Building spaces for play: How mothers design and explore new play environments with pre-walking and walking infants

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The physical environment is the backdrop for infant development. Yet researchers know little about how infants' spaces come to be. For infants, play spaces are typically structured by caregivers who choose objects, furnishings, and their organization. As infants' locomotor skills develop so does their agency for engaging with space. Learning to walk, for example, changes how infants interact within the environment. Compared to pre-walkers, walkers move more, travel more, and spend more time playing at a distance from caregivers. As a result, caregivers likely update the arrangements of infants' spaces in response to an advancing repertoire for action. But how do caregivers build spaces for infant play? Does infant motor ability shape the spaces caregivers construct? This dissertation introduced a novel paradigm to examine how mothers of pre-walking and walking infants created a new play space and engaged in play in different environments. We observed 52 12-month-old infants (35 pre-walkers, 17 walkers) and their mothers. Mothers were asked to design a playroom using a set of building blocks in an empty room. We examined relations among infants' locomotor status, mothers' design choices, and patterns of infant and mother behavior during play (eight minutes in an identically organized, standard playroom; eight minutes in mother-designed playrooms). Mothers built spacious playrooms for pre-walkers (multiple constructions spanning a large area) and concentrated playrooms for walkers (one construction covering a small area). In the standard playroom, walkers moved more, traveled more, and engaged in more complex patterns of interpersonal distance to mothers compared to pre-walkers. Mothers directed similar amounts of language and gesture to infants, but communicated more frequently while infants were moving. In mother-designed playrooms, patterns of infant and mother behavior were similar. Differences in mothers' playroom design (indexed by built area) only related to one behavior: infants generated more room layout changes (by moving blocks) when playrooms were larger. Taken together, this study expands our understanding of how infant motor development shapes caregiver behavior by extending connections to spatial construction. Most importantly, we contribute new insights about the dynamics of infant and caregiver behavior as a process embedded in the physical environment.

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Preface

This dissertation marks the culmination of six years of graduate study—six years of research questions, friendships, dinners, cocktails, meetings, manuscripts, babies, and of course, cake and champagne. I am indebted to everyone that has been a part of my journey and am forever grateful. I will do my best to express my thanks in words.

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1.0 Introduction

The physical environment is the backdrop for infant development. Indeed, all infant behavior—movement, exploration, social interaction, and communication—occurs in the context of a physical space. Yet researchers know surprisingly little about how the spaces that infants inhabit come to be. For infants, everyday play spaces are typically structured by caregivers. Caregivers choose the objects and furnishings that dress playrooms and living spaces and organize them in particular ways. As infants' postural and locomotor skills develop, however, so does their agency for engaging with the spaces of everyday play and potentially altering them.

Learning to walk, for example, changes how infants interact with the world around them. Compared to pre-walking infants, walkers spend more time moving during play (Adolph et al., 2012; Schneider & Iverson, 2022), are more likely to use movement to travel and explore distal places (Clearfield, 2011; Karasik et al., 2011; Thurman & Corbetta, 2017), and spend more time playing at a distance from adults (Chen et al., 2023). The cascading effects of walking on other infant behaviors suggest that walking may expand how infants explore and interact with the spaces of everyday life. In light of these changes, caregivers likely update and reconfigure the physical arrangements of infants' spaces to meet their developmental level, structure safe environments for play, and respond to a continually advancing repertoire for action.

1.1 Taking a developmental perspective

Developmental scientists have long considered the importance of situating patterns of infant-caregiver interaction in the physical contexts within which they occur. In fact, many prominent theoretical perspectives position the developing infant at the center of increasingly complex levels of interaction with the surrounding environment. For example, Bronfenbrenner (1979) suggested that infants' interactions with their most proximal environments (i.e., those containing the immediate physical characteristics of daily life; objects, people, spaces, places) set the stage for development. In other words, the contents and layout of infants' spaces create the interactional environment within which development takes place (see also Bronfenbrenner & Morris, 2007).

The developing infant, however, is not a passive bystander. Infants are active agents of their own experiences. In Gibson's (1979) view, development is built on the interactions that occur between people and their environments. That is, features of an environment—objects, surfaces, and their organization—provide possibilities for action, but the subsequent expression of action is modulated by the abilities of the actor. Thus, although the structure and contents of infants' everyday spaces (largely determined by caregivers) may be brimming with opportunities for play and exploration, the successful uptake of these possibilities depends on what infants are able to do in the moment (i.e., if infants can make a match between their abilities and what the environment allows).

Moreover, the dynamic nature of infant motor development (e.g., Thelen & Smith, 1994) suggests that the acquisition of new motor skills in infancy broadly influences other areas of development (i.e., other infant and caregiver behaviors; Iverson, 2022). This view of developmental process—as a system of cascades—has been primarily drawn from research examining relations between infants' motor actions and caregivers' behaviors in the context of play. However, it is also possible that new motor skills similarly shape how caregivers structure the spaces within which play takes place.

Although the physical environment has been an important feature of many perspectives on development, it has rarely been considered as a construct of interest. Rather, space has been acknowledged as part of the larger context that shapes the expression of behavior. As a result, little empirical evidence exists to address the ontogeny of the relations between how caregivers create infants' play environments and reciprocally, how infants' abilities may shape the spaces they inhabit.

How do caregivers build spaces for infant play? And does infant motor ability shape the characteristics of the spaces that caregivers construct? This dissertation study provides a new lens on these developmental questions by assessing relations among infants' locomotor status (as pre-walker or walker), mothers' choices for spatial design, and infant and mother behavior during play. We examined how 12-month-old infants and their mothers played in a standard play space (in which the characteristics of the environment were held constant); how mothers created a novel play space using a large set of building blocks in an otherwise empty room; and how infants and mothers played together in spaces designed by mothers (that varied in their characteristics).

1.2 The structure of the physical environment creates opportunities for infant play

Researchers know surprisingly little about how caregivers structure infants' everyday spaces for play. However, there is a substantial literature describing how the physical layouts of intentionally curated environments (e.g., daycares, preschools, and other early learning institutions) are designed and in turn, elicit infants' play behaviors (see van Liempd et al., 2020 for a review). Specifically, several studies have examined the effects of the spatial configuration of a space on patterns of infant play and exploration. In general, this work suggests that different layouts of spaces differentially influence how infants engage within them, and intentional design choices appear to play a role in facilitating these connections.

An early study examining relations between space and infant behavior asked how the physical arrangement of play spaces in daycare centers related to infant play (Moore, 1986). Using a quasi-experimental design comparing different types of spatial layouts found in various centers, researchers demonstrated that playrooms with a higher degree of "spatial definition" (i.e., those containing a greater number of concretely defined areas) corresponded to higher levels of social engagement and a greater breadth of exploration compared to playrooms with loosely defined interaction areas. The relative openness of a space—defined by the amount of empty floor space, visibility from different parts of a room, and concentration of activity areas for different types of play—also appeared to modulate patterns of exploration and social interaction. Infants were more likely to congregate for group play, engage with a larger variety of objects, and explore the breadth of spaces organized with more open floor space compared to those with denser configurations (e.g., Burgess & Fordyce, 1989; Campos de-Carvalho & Rossetti-Ferreira, 1993).

Another study examining connections between infants' exploratory play behaviors and characteristics of childcare spaces underscores important links between the layout of space and infant action (van Liempd et al., 2018). Infants routinely explored a variety of spatial components when they were available (e.g., the open floor, large objects, furniture) and exploited their affordances for action (e.g., by manipulating objects with their hands or locomoting across different surfaces). The predominant locations of play, however, were open floor spaces and activity areas that provided the most opportunities for different kinds of exploration (e.g., spaces to practice motor skills like crawling and climbing).

The effects of spatial design are not limited to indoor spaces. They also appear to shape infants' motor actions, play, and social engagement in outdoor areas, a common locale of infants' daily lives. For instance, a study examining the responses of approximately 200 infants and toddlers to a redesigned outdoor play space in a childcare center revealed change in infants' play patterns, especially movement and locomotor exploration of obstacles (e.g., walking up and down inclines, crossing bridges, and climbing on elevations; Morrissey et al., 2015). The intentional change in the layout and contents of space that this study implemented (e.g., introducing new furniture like large pedestals and slides, repositioning existing structures) highlights the idea that outfitting spaces with a variety of different furnishings that afford different types of actions shapes infants' exploratory behaviors.

Collectively, these studies demonstrate the possibility of direct connections between how spaces are arranged and how infants play (e.g., by moving, exploring, and interacting with others). Here we expanded on these ideas by examining how infants and mothers played together in two kinds of environments: (1) a standard playroom organized in an identical fashion for all dyads; and (2) a playroom designed by mothers.

1.3 Caregivers may design different play spaces based on their infants' abilities

Caregivers are sensitive to their infants' developing skills and respond to advances in infants' capabilities for action by adapting their own behaviors (e.g., Schneider & Iverson, 2022). Indeed, it appears that the acquisition of new motor skills (like walking) spurs a reorganization in how caregivers interact with their infants, resulting in new ways to play, explore, and engage (see Iverson et al., 2023 for an overview). For example, caregivers are more likely to use movement-focused language and gestures to comment on or direct infants' actions when infants walk compared to when they crawl. Caregivers produce utterances that contain whole-body, motion verbs (e.g., go, get, climb, walk) and gestures that beckon infants with outstretched arms, hands, or fingers (Schneider & Iverson, 2022; West et al., 2022).

Caregivers' behaviors are also shaped by their infants' behaviors: they mirror infants' postures by staying upright while infants are upright and getting down when infants are down (Franchak et al., 2018). Moreover, infants and caregivers frequently reposition their bodies during play to structure shared interaction spaces (e.g., by switching between postures; Schneider et al., 2023; Yamane et al., 2022), a behavior that may be amplified after infants learn to walk. And more generally, caregivers have reported changes in how they perceive their infants as they acquire new locomotor skills (e.g., viewing their walking infants as more mature; Biringen et al., 1995; Walle, 2016).

There is an abundance of evidence to suggest that infants' motor skills shape caregivers' interactive behaviors (i.e., how they play, communicate, and position their bodies), but less is known about whether infants' developing motor abilities are also related to the spaces that caregivers construct for play. Caregivers are the primary architects of infants' environments, as they continuously select and update the objects, furnishings, and layouts of play spaces. And although limited, some research points to the central role that caregivers play in the creation and management of infants' everyday spaces at home.

A handful of qualitative investigations have suggested that caregivers alter how they organize infants' play environments based on their infants' developmental level. In one of the few longitudinal studies in the literature, researchers provided a rich description of the ways in which mothers managed and updated home spaces for infant play across the first 18 months of life (Pierce, 2000). The study described the vast array of decisions that mothers made about the structure of their infants' spaces and how these choices changed over time. For example, mothers provided the objects of play and exploration; they furnished the home with infant-designed furniture and equipment (e.g., large blocks, activity tables) to promote the practice of new motor skills as they appeared in their infants' repertoires; and they selected the places and spaces of play by sectioning off living rooms with baby gates and other enclosures. Critically, mothers' practices around the spatial organization of home spaces were remarkably malleable: they changed in relation to infant age and the attainment of new skills (e.g., advances in locomotion and communication). This suggests a bidirectional link between infant development (e.g., how infants' skills prompt changes in the ways they engage with spaces) and how caregivers maintain and adapt spaces for their infants (Coughlan & Lynch, 2011; Lynch et al., 2016; Pierce, 2000).

Taken together, existing research indicates that infant locomotor development has broad cascading connections to caregiver behavior during play, and that it may also be related to how caregivers build and design play environments. Moreover, findings from qualitative studies suggest that caregivers actively consider how they structure spaces for their infants. To assess relations between infant locomotor ability and caregiver choices for spatial construction, this study examined how mothers designed a new play space for their infants and whether infants' locomotor status (as pre-walker or walker) shaped the environments mothers created.

1.4 Motor skills are related to how infants play and explore in different spaces

Infants' motor behaviors—how they move and position their bodies—are inherently tied to the physical spaces within which they are produced. To date, however, most of the research examining how infants play and explore in different kinds of environments has expanded on Gibson's (1979) foundational concepts by examining how infants with varying motor abilities navigate novel obstacles in laboratory spaces (e.g., locomoting on a sloping walkway; Adolph, 1997). Most often, these studies take place in uniquely curated experimental environments that utilize adjustable apparatuses (or modular structures that can be changed and reorganized during an experiment) and psychophysical procedures to increasingly vary the degree of difficulty for traversing the obstacle (see Adolph, 1995). To this end, studies have assessed the specificity of infants' developing perception-action systems; that is, the ability to detect the "fit" between what infants can do and what the environment allows.

Of course, the composition of the physical environment (i.e., what it contains and how it is structured) creates possibilities for action. This is evident for various motor skills and in various types of environments. For example, studies have asked whether infants can detect whether they can reach for objects while seated at the edge of a platform (Adolph, 2000), perceive possibilities for cruising along hand railings that vary in their stability (e.g., Berger et al., 2014; Ossmy & Adolph, 2020), or cross walkways that contain gaps in the floor (Adolph et al., 2011). Similarly, researchers have also assessed infants' decisions for whether or not locomotion (mainly crawling and walking) is possible when traversing sloping walkways that vary in their degree of slant (Adolph, 1997; Adolph et al., 1995; Gill et al., 2009), crossing bridges that vary in width (Kretch & Adolph, 2013a), or approaching drop-offs that vary in height or medium (e.g., a real, visual, or water cliff; Burnay et al., 2020; Kretch & Adolph, 2013b; Karasik et al., 2016). In all cases, and regardless of the environmental design, infants' ability to successfully navigate each type of terrain was dependent on their experience with a particular motor skill. That is, infants with differing levels of motor ability explored and moved through each space differently, sometimes successfully and sometimes not.

Interactions between infants' motor abilities and the characteristics of space have also been demonstrated in studies of other curated environments. In one study of infant locomotor exploration, for example, researchers observed patterns in walking infants' movements in two settings: an empty room and one filled with toys (Hoch et al., 2019). Interestingly, room type did not modulate the sheer quantity of movement, as infants spent similar proportions of their observation time locomoting in both rooms. The extent to which infants explored each room, however, was differentiated by the presence of toys, such that infants covered more unique area in the toy-filled room compared to the empty one.

Differences in toy quantity and function appear to have similar influences on other play behaviors. When testing the effects of the number of toys available for play on infants' level of engagement, researchers discovered that a room with just four toys resulted in longer episodes of sustained interaction (e.g., time spent in contact with toys) compared to a room with 16 (Dauch et al., 2018). And similarly, another study employing a physical manipulation of the environment showed that the kinds of toys present in a playroom shape the amount of time that infants spend in motion (Hoch et al., under review). Specifically, infants moved more while playing with locomotor toys (i.e., toys designed to be moved with like a stroller or large beach ball) compared to stationary toys (e.g., a shape sorter or stuffed animal).

Thus, these studies suggest that differences in infants' motor abilities and the characteristics of infants' play environments (their layout and contents) may work together to provide different opportunities for infant exploration and interaction. To further these ideas, we examined connections among infants' locomotor status, the characteristics of mother-designed playrooms, and patterns of infant movement, travel, and social interaction with mothers within the context of a single study.

1.5 Current study: How do mothers build spaces for infant play?

This dissertation introduced a new laboratory paradigm to examine relations among infant locomotor ability, mothers' design choices when constructing play spaces for their infants, and infant-mother behavior during play in a standard environment and environments created by mothers. The study had three aims, anchored to three developmental questions. First, we asked whether there were differences in how 12-month-old pre-walking and walking infants and their mothers engaged in play in a standard playroom (i.e., a space that was constructed identically for all participants). Second, we asked how mothers designed a new playroom for their infants and whether this differed based on infants' locomotor status. And third, we asked whether there were group differences in how infants and mothers engaged in play in mother-designed playrooms; and if the characteristics of mothers' spaces (which varied freely) were related to patterns of infant and mother behavior. We expand on the specific details of each aim below.

Aim 1. Examine patterns of infant and maternal behavior during play in a standard playroom. Our first aim was to examine infant and mother behavior during play in a standard space that was identically organized for all dyads. The use of a standard playroom allowed us to assess the extent to which infants' locomotor status (pre-walker vs. walker) shaped infant and mother behavior during play when characteristics of the physical environment were held constant.

We created four measures of infant behavior to construct a comprehensive account of infants' locomotor and exploratory actions. These included: (1) infant engagement with blocks (e.g., time in physical contact with blocks; Karasik et al., 2011); (2) infant movement (e.g., time in motion; Adolph et al., 2012), (3) infant travel (e.g., distance traveled; Clearfield, 2011), and (4) infant-mother proximity (e.g., exploration within vs. beyond mothers' arm's reach; Chen et al., 2023).

Given the literature on differences in locomotor exploration across the transition to walking, we generally expected that walking infants would demonstrate a more expansive profile of locomotor exploration compared to pre-walking infants. For example, we hypothesized that walkers would spend more time in motion, travel farther distances, and be more likely to engage in proximity transitions compared to pre-walkers (Adolph et al., 2012; Chen et al., 2023; Clearfield, 2011; Karasik et al., 2011; Schneider & Iverson, 2022). However, we did not anticipate differences in how much time infants would spend in contact with blocks, as research indicates that infants spend approximately 50% of every hour in contact with objects (of any kind), regardless of age or locomotor status (Karasik et al., 2011; Herzberg et al., 2022).

We also created four measures of maternal behavior to gather a comprehensive account of mothers' communicative, postural, and physical actions. These included: (1) language input (e.g., total number of utterances, proportion of utterances containing whole-body motion verbs; Schneider & Iverson, 2022; West et al., 2022), (2) gesture input (e.g., total number of gestures, proportion of gestures that requested movement; Schneider & Iverson, 2022), (3) posture (e.g., time upright vs. down on floor; Franchak et al., 2018), and (4) physical actions (e.g., number of times mothers repositioned infants' bodies; Yamane et al., 2022).

We hypothesized that mothers would communicate differently with their pre-walking and walking infants during play. Specifically, we expected that mothers of walkers would produce more language and gesture input compared to mothers of pre-walkers (e.g., Schneider & Iverson, 2022). We also anticipated that that a larger share of communication directed to walkers would be movement-focused (e.g., containing whole-body motion verbs and movement gestures; Schneider & Iverson, 2022; West et al., 2022). We hypothesized that mothers would spend more time down on the floor given the context of the play interaction, but that they might engage in more frequent posture transitions based on the breadth of infant exploration (i.e., getting up and down more often to follow infants who moved across the room; Franchak et al., 2018). Finally, little research exists on the prevalence of mothers' physical actions with infants (i.e., moving their bodies) during play and thus analysis of this behavior was exploratory.

Aim 2. Examine differences in the characteristics of mother-designed playrooms for pre-walking vs. walking infants. This study is the first (to our knowledge) to use a playroom construction paradigm in which mothers were asked to design a play area for their infants. Thus, our second aim leveraged this novel method to examine how mothers of pre-walkers vs. walkers built a play space in an otherwise empty room. Using a large set of building blocks (e.g., blocks of varying size, a staircase, slopes), mothers were asked to construct a playroom for their infants in any way they wished. Mother-designed playrooms were assessed on five dimensions to quantify their characteristics (e.g., number of blocks used, number of unique block constructions, area of the built space) and allow for group comparisons.

We generally expected that mothers of walkers and pre-walkers would structure different spaces for play. Given differences in the breadth of infant movement and exploration during play (e.g., walkers move and travel more than pre-walkers; Adolph et al., 2012; Hoch et al., 2019;

Schneider & Iverson, 2022) and links between change in infant motor skill and caregivers' spatial behaviors at home (e.g., mothers introduce new and varied furnishings as infants acquire new locomotor skills; Pierce, 2000), we expected that mothers of walkers would build playrooms that contained more blocks, unique blocks constructions, and a larger overall area than mothers of pre-walkers.

Aim 3. Examine patterns of infant and maternal behavior (and relations to the characteristics of mothers' spaces) during play in mother-designed playrooms. Our third aim was to examine infant and mother behavior during play in mother-designed playrooms. The mother-designed playrooms allowed us to assess the extent to which infants' locomotor status (pre-walker vs. walker) *and* the characteristics of the physical environment (which varied between mothers) shaped infant and mother behavior during play. We examined the same set of infant and mother behaviors described above.

We hypothesized locomotor status differences (as we did in Aim 1) for all infant and mother behaviors. For example, we expected that walkers would move more, travel more, and engage in more changes in interpersonal distance to their mothers compared to pre-walkers. We also generally expected that differences in the characteristics of mother-designed playrooms (e.g., the size of the built area occupied by blocks) would be related to patterns of infant and mother behavior. However, given the lack of existing literature about relations between space and infant-mother interactions during play, this aim was largely exploratory.

Nevertheless, based on literature from other fields of study, we suspected that there might be associations between space and infant and mother behavior during play (e.g., Burgess & Fordyce, 1989; Moore, 1986; van Liempd et al., 2018). On the one hand, spacious playrooms covering larger areas (i.e., in which blocks were strewn throughout the space) may support more infant movement and travel given the greater number of destinations for infants to explore (Moore, 1986). On the other hand, smaller playrooms with one or two constructions (i.e., many blocks piled together) may provide an abundance of empty floor space for infants to move through, resulting in more time in motion and travel (van Liempd et al., 2018). Similarly, mothers' communication may also differ in spaces that vary in their size and contents. For instance, larger playrooms with more unique block constructions may be provide more referents to structure language and gesture input (e.g., more places to talk about, more locations to point to).

2.0 Method

2.1 Participants

Fifty-two 12-month-old infants and their mothers participated in this study. Thirty-five infants were pre-walkers (18 boys, 17 girls; M = 12.16 months, SD = 0.19) and 17 infants were walkers (7 boys, 10 girls; M = 12.37 months, SD = 0.34). Infants' locomotor status was determined through parent report during a structured interview. Infants were considered walkers if they could walk 3 m across a room without stopping or falling. Pre-walkers could not walk (i.e., take any independent walking steps), but could move by other means (crawling, cruising). Families were recruited through a university-based recruitment service, advertisements placed in the general community, social media posts, and word of mouth. All infants were neurotypically developing, from full-term pregnancies, and from predominantly English-speaking households. All participants provided written informed consent as approved by the Institutional Review Board at the University of Pittsburgh (STUDY 22060184; "Creating Spaces for Infant Play").

Mothers identified their infant's race and ethnicity: 37 infants were White, two Black, two Asian, two Middle Eastern or North African (MENA), and nine were multiracial (seven Asian and White, one Black and White, and one Asian, Pacific Islander, and White). Five infants were of Hispanic or Latino heritage. Approximately half of infants had a sibling (51.9%; Mdn = 1, range = 1-6) and additional childcare provided by other caregivers (e.g., grandparents, nanny; 50.0%); 12 infants attended daycare (23.1%).

Mothers and their partners (primarily fathers; 96%) were similar in age (M mothers = 34.23 years, SD = 4.23; M partners = 36.53 years, SD = 4.99) and education (82.7% of mothers and

78.8% of partners held a bachelor's degree or higher). These demographic characteristics did not differ by infants' locomotor group (all *p*s > .05).

2.2 Procedure, playroom, and materials

The study took place in a large laboratory playroom (4 m x 4.7 m) outfitted with a foam-tiled floor (0.61 m x 0.61 m tiles) but no other furniture. Each visit was staffed by a primary experimenter (the first author) and an undergraduate research assistant. Sessions lasted approximately 1-1.5 hours. Upon arrival, the experimenter greeted families and escorted them to the playroom. The experimenter explained the study to mothers and obtained consent for participation and sharing of video data in an online repository. During this time, infants were given a handful of toys to play with as they acclimated to the new space.

After the consent process was completed, the experimenter and research assistant prepared the space for mothers to build their playrooms. We gave mothers a large building blocks set (foamnasium.com) containing 16 different blocks that could be combined and arranged in any way to create a new play space (e.g., blocks of varying size, a small staircase, slopes; see Figure 1 for an illustration of each block and corresponding dimensions). The set was selected to provide a wide range of options for playroom construction. Twenty-four infants played with similar blocks at least once (e.g., modular couch systems, large blocks at a museum or public library; 42.6%), but only seven mothers reported owning something similar at home (13.5%). Thus, our building blocks set was largely novel to infants.

The blocks were placed in a row against one wall so that mothers were able to see all the options that they could choose from for building. Mothers were given five minutes (*M* building time = 2.82 min, *SD* = 1.01) to construct a playroom for their infants. We asked mothers to use at least eight blocks to ensure the playroom was sufficiently interesting for sustained play, but no limit was placed on the total number of blocks they could select. Moreover, no specific instructions were provided to mothers about how to choose the blocks or where to place them. Infants were seated in a nearby highchair and occupied with small toys and snacks while mothers built their space. Any unused blocks were taken out of the room after mothers finished building. Mothers and infants then played in the *mother-designed playrooms* for eight minutes (*M* play duration = 8.17 min, *SD* = 0.16) on their own (the experimenter and research assistant waited outside the playroom during this time).

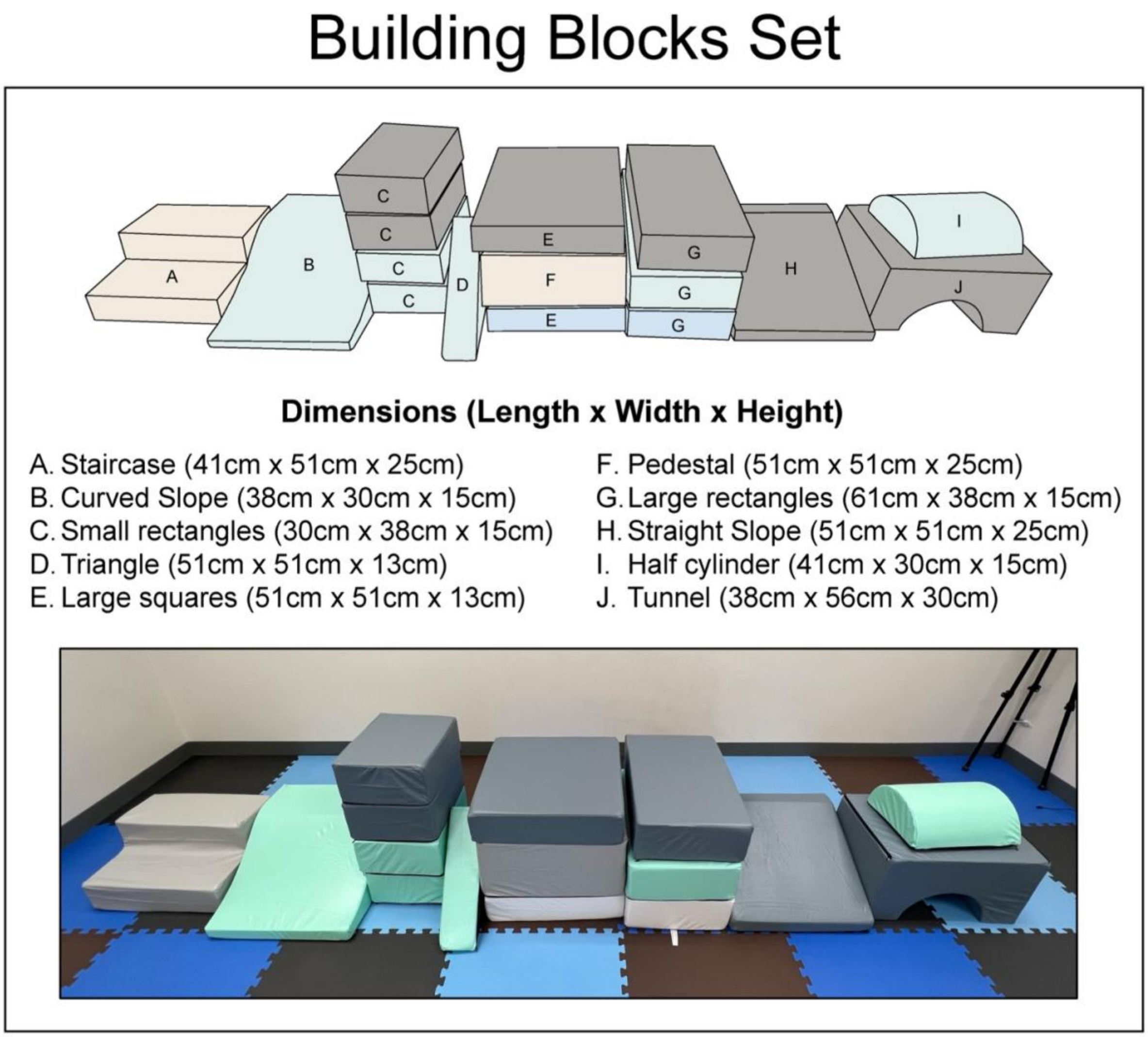

Figure 1. Drawings and image of the building blocks set. Mothers and infants were provided a total of 16 blocks for play (a staircase, slopes, a variety of small, medium, and large blocks, a triangle, a curved block, and a tunnel). Blocks were made of high-density foam and covered with vinyl slipcovers (foamnasium.com).

After eight minutes elapsed, the room was reconfigured into a standard playroom that all dyads experienced (see Figure 2 for a schematic). The standard playroom was designed to be a large play space that utilized all 16 blocks spread across three constructions that varied in location. The playroom also covered a broad area (11.15 m^2) to maximize opportunities for play. Infants and mothers played on their own in the *standard playroom* for another eight minutes (*M* play duration = 8.17 min, *SD* = 0.11). To prevent bias in how mothers constructed their playrooms (i.e., so that mothers were not influenced by the design of our standard playroom), we presented the two room conditions in the same order for all participants. That is, mothers were always asked to build and play in their playrooms first, followed by play in the standard playroom.

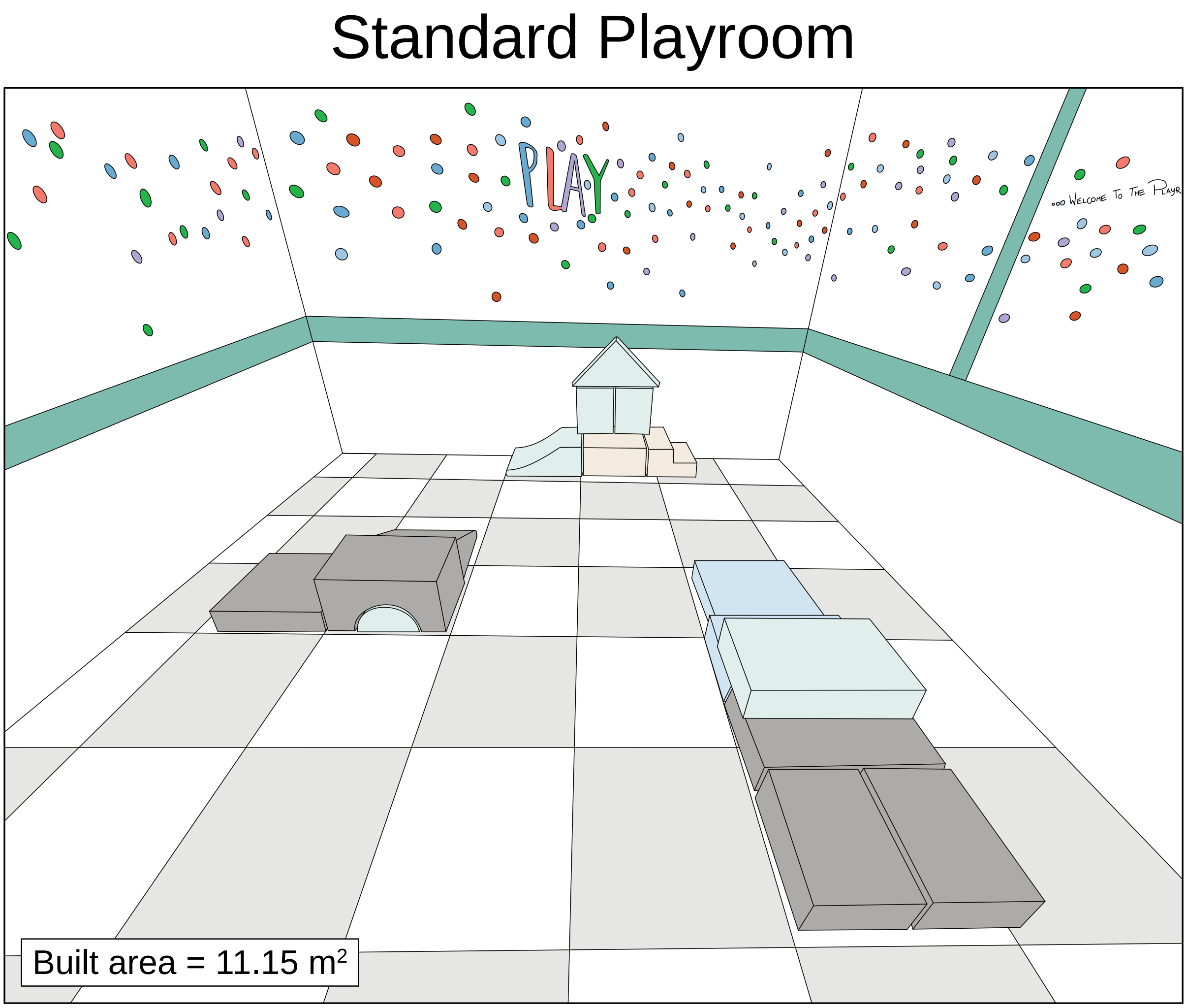

Figure 2. Schematic of the standard playroom. The drawing depicts the standard playroom that all infants and mothers experienced. The standard playroom used all 16 blocks, contained three unique block constructions, and covered a large area of the playroom (11.15 m^2).

Once the final play session was completed, the experimenter and research assistant re-entered the room. While the research assistant occupied infants with toys and snacks, mothers completed a series of questionnaires that collected demographic information, data on the ages at which infants acquired various locomotor skills (e.g., crawling, cruising, walking), and a catalog of the contents of infants' homes (see below for more detail). At the conclusion of the study, families received a choice from a variety of toys (e.g., books, puppets) to take home as a souvenir of their participation.

All study activities were videorecorded using two cameras affixed to tripods located in opposite corners of the playroom to ensure that the entire space was in view at all times. External microphones were mounted on each camera to improve audio quality. The two audio-video streams were synchronized for later behavioral coding of infant-mother play. Recording began after the consent process was completed.

2.3 Locomotor experience interview

Infants' locomotor skills were assessed using a structured interview in which mothers reported their infants' locomotor experience (e.g., Adolph et al., 2003). The experimenter interviewed mothers with a predetermined series of questions developed in previous work (e.g., Adolph, 1995). During the interview, mothers were asked to refer to calendars, baby books, and other media from cell phone records (e.g., pictures, videos, content from social media platforms) to aid their memories. Mothers were asked about five commonly acquired locomotor skills to develop a comprehensive account of infants' locomotor experience. Each skill, its onset criteria, and relevant citations from the literature can be found in Table 1.

Table 1. Locomotor skill onset criteria

Motor Skill	Onset Criteria
Walking	**3 m** without holding on to anything or anyone, without stopping or falling
Cruising	**1 m** while holding on to furniture, without stopping or falling
Crawling	**3 m** on hands and knees with belly off the floor, without stopping or falling
Belly crawling	**3 m** on with belly touching the floor, without stopping or falling
Bum shuffling	**3 m** scooting on bum, without stopping or falling

Note. Onset criteria were derived from previously used criteria reported in the literature. Walking (Adolph et al., 2003); cruising (Adolph et al., 2011); crawling and belly crawling (Adolph et al., 1998); and bum shuffling (Adolph & Berger, 2015).

2.4 Affordances in the home environment scale

The Affordances in the Home Environment for Motor Development-Infant Scale (AHEMD-IS; Caçola et al., 2015) was also administered. The AHEMD-IS is a parent report measure designed to assess affordances in the home environment conducive to motor development for infants aged 3-18 months. It primarily asks about the kinds of spaces that are available to infants at home (indoors and outdoors) and the contents of infants' everyday home environments (e.g., variety of fine- and gross-motor toys). The instrument has high inter- and intra-rater reliability, consistently high construct validity, predictive validity with other experimenter-administered measures, and has been used in research settings in at least 10 countries.

2.5 Data coding

To address our three aims, we employed video coding to capture the characteristics of mother-designed playrooms and identify all infant and mother behavior during play in each room condition (a total of 16 minutes of video per dyad). All coding was completed using Datavyu (datavyu.org) by a team of 13 coders (the first author, two staff researchers, and 10 undergraduate researchers). Coders were divided into three teams, each focusing on a primary construct of interest: (1) *room coders* scored playroom characteristics and room layout changes; (2) *infant coders* scored infant engagement with blocks, movement, travel, and proximity to mothers; and (3) *mother coders* identified mothers' language input, gesture input, posture, and physical actions. Table 2 displays each construct and the specific behaviors that were identified using this coding system.

Table 2. Primary constructs and accompanying behavior codes

Construct	Behavior codes
Room characteristics	# of blocks; # of constructions; area of built space (m^2); % blocks stacked; construction positioning
Room layout changes	# of room layout changes; # initiated by infants
Infant Movement	# of bouts; % time in motion; % time bum shuffling, crawling, supported upright, walking
Infant Travel	distance traveled (m)
Infant-mother proximity	% proximal, distal, transitions; % infant-initiated transitions
Infant blocks engagement	% time in physical contact with blocks
Mother language input	# infant-directed utterances; % whole-body motion verbs; % motion verbs with action specified
Mother gesture input	# gestures, % movement, conventional, pointing
Mother postures	% upright, down, transitions
Mother physical actions	# of repositions

All coders engaged in a rigorous training process prior to independent coding. For each team, coders were trained on a set of pilot videos in which they coded 100% of each video against the first author. After coders achieved reliability scores that met threshold (≥ 90% on all coding categories) on three consecutive videos, they were deemed reliable. Following this training period (approximately 6-8 weeks), all videos were coded by two coders: a primary coder who scored 100% of each infant's and mother's video data, and a reliability coder who scored 25% of each video to verify inter-observer reliability. All playroom characteristics were scored by a primary coder and independently checked by a reliability coder. Disagreements were discussed and resolved during weekly reliability meetings. Reliability statistics were calculated based on original codes and are reported as mean correlations, percent agreement, and Cohen's kappas across participants. Specific details about all coding procedures and copies of coding manuals can be found in Appendix A. All coding materials (e.g., video data and coding spreadsheets) are also shared with authorized researchers on Databrary (https://nyu.databrary.org/volume/1502).

2.5.1 Characteristics of mother-designed playrooms and room layout changes

2.5.1.1 Playroom characteristics

Room coders first scored the characteristics of each mother-designed playroom on five dimensions. These included counts of: (1) the total number of blocks that mothers used from the set (maximum of 16 blocks); and (2) the number of unique block constructions that mothers built in the room (i.e., a self-contained grouping of blocks with an empty one-square border around its perimeter). We also identified: (3) the area of the built space that the blocks occupied; (4) construction positioning (i.e., whether block constructions were touching a wall or free-floating in the room); and (5) the number of blocks used to create stacked constructions.

2.5.1.2 Room layout changes

Coders then identified how frequently mothers and infants changed the layout of the room during play (i.e., by moving a block to a different location). A layout change occurred when any of the blocks in the room were moved or repositioned (e.g., shifted, picked up and transported to another place, stacked, etc.). We required the block to be moved by at least one square floor tile to ensure that the change in layout was meaningful (i.e., to avoid coding small movements of blocks that did not actually change the layout of the room). Coders identified instances of layout changes as point events that corresponded to a single frame of video. The onset of point events were set to the first frame in which the block started to move. When a layout change occurred, coders also noted who made the change (mothers or infants). Inter-observer agreement was high for identifying onsets of layout changes (coders agreed within 1 s of one another on 96.4% of changes) and categorizing the initiator of layout changes (percent agreement = 95.0%; κ = .86).

2.5.2 Infant engagement with blocks, movement, travel, and proximity to mothers

2.5.2.1 Infant engagement with blocks

Infant coders first identified when infants were in physical contact with blocks to gauge infants' level of interest in the study materials. We coded engagement in *bouts*, or episodes during which infants were in continuous contact with any block in the playroom with any part of their body (e.g., hands, arms, legs, bum). A bout of blocks engagement began when any part of infants' bodies contacted a block, and the offset was marked at the first video frame when infants broke contact with a block for at least 3 s (e.g., Herzberg et al., 2022; Karasik et al., 2011). Instances in which infants transitioned from one block to another in quick succession (i.e., less than 3 s) were coded as a single episode of blocks engagement. In cases of multi-block episodes, contact with the first block denoted the onset and a break in contact with the last block signaled the offset. Fleeting block contacts (lasting < 1 s) were not identified. There was a high level of agreement between coders for identifying onsets and offsets of blocks engagement bouts (*r*s > .99, *p*s < .001).

2.5.2.2 Infant movement

Coders then identified all times when infants moved during play. We coded movement in *bouts*, or a series of steps separated by a pause in which the infant came to a complete stop for at least 0.5 s (e.g., Adolph et al., 2012; Schneider & Iverson, 2022). A step was defined as any movement of the feet, knees, or bum that resulted in omnidirectional displacement of infants' bodies through space. A bout of movement began when an infant's foot, knee, or bum moved across the floor and ended when the foot, knee, or bum came to rest at the end of the series (Adolph et al., 2012).

We identified all bouts of bum shuffling (scooting on the bum), crawling and climbing (moving on hands and knees or hands and feet), supported upright movement (cruising along a block in the room or supported walking with the mother), and independent walking. Crawling and climbing were coded for pre-walkers and walkers. Supported upright movement was coded for all upright locomotion that pre-walkers generated on the floor, but only identified for walking infants if they did so on an elevation (e.g., on top of a block) as we could reliably assume (from video alone) that infants required support when walking on top of a high place. All upright movement that walkers generated on the floor was coded as walking. Finally, coders also identified all instances of holding (i.e., when mothers held infants in their arms or restrained them in their laps) and falling (i.e., losses of balance). Inter-observer reliability was high for identifying onsets and offsets of movement bouts (*r*s > .99, *p*s < .001) and categorizing locomotion type (percent agreement = 99.4%; $\kappa = 0.99$).

2.5.2.3 Infant travel

In a subsequent pass, coders captured the breadth of infants' exploratory movements. Specifically, we coded infant travel by counting the number of square crossings during each bout of movement (see Clearfield, 2011 for a similar application). We used the tiled floor as anchors for determining whether infants crossed into a new square. Different criteria were used for determining crossings based on infants' locomotor posture. For example, while prone, we required the infant's torso to cross the line of one square and into another; and while upright, we required infants to traverse the entirety of the square (from edge to edge). Regardless of locomotor posture, infants had to move through the square for a crossing to count. That is, if infants were sitting in one square and reached out their arm into another, this did not count as a crossing. Similarly, if infants took walking steps in place and remained within the same square for the entire bout, this did not count as a crossing. Infants were credited with crossings regardless of their direction of heading (i.e., forward, backward, sideways, diagonally). Given that each square was exactly 0.61 m long x 0.61 m wide, we also calculated an approximation of overall distance traveled. There was a high level of agreement between coders for counts of square crossings ($r = .98$, $p < .001$).

2.5.2.4 Infant-mother proximity

Finally, coders also classified infants' level of proximity to their mothers during bouts of movement. We scored infant-mother proximity using three mutually exclusive categories (see Chen et al., 2023) to determine whether dyads: (1) remained *proximal* to one another (i.e., within arm's reach) throughout the entire bout, (2) remained *distal* (i.e., out of arm's reach) throughout the entire bout, or (3) engaged in *proximity transitions* (i.e., by switching between proximity states) during the bout. Mothers' wingspans were used to determine whether infants were proximal or distal. Specifically, if mothers could fully outstretch their arms and touch infants without needing to move or change positions, infants were considered proximal. Coders also noted which partner (mothers or infants) was responsible for proximity transitions when they occurred. Coders agreed on 93.4% of bouts when categorizing proximity (κ = .88) and 93.2% of bouts when identifying the initiator of proximity transitions (κ = .82).

2.5.3 Mother language, gestures, posture, and physical actions

2.5.3.1 Mother language

Mother coders first coded language input, which included the identification of all infant-directed utterances and subsequent categorization of utterances into types of language. An utterance was defined as a meaningful unit of speech separated by a prolonged pause, grammatical closure, or intake of breath (i.e., natural "breaks" during speech). Coders segmented mothers' speech into utterances by identifying each instance of speech as a point event (i.e., a single frame of video). The onset of point events was set as close as possible to the start of each utterance.

In a second pass, coders classified mothers' utterances by identifying whether each utterance contained a *whole-body motion verb* which either commented on or directed a whole-body action (e.g., go, get, climb, crawl, cross, stand, walk; Schneider & Iverson, 2022). Utterances containing motion verbs were further categorized as *specifying an action* by providing information about how to traverse an obstacle or engage with blocks in the playroom with a concrete noun, pronoun, or preposition (e.g., "Climb up the stairs!", "Are you going down the slide?", "Can you jump on that?"; West et al., 2022). Inter-observer reliability was high for identifying the onsets of utterances (coders agreed within 1 s of one another on 93.0% of utterances) and categorizing types of language (percent agreement = 95.9%-96.5%, κs = .86-.88).

2.5.3.2 Mother gestures

Next coders identified and categorized all gestures that mothers produced during play. Gestures were also coded as point events (i.e., a single frame of video), such that the onset of the point event was set as close to the start of each gesture as possible. Coders identified three gesture categories (see Schneider & Iverson, 2022). These included: (1) *movement gestures* which directly requested infant movement (e.g., when mothers beckoned to their infants with outstretched arms, hands, or fingers, pat the ground beside them, traced paths through space either toward themselves or away to specific blocks and locations, or hit the floor with their fists as if mimicking a trotting horse); (2) *pointing gestures* (i.e., when mothers pointed to specific blocks or locations in the room with an extended index finger); and (3) *conventional gestures* (i.e., culturally-specific hand motions that conveyed a common message, such as clapping to praise or shrugging the shoulders to suggest confusion). Inter-observer reliability was also high for identifying the onsets of gestures (coders agreed within 1 s of one another on 87.0% of gestures) and categorizing types of gestures (percent agreement = 92.0%-99.0%, κs = .69-.90).

2.5.3.3 Mother posture

We also classified mothers' posture during bouts of infant movement to examine how mothers positioned their bodies while infants explored the playroom. Specifically, we coded posture using three mutually exclusive categories (see Franchak et al., 2018) to determine if mothers were: (1) *upright* (e.g., standing, walking) during each bout of infant movement; (2) *down* (e.g., sitting, squatting, kneeling, crawling, lying down); or (3) *transitioning* between postures (e.g., sitting to standing). Coders agreed on 99.3% of bouts when categorizing mother posture (κ = .98).

2.5.3.4 Mother physical actions

Finally, coders identified the number of times that mothers repositioned their infants' bodies during play. A reposition was defined as any physical action initiated by mothers that changed infants' posture or position in space (e.g., Yamane et al., 2022). These actions included instances in which mothers picked up or shifted infants to place them in a new location, moved their limbs to help them navigate an obstacle, or restrained infants by pulling on clothing to shift them backward. Repositions were coded as point events (i.e., a single frame of video), and the onset of each point event was set to the first frame when mothers began to move their infants. Inter-observer agreement was high for identifying repositions (coders agreed within 1 s of one another on 94.0% of repositions).

3.0 Results

This study had three primary aims. First, we examined whether infants' locomotor status was related to infant and mother behavior during play in a standard space. Second, we assessed whether characteristics of mothers-designed play spaces differed for pre-walking and walking infants. And third, we examined whether infant and mother behavior during play in mother-designed playrooms varied by infants' locomotor status; and whether variation in the features of mother-built environments were associated with patterns of infant and mother behavior.

The two room conditions (standard playroom, mother-designed playrooms) allowed us to assess relations among infants' locomotor status as pre-walker or walker, the characteristics of space, and infant and mother behavior during play in different ways. In the standard playroom, we examined how infants' locomotor status related to infant and mother behavior during play in an identically organized space. And in the mother-designed playrooms, we examined how infants' locomotor status was related to the spaces mothers constructed and in turn, how variation in the characteristics of mothers' playrooms were associated with infant and mother behavior.

We first computed descriptive statistics (e.g., means, distributions, coefficients of variation) for all dependent variables and correlations among them. Then, we used t-tests and analysis of variance (ANOVA) to assess group differences in infant and mother behavior during play (e.g., infants' time in motion, levels of infant-mother proximity); and generalized estimating equations (GEEs) to assess relations among locomotor status, characteristics of mother-designed playrooms, and infant and mother behavior. All measures of infant and mother behavior were normally distributed (all *p*s > .05). Data were also assessed for the presence of outliers; removal of extreme values did not significantly change any results so all data were included to reflect the full range of values for each measure. All analyses were conducted in SPSS (version 29.0.1).

3.1 Preliminary analyses

Prior to conducting primary analyses, preliminary analyses were completed in order to: (1) examine group differences based on demographic characteristics; (2) characterize locomotor experience for each group; (3) examine group differences in AHEMD-IS scores; (4) test for potential effects of room order; (5) examine the time infants spent in contact with blocks to gauge their general interest in the materials we provided for play; and (6) test for group differences in play durations.

3.1.1 Demographic characteristics

There were no group differences based on infants' natal sex, birth order, caregiving arrangements, mothers' age and education level, or partner's age and education level, all ps > .05. There were also no relations between these characteristics and infant and mother behavior during play, all ps > .05.

3.1.2 Locomotor experience

All infants in this study were mobile. The pre-walking group primarily moved by crawling and climbing, cruising with support from blocks, and supported walking with help from their mothers. Of the 35 pre-walkers, mothers reported that 18 infants could belly crawl (*M* age belly crawl onset = 8.19 months, *SD* = 1.53), 29 could crawl on hands and knees (*M* age crawl onset = 9.16, *SD* = 1.23), and 31 could cruise (*M* age cruise onset = 10.45, *SD* = 1.16). Four infants could also bum shuffle (*M* age bum shuffle onset = 10.28, *SD* = 0.67), and one infant used log rolling as their primary method of locomotion (age log roll onset = 9.47 months).

The walking group primarily walked, but also crawled and climbed. On average, mothers reported that infants began to walk at 11.66 months (*SD* = 0.68), having had accumulated approximately 22 days of walking experience (*M* = 21.71 days, range = 0-66). Of the 17 walkers, eight could also belly crawl (*M* age belly crawl onset = 6.97 months, *SD* = 0.99) and 17 could crawl on hands and knees (*M* age crawl onset = 8.21, *SD* = 1.33). No walking infants bum shuffled or log rolled.

Onset ages were intercorrelated for both groups. For pre-walkers, younger belly crawlers were also younger hands-knees crawlers ($r = .596$, $p = .019$), and younger hands-knees crawlers were younger cruisers ($r = .758$, $p < .001$). For walkers, younger belly crawlers were also younger hands-knees crawlers ($r = .906$, $p < .001$), younger hands-knees crawlers were younger cruisers ($r = .646$, $p = .005$), and younger hands-knees crawlers were also younger walkers ($r = .536$, $p = .027$). In general, walking infants had acquired all motor skills at younger ages than pre-walkers, all ts ≤ 4.20, all ps $< .001$. Finally, infants' locomotor experience was not related to any of the main study variables (all ps $> .05$), so we did not include them as covariates in analyses.

3.1.3 AHEMD-IS

We next examined scores from the AHEMD-IS to test for group differences and assess the possibility of using this measure in subsequent analyses. There were no differences between pre-walkers and walkers on any scale of the AHEMD-IS (subscale scores or total scores; see Table 3), all *t*s $\leq$ 1.50, all *p*s $\geq$ .070. Thus, we did not include this measure in further analyses.

Table 3. Descriptive statistics: Affordances in the Home Environment for Motor Development Scale

	Pre-Walkers (*n* = 35)			Walkers (*n* = 17)		
Measure	*M*	*SD*	*range*	*M*	*SD*	*range*
Physical space	6.03	1.67	2.00-7.00	6.24	1.52	2.00-7.00
Variety of stimulation	13.06	2.09	7.00-17.00	13.47	1.55	10.00-16.00
Gross motor toys	10.29	2.32	4.00-14.00	9.35	1.54	7.00-13.00
Fine motor toys	14.89	3.18	7.00-20.00	14.59	2.79	10.00-20.00
Total affordances	44.26	6.59	20.00-53.00	43.65	4.74	35.00-51.00

3.1.4 Room order effects

Because play in mother-designed playrooms always preceded play in the standard playroom, we tested for possible order effects on our key variables. There were no significant differences in any infant or mother behavior between the two room conditions with one exception: there were fewer room layout changes during play in the standard playroom compared to the mother-designed playrooms for pre-walkers and walkers (*M* standard playroom = 6.85, *SD* = 10.79; *M* mother-designed playrooms = 19.81, *SD* = 14.72; *t*s $\leq$ 4.13, *p*s $\leq$ .002). We attribute this difference to mothers' interpretation that they should endeavor to keep the layout of the standard playroom based on its original design (even though we asked them to play however they wished). All other measures showed no differences between the two room conditions (all *t*s $\leq$ 1.71, all *p*s $\geq$ .078), suggesting that infants and mothers did not tire or play differently due to the order in which the contexts were presented.

3.1.5 Infant engagement with blocks

Finally, to assess infants' interest in the blocks we provided, we examined the amount of time that infants spent in contact with blocks during play. We calculated percentages to reflect the time that infants were in physical contact with blocks out of the total observation time of each play session. Overall, all infants were similarly engaged with blocks. As shown in Figure 3A-B, infants spent approximately half of their play time in contact with blocks in the standard playroom (*M* pre-walkers = 49%, *SD* = 20; *M* walkers = 51%, *SD* = 12) and the mother-designed playrooms (*M* pre-walkers = 58%, *SD* = 17; *M* walkers = 56%, *SD* = 24). This did not differ by infants' locomotor status in either room condition, all *t*s ≤ -.297, *p*s ≥ .334. Thus, infants were generally interested in the blocks and interacted with them regularly.

3.1.6 Play durations

There were no differences in play durations between pre-walkers and walkers in either room condition or between the two room conditions, all *p*s > .05. We conducted all analyses while accounting for play durations, but there were no significant differences when compared to analyses that did not include this control, all *p*s > .05. Thus, all data are presented as raw frequencies without controlling for small variations in observation time.

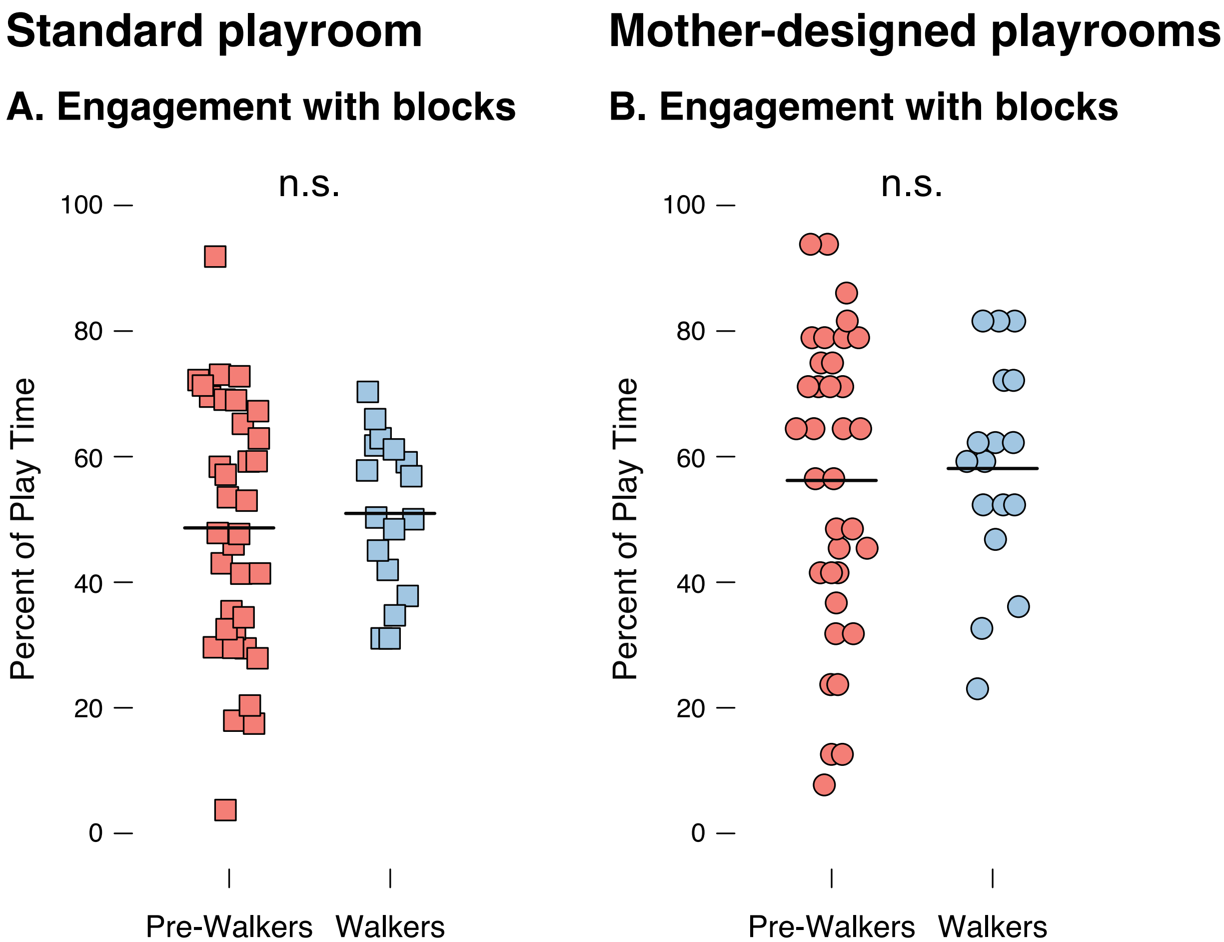

Figure 3A-B. Infant engagement with blocks in standard and mother-designed playrooms. Data show percentages of time that infants were in physical contact with blocks during play. Symbols represent data from individual infants and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom; circles = mother-designed playrooms) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

n.s. = not significant

3.2 Primary analyses

We present data for each of our three aims in turn. We begin by describing results from the standard playroom to provide an overview of pre-walking and walking infants' (and their mothers') play behaviors while interacting in an identically organized environment. Next, we present data on the characteristics of mother-designed playrooms to evaluate group differences in how mothers created spaces for play. Finally, we examine infant and mother behavior during play in mother-designed playrooms in which the structure of the environment varied freely. We also assessed relations between characteristics of mothers' playrooms and infant and mother behavior to understand whether differences in opportunities for play afforded by different spaces shaped subsequent interactions.

3.2.1 Aim 1: Examine infant and mother behavior in a standard playroom

Our first aim was to examine infant and mother behavior during play in an identically organized, standard playroom. This room condition allowed us to assess the extent to which infants' locomotor status (as pre-walker or walker) shaped how infants and mothers played together while controlling for the characteristics of the environment. Descriptive statistics for infant and mother behavior during play in the standard room are presented in Table 4.

Table 4. Descriptive statistics: Infant and mother behavior during play in the standard playroom

	Pre-Walkers (*n* = 35)			Walkers (*n* = 17)		
Measure	*M*	*SD*	*range*	*M*	*SD*	*range*
Room layout changes						
Number of layout changes	5.97	10.93	0.00-55.00	8.65	10.59	0.00-39.00
Number of infant changes	2.60	5.33	0.00-27.00	4.94	5.61	0.00-19.00
Infant locomotor exploration						
Number of bouts	29.57	13.32	4.00-53.00	41.00	7.75	27.00-57.00
Percent time in motion (%)	31.75	14.90	1.15-55.72	47.69	10.10	27.43-67.03
Percent time bum shuffling (%)	3.50	11.79	0.00-57.00	0.00	0.00	0.00-0.00
Percent time crawling (%)	66.70	31.73	0.00-100.00	39.62	23.40	9.68-85.93
Percent time supported upright (%)	29.79	26.37	0.00-100.00	0.00	0.00	0.00-0.00
Percent time walking (%)	0.00	0.00	0.00-0.00	60.38	24.27	11.87-86.34
Number of falls	6.34	5.01	0.00-20.00	9.71	6.64	0.00-25.00
Infant travel						
Distance traveled (m)	8.59	6.58	0.00-25.30	18.16	9.04	7.01-35.66
Infant-mother proximity						
Percent proximal (%)	69.22	19.53	20.83-100.00	57.60	13.41	31.25-87.88
Percent distal (%)	12.34	11.20	0.00-41.51	15.74	9.59	0.00-38.64
Percent transitions (%)	18.44	13.02	0.00-54.17	26.66	8.23	12.12-40.91
Percent infant-led transitions (%)	67.12	36.50	0.00-100.00	84.10	11.44	60.00-100.00
Infant engagement with blocks						
Percent engagement with blocks (%)	48.64	20.25	3.71-91.84	50.95	12.41	31.04-70.30
Mother language input						
Number of utterances	138.40	51.49	22.00-271.00	122.88	33.66	64.00-195.00
Percent whole-body motion verbs (%)	19.12	8.42	4.55-45.16	21.72	9.40	4.10-46.88

Table 4. Descriptive statistics: Infant and mother behavior during play in the standard playroom (continued)

Percent action specified (%)	62.08	19.81	0.00-88.89	61.35	19.25	15.38-91.30
Rate of moving utterances	23.83	11.92	12.54-73.15	18.75	4.23	10.26-26.27
Rate of moving whole-body motion verbs (%)	3.58	2.58	0.00-9.14	3.14	1.61	0.53-6.28
Rate of moving action specified (%)	2.10	1.97	0.00-9.14	2.23	1.29	0.31-4.55
Rate of stationary utterances	18.87	9.79	2.47-45.07	14.82	7.22	3.41-30.21
Rate of stationary whole-body motion verbs (%)	3.73	1.93	0.15-9.68	3.69	1.92	1.18-9.05
Rate of stationary action specified (%)	2.41	1.34	0.00-5.66	2.15	1.08	0.21-3.90
Mother gesture input						
Number of gestures	16.89	9.30	5.00-39.00	19.59	9.10	7.00-35.00
Percent movement (%)	43.94	22.20	0.00-83.33	48.51	25.97	7.69-82.86
Percent conventional (%)	33.21	23.45	0.00-100.00	35.75	25.38	0.00-92.31
Percent pointing (%)	22.85	17.35	0.00-60.00	15.75	11.43	0.00-41.67
Rate of moving gestures	1.51	1.41	0.00-6.04	2.28	1.11	0.53-4.26
Rate of moving movement gestures	0.90	1.09	0.00-6.04	1.28	1.00	0.00-3.72
Rate of stationary gestures	2.79	1.65	0.72-6.59	3.02	1.61	0.78-5.77
Rate of stationary movement gestures	1.16	1.02	0.00-4.71	1.31	1.21	0.24-4.18
Mother posture						
Percent upright (%)	8.49	13.80	0.00-53.33	15.00	19.22	0.00-64.52
Percent down (%)	90.05	14.72	42.22-100.00	80.71	20.98	29.03-100.00
Percent posture transitions (%)	1.46	2.06	0.00-5.71	4.29	3.93	0.00-14.29
Mother physical actions						
Number of repositions	10.60	7.07	2.00-27.00	9.35	7.71	1.00-25.00

3.2.1.1 Infant room layout changes, movement, travel, and proximity to mothers

3.2.1.1.1 Pre-walkers and walkers produced similar numbers of layout changes

We first examined the number of times that infants and mothers rearranged the room during play by changing its layout (e.g., by moving or repositioning a block). These data are presented in Figure 4A-B. In the standard playroom, there were no group differences in the total number of layout changes (*M* pre-walkers = 5.97, *SD* = 10.93; *M* walkers = 8.65, *SD* = 10.59; $t(50) = -.836$, $p = .204$, $d = .247$). And there were also no differences in the number of layout changes initiated by infants (*M* pre-walkers = 2.60, *SD* = 5.33; *M* walkers = 4.94, *SD* = 5.61; $t(50) = -1.46$, $p = .075$, $d = .432$).

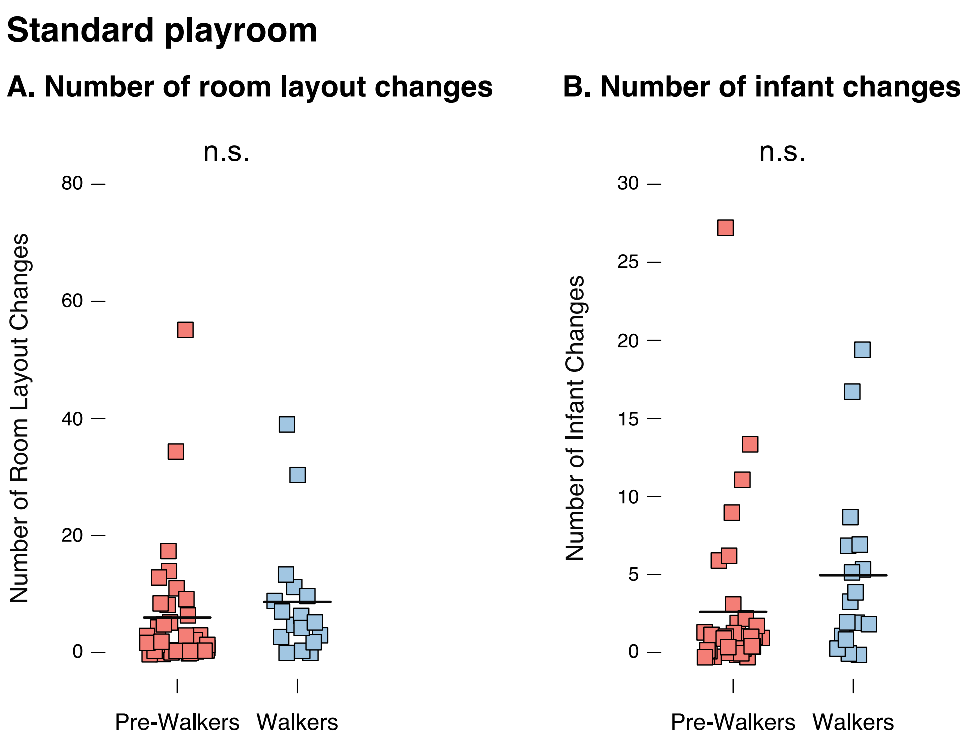

Figure 4A-B. Room layout changes in the standard playroom. Data show: (A) the total number of layout changes and (B) the number of layout changes initiated by infants. Symbols represent data from individuals

and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom; circles = mother-designed playrooms) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

n.s. = not significant

3.2.1.1.2 Walkers moved more than pre-walkers

We examined group differences in how and how much infants moved during play. To do so, we calculated the time that infants were free to move by subtracting the time that infants were held by their mothers from the total observation time of each play session. On average, pre-walkers were free to move independently for 91% of their observation time (*SD* = 11) and walkers for 93% of their observation time (*SD* = 10). We indexed infant movement using two measures: (1) the number of bouts infants produced (i.e., episodes of locomotion); and (2) how much time infants spent in motion (i.e., total locomotion time out of the time that infants were free to move). These data are shown in Figure 5A-C.

In the standard playroom, walkers initiated more bouts of movement than pre-walkers (*M* bouts walkers = 41.00, *SD* = 7.75; *M* bouts pre-walkers = 29.57, *SD* = 13.32; $t(50) = -3.26$, $p < .001$, $d = .966$). Walkers also spent more time in motion compared to pre-walkers (*M* time walkers = 48%, *SD* = 10; *M* time pre-walkers = 32%, *SD* = 15; $t(50) = -3.98$, $p < .001$, $d = 1.18$). Pre-walkers spent most of their moving time crawling and climbing (*M* = 67%, *SD* = 32), followed by cruising and supported walking (*M* = 30%, *SD* = 26), and bum shuffling (*M* = 3%, *SD* = 12), in that order. Walkers split their time between walking (*M* = 60%, *SD* = 24) and crawling and climbing (*M* = 40%, *SD* = 23). Walkers fell more often than pre-walkers (*M* walker falls = 9.71, *SD* = 6.64; *M* pre-walker falls = 6.34, *SD* = 5.01; $t(50) = -2.04$, $p = .024$, $d = .602$.

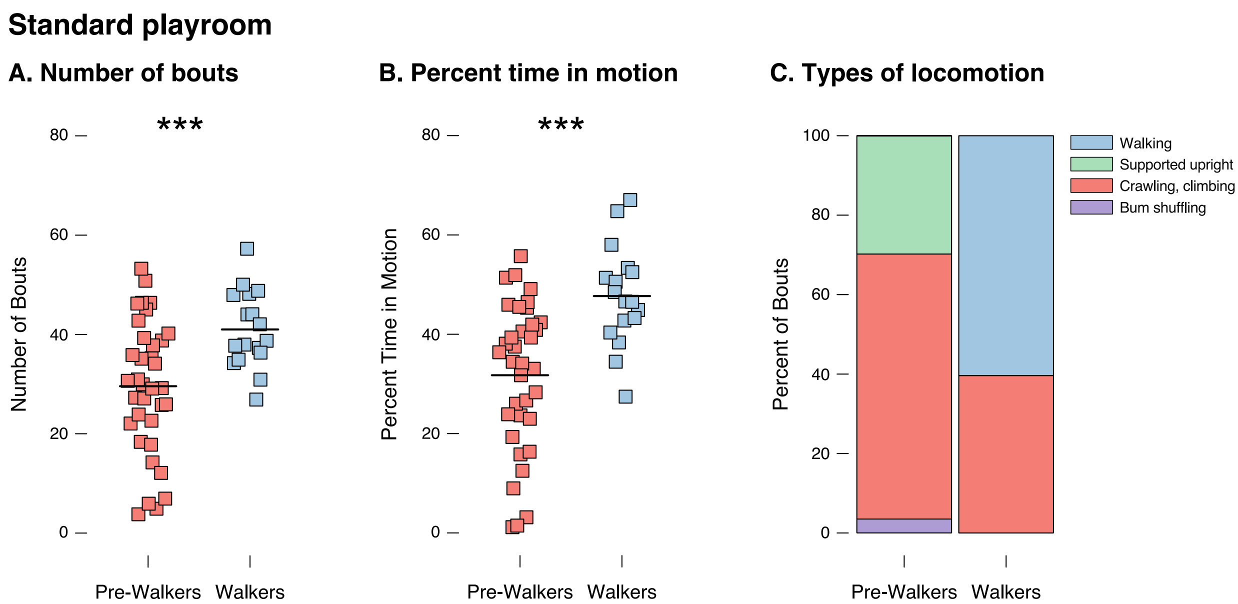

Figure 5A-C. Infant movement in the standard playroom. Data show: (A) the total number of bouts infants initiated during play, (B) the percent of observation time (when not held by mothers) that infants spent in motion, and (C) the distribution of movement time by type of locomotion (bum shuffling in purple; crawling/climbing in red; cruising/supported walking in green; walking in blue). Symbols represent data from individual infants and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom; circles = mother-designed playrooms) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

*****p < .001**

3.2.1.1.3 Walkers traveled more than pre-walkers

We next assessed group differences in infant travel during play. We calculated the total number of square crossings and expressed this value in meters (by multiplying the number of crossings by the dimensions of each floor tile). As shown in Figure 6A, walkers traveled twice as far as pre-walkers while exploring the standard playroom (*M* distance walkers = 18.16 m, *SD* =

9.04; *M* distance pre-walkers = 8.59 m, *SD* = 6.58; $t(50) = -4.32$, $p < .001$, $d = 1.28$). And naturally, infants who moved more also traveled more, $r = .688$, $p = .002$.

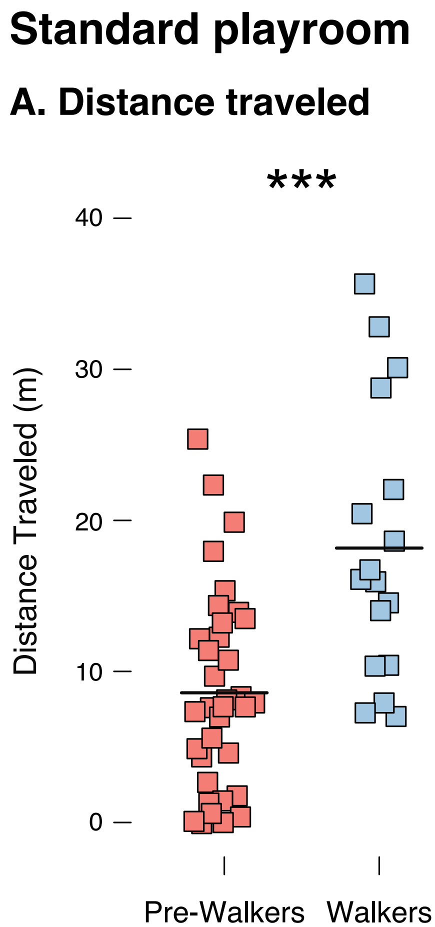

Figure 6A. Infant travel in the standard playroom. Data show the total distance (in meters) infants traveled during eight minutes of play. Distance was derived from counts of square crossings. Symbols represent data from individual infants and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

********p*** < .001**

3.2.1.1.4 Infants and mothers were generally close to one another during play

We examined interpersonal distance between infants and mothers while infants were moving by calculating percentages to reflect the number of movement bouts in which infants were proximal to their mothers (within arm's reach), distal to their mothers (out of arm's reach), or engaged in proximity transitions (e.g., approaching their mothers and then leaving). These data are presented in Figure 7A-B.

In the standard playroom, there were group differences in the percentages of infants' bouts spent proximal to mothers. Compared to pre-walkers, a smaller percentage of walkers' locomotor bouts occurred near their mothers (*M* walkers proximal = 58%, *SD* = 13; *M* pre-walkers proximal = 69%, *SD* = 20). Instead, walkers experienced more proximity transitions (i.e., a back-and-forth pattern of exploration by going toward their mothers and then away) during play relative to pre-walkers (*M* walkers transitions = 27%, *SD* = 8; *M* pre-walkers transitions = 18%, *SD* = 13). A 2 (Proximity State: proximal, transitions) x 2 (Locomotor Status) repeated measures ANOVA confirmed these patterns with a significant main effect of Proximity State, $F(1,50) = 96.35$, $p < .001$, $\eta^2 = .658$, and a significant Proximity State x Locomotor Status interaction, $F(1,50) = 5.68$, $p = .021$, $\eta^2 = .102$.

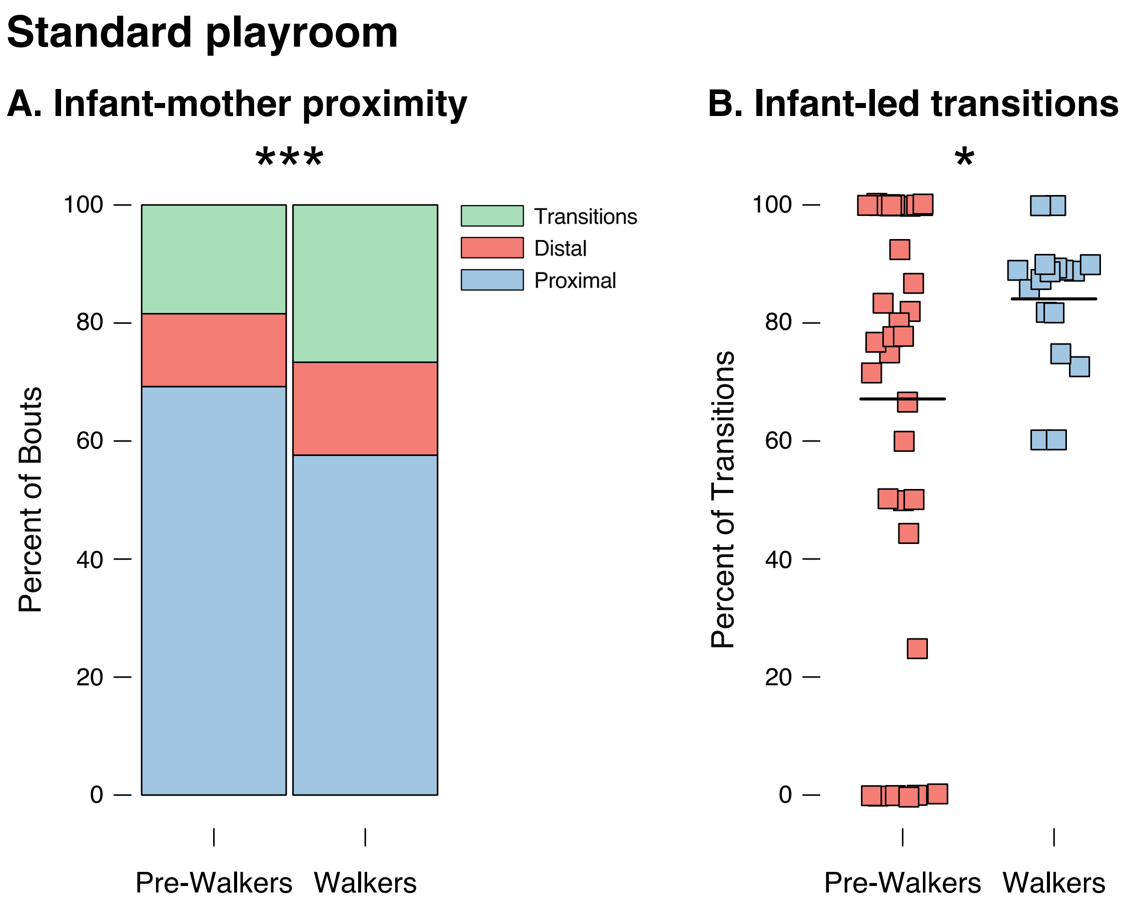

Figure 7A-B. Infant-mother proximity in the standard playroom. Data show: (A) the distribution of movement bouts spent proximal (blue), distal (red), or in proximity transitions (green) with mothers; and (B) the percent of proximity transitions led by infants. Symbols represent data from individual infants and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers). ****p* **< .05; ******p* **< .001

3.2.1.1.5 Walkers were more likely to lead changes in proximity than pre-walkers

We next analyzed the extent to which infants were responsible for initiating transitions in proximity during play. In the standard playroom, infants were responsible for the vast majority of proximity transitions (M = 73%, SD = 32). Moreover, there was an effect of locomotor status on infants' propensity to use locomotion to increase and decrease distance from their mothers.

Specifically, walkers were more likely than pre-walkers to lead proximity transitions when they occurred (*M* walkers = 84%, *SD* = 11; *M* pre-walkers = 67%, *SD* = 36; *t*(50) = -1.87, *p* = .034, *d* = .551).

3.2.1.2 Mother language, gestures, posture, and physical actions

3.2.1.2.1 Mothers' overall language input was similar for pre-walkers and walkers

We first examined the total amount of language that mothers produced during play and whether this differed by infants' locomotor status. As shown in Figure 8A-C, in the standard playroom, there were no group differences in the total number of utterances mothers directed to infants (*M* pre-walkers = 138.40, *SD* = 51.49; *M* walkers = 122.88, *SD* = 33.66; *t*(50) = 1.13, *p* = .132, *d* = .333). Moreover, there were also no group differences in the percent of utterances containing whole-body motion verbs (*M* pre-walkers = 19%, *SD* = 8; *M* walkers = 22%, *SD* = 9; *t*(50) = -1.01, *p* = .160, *d* = .297) or the percent of motion verb utterances that specified a particular action (*M* pre-walkers = 62%, *SD* = 20; *M* walkers = 61%, *SD* = 19; *t*(50) = .126, *p* = .450, *d* = .037).

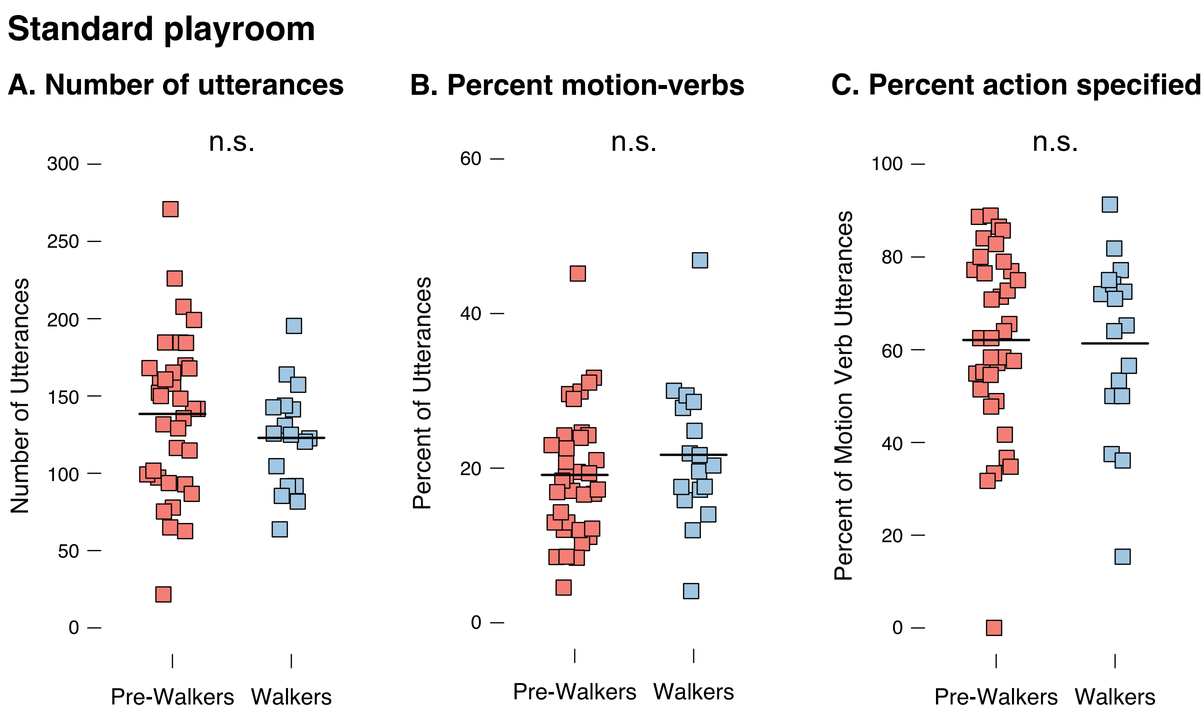

Figure 8 A-C. Mother language input in the standard playroom. Data show: (A) the total number of utterances, (B) the percent of utterances containing whole-body motion verbs (e.g., go, get, crawl, walk), and (C) the percent of motion verb utterances that specified a particular action (e.g., "Can you walk across?"). Symbols represent data from individual infants and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

n.s. = not significant

3.2.1.2.2 Mothers produced more language when infants moved

We next examined how mothers' language input was shaped by infant movement (given group differences in the time that pre-walkers and walkers spent in motion). We calculated a new set of variables to reflect the rate of total utterances, utterances containing a motion verb, and utterances that specified an action out of the total time that infants were in motion.

In the standard playroom, there were no group differences in total utterances per minute in motion (*M* pre-walkers = 23.83, *SD* = 11.92; *M* walkers = 18.75, *SD* = 4.23; $t(50) = 1.70$, $p = .096$, *d* = .502), motion verb utterances per minute in motion (*M* pre-walkers = 3.58, *SD* = 2.58; *M* walkers = 3.14, *SD* = 1.61; *t*(50) = .640, *p* = .263, *d* = .189), or specified action utterances per minute in motion (*M* pre-walkers = 2.10, *SD* = 1.97; *M* walkers = 2.23, *SD* = 1.29; *t*(50) = -.260, *p* = .398, *d* = .077).

Given that there were no apparent locomotor status differences in mothers' language input while infants moved, we asked whether movement itself organized language. To do so, we compared rates of mother talk while infants were moving vs. stationary (e.g., total utterances per minute in motion vs. total utterances per minute stationary). In the standard playroom, mothers produced more utterances while infants moved than they did while infants were stationary (*M* rate moving utterances = 22.17, *SD* = 10.30; *M* rate stationary utterances = 17.55, *SD* = 9.16; *F*(1,50) = 6.46, *p* = .014, η^2 = .114). However, this was not the case when we compared rates of moving vs. stationary motion verb utterances and action specified utterances. Mothers produced similar amounts of each language type, regardless of whether infants were moving or not, all *p*s ≥ .391 (see Table 4).

3.2.1.2.3 Mothers' overall gesture input was similar for pre-walkers and walkers

We next assessed the total amount of gesture input that mothers produced during play and whether this differed based on infants' locomotor status. As shown in Figure 9A-B, in the standard playroom, there were no group differences in the total number of gestures that mothers directed to their infants (*M* pre-walkers = 16.89, *SD* = 9.30; *M* walkers = 19.59, *SD* = 9.10; *t*(50) = -.990, *p* = .164, *d* = .293). Moreover, there were also no differences in the distribution of gesture types between pre-walkers and walkers. That is, mothers produced similar percentages of movement gestures (*M* pre-walkers = 42%, *SD* = 22; *M* walkers = 49%, *SD* = 26; *t*(50) = -.658, *p* = .257, *d* = .195), conventional gestures (*M* pre-walkers = 33%, *SD* = 22; *M* walkers = 36%, *SD* = 25; *t*(50) =

-.357, *p* = .361, *d* = .106) and pointing gestures (*M* pre-walkers = 23%, *SD* = 17; *M* walkers = 16%, *SD* = 11; *t*(50) = 1.53, *p* = .066, *d* = .453) to infants during play.

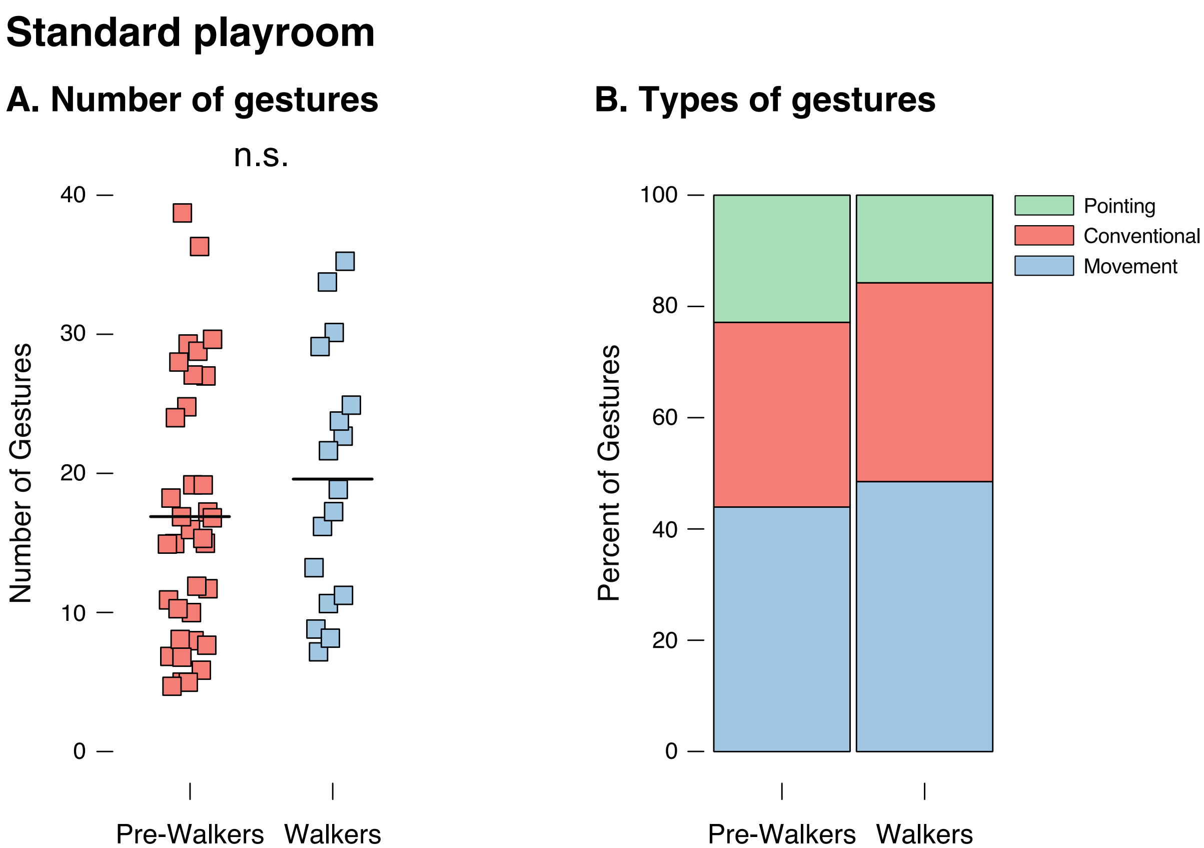

Figure 9A-B. Mother gesture input in the standard playroom. Data show: (A) the total number of gestures mothers produced and (B) the distribution of gestures by type (movement in blue; conventional in red; pointing in green). Symbols represent data from individual infants and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

n.s. = not significant

3.2.1.2.4 Mothers produced more gestures when walkers moved

We also asked whether mothers' gesture input was shaped by infant movement. We calculated new variables to reflect the rate of total gestures and movement gestures (given that the communicative intent of this gesture category best matched verb-based language) out of the total time that infants spent in motion.

There was an effect of infants' locomotor status on mothers' total gesture rate. Specifically, in the standard playroom, mothers of walkers produced more gestures while infants moved compared to mothers of pre-walkers (*M* walkers = 2.28, *SD* = 1.11; *M* pre-walkers = 1.51, *SD* = 1.41; $t(50) = -1.97$, $p = .027$, $d = .584$). However, this was not the case for rates of movement gestures (*M* walkers = 1.28, *SD* = 1.00; *M* pre-walkers = 0.90, *SD* = 1.09; $t(50) = -1.21$, $p = .115$, $d = .359$).

3.2.1.2.5 Mothers were generally down when infants moved

Next we examined how mothers organized their body positions while infants were in motion. We calculated percentages to reflect when mothers were upright (e.g., standing, walking), down (e.g., sitting, squatting, crawling), or transitioning between postures (e.g., from sitting to standing) out of the total number of infants' movement bouts.

As shown in Figure 10A, in the standard playroom, mothers spent the vast majority of infants' bouts down on the floor (*M* = 87%, *SD* = 17), followed by upright (*M* = 11%, *SD* = 16) and posture transitions (*M* = 2%, *SD* = 3), in that order. However, there were differences based on infants' locomotor status. Specifically, mothers of walkers spent a smaller percentage of bouts down on the floor compared to mothers of pre-walkers (*M* down walkers = 81%, *SD* = 21; *M* down pre-walkers = 90%, *SD* = 15). Instead, mothers of walkers engaged in a larger percentage of posture transitions (e.g., getting up and down, following their infants; *M* transitions walkers = 4%, *SD* = 4; *M* transitions pre-walkers = 1%, *SD* = 2). A 2 (Posture Type: down, transitions) x 2 (Locomotor Status) repeated measures ANOVA confirmed these patterns with significant main effects of Posture Type, $F(1,50) = 905.45$, $p < .001$, $\eta^2 = .948$, and Locomotor Status, $F(1,50) =$

1439.203, $p < .001$, $\eta^2 = .966$, and a significant Posture Type x Locomotor Status interaction, $F(1,50) = 4.92$, $p = .031$, $\eta^2 = .090$.

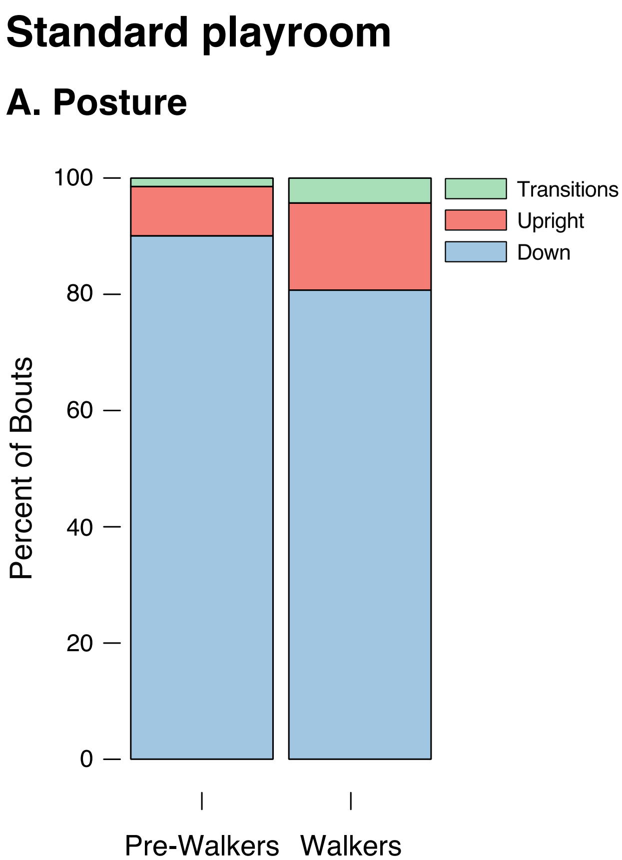

Figure 10A. Mother posture in the standard playroom. Data show the distribution of mothers' postures during play. Mother could be down on the floor (e.g., sitting, squatting, crawling; in blue), upright (e.g., standing walking; in red), or transitioning between postures (e.g., getting up or down; in green).

3.2.1.2.6 Mothers often repositioned pre-walkers and walkers

Finally, we assessed mothers' physical actions during play. Specifically, we identified all times when mothers repositioned their infants' bodies by picking them up, transporting them to a new place, or moving their limbs to help infants traverse an obstacle in the playroom. As shown in Figure 11A, mothers frequently repositioned their pre-walking and walking infants during play in the standard playroom (*M* pre-walkers = 10.60, *SD* = 7.07; *M* walkers = 9.35, *SD* = 7.71); and there were no group differences, $t(50) = .579$, $p = .283$, $d = .171$.

We further examined whether mothers' repositions were related to infant movement. Specifically, we asked whether differences in the time that infants spent moving shaped how often their mothers repositioned them. There was a significant negative relation between infants' time in motion and the frequency with which mothers repositioned infants, but only for pre-walkers, $r = -.586$, $p = .011$. Thus, pre-walkers who spent more time in motion were less likely to be repositioned by their mothers.

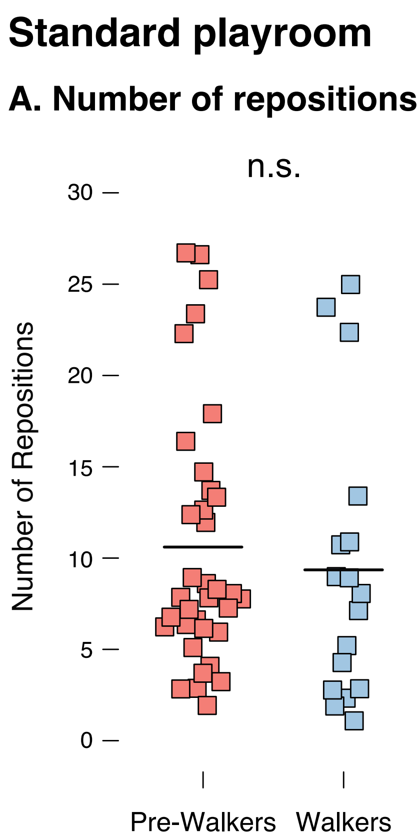

Figure 11A. Mother physical actions in the standard playroom. Data show the total number of times that mothers repositioned infants during play. Symbols represent data from individual infants and horizontal

lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers). n.s. = not significant

3.2.2 Aim 2: Examine characteristics of mother-designed playrooms

3.2.2.1 Mothers built different play spaces for pre-walkers and walkers

Our second aim was to examine how mothers created a new play environment for their infants and if their design choices differed for pre-walkers and walkers. Table 5 presents descriptive statistics for all playroom characteristics; and Figure 12 displays individual differences and group averages. Figure 13 illustrates representative playrooms from mothers in each locomotor group. The drawings show examples of small, average, and large playrooms for pre-walkers (top panel with red banners) and walkers (bottom panel with blue banners).

As shown in the table and both sets of figures, there were no group differences in the number of blocks mothers used from the set. Of the 16 blocks available, mothers of pre-walkers averaged 14.03 blocks (*SD* = 2.51) and mothers of walkers 12.88 blocks (*SD* = 2.45) to build their spaces, $t(50) = 1.56$, $p = .063$, $d = .46$. However, there were differences in the number of constructions (i.e., individual block groupings with an empty one-square border around their perimeter) that mothers built based on their infants' locomotor status. Mothers of pre-walkers created twice as many constructions (*M* = 3.37, *SD* = 1.69) as mothers of walkers (*M* = 1.41, *SD* = 0.62; $t(50) = 4.64$, $p < .001$, $d = 1.37$). Moreover, the built area (i.e., the area occupied by blocks) of pre-walkers' playrooms was nearly twice the size of walkers' playrooms (*M* pre-walker area = 8.61 m^2, *SD* = 3.70; *M* walker area = 4.98 m^2, *SD* = 1.73; $t(50) = 3.83$, $p < .001$, $d = 1.13$).

There were no group differences in the percentages of blocks mothers used in stacked constructions (*M* pre-walker stacked = 43%, *SD* = 22; *M* walker stacked = 45%, *SD* = 22; $t(50) = -.393$, $p = .348$, $d = -.12$). Finally, although more mothers of pre-walkers placed constructions against a wall compared to mothers of walkers (14/35 pre-walkers vs. 3/17 walkers), this difference did not reach significance, $p = .095$.

We used built area as our primary measure of playroom design for all analyses examining associations between the characteristics of mothers' spaces and patterns of infant and mother behavior in Aim 3 below. Area was chosen for two reasons. First, area represented an intuitive measure of space, capturing the overall size of the spaces mothers created (i.e., how expansive vs. how small spaces were). And second, area was a continuous measure with sufficient variability from which to examine relations with measures of infant and mother behavior. Results were similar when we conducted a set of analyses that used the number of block constructions as the primary measure of space (all *p*s < .05).

Table 5. Descriptive statistics: Characteristics of mother-designed playrooms

	Pre-Walkers (n = 35)				Walkers (n = 17)			
Measure	*M*	*SD*	*range*	*CV*	*M*	*SD*	*range*	*CV*
Number of blocks	14.03	2.51	9.00-16.00	0.18	12.88	2.45	8.00-16.00	0.19
Number of constructions	3.37	1.68	1.00-7.00	0.50	1.41	0.62	1.00-3.00	0.44
Built area (m^2)	8.61	3.70	2.23-18.12	.43	4.98	1.73	1.11-8.92	0.35
Percent stacked	42.90	21.68	0.00-87.50	0.51	45.42	21.81	0.00-75.00	0.48
Construction positioning (%)	40.00	50.00	0.00-100.00	1.25	17.65	39.30	0.00-100.00	2.23

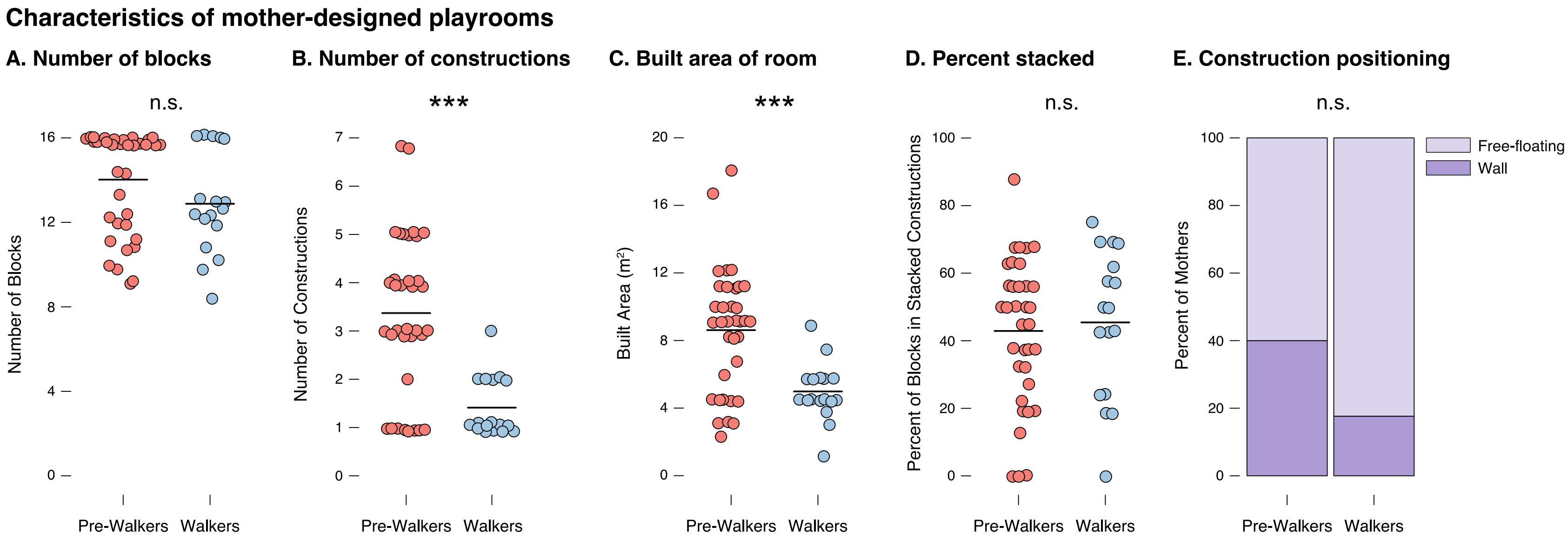

Figure 12. Characteristics of mother-designed playrooms. Data show: (A) number of blocks used, (B) number of block constructions, (C) built area, (D) percent of blocks in stacked constructions, and (E) construction positioning. Symbols represent data from individual mothers and horizontal lines describe group averages. Infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

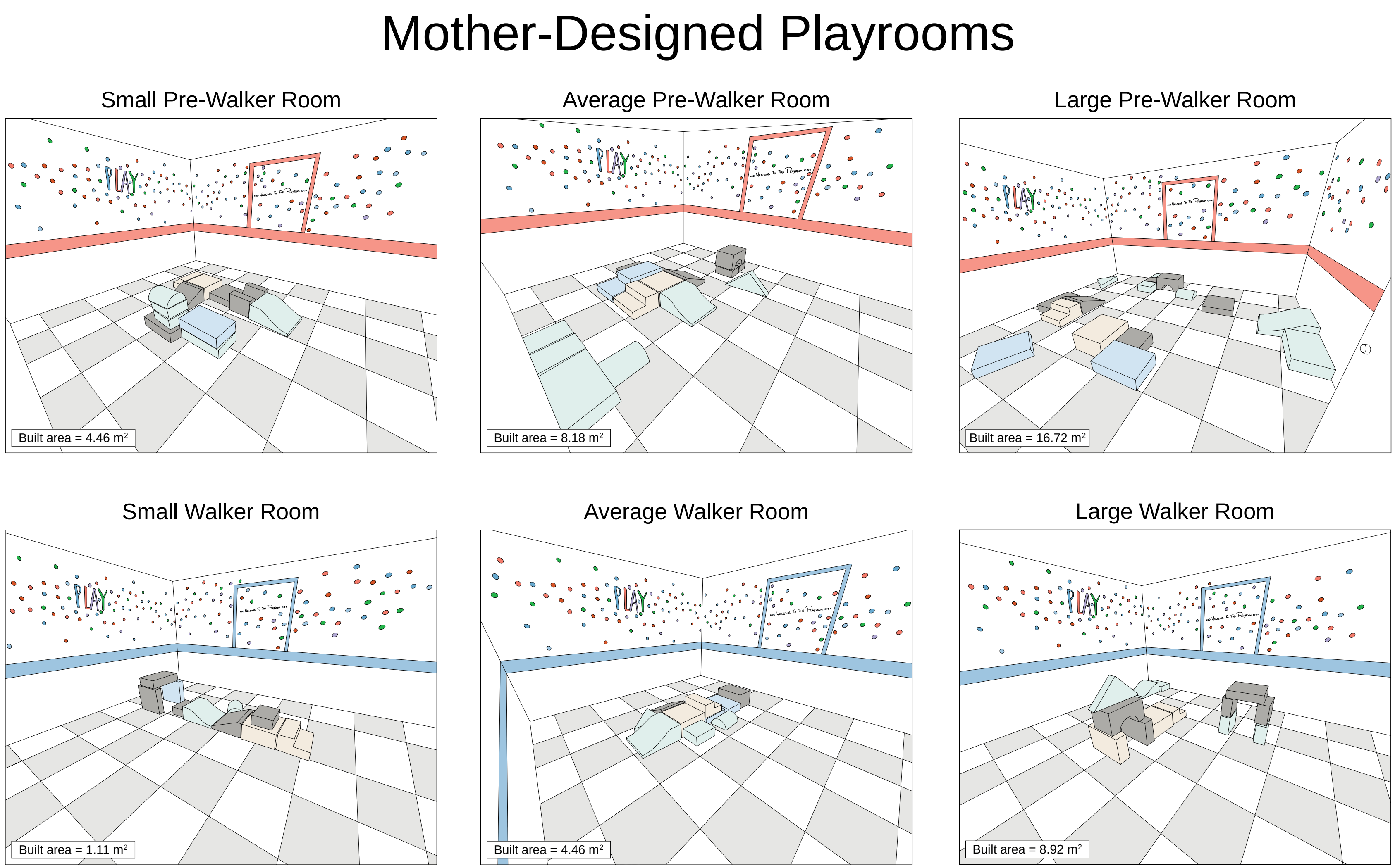

Figure 13. Representative playrooms from each locomotor group. Drawings depict examples of small, average, and large playrooms that mothers built for their pre-walking (top panel, red banners) and walking (bottom panel, blue banners) infants.

3.2.3 Aim 3: Examine infant and mother behavior in mother-designed playrooms

The final aim of this study was to examine infant and mother behavior during play in mother-designed playrooms. This room condition allowed us to assess relations among infants' locomotor status and infant and mother behavior during play *and* examine whether patterns of behavior were associated with the characteristics of mothers' spaces (indexed by built area). We conducted an identical set of analyses as presented above for the standard playroom. Descriptive statistics for infant and mother behavior during play in mother-designed playrooms are displayed in Table 6.

3.2.3.1 Infant room layout changes, movement, travel, and proximity to mothers

3.2.3.1.1 Pre-walkers and walkers produced similar numbers of layout changes

There were no locomotor status differences in the total number of room layout changes (*M* pre-walkers = 19.83, *SD* = 16.56; *M* walkers = 19.76, *SD* = 10.40; $t(50) = .015$, $p = .494$, $d = .004$) or the number of infant-initiated changes (*M* pre-walkers = 4.86, *SD* = 4.91; *M* walkers = 7.47, *SD* = 7.33; $t(50) = -1.53$, $p = .067$, $d = .451$) in mother-designed playrooms (see Figure 4C-D).

3.2.3.1.2 Infants initiated more layout changes in larger rooms

Next, in order to examine the extent to which the characteristics of mothers' spaces shaped infants' room change behaviors, we also assessed relations between the built area of mothers' playrooms and the frequency with which infants initiated layout changes. There was a positive relation between these two measures, such that infants produced a larger number of layout changes in larger initial rooms. Moreover, this association was stronger for walkers ($r = .654$, $p = .004$) than pre-walkers ($r = .343$, $p = .044$). GEEs confirmed these patterns with significant main effects of Locomotor Status, $X^2 = 5.36$, $p = .021$, Room Size, $X^2 = 4.93$, $p = .026$, and a Locomotor Status x Room Size interaction, $X^2 = 11.98$, $p < .001$.

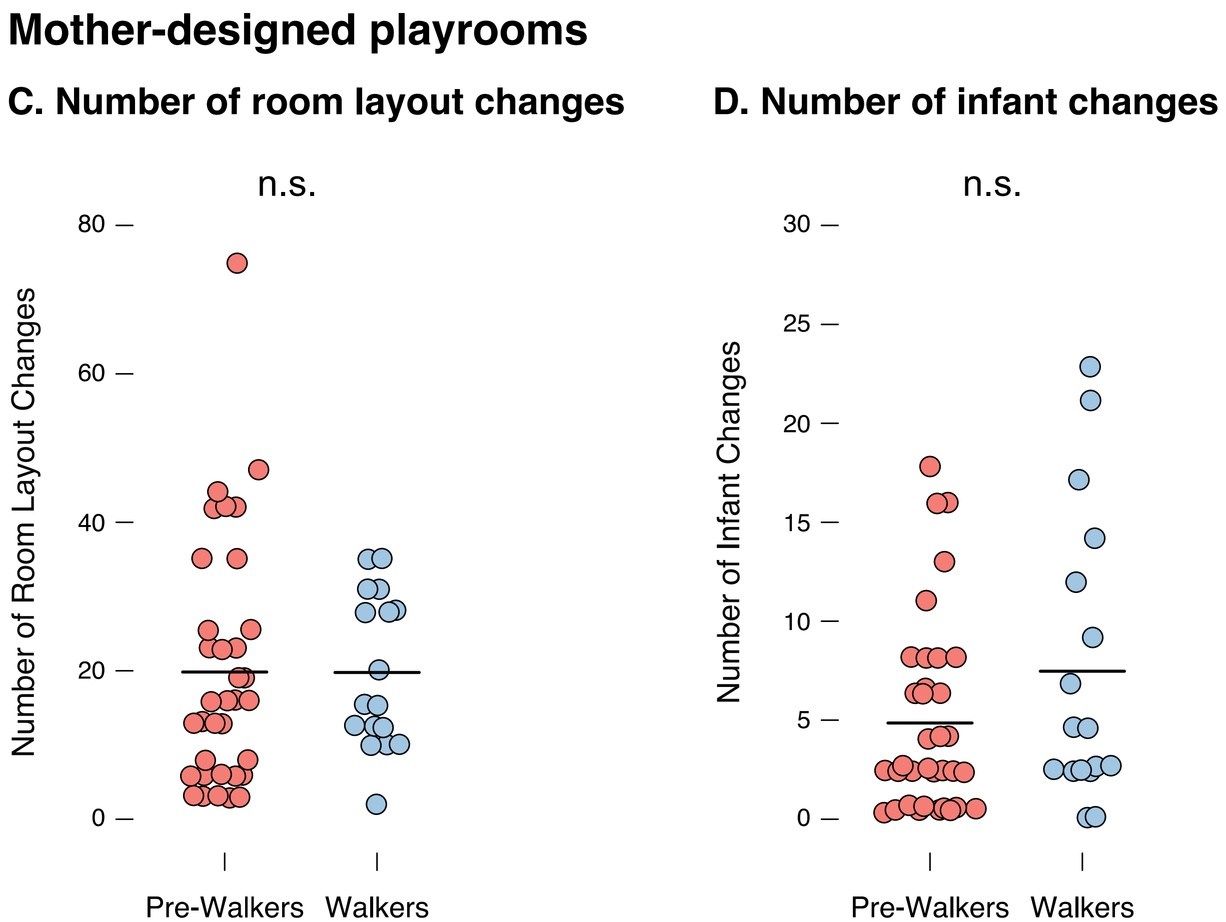

Figure 4C-D. Room layout changes in mother-designed playrooms. Data show: (A) the total number of layout changes and (B) the number of layout changes initiated by infants. Symbols represent data from individuals and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom; circles = mother-designed playrooms) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

n.s. = not significant

Table 6. Descriptive statistics: Infant and mother behavior during play in mother-designed playrooms

	Pre-Walkers (n = 35)			Walkers (n = 17)		
Measure	*M*	*SD*	*range*	*M*	*SD*	*range*
Room layout changes						
Number of layout changes	19.83	16.56	2.00-75.00	19.76	10.40	2.00-36.00
Number of infant changes	4.86	4.91	0.00-18.00	7.47	7.33	0.00-23.00
Infant movement						
Number of bouts	30.91	11.37	1.00-51.00	42.24	11.79	30.00-77.00
Percent time in motion (%)	33.68	16.35	0.81-65.27	45.95	13.12	26.96-72.97
Percent time bum shuffling (%)	3.76	14.58	0.81-82.91	0.00	0.00	0.00-0.00
Percent time crawling (%)	65.47	31.39	0.00-100.00	48.29	27.26	3.63-97.01
Percent time supported upright (%)	30.77	27.28	0.00-100.00	0.00	0.00	0.00-0.00
Percent time walking (%)	0.00	0.00	0.00-0.00	51.71	27.21	2.99-93.49
Number of falls	6.14	6.59	0.00-39.00	9.29	5.87	0.00-16.00
Infant travel						
Distance traveled (m)	9.17	7.39	0.00-27.13	15.06	8.47	3.05-32.00
Infant-mother proximity						
Percent proximal (%)	68.12	22.30	11.36-100.00	59.57	20.58	21.62-89.47
Percent distal (%)	13.36	13.65	0.00-63.64	16.94	11.36	0.00-40.54
Percent transitions (%)	18.52	12.47	0.00-48.84	23.49	16.18	2.63-59.38
Percent infant-led transitions (%)	64.61	35.77	0.00-100.00	90.20	9.27	75.00-100.00
Infant engagement with blocks						
Percent engagement with blocks (%)	56.20	23.73	7.72-95.41	58.12	17.13	23.03-82.79
Mother language input						
Number of utterances	142.23	46.38	32.00-274.00	126.47	32.43	84.00-174.00
Percent whole-body motion verbs (%)	24.32	10.37	10.13-56.25	24.35	10.71	5.99-57.14

Table 6. Descriptive statistics: Infant and mother behavior during play in mother-designed playrooms (continued)

Percent action specified (%)	61.51	16.89	2.22-86.67	64.78	17.05	23.33-86.96
Rate of moving utterances	21.48	4.43	13.97-34.75	19.77	4.73	11.39-26.58
Rate of moving whole-body motion verbs (%)	4.13	2.42	0.00-10.78	3.63	1.47	1.03-6.52
Rate of moving action specified (%)	2.46	1.42	0.00-5.23	2.38	1.10	0.50-4.23
Rate of stationary utterances	18.16	8.99	2.55-40.61	13.55	4.95	4.97-20.58
Rate of stationary whole-body motion verbs (%)	4.51	2.30	1.59-12.14	3.92	1.52	1.49-7.32
Rate of stationary action specified (%)	2.79	1.65	0.41-7.29	2.46	1.18	0.89-4.59
Mother gesture input						
Number of gestures	17.69	9.24	3.00-38.00	19.24	7.38	7.00-33.00
Percent movement (%)	49.49	24.29	0.00-91.30	45.78	27.17	0.00-85.71
Percent conventional (%)	34.29	19.61	0.00-84.62	33.51	18.14	5.00-60.00
Percent pointing (%)	16.22	14.45	0.00-50.00	20.70	21.47	0.00-87.50
Rate of moving gestures	1.52	1.25	0.00-4.13	2.07	0.95	0.00-3.66
Rate of moving movement gestures	0.88	0.95	0.00-3.58	1.26	0.95	0.00-2.94
Rate of stationary gestures	2.75	1.56	0.27-6.82	2.80	1.37	0.00-4.97
Rate of stationary movement gestures	1.31	0.94	0.00-3.95	1.23	0.97	0.00-3.41
Mother posture						
Percent upright (%)	7.98	12.29	0.00-47.37	11.89	18.87	0.00-54.35
Percent down (%)	88.28	14.97	42.11-100.00	85.21	20.44	38.30-100.00
Percent posture transitions (%)	3.74	4.64	0.00-16.67	2.90	4.72	0.00-13.79
Mother physical actions						
Number of repositions	9.69	7.48	0.00-29.00	8.47	6.33	0.00-24.00

3.2.3.1.3 Walkers moved more than pre-walkers

We assessed group differences in how and how much infants moved (see Figure 5D-F). In mother-designed playrooms, walkers initiated more bouts of movement than pre-walkers (*M* bouts walkers = 42.24, *SD* = 11.79; *M* bouts pre-walkers = 30.91, *SD* = 11.37; $t(50) = -3.33$, $p < .001$, $d = .984$). Walkers also spent more time in motion compared to pre-walkers (*M* time walkers = 46%, *SD* = 13; *M* time pre-walkers = 34%, *SD* = 16; $t(50) = -2.70$, $p = .005$, $d = .798$). Pre-walkers spent most of their moving time crawling and climbing (*M* = 65%, *SD* = 31), followed by cruising and supported walking (*M* = 31%, *SD* = 27), and bum shuffling (*M* = 4%, *SD* = 15), in that order. Walkers split their time between walking (*M* = 52%, *SD* = 24) and crawling and climbing (*M* = 48%, *SD* = 23). Walkers fell more often than pre-walkers (*M* walker falls = 9.29, *SD* = 5.87; *M* pre-walker falls = 6.14, *SD* = 6.59; $t(50) = -1.67$, $p = .045$, $d = .495$.

We also examined if differences in the built area of mothers' playrooms related to patterns of infant locomotion. However, there were no significant relations between room size and any measure of infant movement for pre-walkers or walkers, all *r*s ≤ .345, *p*s ≥ .175. That is, infants moved just as much and in similar ways, regardless of the size of mothers' spaces.

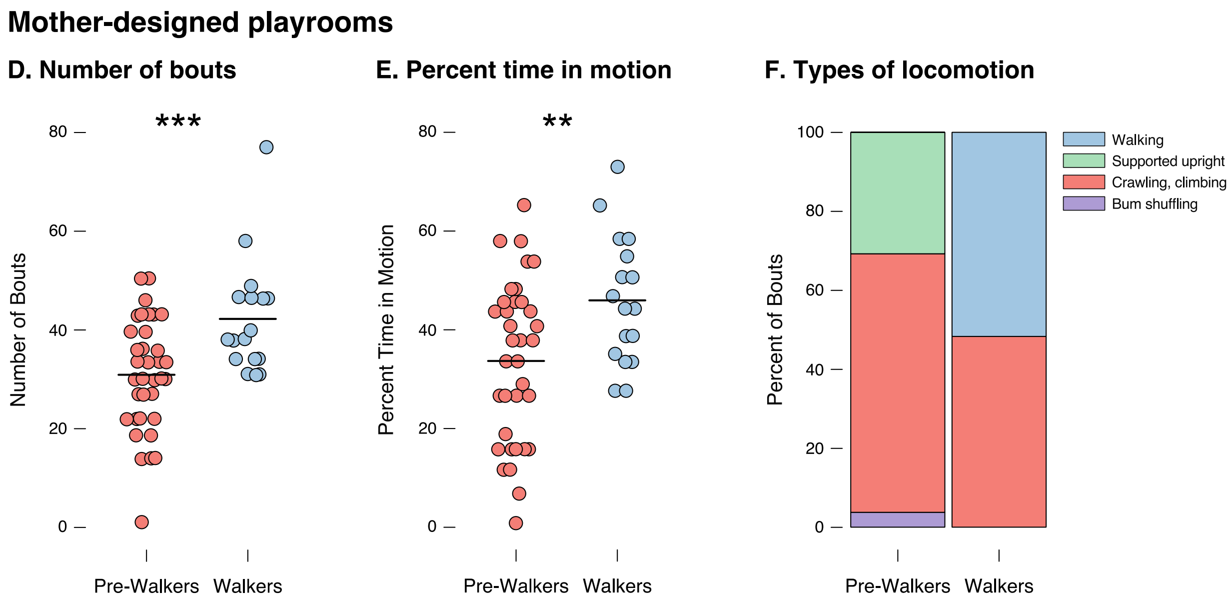

Figure 5D-F. Infant movement in mother-designed playrooms. Data show: (A) the total number of bouts infants initiated during play, (B) the percent of observation time (when not held by mothers) that infants spent in motion, and (C) the distribution of movement time by type of locomotion (bum shuffling in purple; crawling/climbing in red; cruising/supported walking in green; walking in blue). Symbols represent data from individual infants and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom; circles = mother-designed playrooms) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

*******p* **< .01; ******p* **< .001**

3.2.3.1.4 Walkers traveled more than pre-walkers

As shown in Figure 6B, walkers traveled more than pre-walkers while exploring mother-designed playrooms (*M* distance walkers = 15.06 m, *SD* = 8.47; *M* distance pre-walkers = 9.17 m, *SD* = 7.39; $t(50) = -2.57$, $p = .007$, $d = .760$). And again, infants who moved more also traveled more, $r = .720$, $p < .001$. There were no relations between the built area of mothers' playrooms and the distances traveled by pre-walkers or walkers, all rs $\leq -.021$, ps $\geq .593$.

Mother-designed playrooms

B. Distance traveled

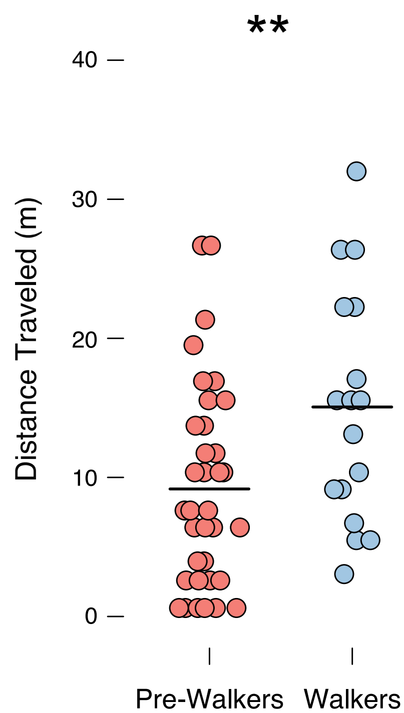

Figure 6B. Infant travel in the mother-designed playrooms. Data show the total distance (in meters) infants traveled during eight minutes of play. Distance was derived from counts of square crossings. Symbols represent data from individual infants and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

$**p < .01$

3.2.3.1.5 Infants and mothers were generally close to one another during play

We also examined patterns of interpersonal distance between infants and mothers during play (see Figure 7C-D). In mother-designed playrooms, infants and mothers remained proximal to one another during the majority of infants' bouts, regardless of infants' locomotor status (*M* walkers proximal = 60%, *SD* = 21; *M* pre-walkers proximal = 68%, *SD* = 22). However, there were no group differences in the percentages of bouts that contained proximity transitions (see Table 6). A 2 (Proximity State: proximal, distal) x 2 (Locomotor Status) repeated measures ANOVA confirmed these relations with a significant main effect of Proximity State, $F(1,50) = 99.26$, $p < .001$, $\eta^2 = .665$. There was no effect of Locomotor Status, and the interaction was not significant, all $ps \geq .221$. There were also no relations between the size of mothers' playrooms and patterns of infant-mother proximity, all $rs \leq .274$, $ps \geq .089$.

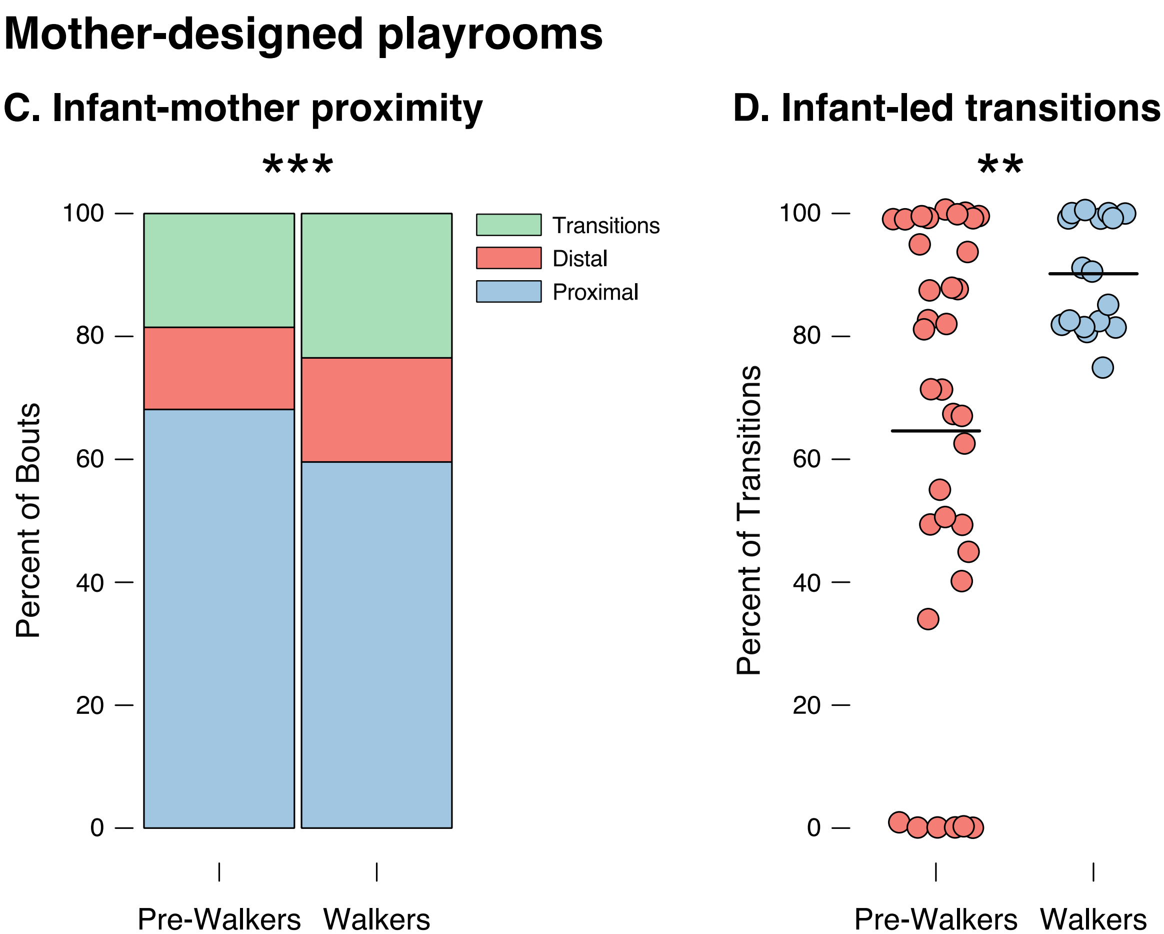

Figure 7C-D. Infant-mother proximity in mother-designed playrooms. Data show: (A) the distribution of infants' bouts spent proximal (blue), distal (red), or in proximity transitions (green) with mothers; and (B) the percent of proximity transitions led by infants. Symbols represent data from individual infants and

horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers). **$p < .01$; ***$p < .001$

3.2.3.1.6 Walkers were more likely to lead changes in proximity than pre-walkers

There was an effect of locomotor status on infant-led changes in proximity during exploration in mother-designed playrooms. Indeed, not only were infants responsible for the majority of proximity transitions (*M* = 73%, *SD* = 32), but walkers were more likely to do so than pre-walkers (*M* walkers = 90%, *SD* = 9; *M* pre-walkers = 65%, *SD* = 36; $t(50) = -2.89$, $p = .003$, $d = .854$). Given that there were group differences in how much infants moved and how likely they were to engage in proximity transitions that resulted in a to-and-fro pattern of exploration, we also assessed connections between this category of interpersonal distance and the time that infants spent in motion. We discovered one significant relation: infants who spent more time moving were also more likely to initiate proximity transitions in mother-designed playrooms, regardless of locomotion status, $r\text{s} \geq .547$, $p\text{s} \leq .023$.

3.2.3.2 Mother language, gestures, posture, and physical actions

3.2.3.2.1 Mothers' overall language input was similar for pre-walkers and walkers

We next examined the total amount of language that mothers produced during play and whether this differed by infants' locomotor status. As shown in Figure 8D-F, in mother-designed playrooms, there were no differences in the total number of utterances mothers directed to their pre-walking and walking infants (*M* pre-walkers = 142.23, *SD* = 46.38; *M* walkers = 126.47, *SD* = 32.43; $t(50) = 1.26$, $p = .107$, $d = .372$). Moreover, there were also no group differences in the percent of utterances containing whole-body motion verbs (*M* pre-walkers = 24%, *SD* = 10; *M* walkers = 24%, *SD* = 11; *t*(50) = -.008, *p* = .497, *d* = .002) or the percent of motion verb utterances that specified a particular action (*M* pre-walkers = 62%, *SD* = 17; *M* walkers = 65%, *SD* = 17; *t*(50) = -.653, *p* = .258, *d* = .193). There were no significant relations between room size and any measure of mother language input, all *r*s ≤ .340, *p*s ≥ .159.

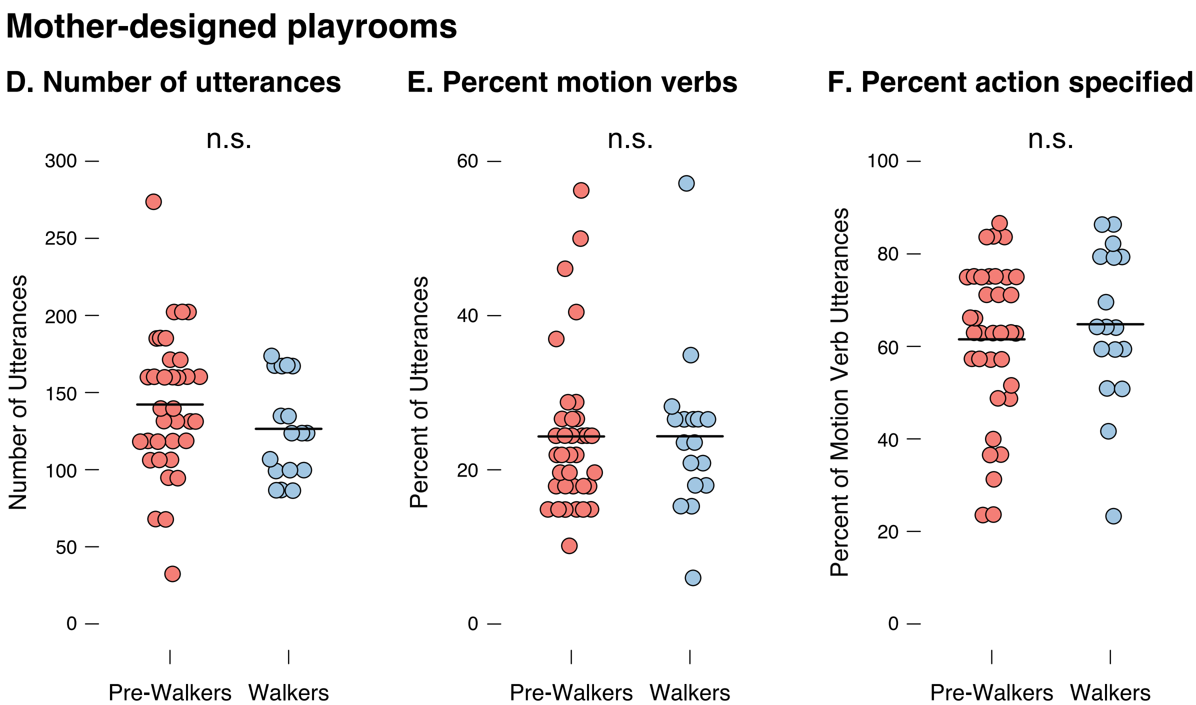

Figure 8D-F. Mother language input in mother-designed playrooms. Data show: (A) the total number of utterances, (B) the percent of utterances containing whole-body motion verbs (e.g., go, get, crawl, walk), and (C) the percent of motion verb utterances that specified a particular action (e.g., "Can you walk across?"). Symbols represent data from individual infants and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

n.s. = not significant

3.2.3.2.2 Mothers produced more language when infants moved

Infant movement also shaped mothers' language input during play in mother-designed playrooms. There were no group differences in total utterances per minute in motion (*M* pre-walkers = 21.48, *SD* = 4.34; *M* walkers = 19.77, *SD* = 4.73; $t(50) = 1.28$, $p = .104$, $d = .378$), motion verb utterances per minute in motion (*M* pre-walkers = 4.13, *SD* = 2.43; *M* walkers = 3.63, *SD* = 1.47; $t(50) = .795$, $p = .215$, $d = .235$), or specified action utterances per minute in motion (*M* pre-walkers = 2.46, *SD* = 1.42; *M* walkers = 2.38, *SD* = 1.10; $t(50) = .193$, $p = .424$, $d = .057$). But there were differences in the rate of total utterances while infants were moving compared to when they were stationary (*M* rate moving utterances = 20.92, *SD* = 4.56; *M* rate stationary utterances = 16.65, *SD* = 8.15; $F(1,50) = 22.19$, $p < .001$, $\eta^2 = .307$). There was no movement effect, however, when we compared moving vs. stationary motion verb utterances and action specified utterances. That is, mothers produced more language overall while infants moved compared to when they were stationary, but similar amounts of action-based language, regardless of whether infants were moving or not, all $ps \geq .249$ (see Table 6).

3.2.3.2.3 Mothers' overall gesture input was similar for pre-walkers and walkers

As shown in Figure 9C-D, in mother-designed playrooms, there were no locomotor status differences in the total number of gestures that mothers directed to their infants (*M* pre-walkers = 17.69, *SD* = 9.24; *M* walkers = 19.24, *SD* = 7.38; $t(50) = -.603$, $p = .275$, $d = .178$). There were also no differences in the distribution of gesture types between pre-walkers and walkers. Mothers produced similar percentages of movement gestures (*M* pre-walkers = 50%, *SD* = 24; *M* walkers = 46%, *SD* = 27; $t(50) = .496$, $p = .311$, $d = .147$), conventional gestures (*M* pre-walkers = 34%, *SD* = 20; *M* walkers = 34%, *SD* = 18; $t(50) = .138$, $p = .445$, $d = .041$) and pointing gestures (*M* pre-walkers = 16%, *SD* = 14; *M* walkers = 21%, *SD* = 21; $t(50) = -.891$, $p = .189$, $d = .263$) to all infants during play. And as we observed with language above, there were also no relations between the area of mothers' spaces and any measure of gesture input, all *r*s ≤ .241, *p*s ≥ .163.

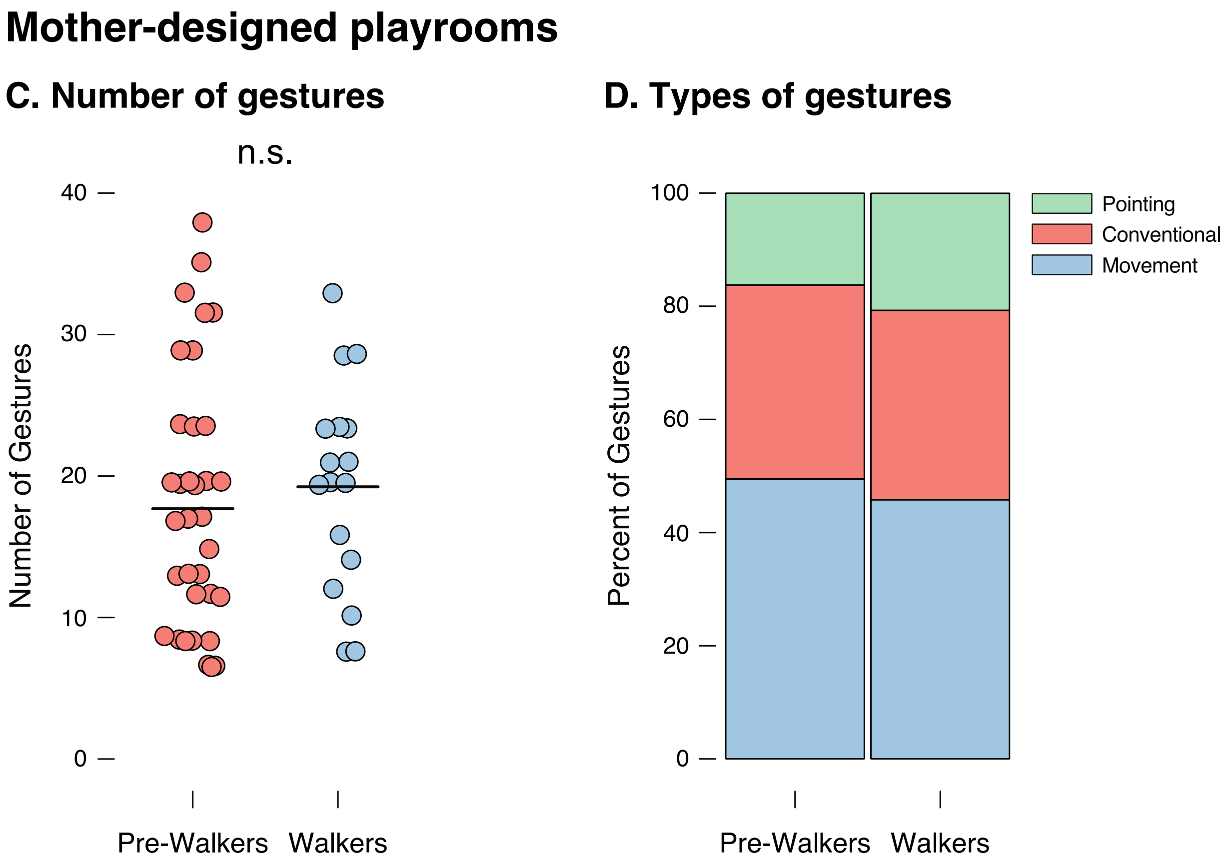

Figure 9C-D. Mother gesture input in the standard playroom. Data show: (A) the total number of gestures mothers produced and (B) the distribution of gestures by type (movement in blue; conventional in red; pointing in green). Symbols represent data from individual infants and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers).

n.s. = not significant

3.2.3.2.4 Mothers produced more gestures when walkers moved

However, there was an effect of infants' locomotor status on mothers' total gesture rate. Specifically, in mother-designed playrooms, mothers of walkers produced more gestures while infants moved compared to mothers of pre-walkers (*M* walkers = 2.07, *SD* = 0.95; *M* pre-walkers = 1.52, *SD* = 1.25; $t(50) = -1.59$, $p = .044$, $d = .470$). This was not apparent when we examined rates of movement gestures (*M* walkers = 1.26, *SD* = 0.95; *M* pre-walkers = 0.88, *SD* = 0.95; $t(50) = -1.35$, $p = .092$, $d = .398$).

3.2.3.2.5 Mothers were generally down when infants moved

As shown in Figure 10B, in mother-designed playrooms, mothers spent a larger share of infants' bouts down on the floor (*M* pre-walkers = 88%, *SD* = 15; *M* walkers = 85%, *SD* = 20) than they did upright (*M* pre-walkers = 8%, *SD* = 12; *M* walkers = 12%, *SD* = 19) or in posture transitions (*M* pre-walkers = 4%, *SD* = 5; *M* walkers = 3%, *SD* = 5). However, there were no differences in mother posture based on infants' locomotor status. A 2 (Posture Type: down, upright) x 2 (Locomotor Status) repeated measures ANOVA confirmed these patterns with a significant main effect of Posture Type, $F(1,50) = 274.58$, $p < .001$, $\eta^2 = .846$. There was no effect of Locomotor Status, and the interaction was not significant, all ps $\geq .454$. There were also no relations to room size, rs $\leq .161$, ps $\geq .228$.

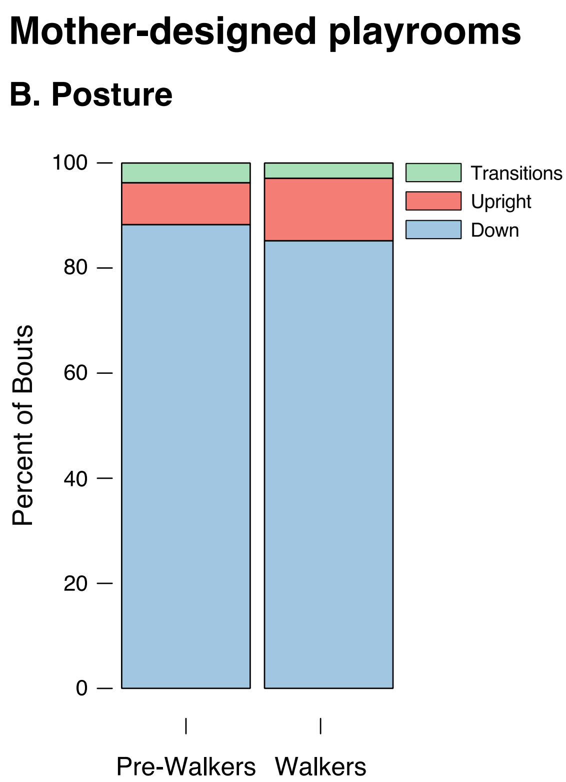

Figure 10B. Mother posture in mother-designed playrooms. Data show the distribution of mothers' postures during play. Mother could be down on the floor (e.g., sitting, squatting, crawling; in blue), upright (e.g., standing walking; in red), or transitioning between postures (e.g., getting up or down; in green).

3.2.3.2.6 Mothers often repositioned pre-walkers and walkers

Finally, we examined how frequently mothers repositioned their infants during play in mother-designed playrooms (see Figure 11B). There were no differences in how often mothers repositioned pre-walkers and walkers (*M* pre-walkers = 9.69, *SD* = 7.49; *M* walkers = 8.47, *SD* = 6.33; $t(50) = .577$, $p = .283$, $d = .170$). And there were also no relations between the number of repositions and the size of mothers' initial playrooms, all *r*s ≤ -.097, *p*s ≥ .469. However, when we examined associations with the time that infants spent in motion, we again observed a significant negative relation between movement time and the frequency of repositions for pre-walkers, $r = -.583$, $p < .001$.

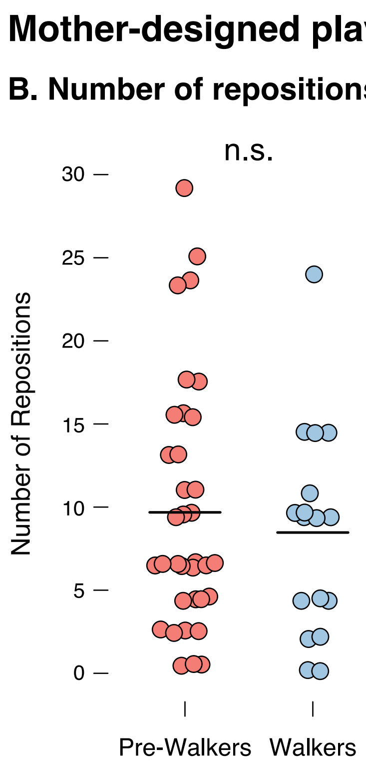

Figure 11B. Mother physical actions in mother-designed playrooms Data show the total number of times that mothers repositioned infants' bodies during play. Symbols represent data from individual infants and horizontal lines describe group averages. Room conditions are denoted with different shapes (squares = standard playroom) and infant locomotor status is color-coded (red = pre-walkers; blue = walkers). n.s. = not significant

4.0 Discussion

Infant development is embedded in the physical environment. Infants learn, play, and grow in physical spaces that contain opportunities for development to unfold. As infants' locomotor abilities advance over time, so do their interactions with the environment. However, the nature of infants' environments and their access to them are generally determined by caregivers. Caregivers choose objects and furniture, arrange rooms, and update the layout of infants' everyday spaces. To date, the relations between infants' developing locomotor skills and the ways in which caregivers structure the environment are largely unknown. Thus, the overarching goal of this dissertation was to examine how mothers designed a new play space for their infants, whether infants' locomotor status (as pre-walker or walker) related to the spaces that mothers constructed, and how infants and mothers engaged in play in different kinds of spaces. We leveraged an age-held-constant design to address these issues while accounting for potential effects of maturation. Findings for each of our three aims are discussed in turn.

4.1.1 Infant and mother behavior in a standard play environment

The first aim of this study was to examine differences in how pre-walking and walking infants (and their mothers) engaged in play in an identically organized, standard space. The standard playroom allowed us to hold characteristics of the environment constant and assess the extent to which infants' locomotor abilities mattered for locomotor exploration and social interaction with mothers.

4.1.1.1 Walkers displayed a more expansive profile of locomotor exploration

As hypothesized, walkers engaged in a more complex pattern of locomotor exploration than pre-walkers. Indeed, there were group differences on every measure of infant activity that we assessed. Our findings replicate existing knowledge about infant locomotor action in a new play setting with a new cohort of infants. Walkers spent more time in motion than pre-walkers (Adolph et al., 2012; Hoch et al., 2020; Schneider & Iverson, 2022), traveled twice the distance (Clearfield, 2010; Thurman & Corbetta, 2017), and lead more proximity transitions while exploring the playroom with their mothers (Chen et al., 2023; Salo et al., 2021). And importantly, these results contribute to a foundational understanding of how advances in infant locomotor development relate to changes in infants' ability to move efficiently through and explore everyday environments (their homes) and new spaces (a playroom or a playground).

4.1.1.2 Mothers' language input was related to infant movement

Mothers' overall language input did not differ by infants' locomotor status; indeed, it was nearly identical for pre-walkers and walkers. Mothers provided a massive influx of linguistic information during play with their 12-month-old infants—approximately 130 utterances in just eight minutes. Not only did mothers talk to their infants at a high rate (16.25 utterances per minute on average), but their language was rich with information about infants' locomotor actions. Nearly one quarter of mothers' utterances contained whole-body motion verbs, utterances that commented on or directed infants' actions (e.g., go, get, come, climb, cross, walk). Moreover, more than half of utterances containing motion verbs specifying how infants could traverse an obstacle or navigate the unique features of a block construction in the playroom (e.g., "Climb up the stairs!", "Put both feet down before you can slide!").

Although there were no locomotor status differences in mothers' total language input, infant movement shaped rates of mother talk. That is, mothers talked more frequently when infants were moving compared to when they were stationary. This suggests that movement itself may be a salient cue for language input. This association, however, was only apparent for rates of overall language input and was not the case for utterances containing motion verbs or those that specified particular actions. Infants heard just as many utterances with motion verbs and about specific actions while moving as they did while stationary.

Research suggests that caregivers' language input is attuned to infants' moment-to-moment actions and may create opportunities for learning. Caregivers provide language within seconds of infants' actions (Schatz et al., 2022; Suarez-Rivera et al., 2022), prompt infants' success at achieving new goals (Kaplan et al., 2022), and may even help infants learn the meanings of common verbs (West et al., 2022). Thus, caregivers may use language to describe possibilities for action and potentially teach their infants how to perform a required action to succeed at a task.

Indeed, the prevalence of action-based language that we observed may have been a means for mothers to scaffold how infants accessed different areas of the playroom. For instance, while infants were moving, mothers used motion verbs to tell infants where to go ("Go across the room"), how to go ("Walk on over!"), and why to go ("Come explore this one with me!"). But while stationary, mothers may have used similar language to encourage infants' future actions rather than comment on or direct their ongoing locomotor pursuits—by telling infants where to go next ("Let's climb on those blocks next"), how to go next ("You can walk down the stairs one step at a time"), and why to go next ("Did you jump on this block yet?").

The function of caregivers' language input for structuring infants' opportunities for learning about what is possible for action (compared to what is not) and scaffolding infant exploration of the environment is poorly understood. Future research aimed at disentangling the utility of caregivers' language input (verb-based or otherwise) for infant locomotor action will help elucidate how caregivers encourage infants' actions and teach infants about the requirements for navigating the environment (e.g., how to get down from a couch at home, climb to the top of a slide at the playground).

4.1.1.3 Mothers' gesture input was related to infant movement and locomotor status

Mothers' overall gesture input was also strikingly similar for pre-walkers and walkers. Indeed, there were no group differences in the total number of gestures that mothers directed to their infants or in the distribution of gesture types. Nevertheless, mothers used gestures frequently—approximately 18 gestures in eight minutes—with movement gestures occupying nearly half of mothers' gestural repertoires. These data suggest that mothers' communicative behaviors in the context of play with the block set we provided were characterized by extensive use of gestures about infant movement and locomotor action. Indeed, this relatively large number of gestures highlights the idea that laboratory studies may elicit peak levels of a behavior compared to naturalistic home observations which reflect the ebb and flow of a behavior over time (some high peaks, some low valleys; see Tamis-LeMonda et al., 2017).

We originally hypothesized that mothers of walking infants would gesture more frequently than mothers of pre-walking infants. However, a group difference in total gesture input was not apparent. Instead, we only observed locomotor status differences when we examined rates of gesture that co-occurred with infant movement. Specifically, compared to pre-walkers, mothers gestured more frequently when walkers moved (though the difference was small).

This connection supports existing accounts of the cascading effects of infant postural development on caregiver gesture input. In particular, research has shown that the acquisition of walking is associated with gains that enable infants to engage in social interactions more effectively (e.g., an elevated vantage point, increased propensity to share objects; Kretch et al., 2014; Karasik et al., 2011). Given that walkers spent most of their movement time walking (i.e., an upright locomotor posture) whereas pre-walkers spent their time crawling and climbing (i.e., a prone locomotor posture), it is possible that mothers capitalized on this difference in infant locomotor posture and provided more gestures when their infants could potentially see them. Indeed, this explanation has been suggested in previous work examining links between infant posture and gesture input during everyday play at home (Schneider & Iverson, 2022) and even during gestural exchanges between adults during times when interlocuters were visually available to one another vs. occluded behind a screen (Alibali et al., 2001).

4.1.1.4 Mothers' posture was related to infants' locomotor status

Mothers spent the vast majority of play positioned down on the floor—they chose to sit, squat, kneel, and sometimes crawl. At times, mothers also stood and walked around the playroom, but this was rare. We anticipated that mothers would organize their body positions in this way given the context of the interaction (predominantly locomotor play in a single room) and research indicating that mothers often match their posture to that of their infants (e.g., Franchak et al., 2018). Pre-walking and walking infants spent a great deal of time crawling and climbing (though to different extents), so it is possible that mothers also stayed down to match their infants' body position.

Although there was a clear preference for mothers to be down on the floor during play, we observed group differences in how likely mothers were to engage in posture transitions. Mothers of walkers were more likely to change their posture than mothers of pre-walkers. By definition, posture transitions required mothers to move their bodies in order to switch from being down to being upright (or vice versa). And in most cases, mothers did so to follow their infants in response to infant-led changes in interpersonal distance (e.g., infants ventured away to explore a new area or location in the playroom and mothers followed). In the context of group differences in infant movement and travel among pre-walkers and walkers, this pattern of mother behavior was rather practical. Walkers explored the playroom more expansively and in turn, mothers followed their infants lead by joining in on their exploratory travels (see Hoch et al., 2021). Moreover, although we did not measure walking and crawling speed in this study, research suggests that infants are faster during their very first week of walking as compared to after 21 weeks of crawling (Adolph, 2008; Adolph et al., 1998). Thus, when walkers traveled across the room, mothers had to get up and go to catch up to their infants, follow their interests, and ensure their safety.

4.1.1.5 Mothers' physical actions were related to infant movement

Mothers can also provide their infants with hands-on support during play by repositioning their bodies. We coded this relatively unexamined behavior in the context of our interaction to assess its prevalence among pre-walking and walking infants. Mothers repositioned their infants rather frequently—nearly 10 times in eight minutes—and this did not vary with infants' locomotor status. There are a few possible reasons as to why mothers produced this behavior with such abundance. First, body repositions may have been a way for mothers to teach their infants how to traverse an obstacle in the playroom (e.g., by moving infants' arms and legs down the stairs, one by one). Mothers could also have used repositions to direct where play took place by transporting infants to different locations. And finally, there may have been more practical reasons for repositions, such as redirections from potential dangers (e.g., moving infants away from a covered outlet).

Of course, infants constantly reposition their own bodies as they move. This is particularly the case when infants engage in crawling, as the biomechanics of crawling force infants to redirect their bodies an average of 90 degrees away from their original direction of heading when transitioning in and out of the crawling posture (Soska et al., 2015). Thus, we asked if the time that infants spent in motion (and by extension, repositioning themselves) was related to how often mothers repositioned them. We found one relation and it was unique to pre-walking infants. Specifically, pre-walkers who spent more time in motion (in reality, more time crawling as this was the predominant method of locomotion for pre-walkers) were repositioned less frequently by their mothers. Taken together, it is possible that mothers modified how often they repositioned their infants when infants were more active in reorienting themselves and structuring the direction of play.

4.1.2 A new method, a new cascade

4.1.2.1 Mothers designed different play spaces for pre-walking and walking infants

Our second goal was to examine how mothers created a new play space for their 12-month-old infants and assess the extent to which infants' locomotor status related to the spaces mothers designed. To do so, we introduced a novel room construction paradigm in which mothers were able to create a playroom using a large set of blocks in an otherwise empty space. We discovered that mothers indeed built different spaces for their pre-walking and walking infants. Mothers of pre-walkers designed expansive spaces with many unique block constructions scattered across the room. But mothers of walkers did the opposite: they created smaller spaces with one or two primary constructions in one area of the room surrounded by an abundance of empty floor space. This finding suggests the presence of a new cascading connection between infant locomotor development and caregiver behavior, one that extends our understanding of these relations to the domain of spatial design.

We originally hypothesized that mothers of walkers would construct larger spaces given walking infants' propensity to move, travel, and explore more of the environment compared to pre-walkers. However, this was not the case. Why did mothers build smaller rooms for walkers but bigger rooms for pre-walkers? One possibility is that mothers of walkers may have focused their design goals to create spaces that promoted practice with walking. Indeed, the walkers in our sample were relatively new to walking (M = 21.71 days of walking experience). Seven infants began walking within just two weeks of their lab visit (41% of infants), and one met our onset criterion that morning. Thus, mothers may have provided their infants with a great deal of empty space to encourage them to use walking while exploring the playroom.

Another possibility is that mothers of walkers may have built environments that created opportunities for infants to practice more complex skills (e.g., climbing on elevations, walking up and down stairs). Although there were no group differences in the percentages of blocks used in stacked constructions, mothers of walkers and pre-walkers stacked objects in different ways. Specifically, walker playrooms contained multi-level stacked constructions that spanned various heights (e.g., two to three levels) within a single structure. By contrast, pre-walker playrooms more often contained many two-level structures dotted throughout the room. Thus, although stacking was common, the goals of stacking may have differed. In fact, mothers of walkers often spontaneously shared that they created complex structures like a "fort" or "playground" to encourage their infants to climb up and down, figure out how use the stairs, and create opportunities to explore high elevations. Mothers of pre-walkers shared different goals: they aimed to create "obstacle courses" and "pathways for play" to encourage their infants to explore the entirety of their constructed playroom and travel from place to place to discover what each station contained.

4.1.2.2 Similar spaces, possibly different functions: A closer look at walkers and bum shufflers

It was striking that nearly all mothers of walkers followed some common principle for playroom design (i.e., few constructions in a small area). Indeed, there was less variability in the built area of walkers' spaces than those of pre-walkers, suggesting the distinct possibility that infants' locomotor skills influenced how mothers organized spaces for play. This is underscored by the fact that walkers' playrooms were similar regardless of infants' walking experience, be it just one day or 66 days. There was more variability in pre-walker playrooms. That is, although mothers of pre-walkers generally built larger spaces for their infants, some of the spaces they designed shared elements with those created by mothers of walkers.

To better understand why some pre-walker playrooms had overlapping characteristics with walker playrooms, we examined the four pre-walker rooms with the smallest built areas (i.e., those that fell at the bottom of the distribution). Interestingly, these rooms belonged to infants who bum shuffled as their primary method of locomotion. The playrooms of bum shufflers and walkers were very similar—they contained just one or two constructions and covered a small footprint in the larger room. Nevertheless, it is likely that the concentrated design of these spaces served different functions for each group of infants. For walkers, a small room might function to create more empty space for infants to move around in. But for bum shufflers, a small room might function to contain infants in a particular area if they are not as efficient at using locomotion to get around and explore a new space. Thus, it is possible that even though mothers designed similar environments for infants with very different locomotor abilities, mothers may have had different goals in mind for the space (i.e., creating spaces for expansive exploration vs. constraining spaces to contain infants).

Indeed, research suggests that caregivers bring the world closer to pre-locomotor infants by placing toys within infants' reach and positioning themselves or repositioning their infants so they face one another during play (de Barbaro et al., 2016; Fogel et al., 1993; Schneider et al., 2023). But as infants learn to move, they acquire new ways to actively explore the world on their own. Infants can venture off to distal places, locate objects, and return to share their discoveries (Chen et al., 2023; Karasik et al., 2011). Caregivers, in turn, may update infants' spaces based on their concurrent locomotor abilities to support this process. Future research is needed to examine how caregivers arrange spaces for infants with more varied motor abilities than those documented here (e.g., pre-locomotor infants, experienced walkers) and across transitions to new skills (e.g., longitudinally as infants learn to walk). This will provide additional information on the evolution of infants' spaces as a developmental process linked to skill acquisition.

4.1.3 Infant and mother behavior in mother-designed play environments

The final aim of this study was to examine patterns of play in mother-designed playrooms and relations between the characteristics of mothers' spaces and infant and mother behavior. We leveraged naturally occurring variability in how mothers arranged their play spaces to ask if differences in the physical environment (indexed by built area) shaped patterns of infant and mother behavior.

In general, infant and mother behavior during play in mother-designed playrooms was similar to what we observed in the standard playroom. Walkers moved more, traveled more, and engaged in similar patterns of proximity to their mothers. And mothers directed just as much language and gesture to pre-walkers and walkers, spent the majority of play down on the floor, and frequently repositioned their infants.

Room layout changes, however, did differ between the standard and mother-designed playrooms. Indeed, mothers rarely rearranged the standard playroom but often rearranged their own playrooms. We attribute this difference to mothers' interpretation that they needed to maintain the original layout of the playroom that we presented. Of course, we told mothers to play however they wished in both room conditions, but it is possible that the presentation of a new space "designed just for them" might have influenced mothers' propensity to change its layout. As a result, we only interpret this behavior based on data from mother-designed playrooms.

4.1.3.1 The characteristics of mothers' spaces were generally unrelated to infant and mother behavior

Contrary to our overarching suspicion that the characteristics of mother-designed playrooms would be related to differences in infant and mother behavior broadly, there were virtually no connections among these measures. Instead, we discovered only one significant relation between these domains: infants initiated a larger number of room layout changes in playrooms with larger initial areas. This association was stronger for walkers than pre-walkers, suggesting that both the physical environment *and* infants' locomotor status shaped the expression of this behavior. Room layout changes represented instances in which infants moved a block in the playroom that resulted in a change in the configuration of the larger space (e.g., by pushing a block to the other side of the room). This behavior demonstrates agency on the part of infants in actively redesigning spaces for play in real time. That is, infants' actions changed the moment-to-moment layout of the environment which may have resulted in new ways to play and interact with their mothers.

It is likely that infants produce similar behaviors during everyday play at home. For example, infants might reorganize a room by transporting objects to different locations or by moving small pieces of furniture (e.g., infant chairs, strollers, locomotor toys) while cruising and supported walking. Additional research is needed to understand whether and how infants manipulate and arrange their home spaces, and how locomotor development plays a role in this process (e.g., by providing infants with new means for changing the layouts of their spaces).

Why were the characteristics of the spaces mothers designed largely unrelated to infant locomotor exploration and mother communication? One possibility is the context of our laboratory study. Infants and mothers played in a new space with new toys; the majority of infants had never played with our block set and very few had something similar at home. Thus, it is possible that the novelty of the space and materials for play overshadowed potential effects of the configuration of the environment.

Another possibility is that infants' locomotor status (and associated differences in how and how much infants engage in locomotor exploration) were more robust in shaping play relative to differences in the characteristics of the play space. Mothers' spaces spanned a wide distribution of values—built area ranged from 1.11 m^2 to 18.12 m^2—suggesting that there was sufficient variability for examining relations between this measure of space and our measures of infant and mother behavior. However, regardless of the size of the playroom, pre-walkers and walkers moved just as much, traveled just as far, and were similarly likely to move back and forth between their mothers and other locations in the room. And mothers produced just as much language and gesture input, were similarly down on the floor during play, and repositioned their infants just as frequently. Taken together, although infants' locomotor status shaped the kinds of spaces that mothers constructed, the characteristics of mothers' playrooms did not appear to influence the behaviors that occurred within them.

4.1.4 Study limitations and methodological considerations

Several limitations warrant mention when interpreting the results of this dissertation. First, this study was conducted in a laboratory playroom to allow for precise examination and quantification of how mothers designed new spaces and played with their infants in different environments. This methodological decision (rather than a more naturalistic approach in the home) allowed us to minimize factors that may have otherwise confounded our results (e.g., differences in the size of infants' home spaces). This study represents an initial investigation of how caregivers create play spaces for infants and thus required experimental control to ensure that our measures of space were consistent and standardized across all families.

Second, the short durations of our play tasks (8-minute sessions, 16 minutes total) may not represent the breadth of infant and mother behavior that occurs across the longer timescales of daily life at home. In fact, our data may only be representative of peak levels of behavior that infants and mothers express given the novel environment and materials for play (as mentioned above; see Tamis-LeMonda et al., 2017). Nevertheless, the duration of play in our study was similar to that reported in many other studies that have measured infant-mother play in the laboratory (e.g., Arnold & Claxton, 2023, 20 min; Hoch et al., 2021, 20 min; Long et al., 2022, 15-20 min; Thurman & Corbetta, 2017, 10 min; Walle & Campos, 2014, 10 min).

Third, we used a specific block set to provide mothers with a wide variety of options for playroom construction, promote locomotor play, and maximize the likelihood that our play materials would be novel for infants. And although we were successful in achieving each of these goals, it is important to note that infants' everyday spaces contain far more toys, objects, and furnishings than the environments created and measured in this study (e.g., Herzberg et al., 2022). Thus, future variations of this research are needed to document how caregivers arrange spaces with other kinds of objects and materials (e.g., small toys, locomotor toys, furniture).

Finally, our recruitment efforts resulted in a sample of families that represented a broad range of racial and ethnic identities. Nevertheless, the mothers in our sample were all from one Midwestern city where commonly shared childrearing practices may have shaped their perspective on how infants' spaces should be structured. Indeed, it is possible that the behaviors around spatial design that we uncovered here may only be representative of samples of infants and mothers from a Western culture. Future research aimed at uncovering relations among the physical environment and dyadic interaction should endeavor to examine these measures in other cultural communities across the globe who differ in their approaches to caregiving, expectations for infant development, and ideas about the kinds of spaces that are appropriate for infants, what those spaces should contain, and how they should be organized.

4.1.5 General conclusions and directions for future research

This study provides the literature with methodological innovation and important insights about relations between infant motor development and infant and caregiver behavior. We introduced a novel laboratory paradigm to gather a first look at connections among spatial design, infant locomotor exploration, and maternal communication and physical interaction in a relatively controlled play task. Our approach suggests the presence of a cascading connection between infant locomotor development and mothers' spatial design, but not between spatial design and subsequent infant and mother behavior during play. Instead, we replicated previously reported robust group differences in infant locomotor exploration between pre-walkers and walkers (e.g., Adolph et al., 2012; Clearfield, 2010; Karasik et al., 2011), underscoring that infants' locomotor status (pre-walker vs. walker) and locomotor action (time spent moving) were more closely related to how and how much mothers interacted with their infants.

Nevertheless, the environment likely creates and constrains opportunities for movement, exploration, communication, and social engagement between infants and mothers. Our results open a constellation of new research questions that can continue to uncover the dynamics of these associations. For instance, longitudinal investigations can follow infants across the first years of life as they acquire fundamental motor skills—sitting, crawling, cruising, standing, walking—to chart a developmental history of how the home environment changes in relation to infant age and skill acquisition. Targeted cross-sectional studies can continue to employ age-held-constant methods (as we did here) but at different infant ages and in relation to different motor skills (e.g., 6-month-old sitters vs. pre-sitters; 8-month-old crawlers vs. pre-crawlers). Moreover, studies can leverage multi-method approaches by combining qualitative and quantitative methods to not only capture how caregivers structure spaces for infants, but to also ask about and assess their reasons for doing so.

Taken together, this dissertation provides new evidence for cascading connections among infant motor development, caregiver spatial design, and the dynamics of infant-caregiver interactions during play. And most critically, this work highlights the importance of viewing development as a process embedded within the physical environment—an evolving context co-created by infants and their caregivers.

Appendix A Coding manuals for all behavior codes

ROOM CHARACTERISTICS <pieces> <cluster1> <cluster2> <cluster3> <cluster4> <cluster5> <cluster6> <cluster7> <cluster8> <cluster9> <cluster10> <clusteravg> <area> <wall> <stacked>

General Orientation

- This coding pass will describe the characteristics of mom's playroom. We will assess the design of her space along a few dimensions to capture the characteristics of the space.
- There is no actual coding *per se* in this pass as we will just be counting and noting numbers of things in various arguments.
- We will draw maps of each mom's room to accompany this pass. The maps will visually display what each room looked like, and these numeric values will allow us to quantify the characteristics of the room.

Operational Definitions

- **<pieces>**
  - Code the number of pieces that mom used to build her room.
  - The total number of pieces is 16.
  - Each mom is instructed to use at least 8, but they can use as many from the set as they want.
- **<cluster1> … <cluster10>**
  - Code the # of objects within a unique cluster that mom creates.
  - This can range from 1 to 16, but will vary.
  - A cluster is a grouping of objects that is self-contained. This means that there is an empty 1-square border around the entire cluster that does not overlap with another grouping of objects.
  - e.g., The standard room (see protocol) has 3 unique clusters.
- **<clusteravg>**
  - Code the average number of objects per cluster.
  - = total # of objects / number of clusters
  - Enter the number as a decimal "X.X"
- **<area>**
  - Code the area of mom's built space in square feet.
  - This measure reflects the square footage of the area that all of mom's pieces occupy in her playroom.
  - To code this, count the number of squares for length and the numbers of square for width.
  - Multiply these numbers.
  - Then multiply by 2 (each square is 2 ft. x 2 ft.).
  - Enter the final square footage.
- **<wall>**
  - Code the number of clusters that are touching a wall.
  - This is to get a sense if mom's room is entirely free floating (throughout the room) or against the wall.
- **<stacked>**
  - Code the number of blocks are involved in stacked constructions.
  - This is to get a sense if how many blocks are on the floor with nothing on top or included in larger structure that go higher up.

ROOM LAYOUT CHANGES <change> <mombaby>

General Orientation

- This code captures how often mothers and infants reorganize or change the layout of the playroom on the fly. That is, we want to know how many times moms and babies change room layout by moving or repositioning one of the objects from the play set.
- A room change has to be significant. They have to move something across the room, flip something, stack something, etc.
- This has to be a big change that actually reflects a different layout in the room as a result.
- Small changes (< 1 square) that do not change room layouts will not count.
- This pass will be coded as point event to get a quick y/n code of whether or not there was a room change.
- We will also determine who was responsible for room changes when they occur (mom or baby) in a second argument.

Operational Definitions

- **<change>**
  - Code "**y**" if there is a room change.
  - Code "**n**" if there is no room change.
- **< mombaby >**
  - Code "**m**" if mom was responsible for the room change.
  - Code "**b**" if baby was responsible for the room change.
  - Code "**bm**" if they both did a room change.
  - Code "**n**" if there was no room change.

BABY MOVEMENT <movetype>

General Orientation

- This code captures all times that the baby moves during the two play tasks ("m" and "s"). We will be using a nuanced version of the original "babyloc" from JLS masters and "locomotion" from WalkTalk.
- Movement in this study will reflect times when infants are crawling/climbing, cruising, supported walking, and independent walking.
- We will also identify all falls and times when baby is being held.
- Bouts of movement are coded as events. There will be grey spaces between cells that are also automatically identified since we are coding events. In our case, grey space means the baby is stationary or is transitioning between different postures.
- Transitions between postures will not be coded BUT we are relaxing the crawling/climbing transition rules in this study since babies are going to climb on the play objects all the time. This is really only in relation to the confusing steps that sometimes happen (see below) but does not affect the big transition movements (e.g., criss-cross, going in and out of prone from sitting, etc.).
- Coders are watching/tagging the duration of each of these events (movement, falls, held) by marking onset/offset times. To determine locomotion, coders are watching for steps with the feet and the knees. Any other movements that are not initiated from these two body locations are considered to be a transition between postures and will not be coded.
- When coding bouts, there may be instances where pauses between steps are greater than 0.5 seconds, but still *feel* ambiguous as to whether it was actually a pause or not. In these cases, go with one bout instead of splitting. Often, these are cases when it feels like baby is still in motion (e.g., lower body—legs—is still moving or baby is rocking back and forth) even if the 0.5 s rule has elapsed; err on being conservative and coding as 1 bout. As long as the torso/legs/feet are still in fluid motion, count the steps surrounding the motion as one bout.

- For bouts where it can be inferred a step was taken but the foot/knee is not visible, code it to the best you can using hip movement/shadows/other body movement as guidance. Any discrepancies will be caught in reliability.
- Occasionally, there will be instances where baby is moving but it is unclear what kinds of steps are being used (e.g., baby knee crawling on experimenter while holding her hands and then stepping down), or the steps feel weird. If they feel like as part of crawling/climbing then keep the bouts going (this is the relaxed part of this code). But, if these are totally different, comment it out for discussion during reliability.
- This code is used differently based on whether the infant is a pre-walker or a walker. Pre-walkers should always be coded as cruising and/or supported walking when in the floor, but walkers can only do so if they are using support while on top of one of the object pieces (i.e., on an elevation with support from mom).
- We are not coding steps!

<u>**Operational Definitions**</u>

- **<movetype>**
  - c = crawling/climbing
  - Code "**c**" when the baby is crawling (hands-knees, hands-feet, hitching, crab crawling, etc.) or climbing.
  - A standard of crawling/climbing occurs in a cycle: infant moves one knee or foot first, then one arm, the next knee/foot and the subsequent arm.
  - As such, the crawling/climbing posture is defined by at least 3 limbs being down on ground or another surface of support (e.g., the playroom objects) while moving on knees/feet. Baby can be moving forward, backward, sideways or in place.
  - When differentiating crawling/climbing from cruising, you may use the position of the infant's torso. If parallel to the ground or object the infant is traversing (or close to it), then you would code crawling/climbing. If the infant's torso is more perpendicular to the ground or object, this would be cruising.
  - The onset of crawling/climbing is determined by knee/foot movement. Don't look at the arm movements to determine when crawling/climbing begins!
  - Sometimes babies will make use of alternative crawl/climb strategies like bear crawling (on hands and both feet with both knees up off the ground); this counts.
  - We are coding hitching in this pass. Hitching is when baby "crawls" with bum on floor/ground and one knee/foot. When hitching, infants often rest their butt on the knee that is tucked under their body and propel forward by taking steps with the other foot and then dragging the knee+bum afterward. This will likely happen on the objects or just in general (many babies do this) so we will lump it all together as crawling/climbing to reflect all time spent moving in a majority prone position.
  - We are not coding steps but it will still be helpful to count in your head to get precise onsets/offset.
  - Crawling can also occur in place. Similar to a footstep in place, if the knee and foot lifts off the ground and returns to the same position, this counts as part of the crawling/climbing bout and should be coded.
  - Transitions to/from other postures will not be coded. A common transition is from crawling into sitting. The last step that brings baby to sitting position is part of transition and does not count as part of the bout.
  - Sometimes crawl steps occur when baby buries face into mom's torso. This is only crawling when baby is in all-4s posture and taking steps.
  - **We are still not coding knee walking steps. Knee walking is when torso is upright and baby takes knees steps in any direction (looks like walking on the knees).**
  - Crawlers can also pivot. This happens when the knee turns at some angle but does not result in locomotion. Think about pivoting in walking steps where the foot turns but does not result in a full step. Typically we ignore this and do not include if at the start or end of a bout using transitions rules, but this can be relaxed in this study. We just want to know the times when baby is moving.

- Sometimes, infants will slide backwards down some of the slopes. These do not count as crawling/climbing steps. Only self-generated backwards steps would count, where the leg is moving independently from the rest of their body.
- We are still NOT coding belly crawling steps. These are steps in which baby is moving their hands & knees/feet similarly to a typical bout of crawling, but their belly is in contact with the floor (or other support surface if on an elevation) so their limbs are not supporting them from being up off the floor. Commonly referred to as "army crawling".
- **Onset** of a crawling/climbing bout is the first frame when baby moves a knee/foot in any direction. We are watching the knees/feet ONLY!
- Look for when either the knee or foot lifts up and goes in any direction across the floor. This is the first movement in the crawling/climbing cycle and will be used for the onset. If the knee/foot is not visible, use the first frame when the trunk/torso starts to move or sway/twist.
- For sliding steps, the onset is the first frame when the knee/foot begins to slide.
- **Offset** is the frame when the baby takes the last step (with knee/foot) in the crawling/climbing cycle to pause in place (in the same posture) or to transition to a stationary posture (e.g., crawling to sitting). In other words, this is the exact frame when the last knee or foot hits the ground.
- A pause must last at least 0.5 s. If a new crawling/climbing cycle begins within that duration, this is part of the same crawling/climbing bout and should be coded as one.
- For more details on how to handle coding transitions for crawling, see the **Transitions** section below.

- u = cruising
- Code "**u**" when the baby is cruising.
- Cruising occurs when baby uses a stationary base of support to take steps. For us, cruising can only occur on the playground pieces or on mom.
- Cruising occurs with mom when she acts as a base of support. This is only cruising if mom is stationary. If mom (or her arms) is moving along with baby, this is *supported walking*.
- **Onset** of a bout of cruising is the frame when the whole foot lifts up off the ground. A step can also happen if the foot doesn't come off the ground, but the foot has to slide forward, backward or sideways. In the case of sliding steps, the onset is the first frame when foot begins to displace from its starting point.
- Cruising steps can be omnidirectional (forward, backward, sideways) and are steps that move baby through space or steps that do not result in locomotion, like marching in place, jumping, and hopping.
- A good tip for picking the exact frame of a "step" is to watch for baby's toes, as there are usually 1-2 frames where this is a precise indicator of whether or not the foot has lifted off the ground.
- Only capture sliding steps that feel real (e.g., entire foot is displaced by meaningful amount, like the size of the foot). We do not want to capture tiny shifts or pivots.
- **Offset** of a cruising bout is the frame when the baby takes the last step of the sequence to pause in place (in the same posture) or to transition to another posture (e.g., cruising to sitting).
- The pause must last 0.5 s to count. If baby starts another step within the 0.5 s window, keep the next step (or set of steps) in the same bout. If the next steps occur outside this time window, start a new bout of cruising.
- Do not include any movement with foot as part of a transition to another posture (e.g., cruising to sitting). The final step in the bout has to be a real cruising step (i.e., not the last half step or little attempt-step that looks like part of the transition).
- For more details on how to handle coding transitions for cruising, see the **Transitions** section below.

- s = supported walking
- Code "**s**" when the baby is supported walking.
- This code counts supported walking when baby's balance is supported by a moving object or person.

- For us, this can only happen with mom. This occurs when mom holds baby's hands or arms while baby generates upright steps. Importantly, the part of mom (either mom's entire body or her arms) must be moving along with the baby for this to be supported walking. If mom is stationary while baby is taking steps, this is cruising!
- Supported walking occurs when the entire body is displaced in the forward, backward or sideways directions. For us, supported walking occurs in omnidirectional space including steps in place like marching in place, jumping, and hopping.
- **Onset** of a supported walking bout is the frame when the whole foot lifts up off the ground. A step can also happen if the foot doesn't come off the ground, but the foot has to slide forward, backward or sideways. In the case of sliding steps, the onset is the first frame when foot begins to displace from starting point.
- Only capture sliding steps that feel real (e.g., entire foot is displaced by meaningful amount, like the size of the foot). We do not want to capture tiny shifts or pivots.
- A baby takes a "step" by shifting weight from one foot onto the other. If some part of the foot (likely half) makes a side motion almost like you would when drawing with a compass, this is a "pivot" and not a real step. Do not code pivots!
- Sometimes, baby may look like she is about to start walking (e.g., tip-toe walking) and then decide to either initiate the bout of locomotion or not. The onset of such a bout would be when the foot actually lifts up off the ground and not the balancing act part where foot angles forward and then comes back down.
- A good tip for picking the exact frame of a "step" is to watch for baby's toes, as there are usually 1-2 frames where this is a precise indicator of whether or not the foot has lifted off the ground.
- **Offset** of a supported walking bout is the frame when the baby takes the last step of the sequence to pause in place (in the same posture) or to transition to another posture (e.g., walking to sitting).
- The pause must last 0.5 s to count. If baby starts another supported walking step within the 0.5 s window, keep the next step (or set of steps) in the same bout as the previous. If the next steps occur outside this time window, make this a new bout of walking.
- Do not include any movement with foot as part of a transition to another posture (e.g., supported walking to sitting). The final step in the bout has to be a real supported walking step (i.e., not the last half step or little attempt-step that looks like part of the transition).
- For more details on how to handle coding transitions for supported walking, see the **Transitions** section below.

- w = walking
- Code "**w**" when the baby walking independently.
- For pre-walkers, independent steps are less likely to happen, but may happen so code if it does.
- **Criteria for walk onset for walker = 10 ft/3m.**
- For walkers, all upright locomotion on the floor is considered walking, regardless of whether baby is in contact with any object or person.
- Rationale is that since baby can walk, baby is capable of supporting their own balance and we cannot infer if the surface is being used for support.
- Walking occurs when the entire body is displaced in the forward, backward or sideways directions. For us, walking occurs in omnidirectional space including steps in place like marching in place, jumping, and hopping.
- **Onset** of a walking bout is the frame when the whole foot lifts up off the ground. A step can also happen if the foot doesn't come off the ground, but the foot has to slide forward, backward or sideways. In the case of sliding steps, the onset is the first frame when foot begins to displace from starting point.
- Only capture sliding steps that feel real (e.g., entire foot is displaced by meaningful amount, like the size of the foot). We do not want to capture tiny shifts or pivots (e.g. smidgeons).

- A baby takes a "step" by shifting weight from one foot onto the other. If some part of the foot (likely half) makes a side motion almost like you would when drawing with a compass, this is a "pivot" and not a real step. Do not code pivots!
- Sometimes, baby may look like they are about to start walking (e.g., tip-toe walking) and then decide to either initiate the bout of locomotion or not. The onset of such a bout would be when the foot actually lifts up off the ground and not the balancing act part where foot angles forward and then comes back down.
- A good tip for picking the exact frame of a "step" is to watch for baby's toes, as there are usually 1-2 frames where this is a precise indicator of whether or not the foot has lifted off the ground.
- **Offset** of a walking bout is the frame when the baby takes the last step of the sequence to pause in place (in the same posture) or to transition to another posture (e.g., walking to sitting).
- The pause must last 0.5 s to count. If baby starts another walking step within the 0.5 s window, keep the next step (or set of steps) in the same bout as the previous. If the next steps occur outside this time window, make this a new bout of walking.
- Do not include any movement with foot as part of a transition to another posture (e.g., walking to sitting). The final step in the bout has to be a real walking step (i.e., not the last half step or little attempt-step that looks like part of the transition).
- **Coding CRUISING & SUPP WALKING for walkers**: Cruising and supported walking are only coded when walking infants are on an elevation (e.g., on top of one of our play objects). Elevations are given the distinction for these supported upright behaviors because it can be assumed that infants are using support when they are not on the ground. These are the only instances in walker sessions where supported walking and cruising are coded. Cruising on our pieces will be almost impossible but might happen if a cluster is against the wall and thus the wall can be used for support.

- f = falls
- Code "**f**" if the baby loses control over their body (i.e., a loss of balance) and their body hits the floor.
- All falls count. They can happen while upright, on/off elevations, while stationary, or while moving. Falls can happen while the mom is holding the baby's hand or while the baby is holding onto some support surface.
- A loss of balance must occur before any of the body parts hit the ground. The baby must be out of their own control. Sometimes babies will actively let themselves lose control (e.g., plopping down into a sit). This is not a loss of balance but is a loss of control and should count as a fall.
- **Onset** is frame when baby first begins to lose balance.
- **Offset** is when baby's body (see below) hits the floor.
- *From an upright or squatting position:* a loss of balance results in the baby's knees, head, or bum hitting the ground.
- If the downward movement is gradual (e.g., lowering themselves), it is **not** a fall.
- *From a crawling position:* a loss of balance results in the face, head, chest, or side of torso hitting the ground.
- *From a sitting position:* a loss of balance results in the head, chest, side of torso, or back hitting the ground.
- If the downward movement is gradual (e.g., lowering themselves), it is **not** a fall.
- Falls also count even if the parent catches the baby after the baby loses balance, effectively supporting the baby's entire weight. In this scenario, the baby would have fallen if not for parent rescue (i.e., the body part would have hit the ground).
- Parents must catch after the baby has begun to lose balance. If the parent was already supporting the baby's entire weight before the loss of balance, this is not a fall because technically the baby will not have lost control over her body.
- Even in cases where the infant catches themselves after they lose balance, consider this a fall because we want to account for all instances in which the infant loses control over their body.

- In the case that two falls happen in quick succession (i.e., baby falls onto butt and then falls onto their side), code as one fall such that the onset is the frame that the baby starts to lose balance and the offset is the moment that the last body part hits the floor and the baby stops moving towards the ground.

- h = held
- Code "**h**" when the baby is being held, and/or the baby's body is fully restricted by the mother. In other words, the baby's body/torso is constrained entirely by the mother's body. In the case of a hold up in the air, the baby is fully constrained in mom's arms. The baby can also be constrained by mom's body if the baby is fully sitting in her lap.
- If baby is sitting in caregiver’s lap but her feet or foot are touching the floor, this does not count as held. If any body part is in contact with the floor, then it is not a bout of held. The entire baby’s body should be supported by the caregiver. The same rule applies for when baby is leaning against caregiver.
- The point here is that baby cannot move (e.g., no opportunities for locomotion), as their body is being constrained **or** supported entirely by mom.
- During a hold, the parent can be moving (carrying) or stationary (in arms or in lap).
- If infant is using mom the same way as they would a chair (i.e., foot/feet on the ground and mom’s arms are not around baby), this is not held.
- *Onset* of hold depends on the infant’s posture.
- From an <u>upright position</u>: The last frame where the second foot lifts off the current surface and either onto mom’s lap/body or up in the air in mom’s arms.
- From a <u>crawling position</u>: The last frame where the second knee/foot (depending on crawling style) lifts off of the current surface and either onto mom’s lap/body or up in the air in mom’s arms.
- From a <u>sitting position</u>: the last frame where the bum lifts off the current surface and either onto mom’s lap/body or up in the air in mom’s arms.
- *Offset* of hold is when the **baby starts supporting their own weight in any posture**. However, the frame of offset depends on the infant’s final position.
- <u>Hold ending with infant upright on the floor:</u> offset is the first frame where both feet touch the ground.
- <u>Hold ending with infant sitting on the floor or in furniture:</u> offset is the first frame where infant’s bum touches the ground or furniture.
- <u>Hold ending with infant sitting on caregiver’s lap</u>: offset is the first frame where infant’s bum is touching the caregiver’s lap and at least one foot touches the ground.
- <u>Hold ending with infant in crawling position</u>: the first frame where both knees or feet touch the ground.
- Steps that come out of a hold are not considered a bout of locomotion but, instead, are transition.
- In certain instances, caregivers will restrict movement in ways that are not holding as described above or being placed in restrictive furniture as described below.
- One case is called a “drag held,” such that the parent pulls the baby by the arms or legs across the floor and displaces her through space. This is considered held because baby cannot move during that time since parent is controlling body.
- This is only true when mom moved baby through space. If she spins the baby or pivots the baby, such that baby doesn’t actually move through space but only in a circle (e.g., like the bum was the midpoint on a compass and spun around), this is not a drag held.
- Another instance is if parent is holding on to baby’s clothing in a manner that is preventing baby from moving in any direction. For example, if baby is trying to move but cannot because parent is holding on to her clothing/tugging at it preventing baby from moving.

  To code “drag held,” set the onset to the frame that parent begins to tug or pull baby and offset to the frame

when baby is not being moved anymore.

BABY TRAVEL <squares>

General Orientation

- This code captures the breadth of exploration that infants engage in during bouts of movement. In other words, it capture travel.
- The goal is to count the number of square crossings per bout to get a sense of how far babies go and to use this number calculate a rough approximation of distance traveled.
- A similar coding system was used in Clearfield (2011) in which she did basically the exact same coding (we will cite her for this).
- **Text from the paper: "This variable captured infants' movement about the space by recording the number of squares crossed (the infant moved out of one square and into another). Crossing a square was defined as the infant's trunk crossing the line. In other words, sitting in one square and reaching out to the next square would not count as 'crossing', but moving forwards (or backwards) in a crawling position would count as the infants' trunk crossed the line. Each square was .3 m x .3 m, so this is a loose measure of amount of distance traveled."**
- Our squares are 2 ft. x 2 ft. (twice the size) so we can multiple the number of square crossings per bout by a factor of 2 to derive distance.
- A square crossing means that the baby moves through the entire square (or they "cross" is), which translates to them moving about 2 ft.
- In order to cross a square, the infant's body has to cross the line of each square. While crawling/climbing, this means at least half of the baby's trunk. While walking, the rule is the same but from an upright vantage.
- If half or more than half of the baby's body is already in a square at the onset of the bout of movement, then they cannot cross into that square since they are already in it. In these cases, the first square crossing is when they move into the next square.
- If the floor is occluded by the objects from the playset, we will have to infer if babies cross a square by using the object as an anchor. Almost all of the objects are about the size of one square (in width, length, etc.) so we will be able to use that as a guide.
- If baby is moving right on the line of two squares, count it as one square crossing because the distance they travel is the same.
- When moving through a diagonal, credit as if the baby was moving through 1 square in the same way as if they were crossing a square directly through. A diagonal means that the baby's body is going through multiple squares at the same time based on body position, but they are really only crossing 1 square so count as 1.
- If baby goes through on a diagonal but body goes mostly into two squares, then they get credit for 2. But if perfectly on a diagonal (see image), then they get credit for 1 crossing.
- Baby only gets 2 squares for diagonals if body goes significantly (i.e., most of body) into body squares; otherwise, all diagonals are 1.
- Infants' bodies traverse the squares in different ways based on their locomotor posture (i.e., the trunk fills the square when moving in prone and feet fill the square when moving upright). Because of this, babies cross squares in different ways, such that crawling bouts must cross into a new square and upright bouts must traverse the entirety of the square.
- For an infant to cross a square while crawling, they must go through the line of a new square (i.e., cross into another square).
- For an infant to cross a square while upright (cruising, supported walking, walking), the infant must traverse the entire square to count. That is, if an upright bout starts at the far edge of a square and ends at the parallel edge (i.e., baby travels length of square), then this counts as a crossing and **should be coded as 1 and not 0**.
- For crawling bouts in which basically the same thing happens (i.e., baby starts and stays in same square), this is **coded as 0 and not 1**, since baby never crosses or travels through a square as mentioned above.

Operational Definitions

- **<squares>**
  - Code the number of square crossings that occur during the bout.
  - 0 = baby stays in the same square
  - 1 = baby crosses one square
  - 10 = baby crosses ten squares
  - 100 = baby crosses one hundred squares

BABY-MOM PROXIMITY <proximity> <mombaby>

General Orientation

- This code captures the general level of physical closeness between infants and mothers while infants are moving (i.e., during bouts of movement).
- Physical proximity is divided into two levels: (1) within arm's reach and (2) beyond arm's reach.
- We will go by the mom's wingspan to determine proximity since she has bigger arms.
- We are coding whether the baby is proximal to mom (p) during the entire bout of movement, distal to mom (d) during the entire bout of movement, or if there is a transition in proximity (e.g., proximal to distal = pd; distal to proximal = dp) during the bout of movement.
- We will also note who is responsible for changes in proximity during bouts when they occur, mom (m) or baby (b). This mom-baby initiator code will tell us who initiated the transition from being either within arm's reach to out of arm's reach OR out of arm's reach to within arm's reach. This could either be the infant or a social partner.

Operational Definitions

- <proximity>
  - Code "**p**" if baby is within arm's reach of mom for the entire bout. Proximal means that mom can reach out and touch baby without moving or needing to change postures.
  - Code "**d**" if baby is out of arm's reach of mom for the entire bout. Proximal means that mom can reach out and touch baby without moving or needing to change postures.
  - Code "**pd**" if there is a transition from proximal (within arm's reach) to distal (out of arm's reach) during the bout.
  - Code "**dp**" if there is a transition from distal (out of arm's reach) to proximal (within arm's reach) during the bout.
- <mombaby>
  - Code "**m**" if mom was responsible for the proximity transition. This can only be coded if "pd" or "dp" was coded in the previous argument. Otherwise, code as "n".
  - Code "**b**" if baby was responsible for the proximity transition. This can only be coded if "pd" or "dp" was coded in the previous argument. Otherwise, code as "n".
  - Code "**n**" if there was no proximity transition.

BABY BLOCKS ENGAGEMENT <objects>

General Orientation

- This code captures the amount of time that infants are engaged with the blocks from our play set. Specifically, we are interested in capturing a measure of interaction with the blocks to get a sense of how much they play with them vs. just roam around the room and do other things.

- The code is a continuous duration pass, which means that we are inserting cells to capture times when infants are “on” blocks.
- The grey space in this case refers to time when infants are “off” blocks.
- We will be using an adapted version of the Karasik et al. (2011) codes which were already adapted for WalkTalk.
- The break rules for blocks contact are still 3 seconds, which means that blocks contact cells only get split if the infant is off an block for 3 or more seconds. If the break is < 3 seconds, the cell keeps going.
- The main difference for us (compared to previous codes), is that onsets and offsets are based on the first body part and last body part in contact with any block from the set, not just the hands.
- In other words, an **onset** can occur because the infant touches a block with their hands or it can occur if their leg, thigh, stomach, bottom, etc. comes in contact with a block. Our goal is to start the cell as soon as they is ANY contact between baby and one of the blocks.
- Similarly the **offset** of a blocks cell occurs when the final body part breaks contact with any of the blocks followed by a minimum 3-second break before the next contact.
- The blocks of interest are ONLY the blocks from our set, as there will be no other objects in the room.
- We will ask mothers to remove their infants shoes/socks before play but it is possible that some other object may appear (a pacifier, napkin from mom’s pocket, who knows). Ignore these objects if you see them!
- Fleeting blocks contacts (lasting < 1 s) that are NOT followed by another contact should not be coded. If there is a fleeting touch that is then followed by another touch within 3 s then, start the blocks bout at the first touch.

Operational Definitions

- <blocks>
  - Code “**b**” when the infant is in contact with a block.

MOM UTTERANCE <source>

General Orientation

- The goal of this pass is to identify every infant-directed utterance.
- We are using the coding system already developed as part of the BabyReach project which was based in part, on the PLAY project and Emily Roemer’s dissertation.

Operational Definitions

- <source>
  - This argument captures who is speaking to the infant.
  - This will always be the mother since we are not recruiting any other caregivers for this study.
  - m = mother
  - Code “**m**” for mother as the source of the utterance.

What is an Utterance?

- An utterance is a unit of speech separated by grammatical closure, intonation contour, intake of breath, or prolonged pausing, which can function as a natural “break” during speech.
- Note: Some utterances may contain complete sentences or phrases (e.g., that’s a blue truck), and others incomplete ones (e.g., that’s a……). As a general rule to aid segmenting when you are unsure based on other cues, prolonged pauses are those over 500ms.
- Rules about segmenting utterances are critical to ensure that the data generated from coding is consistent across coders in the number of utterances in a session.
- Coders who fail to segment utterances at points of grammatical closure, for example by running multiple sentences/phrases together (e.g., The ball. The blue ball. Big ball. In a single utterance line), may bias analyses toward more complex utterances. Conversely, if coders over-segment, for example by tagging each word as a

new ‘utterance’, they may bias analyses towards less complex utterances. Tagging at the utterance level strikes a useful balance.

- Examples: “Here you go. That’s a shoe.” should be marked as 2 different utterances. But “shoe, shoe, shoe” without any pauses would be a single utterance.
- If you would write the utterance as two distinct phrases separated by a comma, it should likely be broken into two utterances.
- Utterances that are elongated (e.g., prosody changes throughout the utterance) but are a single thought should be kept together.
- Each “segmented” single utterance is coded as an event/point cell and separated by gray representing time when no utterance is spoken.
- Only the onset of the utterance is tagged. We do not code the offset for the event. Thus, a single time during the utterance is time coded.

How to Code

- Tagging and editing utterances is a process done in two passes through a small section of video. The first part is **tagging utterances**. This is done for about 3-4 minutes, or until a good break in activity is reached. Mother speech will be tagged.
- The second part is **editing utterances**. This involves looping back over the same portion of video to clean up cell onsets and delete cells containing anything other than infant directed language.
- Watch the following videos for an introduction to using Datavyu. These videos are workshops for ‘transcribing,’ which is a process slightly different than tagging and editing utterances. However, these videos are good at familiarizing coders with the appropriate keys to use on the numpad and understanding how to switch in and out of different modes.
- Transcription workshop (watch sections 20-30 min and 40-55 min):
- *https://nyu.databrary.org/volume/686/slot/50826/-?asset=288570*
- Example of 10 minutes of an expert transcribing:
- https://nyu.databrary.org/volume/686/slot/45710/-?asset=288269

Part 1: Tagging Utterances

- This is the first part of a 2-part iterative pass.
- The first thing you will do is tag utterances for small sections of the video at a time (roughly 3-4 minutes, or until a good break in activity is reached).
- **Goal:** Tag all utterances and code <source> of the utterance.
- Turn on Quick Keys mode by hitting Shift-Cmnd-K.
- You will see <QUICK KEY MODE> in the spreadsheet window header.
- Quick Keys mode will enable a function that every time an alphanumeric key is pressed, a new point cell is inserted in your selected column.
- Click on the *momutterance* column name so that it is highlighted blue. This will allow you to insert cells in this column.
- The alphanumeric key you press will be inserted as the code of the argument (<source>) in the utterance column.
- Quick Keys mode will be used to insert the source of the utterance: “**m**” for mother.
- Place your left index finger on the appropriate key for the source of the utterance.
- Use your right hand to start and stop playback on the numpad.
- Play the video at 1/2 or 1/4 speed (depending on how much speech is occurring during the segment you are tagging; more speech may require 1/4 speed for tagging utterances) by pressing PLAY [8] then SHUTTLE BACK [4].

- Press the appropriate source key every time the caregiver has an utterance while you play the video.
- Insert cells as soon as you hear something. Be as alert and attentive as possible.
- **Tip:** If you think you hear an utterance, tag it. It's much better to be fast and insert extra cells, rather than judge yourself and have to go back later to fix the time or insert a cell for an utterance you missed.
- You can easily delete cells or fix the source code using shortcut keys during the actual editing process.
- Set onsets to be as close to the start of the utterance as you can possibly get. Optimize your attention in order to tag as soon as you hear something (reminder: offsets are not coded).
- **Tip:** The best strategy is to have an unbroken playback session of 3-4 mins where you just tag utterances without stopping. Stop playback once 3-4 mins have elapsed or you hit a good breaking point in an activity (e.g., caregiver pauses to get a new toy). Try to stop tagging utterances as soon as you tag a new utterance, rather than playing further into the silence of the video. This will provide an exact marker for where you left off when preparing to tag the next pass, rather than potentially re-playing a same part of video over again. Remember or write down where you left off.

Part 2: Editing Utterances

- This is the second part of a 2-part iterative pass.
- This part should be completed after a set of utterances have already been tagged.
- **Goal:** To edit utterances by cleaning up cell onsets and deleting cells.
- Turn off Quick Keys (Shift-Cmnd-K).
- Run the **AddTime-Identification-MomUtterance.rb** script. This will add 500 ms to the offset of each previously created point cell, which will help in highlighting for the next step.
- To run the script, open your DV file in Datavyu and click: "Script", then click "Run Script". You need to select the file "AddTime-Identification-MomUtterance.rb".
- Set "Jump back by" on the Controller to 5 seconds.
- Scroll up to the first cell from the most recent utterance tagging done. Click on that cell. Find the onset of that first cell (+ key) and then JUMP-BACK-BY 5 s (- key).
- Turn on Highlight and Focus Mode by hitting Shift-Cmnd-F.
- This will highlight each cell (green is the current cell, red cells have past, and white cells are upcoming) as you loop back through the 3-4 mins of utterance you just tagged.
- Press the PLAY key [#8] to play the video at 1x speed.
- Listen to each utterance within the context of the ongoing stream of speech.
- JUMP-BACK and re-listen if you are unsure of the content of the utterance.
- At minimum, the onset of the utterance should occur during the utterance. Do not spend too much time adjusting utterance onset times to be exact. Rather, make sure they are occurring within the utterance and optimally close to the beginning (never at the end!). If you need to change the onset of an utterance, select the correct cell and hit the #7 key to set the onset and offset to the correct time.
- If you get lost in the utterances, JUMP BACK 2-3 cells (by arrowing or jump back key) until you find where you are confident you understand where you are. It's much better to use the keyboard to navigate and loop back (jump back or arrow up or down) rather than using the mouse or scrolling. If you use the mouse, you will lose time. If you jump around, you will get lost.
- If you find a cell for an utterance that was tagged by mistake (you thought there was an utterance but there wasn't) leave a comment at the same onset telling you to delete that cell. JUMP-BACK-BY 5 s before the cell you plan to delete and confirm there was no utterance and that the next utterance is tagged at the correct time. Then delete that cell. Use arrow keys to select the correct cell.
- Words during singing should be tagged. Make a comment or transcribe in the comments if unsure.
- If you find a cell for an utterance in which the caregiver makes a vegetative noise, laughs, sneezes, hums, whistles, sighs, or gasps, then delete that cell. JUMP-BACK-BY 5 s before the cell you deleted and confirm that

it was not in fact speech or a purposeful play sound. Then, delete it. If a none-speech sound leads into speech within the same utterance, only tag the speech.

- Tag all interjections that are purposeful, pronounced, and infant directed (i.e., “uh oh”, “uh huh”, “oh!”, “ouch”, “oops”). Lean on the side of conservative coding. Be careful to make sure the interjection is actually infant directed as opposed to just being a general expression from the caregiver.
- Tag all play sound effects, animal noises, and onomatopoeias that are intentional, infant directed, and imitating the sound of something else. These sounds must be conveying meaning to the child. This includes transcribable words (e.g., “roar”, “quack”, “boo”, “honk”) and sounds that do not have a clear spelling (e.g., a rocket taking off, the growl of a tiger, imitating the baby’s vocalization). Adult babble must be clearly decipherable imitations of the baby that consist of consonant-vowel pairs (‘gagagaga’, ‘ayayaya’).
- All lip-smacking, tongue-clicking, and other non-voiced sounds should not be tagged. Unless the utterance is clearly imitating play (e.g., smacking lips after pretend eating/drinking), do not tag the utterance.
- There are a few instances when vocalizations, interjections, and sound effects are ambiguous. Lean on the side of conservative tagging. If the caregiver’s sound effect is directly corresponding to and imitating the sound of something else in a play activity (i.e., a toy or baby vocalization), tag the utterance. In all other instances, if you cannot clearly transcribe what the caregiver is saying, do not tag it.
- If speech is unintelligible or hard to decipher, play through the utterance 3-4 times using JUMP-BACK-BY 5 s (- key). Transcribe using quotations in the comments to the best of your ability if you believe the utterance contains infant-directed speech.
- If you missed tagging an utterance in the first part, find the time of the utterance onset while you are editing. Hit [=] to set the onset-offset as a point cell. Mark the <source> of the utterance.
- Turn off Highlight and Focus Mode (SHIFT-CMND-F).
- Save the file with CMND-S.
- Now turn on Quick Keys (SHIFT-CMND-K), find [+] the onset of the last cell edited, JUMP BACK BY 5 s, and revert back to the strategy for tagging utterances.
- Repeat until all utterances in the video are tagged and edited.
- After ALL utterances are tagged and edited, make all utterances (and any associated comments) point cells by running a script called “**SubtractTime-Identification-MomUtterance.rb**”. This will change all offsets back to matching the onset.
- To run the script, open your DV file in Datavyu and click: “Script”, then click “Run Script”. Then you need to select the file “SubtractTime-Identification-MomUtterance.rb”.

MOM LANGUAGE <motionverb> <actionspecified>

<u>**General Orientation**</u>

- The goal of this pass is to identify all times that caregiver utterances contained particular types of language.
- In our case, we are most interested in identifying utterances that include whole-body, motion verbs (e.g., go, get, come, crawl, climb, walk, etc.). This category of verbs is adapted from MomComm and Kelsey West’s 2022 Developmental Psych paper.
- We will also note if the verb-based utterance specifies a particular motor action with one of the objects (e.g., go across the bridge, come down the slope, are you going up the stairs?)
- Each utterance will be categorized as containing a motion verb in one argument and further as an action specifier in a second argument.
- **Notes and Exceptions:**
- Whole sentences are occasionally broken into two utterances because of a prolonged pause (>500 ms) in the speech. If the sentence contains a motion verb, only code the first utterance for the meaningful speech and action specified. The second utterance should get no credit for speech. We want to avoid double crediting utterances that are linked by the same sentence.

- When coding an unintelligible utterance, ‘u’ must be coded across both arguments.

<u>Operational Definitions</u>

- <motionverb>
    - This argument captures if a whole-body, motion verb is said by the caregiver to the baby.
    - A whole-body, motion verb is an action verb that refers to whole-body actions—movements that require the use of the entire body (e.g., crawling, climbing, walking, etc.).
    - *Examples: go, get, come, crawl, climb, walk*
    - The motion verb can be in past, present, or future tense.
    - *Example: walk, walking, walked*
    - To find examples of whole-body, motion verbs, open the PlayRoom glossary on the ICL Google Drive.
    - Update and add to this glossary as you code with any specific verbs that would fall under this category.
    - y = yes
    - Code “**y**” if the utterance contains a motion verb.
    - n = no
    - Code “**n**” if the utterance does not contain a motion verb.
    - u = unintelligible
    - Code “**u**” if an utterance directed towards the infant can be heard, but you cannot make out or understand what was spoken. This is a last resort code. It should only be used after the utterance is listened to at least 3 times and is indecipherable.
- <actionspecified>
    - This argument captures if a whole-body, motion verb utterance specifies a particular action with one of the objects in the room.
    - This means that an object word or pronoun (for one of the objects in the room) is needed for this category to be coded.
    - It is possible that mothers will use a pronoun or refer to the object in some way without using a label (e.g., “Can you get on **<u>it</u>**?” “Are you crossing the **<u>big one</u>**?”. If we can reliably determine that she is directing an action with a particular object, then this still counts.
    - An action specified utterance means that mom tells the baby how to act on one of the objects. The idea is not only to note if mom uses a motion verb (the previous argument) but to also see if she is using the verb utterance to shape how the infant interacts with the playroom objects.
    - *Examples: “Climb up the stairs!”, “Are you going down the slide?”, “Can you jump on that?”*
    - To find examples of whole-body, motion verbs with specified actions open the PlayRoom glossary on the ICL Google Drive.
    - Update and add to this glossary as you code with any specific verbs that would fall under this category.
    - y = yes
    - Code “**y**” if the utterance contains a motion verb with a specified action.
    - n = no
    - Code “**n**” if the utterance contains a motion verb with a specified action.
    - u = unintelligible
    - Code “**u**” if an utterance directed towards the infant can be heard, but you cannot make out or understand what was spoken. This is a last resort code. It should only be used after the utterance is listened to at least 3 times and is indecipherable.

MOM GESTURE <gesture>

<u>General Orientation</u>

- This pass takes an integrated approach to characterizing caregivers' gesture input by identifying each gesture as a point event.
- We want to know what mothers are doing with their hands during play with their babies.
- Gestures must be infant directed.
- This code scores gesture type.
- There are 6 mutually exclusive gesture categories. This means that each category has a particular set of definitions and captures one kind of behavior that has specific intent (as we've defined it).
- **Note:** We are only coding inside of "m" and "s" cells in TASK.
- **Note:** Use audio when coding for ambiguous gestures.

Operational Definitions

- **<gesture>**

  m = movement gesture
  - Code "**m**" if mom uses a movement gesture.
  - A movement gesture does not require an object to be present; an object most likely will not be present as it is a hand movement gesture.
  - These are gestures that convey location to promote baby to move.
  - This includes hand motions that direct infants to approach a particular destination and/or move through space.
  - A movement gesture requires space between the infant and caregiver. Prior to bout, the caregiver cannot be touching the infant if coding as movement gesture, a gesture space must be present.
  - When coding a movement gesture, wait to code the point cell until the movement gesture has fully formed. Do not code at initial sign of gesture. Wait until the arms or hands are fully extended and/or outstretched.
  - This might include:
  - Stretch out arms and then back in as a "come" signal
  - Mother moves finger/palm towards direction of herself to beckon baby
  - Tracing path in air with hand/arm to show baby where to go
  - Patting object to entice baby to move, akin to mom saying something like "come here"
  - Patting ground next to body
  - Pointing to a destination while concurrently using movement language (i.e., "Go right there")
  - Stretch out arms as a "hug" or "come" signal when there is distance between caregiver and baby

  p = point gesture
  - Code "**p**" if mom uses a pointing gesture.
  - This gesture category indicates the occurrence of an event or the existence of an object.
  - Pointing gestures express communicative intent by presenting objects for another's attention.
  - Code this when mom points by extending a finger, the index, toward a specific person, object, location, or event.
  - This must be a direct point to a fixed object or location and not the hand tracing a path, as this type of gesture would be coded as a *move* gesture (see above).
  - This can be an open- or close-handed point.
  - When coding a pointing gesture, wait to code the point cell until the pointing gesture has fully formed. Do not code at initial sign of gesture. Wait until the finger is fully extended.

  c = conventional gesture
  - Code "**c**" if mom uses a conventional gesture.
  - A conventional gesture does not require an object to be present; an object most likely will not be present as it is a hand movement/gesture.
  - Conventional gestures are culturally defined hand movements that have a particular meaning for that culture/group.

- Routine hand gesture games are not to be coded as conventional gestures. This includes but is not limited to Peek-a-boo and Patty Cake.
- Snapping fingers and kissing noises are also not considered conventional gesture.
- When coding a conventional gesture, wait to code the point cell until the conventional gesture/movement has fully formed. Do not code at initial sign of gesture. Wait until the gesture is overtly occurring.
- If a gesture is truly conventional, you should be able to understand what it means even if it is shown to you in isolation (w/o context).
- This might include:
- Waving, Clapping, Shaking the head, no, Nodding the head, yes
- Turning and raising the palms upward for all gone, Palm out to signal "stop"
- Blowing kisses, Thumbs up or down, "Talking on the phone" hand motion (hand to face/ear)

MOM POSTURE <posture>

General Orientation

This code captures mom's posture and whether she is moving during bouts of infant movement.

The goal is to know how mothers are positioning their bodies and if they are moving simultaneously with their infants as infants are exploring both playrooms.

This pass will be coded based on the BabyMove pass. A script will inset the column with all of the movement cells and your task is to code mother's posture and whether they are moving using categorical codes.

Posture using two mutually exclusive categories (based on Franchak et al., 2018) to determine if mothers are: (1) upright (e.g., standing, walking) or (2) down (e.g., sitting, squatting, kneeling, on hands-and-knees, lying down) during each bout of infant movement.

Moving will be coded as a y/n code.

If mother's switch postures during the bout, code the majority postures (> 50%). If it is exactly 50/50, go with what happened in the first half.

Operational Definitions

- <posture>
  - Code "**u**" if the mother is <u>upright</u> (i.e., standing, walking) during the bout of infant movement.
  - Code "**d**" if the mother is <u>down</u> (i.e., sitting, squatting, kneeling, on hands-and-knees, lying down) during the bout of infant movement.

MOM PHYSICAL <reposition>

General Orientation

- This code captures the number of times that mothers reposition infants' bodies during play.
- The idea here is to note how often mom physically repositions the infant, either by picking them up and moving them, turning them around, putting them on a new piece, etc.
- We get this code almost for free from the *babymove* pass because all identified holds already count as repositions.
- The job for coders in this pass will be to: (1) watch the play tasks in real time to make sure that the already identified repositions (cells will be copied from holds, set at point cells, and renamed) are actually repositions and (2) catch any other repositions that may have been missed or not coded as holds (e.g., turning the baby but not displacing them or picking them up).

Operational Definitions

- <reposition>
  - Code "**r**" if there is a reposition.

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