Shaping the communicative landscape: The dynamics of infant locomotion and caregiver communication during everyday interactions

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The acquisition of new motor skills expands infants' opportunities for interactions with objects and people in everyday life. Recently, researchers have turned their attention to understanding these processes as infants transition from crawling to walking, documenting changes in infants' locomotor skills and in their engagements with caregivers. Here, we asked how the acquisition of walking shapes caregiver language and gesture input when infants move. Thirty infants were videotaped in the home during everyday activities with their caregivers for approximately 45 minutes. Caregivers were asked to continue activities of their daily routines. We centered each infant's observational window around the onset of walking and coded the 2-month window around that midpoint. For each session, we identified all bouts of crawling and walking and also coded caregiver communication in the window spanning 5 s before infants initiated a bout of locomotion until the end of the bout. Caregiver language and gesture were identified and categorized at the utterance-level into language containing *action verbs* that directly encouraged movement (e.g., go, get) or *object talk* that provided referential information about objects ('That's your green frog'); and gesture as *movement gestures* that directly requested movement (e.g., beckoning with outstretched arms) or *show gestures* in which caregivers held up an object and directed it in their infants' field of view. Results showed that walking bouts were consistently and robustly more likely to be paired with language input than their crawl bouts, two to three times as likely to co-occur with action verbs, and three times as likely to co-occur with object talk.

Similarly, relative to crawl bouts, bouts of walking were nearly twice as likely to overlap with gesture input than their crawl bouts, more likely to co-occur with movement gestures, and more likely to co-occur with show gestures. These results indicate that the ability to walk co-occurs in time with striking changes in the language and gesture input provided by caregivers. Moreover, these findings suggest a developmental cascade between infant locomotion and caregiver communication.

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Preface

I have so many people to thank. First, I want to thank my mentor, Jana Iverson, for her unwavering and phenomenal support, and steadfast ability to listen to me talk about this project over the years. We've had more conversations about these ideas and these data than I could ever count so thank you. I must thank my extremely supportive fellow graduate students (past and present) Kelsey West, Emily Roemer, and Samantha Plate for being solid rocks during the many ups and downs of this project.

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I thank my mother and brother, Lana and Daniel Schneider, for their unquestionable and unconditional love and support. They are now total pros at talking about infancy research if it ever comes up at the next dinner party or family event!

Finally, I thank my father. I know he would have loved this.

1.0 Introduction

The acquisition of new motor skills expands infants' opportunities for social interactions with the objects and people in everyday life. Across the first year, infants develop the locomotor tools necessary for effective exploration; they crawl and walk to objects of interest and share them with caregivers to initiate social interactions (Karasik, Tamis-LeMonda, & Adolph, 2011; Karasik, Tamis-LeMonda, & Adolph, 2014). Recently, researchers have turned their attention to understanding these processes as infants transition from crawling to walking, documenting changes in infants' motor skills and in their engagements with caregivers.

Transitions to new skills in infancy provide a unique opportunity to ask about the specificity with which the new skill shapes infants' broader experiences of the world—how the acquisition of walking, for example, might shape possibilities for infants' own actions and in turn, the communicative input caregivers provide about the people, places, and things of everyday life. Thus, the overall goal of this study was to examine the potential of walking as a reorganizer of the infant-caregiver dyad, shaping caregiver language and gesture input based on infant action.

1.1 The benefits of walking for (social) exploration

Why walking? The literature on the transition from crawling to walking provides especially convincing evidence for its utility in enhancing exploration in the service of social interaction. The onset of walking appears to be particularly important due to the gains with which it is associated (see Adolph & Tamis-LeMonda, 2014, for a review). When infants walk, they spend more time in motion and travel faster and farther than when they crawl (Adolph et al., 2012). In their upright posture, infants' view of the world is also expanded. Exploration with eyes at a higher vantage gives infants the ability to spot distal caregivers and objects, a potentially important precursor for initiation of social interactions (Kretch, Franchak, & Adolph, 2014). Indeed, infants look more at caregivers faces when they are upright compared to prone (Franchak, Kretch, & Adolph, 2018). Moreover, the onset and accumulation of walking experience is associated with language development; after infants give up crawling, their receptive and expressive language increases (Walle & Campos, 2014; West, Leezenbaum, Northrup & Iverson, 2019).

Research has also linked the ability to walk with how infants access and share objects, and how they interact with their caregivers. Home observations of infants across the transition from crawling to walking show that walking infants not only access distal objects more frequently, but engage in more instances of object carrying, and share objects more often by bringing them to their mothers and initiating social interactions (Karasik et al., 2011; Karasik, Adolph, Tamis-LeMonda, & Zuckerman, 2012). Moreover, laboratory studies find that walkers initiate and spend more time engaged in complex social interactions with caregivers, drawing their attention to objects and producing more adult-directed vocalizations and gestures during play (Clearfield, Osborne, & Mullen, 2008; Clearfield, 2011).

Overall, this work suggests that the ability to walk provides unique opportunities that bolster social exploration. Infants learn to walk in everyday social worlds filled with the caregivers, objects, and stuff of real life. The literature to date has mostly focused on how the transition to walking relates to concurrent expansion in infants' other abilities (e.g., Adolph & Tamis-LeMonda, 2014), but to a lesser extent, on how changes in infants' motor skills relate to specific changes in caregiver behavior. Walking (and all its associated gains) exerts cascading effects on infants' own abilities, but does it have similar effects on the ways in which caregivers interact with their infants? How does the transition from crawling to walking relate to concurrent language and gesture input from caregivers? Are there differences in how caregivers communicate with their infants in real time when they crawl and walk during everyday interactions?

1.2 Independent locomotion and changes in the infant-caregiver dyad

Researchers have been interested in the notion of a "reorganization" in the infant-caregiver dyad around the onset of independent locomotion for some time (see Campos et al., 2000, for a review). Early studies asked about how the switch to mobility—crawling and walking—in infancy relate to how caregivers think, see, feel, and interact with their infants (West & Rheingold, 1978; Green, Gustafson, & West, 1980; Gustafson, 1984; Campos, Kermoian, & Zumbahlen, 1992; Biringen, Emde, Campos, & Appelbaum, 1995, 2008). Though addressed with different methods, in different cohorts, and with different questions, the current stance in the literature tells a similar story—infants' ability to move changes the way they interact with caregivers and, in turn, the way their caregivers interact with them.

Crawling, most infants' first success at independent mobility, appears to be an initial point of reorganization. Evidence that the onset of crawling instigates changes in mothers' perceptions of and emotional expressions to their infants comes from an interview-based study of 62 mothers of crawlers and pre-crawlers (Campos et al., 1992). Relative to pre-crawlers, crawling infants increased their attention to distal objects and people, performed more social checking to mothers about prohibited acts, and engaged in more interactive play, all nuanced forms of social exploration that may have resulted from the ability to crawl. Moreover, the study reported that mothers of crawlers (but not pre-crawlers) formed an expectation of compliance and attributed a sense of responsibility to their mobile infants. Similarly, in a study of infants across the transition from crawling to walking, Biringen and colleagues (1995) reported that mothers perceived their walking infants to be more mature and like "individuals," a finding recently echoed in a study on social development across the transition to walking (Walle, 2016).

Gustafson (1984) illustrated a similar phenomenon with an experimental manipulation. In a laboratory study, she compared 8-month-old pre-crawling infants in and out of mechanical walkers during spontaneous interactions with their mothers. Pre-crawlers in walkers explored significantly more area of the novel lab room than pre-crawlers left on their own. Moreover, the group of infants who were able to move while propped upright looked, smiled, and vocalized more towards their mothers during exploration. The nuanced attention-generating behaviors afforded by walker-assisted upright locomotion resulted in an arsenal of social cues at infants' disposals. Thus, infants' increased propensity to display affective cues as a result of enhanced locomotor exploration could potentially prompt mothers to notice their infants on the go and provide rich communicative input during their travels.

The studies described above suggest that independent locomotion is related to changes in how caregivers interact with their infants and potentially shapes the efficacy with which infants elicit input from caregivers while moving about novel and familiar environments. However, these studies do not address the specific concurrent associations between infants' practice of new locomotor skills like walking and what caregivers say and how they gesture as their infants move.

1.3 Caregivers' communicative input to their crawling and walking infants

To date, a small number of studies have directly examined relations between infants' actions and caregivers' communicative input. One set of studies explored how mothers' social messages influenced infants' decisions for action on a specially constructed sloping walkway in the laboratory. The second investigated changes in how infants explored and shared objects at home, and how mothers verbally responded to their infants' bids for social interactions across the transition from crawling to walking.

1.3.1 Evidence from laboratory studies

An initial study examined how mothers used language and gesture to encourage and discourage their crawling and walking infants' actions on slopes (Karasik, Tamis-LeMonda, Adolph, & Dimitropoulou, 2008). Three groups of infants were tested: 12-month-old experienced crawlers, age-matched novice walkers, and 18-month-old experienced walkers. Infants were placed at the top of an adjustable apparatus and descended slopes of varying steepness based on the limits of their abilities (see Adolph, 1995, 1997). As infants navigated the novel obstacle, mothers were asked to either encourage or discourage their infants' descent in any way they chose. Mothers spontaneously performed a large repertoire of communicative bids. They used language to regulate infants' location (e.g., 'come here'), prompted specific motor actions (e.g., 'keep walking'), attempted to keep their infants on task with attentional language (e.g., 'look at mommy'), and provided praise. Mothers also paired their language with a host of different gestures, including outstretched arms that "called" the infant to descend to a particular location, a wagging finger for prohibition, index-finger pointing toward the bottom of the slope, and clapping (Karasik et al., 2008).

Results indicated that mothers' communicative messages were attuned to infants' age and locomotor experience. Mothers communicated differently with experienced crawlers and walkers, using more complex language and gestures to guide action. They also made use of more action-based language to provide their infants with strategies for descending the slope, perhaps keying in on their advanced locomotor abilities.

A second study, conducted with 18-month-old experienced walkers, asked about the effectiveness of mothers' communicative efforts and whether infants made use of their social messages (Tamis-LeMonda et al., 2008). Infants were tested on the slope apparatus at inclines deemed safe, impossibly risky, and ambiguous adjusted to their current skill level. Mothers were asked to encourage and discourage their infants' descent and their language and gestures were coded as in the previous study. Infants only deferred to mothers' social messages, either encouragement or discouragement, when their perceptual resources were least helpful in making decisions for action. Infants used social information from caregivers when navigating the obstacle, but only in the ambiguous slope condition when their own exploratory behaviors were least trustworthy in deciding what to do next (Tamis-LeMonda et al., 2008).

Together, these studies provide evidence that what caregivers say and do with their hands impacts infants' exploration and decision making for action. Infants seem to take in social information from caregivers at times when they are not sure how to proceed. An infant who is just learning to walk, for example, might be particularly uncertain about her skills and hesitate when taking her first steps. An attuned caregiver's language and gesture in these key moments of learning might be the push that the infant needs in making the decision to go (e.g., saying 'Walk to mommy!'). Caregivers may similarly tailor the kinds of language and gestures in their communicative input as infants progress from experienced crawler to novice walker status during everyday interactions at home. However, this possibility has not yet been examined.

1.3.2 Evidence from home studies

In a second line of work, Karasik and colleagues (2011, 2012, 2014) described the complex interactions between infants' locomotor status as crawler or walker, their social exploration with objects, and caregivers' resulting communicative responses. Evidence from their in-home studies of 11- and 13-month-old infants across the transition from crawling to walking revealed that while crawlers opted to share objects with outstretched arms from *stationary* positions, walkers were more likely to access distal objects and initiate social interactions with caregivers by *moving* to them with objects in hand (Karasik et al., 2011, 2012). Unsurprisingly, mothers' responses to these object bids were varied—they acknowledged infants' attempts at sharing, provided informative referential language about the object, and used action directives that told infants what to do with the object with a verb (e.g., 'stack the blocks'). Mothers' response type was related to bid type (moving or stationary), not infants' locomotor status, such that moving bids (which occurred significantly more among walking infants) were best at eliciting action directives during communicative exchanges (Karasik et al., 2014). The critical factor was not the status change from crawler to walker, but the associated gain—sharing objects by moving more often—that generated more complex language input from caregivers. When crawlers shared objects by moving to their mothers, they also received the same kinds of input as walkers, but far less often.

Further support for the potential cascading effects of infant movement on caregiver input comes from a recent study about language input to infants during everyday routines at home

(Tamis-LeMonda, Custode, Kuchirko, Escobar, & Lo, 2019). The study observed a group of 40 13-month-old infants engaged in everyday activities with their mothers. The researchers transcribed mothers' language in relation to the specific activities that were occurring (e.g., book reading, bath time, etc.). Notably, infants heard a greater proportion of gross motor verbs (e.g., go, get, bring) when engaged in what the authors called "transitions," or time spent practicing gross motor skills like crawling and walking and switching between the other activities.

1.4 Current study

This research was designed to examine the dynamic relations between infant locomotion and caregiver communicative input across the transition from crawling to walking. Specifically, we asked whether the transition to walking would not only relate to changes in infants' actions (e.g., how infants moved) but also to caregivers' language and gesture input as infants traveled.

The study had three goals. The first was to describe the distribution of infants' locomotor bouts as they engaged in natural locomotion during everyday interactions at home. Based on recent work on the development of natural locomotion—how infants move during unconstrained activities—we predicted that infants would show a decrease in crawling and an increase in walking across the observation period (e.g., Adolph et al., 2012; Lee, Cole, Golenia, & Adolph, 2018).

Second, we examined the rate of co-occurrence between infant locomotion and caregiver language input. We compared the relative frequencies with which bouts of crawling versus walking were accompanied with caregiver language. We then explored whether specific language types—action verbs and language about objects—were more likely to co-occur with crawl or walk bouts. We had no specific predictions about whether bouts of crawling or walking would be more likely to be accompanied with language input from caregivers based on the current literature. However, given previous findings on the occurrence of action verbs in caregivers' language input to walking infants at home (e.g., Karasik et al., 2014; Tamis-LeMonda et al., 2019), we hypothesized that bouts of walking would be more likely to co-occur with action verbs than bouts of crawling.

Third, we examined whether bouts of walking were more likely to be accompanied with caregiver gestures than bouts of crawling. Research on caregiver gesture production during interactions with infants is limited. Some evidence from a longitudinal study of everyday interactions between Italian infants (aged 16 to 20 months) and their mothers at home suggests that overall, spontaneous gesture input from mothers is relatively low, occurring for roughly 15% of their utterances (Iverson, Capirci, Longobardi, & Caselli, 1999). Similarly, a study of English mothers and their 20-month-old infants showed that gesture input accounted for roughly 29% of mothers' utterances during a 5-minute free play session in the laboratory (O'Neill, Bard, Linell, & Fluck, 2005). Thus, this goal was predominantly descriptive as we had no a priori reason to expect differences in gesturing to crawling versus walking bouts in any direction.

2.0 Method

2.1 Participants

Data for this study were drawn from a large video corpus of infants' everyday experiences in the home (e.g., Iverson, Hall, Nickel, & Wozniak, 2007; Parladé & Iverson, 2011). In the original study, 30 infant-caregiver dyads were visited at home twice a month from infant ages 2 to 19 months to examine the development of vocal-motor behavior in infancy. Data were collected between 2003 and 2006 at two sites: Columbia, MO (18 infants) and Pittsburgh, PA (12 infants). Families were recruited via published birth announcements and word of mouth.

Fourteen infants were males and 16 were females. All were typically developing and born at term free of complications; 28 infants were identified as white and 2 as multiracial. Thirteen infants were first-born and 17 were later-born. Mothers and fathers were similar in age (*M*s = 31.36 and 32.78, *SD*s = 4.31 and 4.11, respectively) and education (87.4% of mothers and 80.4% of fathers held a Bachelors degree or higher). English was the primary language spoken in all homes.

2.2 Procedure

Infants were videotaped in the home every 2 weeks during everyday activities with their caregivers for approximately 45 minutes (*M* = 43.30, *SD* = 5.19, range = 26.85-59.13). Caregivers were asked to continue going about their day as they typically would, engaging in the activities of their daily routines. Caregivers played with their infants, let infants play on their own, engaged in book reading, loaded and unloaded dishwashers, folded laundry, prepared meals, and often went outside. 136 visits were with mothers (90.7%), 9 were with fathers (6.0%), and the remaining 5 were with grandmothers (3.3%).

Home observations were scheduled to occur within 3 days of infants' monthly birth anniversaries and again approximately 2 weeks later. Families were provided baby books to track their infants' development across the duration of the study and to aid in answering questions about newly emerging skills during interviews. At the end of each visit, caregivers were interviewed about the onsets of new motor skills in their infants' repertoires. Experimenters verified when new skills emerged and noted whether these behaviors were just appearing or used more consistently by infants.

2.3 Identifying walk onset

We took a milestone-based approach for the current study, selecting visits for coding that encompassed the 2-month window surrounding the onset of walking. Walk onset was defined as the first day when infants were able to take 5 continuous, independent steps with no support and without stopping or falling. This criterion for walk onset was specifically chosen to capture the earliest emergence of walking. On average, infants began to walk at 11.98 months (SD = 1.31, range = 8.74-14.86).

To create each infant's observational window, we selected the biweekly session that most closely corresponded to the exact date of each infant's walk onset and considered that to be the walk onset visit, rounding to the nearest half-month (e.g., if walk onset age was 11.70 months, we considered the 12-month session as the infant's walk onset session). Monthly sessions prior to and following this midpoint were targeted for coding, resulting in five time points for each infant and 150 sessions across the dataset. There were no missing data.

We refer to each session as follows: the *pre-walk sessions* include the session 2 months before walk onset (walk-2) and 1 month before walk onset (walk-1); the *walk sessions* include the session representing walk onset (walk onset), 1 month after walk onset (walk+1), and 2 months after walk onset (walk+2).

2.4 Data coding

Infant locomotor and caregiver communicative behaviors were coded using Datavyu (datavyu.org), a coding tool that allows for frame-accurate identification and categorization of multiple ongoing behaviors from different actors. Before coding commenced, all coders were trained until overall percent agreement reached ≥90% on all coding categories for 3 consecutive videotapes. After training and for all variables, a primary coder scored 100% of each infant's and caregiver's video data. A second coder independently scored 25% of each video to verify inter-observer reliability. Seven coders (6 undergraduate researchers and the first author) completed all coding. Disagreements were resolved through discussion.

2.4.1 Infant locomotion

Coders first scored each video for locomotion. All times when infants engaged in crawling (moving on hands-and-knees), cruising (moving upright with a stationary source of support), supported walking (moving upright with a mobile source of support), or independent walking were identified. All *bouts* of locomotion, or series of steps separated by a pause in which the infant came to a complete stop for at least 0.5 s, were identified (Adolph et al., 2012; Cole, Robinson, & Adolph, 2016; Lee et al., 2018). A step was defined as any up-and-down movement of the feet or knees that resulted in omnidirectional displacement of infants' bodies through space. The 0.5 s pause criterion has been used widely in the literature on infant locomotion and has been shown to be a meaningful indicator of gait termination for both crawling (Adolph, Vereijken, & Denny, 1998) and walking (Bril & Breniere, 1989; Garciaguirre, Adolph, & Shrout, 2007; Cole et al., 2016).

A bout of locomotion began at the first frame of video when an infant's foot or knee moved across the floor and ended at the first frame when the foot or knee came to rest at the end of the series (Adolph et al., 2012). As described in Hoch et al. (2019), we also did not split bouts of locomotion in cases where the 0.5 s-rule was exceeded but the infant appeared to still be in continuous motion when the video was viewed in real time. This ensured that coders were not over-splitting bouts, especially in sessions where infants were just starting to walk and whose bouts were often very slow and precarious.

Inter-observer reliability reflecting agreement between coders prior to discussion was high for bout identification and steps per bout, rs = .99, ps < .001 and for identification of locomotion type (percent agreement = 99%; Cohen's $\kappa = .98$, $p < 0.001$).

2.4.2 Caregiver communication

In a second coding pass, coders focused on caregiver language and gesture. To increase the likelihood of coding caregiver language and gesture that were temporally connected to bouts of infant locomotion that resulted in infants traveling through space, only bouts with at least four steps were considered for communication coding (e.g., Karasik et al., 2012).

We inserted "coding windows" around each bout of locomotion, such that the *onset* of the window began exactly 5s (or less in cases where infants were stationary for less than 5s between successive bouts of locomotion) before a bout of locomotion was initiated and the *offset* of the window was the frame when the bout ended. Anchoring infant behavior to a 5s window has been used previously in studies focused on infant-caregiver interactions in the home, specifically to determine caregivers' linguistic responses to their infants' object sharing bids (e.g., Karasik et al., 2014).

All instances of caregiver language in the coding windows surrounding locomotion bouts were identified and coded in five mutually exclusive categories. *Action verbs* were utterances that included gross motor verbs that directly encouraged infant movement ('Go, get, bring'); *object talk* included utterances that labeled a concrete noun or provided referential information about objects ('That's your green frog'). We also considered language that generally *encouraged and praised* infant locomotion ('You're almost there! Good job!') and language that *discouraged or cautioned* locomotion ('No! Stop! Be careful.'). Finally, we coded all other utterances that did not contain any of the key aspects of the above language types ('Hello, Thank you') in a catch-all *miscellaneous* category to be excluded from analyses.

Caregiver gestures were identified and classified into six mutually exclusive categories. *Movement gestures* directly requested infant movement and included instances when caregivers beckoned to their infants with outstretched arms, hands, or fingers, patted the ground beside them, traced a path through space, or hit the floor with their fists as if mimicking a trotting horse. *Show gestures* occurred when caregivers held up an object and directed it to their infants' attention.

Caregivers also *pointed* to specific people, places, and things; *requested* objects from their infants by opening their hands as if to create a cup; *indicated* a specific referent by tapping on it with a finger; and used *conventional gestures* such as clapping and waving.

Coders scored language and gesture input within each coding window, noting if a specific type occurred. Communication was coded at the utterance-level which meant that multiple types of language and gesture could occur within the same window. Coders credited each type of communication once, regardless of its frequency. For instance, if a caregiver produced two utterances within the same window, each containing an action verb, one instance of an action verb would be coded. A hierarchical coding system was used to ensure that each utterance was classified independently (e.g., Karasik et al., 2008). For example, if the utterance was "Bring me the ball!", coders marked this utterance as an action verb but not as object talk. If a second utterance occurred in the same window but without a verb, "Yes, the blue ball!", coders then noted that object talk had also occurred for that bout. The same process was applied to coding gesture types.

Inter-observer reliability reflecting agreement between coders prior to discussion was high. Coders agreed on 98-99% of bouts when identifying categorical language and gesture types across the dataset, Cohen's κ coefficients ranged from 0.81-0.89, all $ps < 0.001$.

3.0 Results

This study was designed to examine links between changing patterns of infant locomotion and concurrent communicative input from caregivers across the transition from crawling to walking. We begin by describing the bout-level distribution of infants' natural locomotion during everyday activities at home. Next, we examined the co-occurrence of caregiver language input and infant locomotion and whether there were differences in the types of language caregivers produced when infants crawled versus walked. Finally, we analyzed the gestures produced by caregivers and asked whether production of specific gesture types varied when infants crawled versus walked.

All data were analyzed using repeated measures ANOVAs. Sidak comparisons were conducted to follow up on significant main effects and interactions. Preliminary analyses revealed no effects of gender (all *p*s > .05) or age at walk onset on any of the primary variables (*r*s = -.26-.35, *p*s = .06-.99 for language variables; and *r*s = -.31-.18, *p*s = .09-.97 for gesture variables), so they were not included as factors in subsequent analyses.

3.1 How did infants move?

Our first aim was to describe the bout-level distribution of infants' natural locomotion across the observation period. Overall, coders identified 7,393 bouts of locomotion across the five time points. We calculated proportions for each locomotion type—crawling, cruising, supported walking, independent walking—out of the total number of bouts initiated per session.

3.1.1 Locomotion before walk onset

Data on the distribution of infants' bouts of locomotion are presented in Figure 1. We conducted separate analyses for the pre-walk and walk sessions. We first examined infant locomotion in the 2 months prior to walk onset. As shown in the two left-hand bars in Figure 1, infants were more likely to initiate bouts of crawling than cruising or supported walking at both pre-walking time points. A 3 (Bout Type: crawl, cruise, supported walk) x 2 (Pre-walk Session: walk-2, walk-1) repeated measures ANOVA confirmed a significant main effect of Bout Type, $F(2, 58) = 9.60$, $p < .001$ ($\eta^2 = .25$), a marginal effect of Pre-walk Session, $F(1, 29) = 3.02$, $p = .093$ ($\eta^2 = .10$), and no Bout Type x Pre-walk Session interaction, $F(2, 58) = 1.22$, $p = .303$ ($\eta^2 = .04$). Pairwise comparisons showed that infants initiated proportionately more crawl ($M = .56$, $SD = .35$) than cruise ($M = .23$, $SD = .21$, $p = .002$) and supported walking bouts ($M = .22$, $SD = .34$, $p = .026$) two months before walk onset. Similarly, in the month before walk onset, infants were more likely to crawl ($M = .50$, $SD = .29$) than walk with support ($M = .19$, $SD = .27$, $p = .005$), and marginally more likely to crawl than cruise ($M = .31$, $SD = .25$, $p = .094$).

3.1.2 Locomotion at and after walk onset

Next, we analyzed the distributions of crawling and walking bouts for the three walk sessions. As shown in the three right-hand bars in Figure 1, walking was immediately favored once infants acquired the skill. Infants were more likely to walk than crawl at walk onset (walking bouts $M = .70$, $SD = .19$; crawling bouts $M = .30$, $SD = .19$) and across the remainder of the observation period. On average, walking reflected 94.22% ($SD = .08$) and 96.88% ($SD = .04$) of total locomotion bouts at 1 and 2 months after walk onset, respectively, while crawling became relatively rare (*M* walk +1 = .06, *SD* = .07; *M* walk +2 = .03, *SD* = .04). A 2 (Bout Type: crawl, walk) x 3 (Walk Session: walk onset, walk+1, walk+2) repeated measures ANOVA confirmed a significant main effect of Bout Type, $F(2, 58) = 594.22$, $p < .001$ ($\eta_2 = .95$), a significant Bout Type x Walk Session interaction $F(2, 58) = 54.39$, $p < .001$ ($\eta_2 = .65$), but no significant main effect of Walk Session, $F(2, 58) = .034$, $p = .967$ ($\eta_2 = .001$). Pairwise comparisons showed significant differences between the proportions of walk bouts and crawl bouts at all walk sessions, *ps* < .001.

Although infants moved in ways other than crawling and walking, in the analyses presented below, we focused on caregivers' communicative input to these two types of locomotion given their dominance in infants' locomotor repertoires across the observation period.

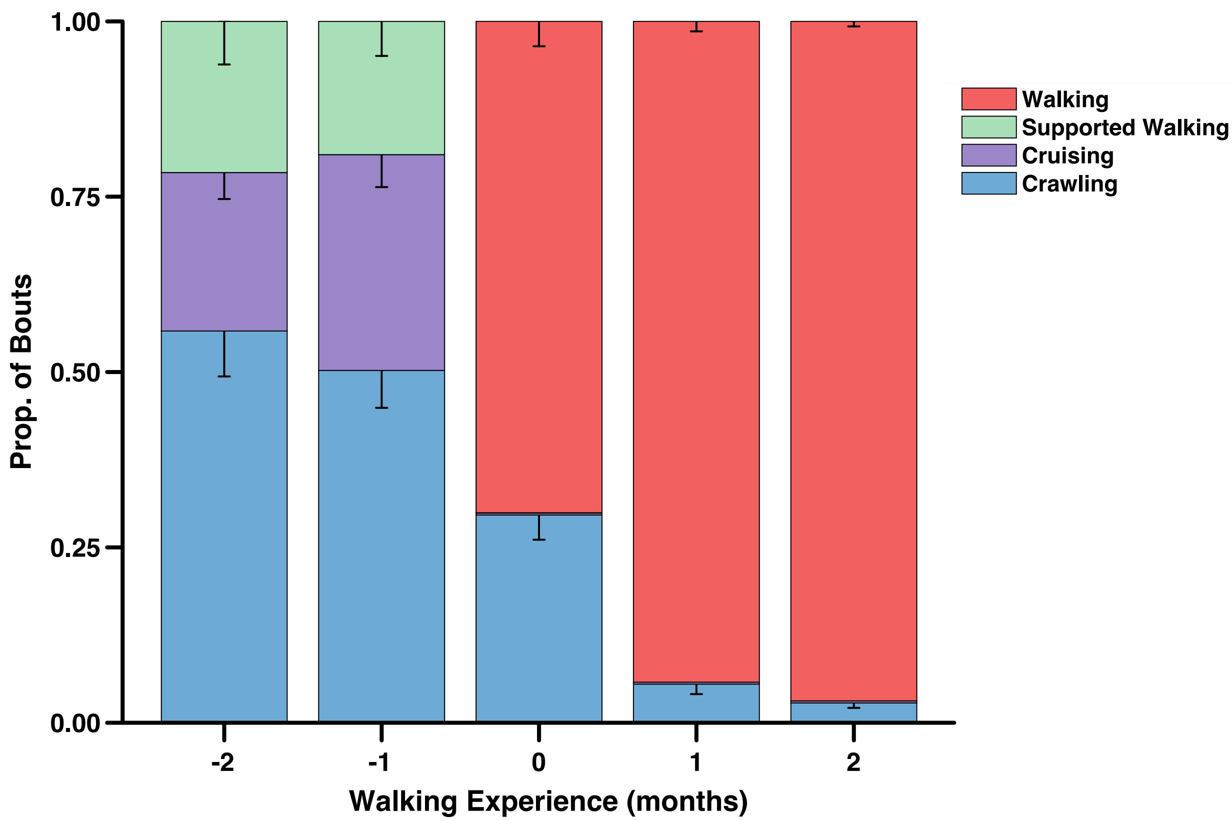

Figure 1. Distribution of infants' crawling (blue bars), cruising (purple bars), supported walking (green bars), and walking (red bars) bouts across the observation period. Error bars show 1 SE.

3.2 Caregiver language input to crawling and walking

In order to examine the dynamic relations between infant locomotion and caregiver communication, we conducted two sets of analyses. The first examined the relative frequencies with which crawling and walking bouts were paired with language input from caregivers. The second focused on the types of language input caregivers produced when their infants crawled and walked. We calculated proportions to control for differences in the base rates of infants' crawling and walking bouts. Each proportion reflected the number of crawling (or walking) bouts that contained language input out of the total number of crawling (or walking bouts) at that session.

3.2.1 Co-occurrence of caregiver language and infant locomotion

How did caregiver language input change as infants transitioned from crawling to walking? To address this question, we first examined whether there were differences in the proportions of crawling and walking bouts paired with caregiver language. These data are displayed in Figure 2. As shown in Figure 2A, there was remarkable stability across the observation period in the proportions of crawling and walking bouts that co-occurred with language input. Considering crawling alone, bouts were paired with language input from caregivers at a steady rate across the five time points (*M* walk-2 = .21, *SD* = .18; *M* walk-1 = .22, *SD* = .19; *M* walk onset = .29, *SD* =.30; *M* walk+1 = .23, *SD* = .31; *M* walk+2 = .26, *SD* =.34), $F(4, 145) = .424$, $p = .791$.

However, infants' walking bouts were more likely to be paired with language input than their crawling bouts at walk onset and at the two subsequent sessions (*M* walk onset = .41, *SD* = .23; *M* walk+1 = .43, *SD* = .12; *M* walk+2 = .40, *SD* = .14). A 2 (Bout Type: crawl, walk) x 3 (Walk Session: walk onset, walk+1, walk+2) repeated measures ANOVA confirmed a significant main effect of Bout Type, $F(1, 29) = 18.53$, $p < .001$ ($\eta^2 = .39$), but no significant main effect of Walk Session, $F(2, 58) = .097$, $p = .908$ ($\eta^2 = .003$), or a Bout Type x Walk Session interaction, $F(2, 58) = .582$, $p = .562$ ($\eta^2 = .02$). Post-hoc pairwise comparisons revealed significant differences between the proportions of walk bouts and crawl bouts paired with language input at all three walking time points, *ps* < .05.

3.2.2 Types of caregiver language to crawling and walking bouts

We further characterized caregivers' language input by examining the types of words they used and whether these varied for crawling and walking bouts. We calculated additional proportions to control for potential variation in the base rates of caregiver speech paired with infant locomotion. For example, the proportion of walking bouts paired with action verbs reflected the total number of infants' walking bouts that contained an action verb out of the total number of walking bouts that contained any language input at all (i.e., the proportion described in the previous analysis).

Preliminary inspection of the data revealed that the *encouragement and praise* and *discouragement and caution* categories comprised an average of 0.99% (*SD* = .04) and 4.99% (*SD* = .08) of crawl and walk bouts paired with language input, respectively. Thus, the analyses presented below included data only on *action verbs* and *object talk.*

3.2.2.1 Action verbs

We first examined caregivers' use of action verbs (e.g., go, get, bring) that directly requested movement from their infants. These data are presented in Figure 2B. There were striking differences in the relative frequencies with which action verbs co-occurred with crawling and walking bouts. Caregivers produced action verbs when infants crawled at a consistent rate across the observation period (*M* walk-2 = .21, *SD* = .26; *M* walk-1 = .13, *SD* = .22; *M* walk onset = .18, *SD* = .26; *M* walk+1 = .10, *SD* = .20; and *M* walk+2 = .08, , *SD* = .26), $F(4, 145) = 1.69$, $p = .16$.

Similar to the results on the co-occurrence of walking and overall language input, there were significant and robust differences in the rates with which action verbs were paired with crawling versus walking bouts at the walk sessions. At walk onset, bouts of walking were almost twice as likely as crawl bouts to be accompanied with action verbs, and walking bouts were 2-3 times as likely to co-occur with action verbs relative to bouts of crawling across the rest of the observation period (see Figure 2B). A 2 (Bout Type: crawl, walk) x 3 (Walk Session: walk onset, walk+1, walk+2) repeated measures ANOVA confirmed significant main effects of Bout Type, $F(1, 29) = 24.94$, $p < .001$ ($\eta_2 = .46$), and Walk Session, $F(2, 58) = 3.22$, $p = .047$ ($\eta_2 = .10$), but no significant Bout Type x Walk Session interaction, $F(2, 58) = .586$, $p = .560$ ($\eta_2 = .02$). Pairwise comparisons revealed significant differences between crawling and walking bouts at all three walking time points ($p < .05$ at walk onset and $ps < .001$ at 1 and 2 months post walk onset).

3.2.2.2 Object talk

Next, we examined language about objects. This category included referential utterances that provided information about objects (e.g., ‘That’s your green frog!’). Figure 2C presents the data on object talk to crawling and walking bouts. As was the case for action verbs, there were no significant differences in the relative frequencies with which crawl bouts were accompanied with object talk across the transition from crawling to walking (*M* walk-2 = .08, *SD* = .14; *M* walk-1 = .14, *SD* = .23; *M* walk onset = .13, *SD* = .26; *M* walk+1 = .06, *SD* = .22; and *M* walk+2 = .10, *SD* = .31), $F(4, 145) = .600$, $p = .66$.

There were no differences in the proportions of walking and crawling bouts paired with object talk at walk onset ($M = .20$, $SD = .23$ to walk bouts and $M = .13$, $SD = .26$ to crawl bouts, $p = .134$). However, differences emerged in the 2 months following walk onset, such that infants' walk bouts were more than three times as likely as their crawl bouts to co-occur with language about objects (see Figure 2C). A 2 (Bout Type: crawl, walk) x 3 (Walk Session: walk onset, walk+1, walk+2) repeated measures ANOVA confirmed a significant main effect of Bout Type, $F(1, 29) = 37.55$, $p < .001$ ($\eta_2 = .56$), a significant Bout Type x Walk Session interaction, $F(2, 58) = 3.36$, $p = .042$ ($\eta_2 = .10$), but no significant main effect of Walk Session, $F(2, 58) = .212$, $p = .810$ ($\eta_2 = .007$). The significant interaction resulted from robust differences in the proportions of walk bouts paired with object talk compared to crawl bouts at 1 and 2 months after walk onset, *p*s $< .001$.

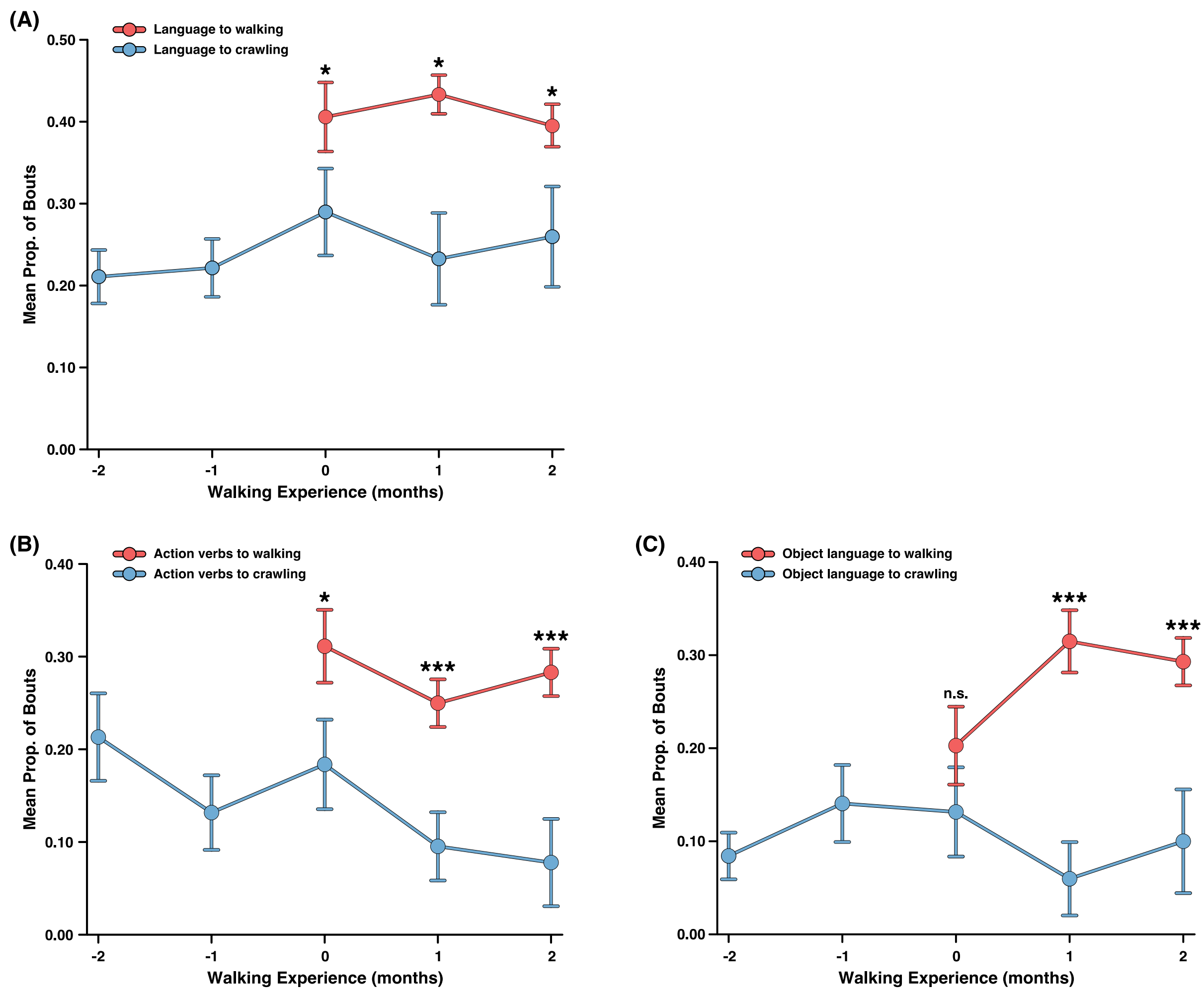

Figure 2. Mean proportions of crawling and walking bouts that co-occurred with (A) overall language input, (B) language containing action verbs, and (C) language about objects. Blue lines are data for crawling; red lines are data for walking. Error bars show 1 SE.

3.3 Caregiver gesture input to crawling and walking

The final aim of this study focused on gesture input from caregivers. We first examined overall rates of overlap between caregivers' gestures and infants' crawling and walking bouts. We then asked about the specific types of gestures that caregivers produced when infants crawled and walked. As in the language analyses described above, we calculated gesture variables as proportions to control for potential differences in the base rates of infants' bouts of crawling and walking. For example, the proportion of walking bouts with overlapping gesture input from caregivers reflected the total number of walking bouts that contained gesture out of the total number of walking bouts for that session.

3.3.1 Co-occurrence of caregiver gestures and infant locomotion

Caregiver gestures accompanied locomotion (collapsed across crawling and walking) at a lower rate than language, on average occurring in 7.18% (*SD* = .10) of infants' bouts. These data are displayed in Figure 3. As shown in Figure 3A, there was striking stability in the likelihoods with which crawling and walking bouts were paired with gesture input from caregivers. Across the observation period, bouts of crawling were accompanied with gesture at a low but consistent rate (*M* walk-2 = .03, *SD* = .05; *M* walk-1 = .04, *SD* = .08; *M* walk onset = .05, *SD* = .09; *M* walk+1 = .05, *SD* = .12; and *M* walk+2 = .04, *SD* = .13), $F(4, 145) = .289$, $p = .885$.

Bouts of walking, however, were twice as likely to overlap with gesture input than crawl bouts at all walk sessions (*M* walk onset = .10, *SD* = .12; *M* walk+1 = .10, *SD* = .08; and *M* walk+2 = .08, *SD* = .05). A 2 (Bout Type: crawl, walk) x 3 (Walk Session: walk onset, walk+1, walk+2) repeated measures ANOVA confirmed a significant main effect of Bout Type, F(1, 29) = 16.81, $p < .001$ ($\eta_2 = .37$), but no main effect of Walk Session, $F(2, 58) = .372$, $p = .691$ ($\eta_2 = .013$), or a Bout Type x Walk Session interaction, $F(2, 58) = .008$, $p = .992$ ($\eta_2 = .000$). Post-hoc pairwise comparisons revealed significant differences in the proportions of walk bouts paired with gesture input compared to crawl bouts at walk onset and 1 month later (*p*s < .05) and a marginal difference at the session 2 months after walk onset ($p = .068$).

3.3.2 Types of caregiver gestures to crawling and walking bouts

We next asked about the types of gestures that caregivers produced when infants crawled and walked. We calculated proportions for gesture types in the same way as for language types. For example, the proportion of walking bouts accompanied by movement gestures reflected the total number of infants' walking bouts paired with a movement gesture out of the total number of walking bouts that contained any gesture input at all (i.e., the proportion described in the analysis on overall gesture input above).

Preliminary examination of the data for each gesture type revealed that *pointing* (M = .04, SD = .16), *requesting* objects (M = .01 SD = .05), *indicating* referents by tapping on them (M = .05, SD = .18), and using *conventional* gestures like clapping and waving (M = .01, SD = .06) accounted for an average of 2.66% (SD = .11) of the gesture input to crawl bouts. Similarly, *conventional* gestures only represented an average of 4.17% (SD = .19) of the gesture input to bouts of walking. Thus, given the low base rate of these gesture types to crawl and walk bouts, we present analyses of gesture input to crawling and walking only for *movement* and *show* gestures.

3.3.2.1 Movement gestures

We first analyzed movement gestures, in which caregivers directly requested crawling or walking from their infants (e.g., beckoning with outstretched arms, hands, or fingers). These data are presented in Figure 3B. There was a marginal difference in the proportions of walking and crawling bouts paired with movement gestures at walk onset (M = .26, SD = .35 to walk bouts and M = .13, SD = .32 to crawl bouts, p = .09). However, at both 1 and 2 months after walk onset, movement gestures to both crawling and walking decreased such that there was a floor effect with respect to crawl bouts (Ms = .00, SDs = .00) and a steady but low rate of movement gestures paired with bouts of walking (*M* walk+1 = .07, *SD* = .12 and *M* walk+2 = .07, *SD* = .12). A 2 (Bout Type: crawl, walk) x 3 (Walk Session: walk onset, walk+1, walk+2) repeated measures ANOVA confirmed significant main effects of Bout Type, $F(1, 29) = 10.77$, $p = .003$ ($\eta^2 = .27$), and Walk Session, $F(2, 58) = 10.91$, $p < .001$ ($\eta^2 = .27$), but no significant Bout Type x Walk Session interaction, $F(2, 58) = .520$, $p = .597$ ($\eta^2 = .02$). Pairwise comparisons revealed significant differences between the proportions of crawling and walking bouts paired with movements gestures at 1 and 2 months post walk onset, *p*s = .003.

3.3.2.2 Show gestures

Caregivers also showed objects by holding them up in their infants' field of view. These data are presented in Figure 3C. Once again, the data revealed a general consistency in the likelihood with which crawl bouts were paired with show gestures from caregivers across the observation period (*M* walk-2 = .13, *SD* = .29; *M* walk-1 = .16, *SD* = .33; *M* walk onset = .05, *SD* = .20; *M* walk+1 = .13, *SD* = .35; and *M* walk+2 = .00, *SD* = .00), $F(4, 145) = 1.86$, $p = .12$.

There were no differences in the proportions of walking and crawling bouts paired with show gestures at walk onset (*M* = .16 *SD* = .32 to walk bouts and *M* = .05, *SD* = .20 to crawl bouts, $p = .113$). However, in the 2 months after walk onset, the rates at which infants' bouts of walking were accompanied with show gestures increased and grew to be 3-4 times higher than those for crawl bouts (see Figure 3C). A 2 (Bout Type: crawl, walk) x 3 (Walk Session: walk onset, walk+1, walk+2) repeated measures ANOVA confirmed these differences with significant main effects of Bout Type, $F(1, 29) = 39.75$, $p < .001$ ($\eta^2 = .58$), and Walk Session, $F(2, 58) = 7.04$, $p = .002$ ($\eta^2 = .20$), and a significant Bout Type x Walk Session interaction, $F(2, 58) = 5.80$, $p = .005$ ($\eta^2 = .17$). Post-hoc pairwise comparisons revealed that the Bout Type x Walk Session interaction was explained by significant differences in the proportions of walk versus crawl bouts paired with show gestures at 1 and 2 months post walk onset, all *p*s < .001.

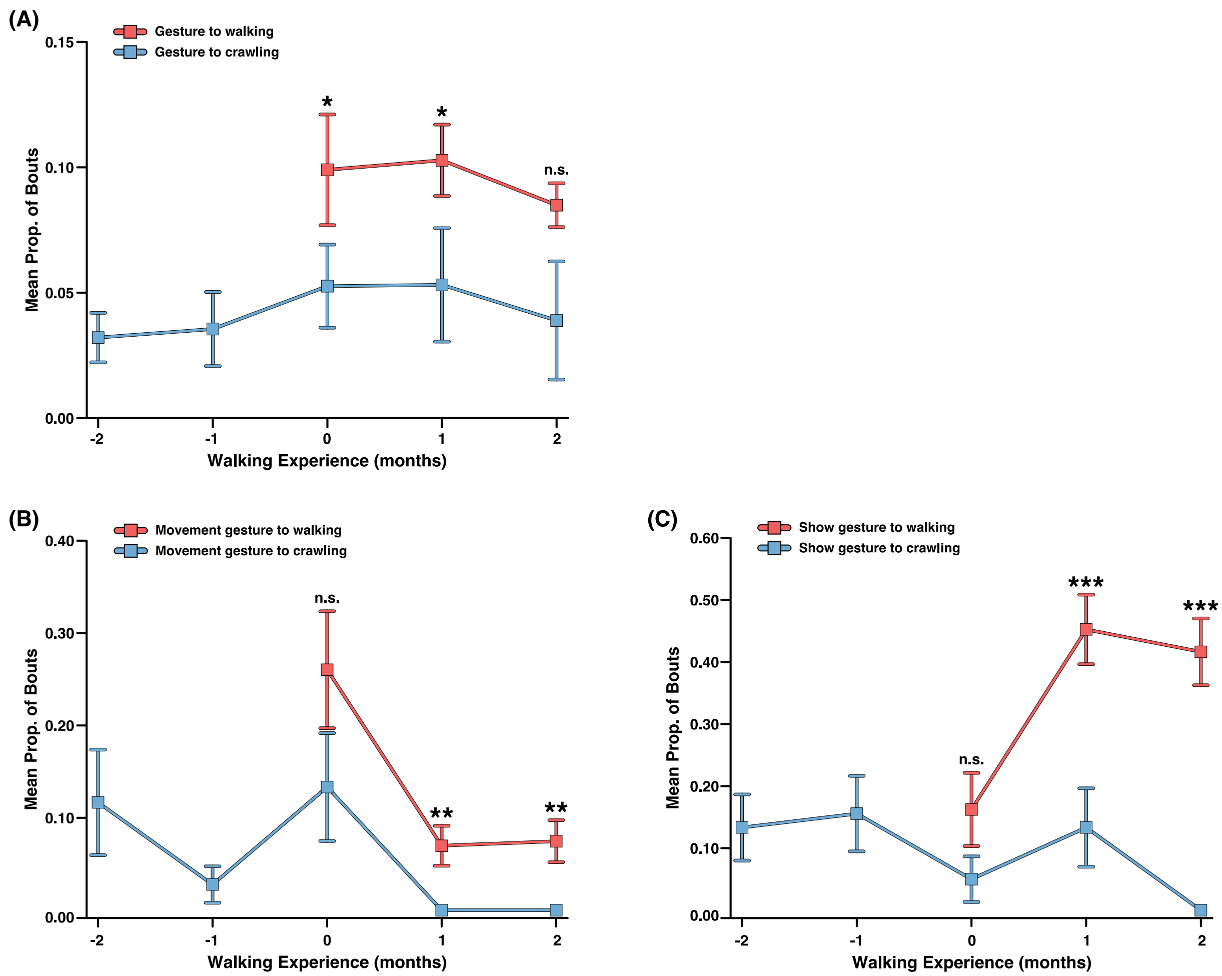

Figure 3. Mean proportions of crawling and walking bouts that co-occurred with (A) overall gesture input, (B) movement gestures, and (C) show gestures. Blue lines are data for crawling; red lines are data for walking. Error bars show 1 SE.

4.0 Discussion

The overall goal of this study was to examine whether and how the onset of walking in infants acts as a "reorganizer" for caregiver communication. Specifically, we tested the hypothesis that the transition to walking would not only relate to changes in infants' own actions—how they moved during everyday activities at home—but would also shape the language and gesture input that caregivers directed to their infants. We took a milestone-based approach, centering each infant's observation period at the onset of walking, and we coded infant locomotion and caregiver communicative input in real time. The time-locked nature of data coding allowed for in-depth analysis of how infant movement—crawling and walking—was interleaved with concurrent language and gesture input from caregivers. Moreover, by including sessions before the onset of walking, we were able to directly examine the extent to which the addition of walking in infants' locomotor repertoires shaped the rates of specific types of communication from caregivers.

4.1 Learning to walk reorganizes the infant-caregiver dyad

Our results contribute to the literature on the cascading dynamics between infant mobility and caregiver communicative input in three ways. First, we replicated and extended prior work on the development of natural locomotion (e.g., Adolph et al., 2012; Lee et al., 2018) by describing the bout-level distribution of infants' crawling, cruising, supported walking, and walking during everyday activities with caregivers at home. Our data support previous studies by providing a detailed, monthly account of the nature of infant locomotion across the transition from crawling to walking. Before infants learned to walk, they were more likely to initiate bouts of crawling than other upright pre-walking strategies (i.e., cruising, supported walking). However, infants' preference for walking at and after its emergence was striking: walking reflected the dominant share of infants' locomotion bouts, while crawling substantially decreased.

Second, data on the temporal coordination of infant locomotion and caregiver language input suggest that the ability to walk tailored input from caregivers, such that walking bouts were consistently and robustly more likely to receive language input than bouts of crawling. Moreover, infants were more likely to hear social messages rich with verbs about action and movement and referential information about objects when they walked compared to when they crawled.

Third, we provide a naturalistic account of caregivers' gestures to infants' crawling and walking bouts during everyday interactions across this motor transition. Not only were caregivers' gestures more likely to co-occur with bouts of walking than with bouts of crawling, but the types of gestures they produced varied in relation to infants' walking experience. Caregivers' gestures shifted from promoting movement at walk onset to communication about objects in the following two months.

4.2 Walking shapes communicative input from caregivers

4.2.1 Language

Although caregivers consistently provided language input to their infants' crawl bouts, once infants began to walk, bouts of walking were significantly more likely to co-occur with language input than bouts of crawling. The stability observed in caregivers' input to crawling, coupled with the robust differences between bout types when walking was introduced, underscore the potential of walking as a powerful elicitor of input from caregivers.

In addition to the greater relative frequency of language input to walking bouts, the content of caregivers' messages during crawling versus walking bouts also varied. Caregivers talked about many things while their infants crawled and walked, but of particular interest were utterances in which caregivers used action verbs (e.g., 'go, get, bring') to encourage movement and talk about objects by providing referential information (e.g., 'Is that your green frog?'). Walking was associated with gains in both of these language types.

With respect to action verbs, our data replicate and extend previous results (e.g., Karasik et al., 2014; Tamis-LeMonda et al. 2019) by documenting how action verbs in caregivers' language input co-occurred with infants' bouts of crawling and walking during everyday interactions. Data from the pre-walk sessions (when infants used crawling to move for roughly 50% of their bouts) illustrate that caregivers did direct action verbs to crawl bouts. In line with our hypothesis that walking bouts would be more likely to co-occur with actions verbs in caregivers' language input, we discovered that infants' walking bouts were nearly 2-3 times as likely to be paired with action verbs as their crawl bouts. Moreover, the striking consistency across the three walk sessions in the likelihood with which action verbs were paired with infant walking compared to crawling underscores the potential of walking as an agent of change in caregivers' communication with their infants. Indeed, as Gustafson (1984) noted, "Locomotion, then, may help to determine the linguistic forms and specific verbal information to which infants are exposed (p. 404).

Caregivers' production of language about objects also changed across the transition from crawling to walking. The proportions of object talk with crawling remained relatively low (and stable) across the observation period. And while there were no differences at walk onset in the proportions of crawl versus walk bouts accompanied with object talk, a rather striking divergence between bout types occurred across the rest of the observation period. Relative to their bouts of crawling, infants' walking bouts were more than 3 times as likely to co-occur with caregiver language about objects at 1 and 2 months post walk onset. Perhaps caregivers were attuned to changes in infants' walking skill and shifted their communicative focus to include proportionally more utterances about objects that infants encountered during their travels. Previous research has shown that walking infants access distal objects more often during everyday play (Karasik et al., 2011). If walking is associated with infants' propensity to explore distal objects, it is possible that this is also related to the changes we observed in caregivers' language input about objects across months of walking experience. Future research is needed to examine the spatial proximity of objects as infants explore the home space via crawling and walking, noting whether the object referents in caregivers' social messages were proximal to or distal from infants when they crawled and walked.

4.2.2 Gesture

Caregivers in our study gestured relatively infrequently; gestures co-occurred with 10.28% of walking bouts and 5.31% of crawling bouts, rates that remained stable across the observation period. We observed two key differences when we compared gesture production to crawling versus walking bouts.

First, bouts of walking were twice as likely to receive gesture input as were bouts of crawling at the three walk sessions. Why might this be the case? When infants crawl, their view of the world consists primarily of the floor in front of them (Kretch et al., 2014). However, while walking, infants' enhanced access to visual information may enable them to reap the communicative benefits of caregivers' gestures. Caregivers may be sensitive to their infants' new visual perspective, and this may be reflected in the nearly doubled rate of gesture input to bouts of walking. Support for this possibility comes from previous research indicating that adults' gesture production varies as a function of the visual availability of their communicative partners. Gestures occur at higher rates when a communicative partner is seated in front of the speaker, compared to when the partner is seated behind a screen and is visually unavailable (Alibali, Heath, & Myers, 2001).

Second, the rates of movement and show gestures varied as a function of walking experience. The rate of movement gestures paired with bouts of walking decreased following walk onset, while the likelihood of show gestures co-occurring with walking sharply increased. This shift suggests that caregivers tailored their gesture input to infants' skill level (see also Karasik et al., 2008). Caregivers were most likely to use movement gestures when infants walked at their walk onset sessions, perhaps providing immediate support for their infant's new locomotor skill. At this session, newly walking infants were still quite unsteady and may have needed the extra communicative "push" from caregivers in making the decision to go (e.g., Tamis-LeMonda et al., 2008).

In the 2 months following walk onset, walking proficiency improves rapidly (see Adolph et al., 2012). Consistent with this change, movement gestures were replaced by show gestures during bouts of walking, almost as if caregivers altered their focus from that of scaffolding a new motor skill to capitalizing on opportunities for more complex communicative exchanges about objects. The data suggest that not only were caregivers attuned to changes in infants' skills, but their communicative input was influenced by these changes. Future work should further explore these associations by examining more fine-grained measures of infant walking proficiency (e.g., standard gait parameters) and communicative input from caregivers as infants accumulate walking experience.

4.3 A developmental cascade: Walking, exploration, and caregiver input

The onset of independent locomotion in infancy has been shown to relate to changes in how infants explore their environments and in their social interactions with caregivers. Infants engage with the world differently when they are able to locomote, and even more so, when they are able to walk. Indeed, a growing body of literature has focused on walking as an agent of change in the actions of infants, but to a lesser extent, on its relations to changes in caregivers' communicative input when infants move (Adolph & Tamis-LeMonda, 2014; Adolph & Hoch, 2019). The gains associated with walking are immense—infants spend more time moving through the environment (Adolph et al., 2012), can better see potential people and objects for play (Kretch et al., 2014), engage in more and more complex social interactions (Karasik et al., 2011, 2012; Clearfield et al., 2008; Clearfield, 2011), and elicit rich language input from caregivers when they walk toward them while showing or offering an object (Karasik et al., 2014). Our findings suggest yet another gain: infants' walking bouts were more likely to co-occur with complex, multimodal communicative input from caregivers rich with language and gestures about action and referential information about objects.

Why might walking engender change in caregiver language and gesture input? It is unlikely that the onset of walking per se is uniquely responsible. Rather, the relations between infant walking and caregiver communication likely operate through a cascade relationship via intermediate associated gains for exploration. Early work has shown that infants' exploratory actions—looking, smiling, object play—affect caregivers' social behaviors (West & Rheingold, 1978; Green et al., 1980; Gustafson, 1984). In fact, Gustafson (1984) proposed that infants' locomotor behaviors might in fact be related to caregiver's language input. The current study reveals this link robustly in its comparison of the rates of crawling and walking bouts paired with caregiver language and gesture. Communication from caregivers changed when infants learned to walk, both immediately at walk onset and across the observation period, such that caregivers were consistently more likely to talk and gesture about actions and objects when infants walked compared to when they crawled.

The autonomy afforded by walking may also play a role in the changes in caregiver input that we observed. When infants cruise, they are bound to the limits of coffee tables and couches; as surfaces end, so do opportunities for locomotion (Adolph, Berger, & Leo, 2011). Similarly, in order to engage in supported walking, infants require a caregiver's hand or locomotor toy designed to move with them, thereby detracting from the ability to get up and go when and where they please.

Could caregivers' attitudes about motor development also play a role in the differences we observed in their language and gesture input? Western mothers and fathers eagerly await the onset of walking. Cultural and societal norms shape caregivers' expectations for their infants' development and might, in turn, be reflected in their perceptions of their infants as new motor skills enter their repertoires (Karasik, 2018). Indeed, research has shown that caregivers often view their new walkers as more mature and like individuals (Biringen et al., 1995; Walle, 2016). Moreover, caregivers are responsible for curating space for infants; they select objects for play, furniture in rooms, gates to section off space, floor coverings, and so on. These decisions might also affect infants' opportunities to practice motor skills during everyday exploration, and further, affect the types of language and gesture input caregivers might offer their infants during their travels. Research on the development of infant walking and its cascading effects on caregiver behavior should consider multi-method approaches in documenting caregivers' beliefs about their infants' motor development, asking about their decisions about organizing home spaces, and quantifying the surfaces and objects that provide natural affordances for action and locomotion in infants' homes (see Franchak, in press, for further discussion).

4.4 Limitations

This study had several notable strengths stemming from the dense monthly observation schedule across the transition from crawling to walking and micro-coding of both infant locomotion and caregiver language and gesture input during everyday activities at home. However, there are some limitations to note.

First, we did not transcribe caregiver speech at the utterance level within our coding windows. We credited each language and gesture type once per window in an effort to be conservative in scoring crawling and walking bouts with overlapping communication. It is possible that although crawling bouts were less likely to be paired with language, caregivers might have produced greater numbers of utterances when infants crawled versus when they walked. Future research should identify the numbers of utterances in each communication type to further distinguish whether the occurrence of multiple utterances of a given type of communication was also differentiated by how infants move.

Second, this study was observational, thereby precluding our ability to draw inferences about direction of causality. We cannot know for certain if walking resulted in the increased likelihoods of caregiver language and gesture input as compared to crawling. The relations between infant locomotion and caregiver input are presumably bidirectional: as infants walk, reach a new object or explore some facet of the environment, caregivers might offer input, which may then elicit more exploration. While the data are correlational in nature, the robust associations observed in this study may lend themselves to establishing a causal relationship. Significant differences emerged after controlling for individual differences over time, both within infants and caregivers, providing foundational evidence for establishing a case for causal inference (Miller, Henry, & Votruba-Drzal, 2016).

Finally, our sample was homogenous in its racial/ethnic and SES composition. Data for this study were drawn from a previously collected sample. Future studies should replicate these findings in a more diverse sample of infant-caregiver dyads

4.5 Conclusions

Infants' actions shape their experiences. The current study illustrates that the ability to walk co-occurs in time with striking changes in the language and gesture input caregivers provide. Research on the gains associated with infant walking stresses its importance for development in other active domains within the infant. In the present study, we found that infant crawling and walking differentially elicit communication from caregivers during everyday interactions. It seems that walking, indeed, reorganizes the infant-caregiver experience. Moreover, our data suggest that researchers must study development in real-time and in the context of daily life. Infants learn to walk amongst the clutter and complexity of the objects and caregivers that constitute their worlds. New motor skills in infants' repertoires unfold in the context of everyday, moment to moment interactions with their caregivers, who are sensitive to changes in their infants abilities and provide communicative input adapted to their developing skills.

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