to spend less time for object exploration than full-term infants at 6 months (Lobo et al., 2015). Following this, Zuccarini and colleagues (2017) demonstrated the same results for extremely preterm infants at 6 months. However, extremely preterm infants closed the gap at 9 months. In line with these findings, we showed that preterm infants' object exploration durations and frequencies were not different from full-term infants at 14 months. Object exploration is considered as an important activity in the first year of life to learn about object features, manipulation of objects and using bodies (Gibson, 1988). Even though preterm infants have delays in object exploration in the first 6 months, possibly due to their motor delays, they can catch up with their full-term peers by time. This improvement in preterm infants may reflect the role of environmental factors in developmental timeline (Sansavini et al., 2021). However, preterm infants may still be behind full-term infants for advanced object exploration skills. Although preterm infants spend similar amount of time for object exploration, they still only explore nearby objects on the ground due to possible delays in gross motor skills (e.g., Kobaş et al., under review). Full-term infants can walk in the second year of their life that requires integration of different skills such as walking while holding an object (Adolph & Hoch, 2019). In line with this, Heiman and colleagues (2019) found that object exploration does not change in developmental timeline, but infants integrate their object exploration skills to walking immediately. Preterm infants may suffer with integration of old skills to new ones. While full-term infants explore distant and bigger objects with walking, preterm infants may follow them behind in developmental timeline. Therefore, even the durations for object exploration similar, the quality of object exploration (e.g., engaging with distant objects vs. near objects) may differ between these groups. Future research should investigate the integration of earlier skills (e.g., object exploration) to new ones (e.g., walking) in preterm infants.

Parents provided similar amounts of spatial input to preterm infants and full-term infants at 14 and 20 months. The cumulative spatial input was also parallel between groups. Previous studies found that cumulative parents' spatial input between 14 months and 42 months predicts spatial skills of infants (Pruden et al., 2011). With preschoolers, Clingan-

Siverly and colleagues (2021) found that parents' spatial input and children's use of spatial words were similar between preterm and full-term groups. Parents' spatial input predicted mental transformation scores through children's spatial language in both groups. Our results also align with this study, providing further support for parental spatial input and children's spatial language from the first two years. Full-term and low-risk preterm infants may follow similar pathways for spatial language. The drawbacks and advantages of parents' spatial input on preterm birth can be investigated with extreme groups like extremely preterm infants or atypical preterm infants who have neurological problems (for other examples, see Oudgenoeg-Paz & Riviere, 2014; Iverson, 2021).

Our correlational results showed a negative relation between object exploration and parents' spatial input, however, after controlling for age and neonatal condition, the relation disappeared. Although parents tailor their spatial language input according to their children's language skills (Kısa et al., 2019), there may be individual differences among parents to respond to the actions of children. For example, when a child searches a toy in a box, parents can respond to this in many ways like "Do you want to get the ball?" or "Are you searching for your ball in the box?". Among these possibilities, some of them include spatial words like "in," but others do not include any spatial words. Therefore, spatial language use of parents seems to depend on infants' language level but not object exploration. This dependency may be more visible before the first year because parents rely more on infants' actions rather than their emerging communication skills. Future research should investigate this relation before infants reach their first birthdays.

In line with the developmental cascades approach (Oakes & Rakison, 2019), we asked the unique and cumulative effects of infants' object exploration and parental spatial input on children's spatial language use. Our findings highlight the interactive effects of object exploration and parents' spatial input at 14 months on spatial language of children at 26 months. The main effects of object exploration and parents' spatial input at 14 months did not predict spatial language at 26 months. This interaction indicates that infants who explore objects more and hear more parental spatial input comprehend and produce more spatial language, regardless of neonatal condition. In a recent study with full-term infants, Kobaş and colleagues (2021) found that parents' input for object features at 20 months predicted children's object word comprehension at 25 months beyond fine motors skills at 14 months. Although fine motor skills were related to object word comprehension, parents' input seems to be a better predictor for object word comprehension. Infants need fine motor skills to hold and manipulate objects. Nevertheless, different from fine motor skills, object exploration provides referent experiences for representations of spatial relations. Parents' spatial input contributes to learning labels for those referents. The frequency of parental input is effective on infants' language development because it promotes the representations of the related words in the input over other words (Lieven, 2010). Therefore, input or its referents (e.g., the visual and manual experiences as a result of object exploration) may not be effective by itself on learning of spatial words, but the interaction of these may enable the process of learning spatial words.

Besides the interaction between object exploration and parents' spatial input, as developmental cascades approach argued (Adolph, 2019; Oakes & Rakison, 2019), there may be several obvious and non-obvious pathways behind a developmental achievement. In the context of spatial language development, infants may also learn spatial language via early literacy or other types of explorations and play settings. Here, we only investigated object exploration with manual and oral actions executed by fine motor skills. However, a previous study (Oudgenoeg-Paz et al., 2015) found that walking attainment predicts spatial language of infants through gross motor exploration (i.e., engaging toys that promote gross motor movements). Therefore, infants may follow additional pathways for the development of spatial language. In line with this, we found that the interaction between object exploration at 14 months and parents' spatial input at 20 months did not predict spatial language at 26 months. The interaction between these variables concurrently predicts spatial language, but the interaction between object exploration at 14 months and parents' spatial input at 20 months did not.

Last, our findings contribute to the processes of how young children learn spatial language. Infants learn object words or names of living things heavily in the first years of their lives (Golinkoff et al., 2019). Leaning spatial words is difficult, but it is important because these words shape our spatial thinking (Gentner, 2016). From the developmental cascade perspective, spatial words enable later developmental achievements related to spatial skills. For example, Gentner and colleagues (2013) investigated deaf children who develop their own gesture system (called homesigners). These children were worse at spatial tasks than hearing children who have a proper linguistic system for spatial relations. This study showed that learning spatial words augment spatial cognition. In a recent study, we found the close link of preschoolers' postposition knowledge and their mental transformation scores (Turan et al., 2021). Learning spatial words enables new pathways for later cognitive skills. However, some cascades also enable pathways to learn spatial words. Language development is based on contingent parent-child engagements that include infants' exploration and parental verbal input (Masek et al., 2021). Following the results and anticipations of our study, and previous studies (e.g., Pruden et al., 2011; Casasola, 2018), the interaction of object exploration and parents' spatial input may lead to cascading effect on spatial language development that will allow new pathways for spatial skills, irrespective of prematurity of children.

Chapter 5:

CONCLUSION

This research investigated the relations among object exploration, parents' spatial input, and spatial language of preterm and full-term infants. We did not find any significant differences between preterm and full-term infants for object exploration, parents' spatial input, and spatial language. These results pointed out that some factors support preterm infants to follow similar developmental pathways with full-term infants. We showed that spatial language at 26 months was predicted by an interaction between object exploration and parents' spatial input at 14 months. Our findings suggest a potential cascade of object exploration and spatial input on spatial language both in preterm and full-term infants. Rather than the unique contributions of these factors, an interactive cascade of object exploration and spatial input can promote children's spatial language development.

REFERENCES

Adams, K. A., Marchman, V. A., Loi, E. C., Ashland, M. D., Fernald, A., & Feldman, H. M. (2018). Caregiver talk and medical risk as predictors of language outcomes in full term and preterm toddlers. *Child Development*, *89*(5), 1674-1690.

Adolph, K. E. (2019). An ecological approach to learning in (not and) development. *Human Development*, *63*(3-4), 180-201.

Adolph, K. E., & Hoch, J. E. (2019). Motor development: Embodied, embedded, enculturated, and enabling. *Annual Review of Psychology*, *70*, 141-164.

Aksu-Koç, A., Acarlar, F., Küntay, A., Maviş, İ., Sofu, H., Topbaş, S., Turan, F. & Aktürk-Ari, B. (2019). *Türkçe İletişim Gelişimi Envanteri (Tige) El Kitabı* (1st ed.). *Detay Yayıncılık.*

Aktan-Erciyes, A., & Göksun, T. (2019). Early event understanding predicts later verb comprehension and motion event lexicalization. *Developmental psychology*, 55(11), 2249.

Anderson, N. J., Graham, S. A., Prime, H., Jenkins, J. M., & Madigan, S. (2021). Linking Quality and Quantity of Parental Linguistic Input to Child Language Skills: A Meta-Analysis. *Child Development*.

de Barbaro, K., Johnson, C. M., Forster, D., & Deák, G. O. (2016). Sensorimotor decoupling contributes to triadic attention: A longitudinal investigation of mother–infant–object interactions. *Child Development*, *87*(2), 494-512.

Benassi, E., Savini, S., Iverson, J. M., Guarini, A., Caselli, M. C., Alessandroni, R., Faldella, G., & Sansavini, A. (2016). Early communicative behaviors and their relationship to motor skills in extremely preterm infants. *Research in Developmental Disabilities*, *48*, 132-144.

Bowerman, M. (1996). *The origins of children's spatial semantic categories: Cognitive versus linguistic determinants.* In J. J. Gumperz & S. C. Levinson (Eds.), *Studies in the social and cultural foundations of language, No. 17. Rethinking linguistic relativity* (p. 145–176). Cambridge University Press.

Clingan-Siverly S., Nelson PM., Göksun T., & Demir-Lira ÖE. (2021). Spatial Thinking in Term and Preterm-Born Preschoolers: Relations to Parent–Child Speech and Gesture. *Frontiers in Psychology, 12,* 651678.

Cannon, J. L., Levine, S. C., & Huttenlocher, J. (2007). *Sex differences in the relation between early puzzle play and mental transformation skill*. Paper presented at the Biennial Meeting of the Society for Research in Child Development, Boston, MA

Caravale, B., Tozzi, C., Albino, G., & Vicari, S. (2005). Cognitive development in low risk preterm infants at 3–4 years of life. *Archives of Disease in Childhood-Fetal and Neonatal Edition*, *90*(6), F474-F479.

Caruso, D. A. (1993). Dimensions of quality in infants' exploratory behavior: Relationships to problem-solving ability. *Infant Behavior and Development*, *16*(4), 441-454.

Casasola, M. (2005). Can language do the driving? The effect of linguistic input on infants' categorization of support spatial relations. *Developmental Psychology,* 41,183-192.

Casasola, M. (2008). The development of infants' spatial categories. *Current Directions in Psychological Science*, *17*(1), 21-25.

Casasola, M. (2018). Above and beyond objects: The development of infants' spatial concepts. *Advances in Child Development and Behavior, 54,* 87-121.

Foster-Cohen, S., Edgin, J. O., Champion, P. R., & Woodward, L. J. (2007). Early delayed language development in very preterm infants: evidence from the MacArthur-Bates CDI. *Journal of Child Language*, *34*(3), 655.

Gentner, D., & Boroditsky, L. (2001). Individuation, relativity, and early word learning. *Language Acquisition and Conceptual Development*, *3*, 215-256.

Gentner, D., Ozyürek, A., Gürcanli, O., & Goldin-Meadow, S. (2013).Spatial language facilitates spatial cognition: Evidence from childrenwho lack language input. *Cognition, 127,* 318–330

Gentner, D. (2016). Language as cognitive tool kit: How language supports relational thought. *American Psychologist*, 71(8), 650–657.

Gibson, E. J. (1988). Exploratory behavior in the development of perceiving, acting, and the acquiring of knowledge. *Annual Review of Psychology*, 39(1), 1-42.

Golinkoff, R.M., Hoff, E., Rowe, M.L., Tamis-LeMonda, C.S., & Hirsh-Pasek, K. (2019), Language Matters: Denying the Existence of the 30-Million-Word Gap Has Serious Consequences. *Child Development, 90,* 985-992

Hoch, J. E., Rachwani, J., & Adolph, K. E. (2020). Where infants go: Real-time dynamics of locomotor exploration in crawling and walking infants. *Child Development*, *91*(3), 1001-1020.

Heiman, C. M., Cole, W. G., Lee, D. K., & Adolph, K. E. (2019). Object interaction and walking: Integration of old and new skills in infant development. *Infancy*, 24(4), 547–569

Hellendoorn, A., Wijnroks, L., Van Daalen, E., Dietz, C., Buitelaar, J. K., & Leseman, P. (2015). Motor functioning, exploration, visuospatial cognition and language development in preschool children with autism. *Research in Developmental Disabilities*, *39*, 32-42.

Hoff, E., & Shatz, M. (Eds.). (2009). *Blackwell handbook of language development*. John Wiley & Sons.

Huttenlocher, J., Vasilyeva, M., Waterfall, H. R., Vevea, J. L., & Hedges, L. V. (2007). The varieties of speech to young children. *Developmental Psychology*, *43*(5), 1062.

Iverson, J. M. (2010). Developing language in a developing body: The relationship between motor development and language development. *Journal of child language*, *37*(2), 229-261.

Iverson, J. M. (2021). Developmental Variability and Developmental Cascades: Lessons From Motor and Language Development in Infancy. *Current Directions in Psychological Science*, 30(3), 228–235.

The jamovi project (2020). *jamovi*. (Version 1.6) [Computer Software]. Retrieved from https://www.jamovi.org.

Jarvis, E. N., West, K. L., & Iverson, J. M. (2020). Object exploration during the transition to sitting: A study of infants at heightened risk for autism spectrum disorder. *Infancy*, *25*(5), 640-657.

Johnston, J. R. (1988). *Children's verbal representation of spatial location.* In J. Stiles-Davis, M. Kritchevsky, & U. Bellugi (Eds.), *Spatial cognition: Brain bases and development* (p. 195–205). Lawrence Erlbaum Associates, Inc.

Kısa, Y. D., Aktan-Erciyes, A., Turan, E., & Göksun, T. (2019). Parental use of spatial language and gestures in early childhood. *British Journal of Developmental Psychology*, *37*(2), 149-167.

Kobaş, M., Aktan-Erciyes, A., & Göksun, T. (2021). Fine motor abilities and parental input of spatial features predict object word comprehension of Turkish-learning children. *Infant and Child Development*, e2243.

Kobaş, M., Kızıldere, E., Doğan, I., Aktan-Erciyes, A., Demir-Lira, E., Akman, İ. & Göksun, T. (under review). Motor Abilities, Language Development, and Visual Perception in Preterm and Full-Term Infants.

Landau, B., & Stecker, D. S. (1990). Objects and places: Geometric and syntactic representations in early lexical learning. *Cognitive Development*, *5*(3), 287-312.

Lausberg, H., & Sloetjes, H. (2009). Coding gestural behavior with the NEUROGES-ELAN system.

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.

Lieven, E. (2010). Input and first language acquisition: Evaluating the role of frequency. *Lingua*, 120(11), 2546-2556.

Lobo, M. A., & Galloway, J. C. (2008). Postural and object-oriented experiences advance early reaching, object exploration, and means–end behavior. *Child Development*, *79*(6), 1869-1890.

Lobo, M. A., Kokkoni, E., Cunha, A. B., & Galloway, J. C. (2015). Infants born preterm demonstrate impaired object exploration behaviors throughout infancy and toddlerhood. *Physical Therapy*, *95*(1), 51-64.

Loewenstein, J., & Gentner, D. (2005). Spatial language and the development of relational mapping. *Cognitive Psychology*, *50*(4), 315-353.

Masek, L. R., McMillan, B. T., Paterson, S. J., Tamis-LeMonda, C. S., Golinkoff, R. M., & Hirsh-Pasek, K. (2021). Where language meets attention: How contingent interactions promote learning. *Developmental Review*, 60, 100961.

Meints, K., Plunkett, K., Harris, P.L., & Dimmock, D. (2002), What is ‘on’ and ‘under’ for 15-, 18- and 24- month-olds? Typicality effects in early comprehension of spatial prepositions. *British Journal of Developmental Psychology, 20*, 113-130.

McQuillan, M. E., Smith, L. B., Yu, C., & Bates, J. E. (2019). Parents influence the visual learning environment through children's manual actions. *Child Development*, *91*(3), e701-e720.

Möhring, W., & Frick, A. (2013). Touching up mental rotation: Effects of manual experience on 6-month-old infants' mental object rotation. *Child Development*, *84*(5), 1554-1565.

Munnich, E., & Landau, B. (2010). Developmental decline in the acquisition of spatial language. *Language Learning and Development*, *6*(1), 32-59.

Needham, A. (2000). Improvements in object exploration skills may facilitate the development of object segregation in early infancy. *Journal of Cognition and Development*, *1*(2), 131-156.

van Noort-van der Spek I. L., Marie-Christine J. P. F., & Nynke W. (2012). Language Functions in Preterm-Born Children: A Systematic Review and Meta-Analysis. *Pediatrics*, *129*(4), 745.

Oakes, L. M., & Rakison, D. H. (2019). *Developmental cascades: Building the infant mind*. Oxford University Press.

Oudgenoeg-Paz, O., & Rivière, J. (2014) Self-locomotion and spatial language and spatial cognition: insights from typical and atypical development. *Frontiers in Psychol*ogy, *5*, 521.

Oudgenoeg-Paz, O., Leseman, P. P., & Volman, M. C. J. M. (2015). Exploration as a mediator of the relation between the attainment of motor milestones and the development of spatial cognition and spatial language. *Developmental Psychology*, *51*(9), 1241.

Oudgenoeg-Paz, O., Volman, M. C., & Leseman, P. P. (2016). First steps into language? Examining the specific longitudinal relations between walking, exploration and linguistic skills. *Frontiers in Psychology*, *7*, 1458.

Parish-Morris, J. (2011). *Relational vocabulary in preschoolers with autism spectrum disorder: The role of dynamic spatial concepts and social understanding.* (Doctoral dissertation). Temple University, Philadelphia.

Polinsky, N., Perez, J., Grehl, M., & McCrink, K. (2017). Encouraging spatial talk: Using children's museums to bolster spatial reasoning. *Mind, Brain, and Education*, *11*(3), 144-152.

Pruden, S. M., Levine, S. C., & Huttenlocher, J. (2011). Children's spatial thinking: Does talk about the spatial world matter?. *Developmental Science*, *14*(6), 1417-1430.

R Core Team (2020). R: A Language and environment for statistical computing. (Version 4.0) [Computer software]. Retrieved from https://cran.r-project.org. (R packages retrieved from MRAN snapshot 2020-08-24).

Rakison, D. H., & Krogh, L. (2011). Does causal action facilitate causal perception in infants younger than 6 months of age? *Developmental Science*, 15(1), 43–53.

Ruff HA, McCarton C, Kurtzberg D, Vaughan HG Jr. (1984). Preterm infants' manipulative exploration of objects. *Child Development,55*(4), 1984.

Quinn, J. A., Munoz, F. M., Gonik, B., Frau, L., Cutland, C., Mallett-Moore, T., Kissou, A., Wittke, F., Das, M., Nunes, T., Pye, S., Watson, W., Ramos, A. A., Cordero, J. F., Huang, W. T., Kochhar, S., Buttery, J., & Brighton Collaboration Preterm Birth Working Group (2016). Preterm birth: Case definition & guidelines for data collection, analysis, and presentation of immunisation safety data. *Vaccine*, *34*(49), 6047–6056.

Saffran, J. R. (2003). Statistical language learning: Mechanisms and constraints. *Current Directions in Psychological Science*, *12*(4), 110-114.

Salerni, N., Suttora, C., & D'Odorico, L. (2007). A comparison of characteristics of early communication exchanges in mother-preterm and mother-full-term infant dyads. *First Language*, *27*(4), 329-346.

Samuelson, L.K. (2021), Toward a Precision Science of Word Learning: Understanding Individual Vocabulary Pathways. *Child Development Perspectives*, *15*, 117-124.

Sansavini, A., Guarini, A., & Caselli, M. C. (2011). Preterm birth: neuropsychological profiles and atypical developmental pathways. *Developmental Disabilities Research Reviews*, *17*(2), 102-113.

Sansavini, A., Libertus, K., Guarini, A., Libertus, M. E., Benassi, M., & Iverson, J. M. (2021). Editorial: Understanding Trajectories and Promoting Change From Early to Complex Skills in Typical and Atypical Development: A Cross-Population Approach. *Frontiers in Psychology*, 12, 647464.

Schröder, E., Gredebäck, G., Gunnarsson, J., & Lindskog, M. (2020). Play enhances visual form perception in infancy–an active training study. *Developmental Science*, *23*(3), e12923.

Schwarzer, G., Freitag, C., & Schum, N. (2013). How crawling and manual object exploration are related to the mental rotation abilities of 9-month-old infants. *Frontiers in Psychology*, *4*, 97.

Scott, N. M., & Sera, M. D. (2018). Language unifies relational coding: The roles of label acquisition and accessibility in making flexible relational judgments. *Journal of Memory and Language*, 101, 136–152.

Simms, N. K., & Gentner, D. (2019). Finding the middle: Spatial language and spatial reasoning. *Cognitive Development*, *50*, 177-194.

Slone, L. K., Moore, D. S., & Johnson, S. P. (2018). Object exploration facilitates 4-month-olds' mental rotation performance. *PLoS One*, *13*(8), e0200468.

Smith, K. E., Landry, S. H., & Swank, P. R. (2000). Does the content of mothers' verbal stimulation explain differences in children's development of verbal and nonverbal cognitive skills?. *Journal of school psychology*, 38(1), 27-49.

Smith, L., & Gasser, M. (2005). The development of embodied cognition: Six lessons from babies. *Artificial Life*, *11*(1-2), 13-29.

Smith, L. B. (2009). From fragments to geometric shape: Changes in visual object recognition between 18 and 24 months. *Current Directions in Psychological Science, 18(5),* 290–294.

Smith, L. B. (2013). It's all connected: Pathways in visual object recognition and early noun learning. *American Psychologist*, *68*(8), 618.

Sommerville, J. A., Woodward, A. L., & Needham, A. (2005). Action experience alters 3-month-old infants' perception of others' actions. *Cognition*, *96*(1), B1-B11.

Soska, K. C., Adolph, K. E., & Johnson, S. P. (2010). Systems in development: motor skill acquisition facilitates three-dimensional object completion. *Developmental Psychology*, *46*(1), 129.

Talmy, L. (1983). How language structures space. In *Spatial orientation* (pp. 225-282). Springer, Boston, MA.

Tamis-LeMonda, C. S., Kuchirko, Y., & Tafuro, L. (2013). From action to interaction: Infant object exploration and mothers' contingent responsiveness. *IEEE Transactions on Autonomous Mental Development*, *5*(3), 202-209.

Turan, E., Kobaş, M., & Göksun, T. (2021). Spatial language and mental transformation in preschoolers: Does relational reasoning matter? *Cognitive Development*, *57,* 100980.

Yu, C., & Smith, L. B. (2012). Embodied attention and word learning by toddlers. *Cognition*, *125*(2), 244-262.

Vicari, S., Caravale, B., Carlesimo, G. A., Casadei, A. M., & Allemand, F. (2004). Spatial working memory deficits in children at ages 3-4 who were low birth weight, preterm infants. *Neuropsychology*, *18*(4), 673.

Wilcox T, Woods R, Chapa C, McCurry S. (2007). Multisensory exploration and object individuation in infancy. *Developmental Psychology, 43(2),* 479-495.

Woods, R. J., & Wilcox, T. (2013). Posture support improves object individuation in infants. *Developmental Psychology*, *49*(8), 1413.

Zuccarini, M., Sansavini, A., Iverson, J. M., Savini, S., Guarini, A., Alessandroni, R., Faldella, G., & Aureli, T. (2016). Object engagement and manipulation in extremely preterm and full-term infants at 6 months of age. *Research in Developmental Disabilities*, *55*, 173-184.

Zuccarini, M., Guarini, A., Savini, S., Iverson, J. M., Aureli, T., Alessandroni, R., Faldella, G., & Sansavini, A. (2017). Object exploration in extremely preterm infants between 6 and 9 months and relation to cognitive and language development at 24 months. *Research in Developmental Disabilities*, *68*, 140-152.

Zuccarini, M., Guarini, A., Iverson, J. M., Benassi, E., Savini, S., Alessandroni, R., Faldella, G., & Sansavini, A. (2018). Does early object exploration support gesture and language development in extremely preterm infants and full-term infants?. *Journal of Communication Disorders, 76,* 91-100.

APPENDIX

Appendix A: Additional analyses for the regression models

Model 1: Frequency of object exploration and parents' spatial input at Time 1 as explanatory variables

In this model, the first step included neonatal condition (i.e., being preterm or not), infants' age, and word comprehension at Time 1. In the second step the frequency of object exploration at Time 1 and parents' spatial input at Time 1 were introduced. Third step included the interaction term. This interaction term between object exploration and parents' spatial input was the cross product of the related mean-centered terms.

Table 1. Regression analyses of Model 1, spatial language of infants at 26 months as the outcome variable.

		Outcome: Spatial language at 26 months				
Step	Predictors	ΔR^2	F-change	β	*t*	*p*
1		0.16	2.59			
	Neonatal Condition			0.01	0.02	0.99
	Age at Time 1			0.16	0.94	0.35
	Word Comprehension at 14 months			0.29	1.74	0.09
2		0.01	0.12			
	Neonatal Condition			0.02	0.06	0.95
	Age at Time 1			0.15	0.83	0.41
	Word Comprehension at Time 1			0.29	1.63	0.11
	Object Exploration at Time 1			-0.07	-0.49	0.63
	Parents' Spatial Input at Time 1			-0.01	-0.06	0.95
3		0.11	5.63			
	Neonatal Condition			-0.03	-0.10	0.92
	Age at Time 1			0.24	1.37	0.18
	Word Comprehension at Time 1			0.30	1.80	0.08
	Object Exploration at Time 1			-0.09	-0.65	0.52
	Parents' Spatial Input at Time 1			0.002	0.01	0.99
	Object Exploration x Spatial Input			0.34	2.37	0.02*

Note. * $p < .05$

This model was significant and accounted for 27% of the variance (see Table 1), $F(6,38)=2.37$, $p=0.048$. Neonatal condition, age at Time 1 and word comprehension were not significant predictors at step 1. Object exploration and parents' spatial input were not significant predictors at step 2. In the third step, the interaction between object exploration and parents' spatial input at Time 1 was the only significant predictor ($\beta=0.34$, $p=.02$). The third step was accounting for additional 11% variance.

Model 2: Duration of caregivers' object manipulation as a control variable

For this model, neonatal condition, age at Time 1, duration of caregivers' object manipulation at Time 1 and word comprehension at Time 1 were entered to step 1. The second step included the frequency of object exploration at Time 1 and parents' spatial input from Time 1. The third step included the interaction term of the frequency of object exploration at Time 1 and parents' spatial input at Time 1.

Table 2. Regression analyses of Model 2, spatial language of infants at 26 months as the outcome variable.

		Outcome: Spatial language at 26 months				
Step	Predictors	ΔR^2	F-change	β	*t*	*p*
1		0.17	2.06			
	Neonatal Condition			0.01	0.03	0.98
	Age at Time 1			0.17	0.99	0.33
	Word Comprehension at 14 months			0.25	1.38	0.18
	Caregivers' Object Manipulation at Time 1			-0.12	-0.75	0.46
2		0.004	0.08			
	Neonatal Condition			0.001	0.002	0.998
	Age at Time 1			0.17	0.96	0.34
	Word Comprehension at Time 1			0.23	1.20	0.24
	Caregivers' Object Manipulation at Time 1			-0.11	-0.66	0.51
	Object Exploration at Time 1			-0.06	-0.39	0.70
	Parents' Spatial Input at Time 1			0.01	-0.04	0.97
3		0.12	6.07			
	Neonatal Condition			-0.11	-0.36	0.72
	Age at Time 1			0.35	1.91	0.06
	Word Comprehension at Time 1			0.23	1.30	0.20
	Caregivers' Object Manipulation at Time 1			-0.02	-0.10	0.92
	Object Exploration at Time 1			-0.16	-1.01	0.32
	Parents' Spatial Input at Time 1			-0.10	-0.62	0.54
	Object Exploration x Spatial Input			0.40	2.46	0.02*

Note. * $p < .05$

This model was not significant (see Table 2), $F(7,37) = 1.44$, $p = 0.06$. There was no significant relation in step 1 and step 2. In the third step, the interaction between object exploration and parents' spatial input at Time 1 was the only significant predictor ($\beta = 0.35$, $p = .02$).

Model 3: Frequency of object exploration and parents' spatial input at Time 2 as explanatory variables

For this model, neonatal condition, age at Time 1 and word comprehension at Time 1 were entered to step 1. The second step included the frequency of object exploration at Time 1 and parents' spatial input at Time 2. The third step included the interaction term of the frequency of object exploration at Time 1 and parents' spatial input at Time 2.

Table 3. Regression analyses of Model 3, spatial language of infants at 26 months as the outcome variable.

		Outcome: Spatial language at 26 months				
Step	Predictors	ΔR^2	F-change	β	*t*	*p*
1		0.16	2.59			
	Neonatal Condition			0.01	0.02	0.99
	Age at Time 1			0.16	0.94	0.35
	Word Comprehension at 14 months			0.29	1.74	0.09
2		0.01	0.12			
	Neonatal Condition			0.002	0.05	0.96
	Age at Time 1			0.15	0.83	0.41
	Word Comprehension at Time 1			0.28	1.66	0.11
	Object Exploration at Time 1			-0.07	-0.46	0.65
	Parents' Spatial Input at Time 2			0.002	0.012	0.99
3		0.02	0.97			
	Neonatal Condition			-0.03	-0.08	0.94
	Age at Time 1			0.19	1.01	0.32
	Word Comprehension at Time 1			0.29	1.71	0.10
	Object Exploration at Time 1			-0.04	-0.26	0.79
	Parents' Spatial Input at Time 2			0.04	0.23	0.82
	Object Exploration x Spatial Input at Time 2			0.15	0.98	0.33

Note. * $p < .05$

This model was not significant (see Table 3), F (6,38)=1.44, p =0.226. There was no significant relation in step 1, step 2, and step 3.

Model 4: Duration of caregivers' object manipulation as control variable

For this model, neonatal condition, age at Time 1, duration of caregivers' object manipulation at Time 1 and word comprehension at Time 1 were entered to step 1. The second step included the frequency of object exploration at Time 1 and parents' spatial input at Time 2. The third step included the interaction term of the frequency of object exploration at Time 1 and parents' spatial input at Time 2.

Table 4. Regression analyses of Model 4, spatial language of infants at 26 months as the outcome variable.

		Outcome: Spatial language at 26 months				
Step	Predictors	ΔR^2	F-change	β	*t*	*p*
1		0.17	2.06			
	Neonatal Condition			0.01	0.03	0.98
	Age at Time 1			0.17	0.99	0.33
	Word Comprehension at 14 months			0.25	1.38	0.18
	Caregivers' Object Manipulation at Time 1			-0.12	-0.75	0.46
2		0.004	0.09			
	Neonatal Condition			-0.003	-0.01	0.99
	Age at Time 1			0.17	0.96	0.34
	Word Comprehension at Time 1			0.23	1.23	0.23
	Caregivers' Object Manipulation at Time 1			-0.11	-0.68	0.50
	Object Exploration at Time 1			-0.06	-0.35	0.73
	Parents' Spatial Input at Time 2			0.02	0.14	0.89
3		0.06	2.66			
	Neonatal Condition			-0.09	-0.29	0.77
	Age at Time 1			0.23	1.27	0.21
	Word Comprehension at Time 1			0.20	1.07	0.29
	Caregivers' Object Manipulation at Time 1			-0.08	-0.50	0.62
	Object Exploration at Time 1			-0.10	-0.60	0.56
	Parents' Spatial Input at Time 2			0.001	0.01	0.99
	Object Exploration x Spatial Input			0.25	1.63	0.11

Note. * $p < .05$

This model was not significant (see Table 4), $F\ (7,37) = 1.58$, $p = 0.17$. There was no significant relation in step 1, step 2, and step 3.

Model 5: Duration of object exploration and parents' cumulative spatial input from Time 1 and Time 2 as explanatory variables

For this model, neonatal condition, age at Time 1 and word comprehension at Time 1 were entered to step 1. The second step included the frequency of object exploration at Time 1 and parents' cumulative spatial input from Time 1 and Time 2. The third step included the interaction term of the frequency of object exploration at Time 1 and cumulative parents' spatial input.

Table 5. Regression analyses of Model 5, spatial language of infants at 26 months as the outcome variable.

		Outcome: Spatial language at 26 months				
Step	Predictors	ΔR^2	F-change	β	*t*	*p*
1		0.16	2.59			
	Neonatal Condition			0.01	0.02	0.99
	Age at Time 1			0.16	0.94	0.35
	Word Comprehension at 14 months			0.29	1.74	0.09
2		0.01	0.14			
	Neonatal Condition			-0.002	-0.01	0.996
	Age at Time 1			0.16	0.92	0.36
	Word Comprehension at Time 1			0.27	1.52	0.14
	Object Exploration at Time 1			-0.08	-0.51	0.61
	Cumulative Parents' Spatial Input			-0.01	-0.04	0.97
3		0.11	5.61			
	Neonatal Condition			-0.12	-0.40	0.69
	Age at Time 1			0.30	1.69	0.10
	Word Comprehension at Time 1			0.22	1.27	0.21
	Object Exploration at Time 1			-0.10	-0.69	0.49
	Cumulative Parents' Spatial Input			-0.05	-0.34	0.74
	Object Exploration x Spatial Input			0.35	2.37	0.02*

Note. * $p < .05$

This model was significant and accounted for 28% of the variance (see Table 5), $F(6,38)=2.37$, $p=0.048$. Neonatal condition, age at Time 1 and word comprehension were not significant predictors at step 1. Object exploration and parents' spatial input were not significant predictors at step 2. In the third step the interaction between object exploration and parents' spatial input at Time 1 was the only significant predictor ($\beta=0.35$, $p=.02$). The third step was accounting for additional 11% variance.