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Transition From Crawling to Walking and Infants' Actions With Objects and People

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Associations between infants' transition to walking and object activities were examined. Fifty infants were observed longitudinally during home observations. At 11 months, all infants were crawlers; at 13 months, half became walkers. Over age, infants increased their total time with objects and frequency of sharing objects with mothers. Bidirectional influences between locomotion and object actions were found. Walking was associated with new forms of object behaviors: Walkers accessed distant objects, carried objects, and approached mothers to share objects; crawlers preferred objects close at hand and shared objects while remaining stationary. Earlier object activities predicted walking status: Crawlers who accessed distant objects, carried objects, and shared objects over distances at 11 months were more likely to walk by 13 months.

Around the end of the 1st year, infants display a number of advances in their interactions with objects and caregivers. Infants engage with objects for extended periods, juxtapose multiple objects, and use objects in functional and symbolic ways (McCune, 1995; Power, Chapieski, & McGrath, 1985; Tamis-LeMonda & Bornstein, 1996). Activities with objects become more intentional as infants engage with objects of their own choosing (Rheingold, Hay, & West, 1976; Tamis-LeMonda & Bornstein, 1993) and readily take the lead in initiating object exchanges by showing and offering objects to adults (Laakso, Poikkeus, Katajamaki, & Lyytinen, 1999; Ross & Goldman, 1977). Showing and offering objects to adults may enable infants to extend periods of social interactions, thereby providing opportunities for infants to learn language and rules of social interaction such as turn taking (Hay, 1979).

During the same time that infants display advances in their interactions with objects and adults, their locomotor skills change dramatically. By the start of their 2nd year, infants transition from moving around on all fours as crawlers, to taking their first upright walking steps (Adolph & Berger, 2006, 2011). Are improvements in infants' object interactions and locomotion coincidental or are they functionally related? It is possible that object interactions and locomotion merely follow a parallel time course, much like infants eating adult food for the first time or growing a first tooth, all of which occur around the start of the 2nd year. Alternatively, improvements in object activities and the transition to walking may be functionally related such that advances in one area support advances in the other.

In this study, we examined whether a functional relation exists between object interactions and the transition from crawling to walking by comparing crawlers and walkers of the same age. We observed the object activities of experienced crawlers and novice walkers at 13 months. Moreover, we tracked infants prospectively beginning at 11 months, when all infants were still crawling, to examine whether the two groups of infants differed in their object activities prior to the transition to walking. At 11 months, infants' age and the average duration of crawling experience were held constant; thus, on these measures, all infants started out in the same place. Inspired by previous work (Biringen, Emde, Campos, & Appelbaum, 1995, 2008), this design enabled an examination of bidirectional associations between object and locomotor behaviors. We considered three aspects of object interaction—infants' interaction with proximal and distal objects, infants' transport of objects, and infants' sharing of objects with their mothers.

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Interactions With Proximal and Distal Objects

The transition from crawling to walking might relate to the time infants spend engaged with proximal and distal objects. Walkers might spend more time with objects overall and be more likely to access objects from different rooms or locations due to a new, elevated vantage point that enables them to see objects at distances. When placed upright in a mechanical walker, crawling infants were more likely to visually attend to remote objects than when they were left on the floor (Gustafson, 1984). Reciprocally, crawlers' view may be more obstructed since they are lower to the ground. In order for crawlers to visually encounter interesting, far-off objects, they have to pull up to a stand, view their surroundings, then shift back into a crawling posture and mosey on toward the object. Thus, perhaps crawlers are more likely to engage with objects in the nearby vicinity. A related speculation is that the ability to walk might serendipitously increase object interactions because walkers take more steps and travel longer distances than crawlers (Adolph, 2008b). The increased activity associated with upright locomotion might consequently lead to more object interactions.

The intrigue of seeking out and playing with remote objects could potentially even facilitate the onset of walking. Attachment theorists have suggested that infants are motivated to move away from the vicinity of their mother in order to explore objects at distal places (Bowlby, 1969; Mahler, Pine, & Bergman, 1975; Rheingold & Eckerman, 1970). One study showed that infants' desire to obtain objects placed in front of them might account for their transitioning from rocking on hands and knees to taking crawling steps (Goldfield, 1989). Perhaps as crawlers pull up and view appealing objects from afar, they might be inclined to take their first walking steps toward objects of interest.

Alternatively, the transition from crawling to walking might be related to transient *declines* in infants' object interactions as walkers focus their energies on their newly acquired skill. When a particular skill first emerges, other abilities may decline temporarily until the newly acquired skill improves. For example, when infants first begin to walk, they revert to more primitive, bimanual reaching for small objects (Corbetta & Bojczyk, 2002). Typically, before infants transition to walking, they are competent crawlers, able to move about their environment and encounter things en route (Adolph, 2008a). It is possible that experienced crawlers will be likely to access and engage with distal objects as they crawl from room to room (e.g., Rheingold, 1969). For example, experienced crawlers were better able to negotiate space to find hidden goals at distal landmarks than novice walkers (Clearfield, 2004).

Carrying Objects

The transition from crawling to walking might also be associated with changes in infants' transporting of objects from place to place (Gibson, 1988). Upright walking frees up the hands from supporting the body, thereby allowing the hands to be used for other functions such as carrying objects. Crawlers, on the other hand, might be at a disadvantage as they use their hands for balance and locomotion. Thus, the ability to walk might enable object carrying so that walkers rather than crawlers might engage in this activity. Reciprocally, the desire to carry things could motivate infants to walk. Scholars have debated about the role of carrying objects in the evolution of upright walking (Stanford, 2003). The desire to reach for and carry food might have contributed to the emergence of early hominids' ability to stand up and walk.

Alternatively, new walkers may be *less* likely to carry objects than crawlers, at least until walking improves. Newly walking infants are inexperienced and clumsy in their novel upright posture (Adolph, Vereijken, & Shrout, 2003); their balance is precarious and falling is commonplace (Adolph, Komati, Garciaguirre, Badaly, & Sotsky, 2011). Although walkers' hands are free from supportive functions, they often keep their arms frozen in a ''high guard'' position to keep balance (Kubo & Ulrich, 2006; Ledebt, 2000). Additionally, carrying objects is extremely difficult for infants (Adolph & Avolio, 2000; Garciaguirre, Adolph, & Shrout, 2007; Vereijken, Pedersen, & Storksen, 2009). Carrying an object shifts the location of infants' center of gravity and may make the task of keeping balance for an already unsteady walker even more difficult. As a consequence, infants' walking patterns are disrupted. For example, when experimenters encouraged 14-month-olds to walk over a straight, short path while loaded with weights, infants fell more frequently than while walking without loads (Garciaguirre et al., 2007; Vereijken et al., 2009). When infants did manage to walk across the path, their gait appeared less mature. In contrast, experienced crawlers might not be as burdened when

carrying objects and might be able to move while carrying objects more flexibly. Crawlers' weight is distributed over four rather than two limbs, making balance steadier. Because crawlers find various ways to move, traveling on hands and knees, feet, or scooting on their bottom (Adolph & Berger, 2010; Adolph, Vereijken, & Denny, 1998), moving with an object might not be that cumbersome.

Social Exchanges With Objects

Finally, the transition from crawling to walking could be related to infants' social exchanges with objects. Although studies have charted the emergence of object sharing over the first 2 years (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Carpenter, Nagell, & Tomasello, 1998), associations between object sharing and motor development remain unexamined. Previous studies have mainly focused on smiles and vocalizations in relation to affective behaviors and looks toward adults, which emerge earlier in development than object sharing. Object sharing requires infants to choose an object, attend to the adult, and extend the object in the adults' direction. This behavior is a more deliberate, intentional action than displays of affect, and is therefore more revealing of infants' role as a social agent.

There is some evidence that the development of walking changes other aspects of the infant–mother interaction. In one study, 8-month-old, precrawling infants were observed for 10 min in the lab while propped upright in a mechanical walker and while out of the walker playing with objects and their mothers (Gustafson, 1984). While in the mechanical walker, infants displayed more smiles and vocalizations to their mothers. When observed longitudinally over the transition from crawling to walking, walking infants were more likely to engage in social looks toward adults than crawling infants (Clearfield, Osborne, & Mullen, 2008) and showed increases in positive and negative emotional expressions (Biringen et al., 1995).

Reciprocally, infants' desire to share objects with their mothers might lead to changes in infants' locomotor abilities. Infants are motivated to approach mothers to engage and share experiences, seek comfort when alarmed, or follow after them when exploring new situations (Ainsworth, 1969; Ainsworth & Bell, 1970; Rheingold & Eckerman, 1970). Although crawlers can leave and return to their caregivers, the onset of walking has been described as the period of ''exhilaration,'' the beginning of infants' psychological independence and individuation from caregivers (Mahler et al., 1975). The transition to walking is marked by a reorganization of the emotional relationship between infants and mothers, particularly for infants who start walking earlier (Biringen et al., 1995).

Finally, social exchanges with objects might temporarily decline with the transition to walking as infants negotiate the new challenges of walking. Because crawlers are well practiced in their familiar crawling posture, their locomotor behaviors might not interfere with their sharing of objects with caregivers.

In this study, we took a unique approach to investigating possible functional relations between the transition from crawling to walking and infants' object interactions. We observed infants longitudinally from 11 to 13 months of age in the natural setting of their homes with their mothers as they went about their daily activities. Because infants' and mothers' activities were unconstrained, we documented infants' spontaneous engagements with distal and proximal objects, carrying of objects, and sharing of objects with their mothers. In doing so, we provide a description of the natural ways that infants use objects in extended, everyday interactions with mothers outside the laboratory with toys of their own choosing. The longitudinal design permitted an investigation of within- and between-session differences in these three aspects of object engagements in infants who continued to crawl at 13 months (crawler–crawler group) versus those who transitioned from crawling to walking (crawler–walker group).

Method

Participants

Fifty infants (26 boys and 24 girls) and their mothers participated. All infants were healthy and born at term; most (80%) were White. All mothers were infants' primary caregivers and spoke English as their primary language. Most (70%) held graduate degrees. Families were recruited from the greater New York City metropolitan area via purchased mailing lists, brochures, referrals, parenting web sites, and the New York University hospital maternity ward. An additional two infants were dropped from the final sample: One family was unreachable after the first session and one infant's video data were lost due to experimenter error. Families received a photo magnet and personalized photo album as souvenirs of participation.

Procedure

An experimenter visited infants in their homes at two time points. At the first session, infants were 11 months old (*SD* = 0.28) and all were crawling. At the second session, infants were 13 months old (*SD* = 0.25) and approximately half (*n* = 24) had begun walking. At the start of the 11-month session, mothers were told that the purpose of the study was to document infants' interactions with their environments and were instructed to go about their everyday activities. Mothers were unaware that infants' activities with objects would be the focus of the study. At the end of the session, the second home visit was scheduled and mothers were sent a reminder photo magnet with the scheduled date. After the 13-month session, mothers were sent the photo album.

Each session lasted approximately 2 hr. At the beginning of each session, the experimenter verified infants' locomotor status and asked mothers about their infants' locomotor experience. Next, infants and mothers were video-recoded for 1 hr. Finally, at the end of each visit, the experimenter asked mothers whether the naturalistic interactions seemed typical and whether the infant seemed comfortable with the experimenter in the room. All mothers reported that the experimenter's presence had minimal effect on their interactions with their infants or infants' comfort.

Locomotor status and experience. To verify infants' locomotor status at both sessions, the experimenter encouraged infants to crawl or walk over a 5-m cloth runway rolled out in the families' home or hallway outside of the apartment. At the 11-month session, all infants could crawl 3 m on hands and knees and none could walk 3 m. Thirty-seven infants (74%) could take steps while holding onto furniture for support (cruising). At the 13-month session, 24 infants (12 boys and 12 girls) could walk 3 m without stopping or falling, and 26 infants were still crawling (14 boys and 12 girls). Thus, infants fell into two groups: infants who crawled at 11 months and continued crawling at 13 months (crawler–crawler), and infants who began walking by 13 months (crawler–walker).

In a structured interview (Adolph et al., 2003), the experimenter asked mothers about their infants' locomotor experience. Mothers reported the first day that they witnessed infants crawling on their belly and/or hands and knees (3 m, typically the length of a room or hallway), cruising along furniture (1.5 m, the length of a couch), and walking independently (3 m). To aid memory, mothers consulted baby books and calendars. Locomotor experience was calculated as the number of days between onset and test dates (Figure 1).

At the 11-month session, crawling experience ranged from 0.33 to 5.06 months (*M* = 2.23 months) and there were no differences between crawler–crawler (*M* = 2.00 months, *SD* = 1.21) and crawler–walker groups (*M* = 2.49 months, *SD* = 1.07), $t(48) = 1.56$, $p > .05$. At the 13-month session, the 26 infants who continued to crawl had accumulated *M* = 3.98 months of crawling experience (*SD* = 1.26). The 24 infants who had begun walking had *M* = 0.96 months of walking experience (*SD* = 0.53). Thus, crawlers had four times more crawling experience compared with walkers' walking experience, $t(48) = 11.18$, $p < .001$. Girls and boys had equivalent amounts of crawling, walking, and total locomotor experience, and all began crawling at similar ages (all *p*s > .05).

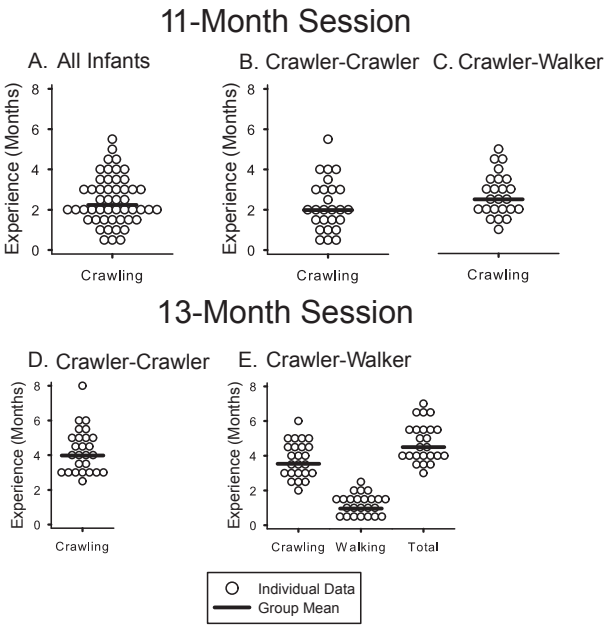

Figure 1. Frequency distributions of infants' locomotor experience: (a) crawling experience for all infants (*n* = 50) at the 11-month session; (b) crawling experience at 11 months in the group of crawlers (*n* = 26) who were still crawling at the second session; (c) crawling experience at 11 months in the group of walkers (*n* = 24) who began walking at the second session; (d) crawling experience for crawlers at the 13-month session; and (e) crawling, walking, and total experience for walkers at the 13-month session.

Note. Open circles represent individual data and horizontal lines describe group means. The crawler–crawler group includes infants who continued to crawl at 13 months; the crawler–walker group includes infants who began walking by 13 months.

Naturalistic interactions. During each hour-long naturalistic interaction, the experimenter videotaped infants and mothers as they went about their daily routines (playing, feeding and changing, household chores). The residences were filled with common furniture, household objects, and children's toys. Mothers were free to interact with their infants or leave them to play by themselves. Infants could choose to engage with objects or not. Mothers could leave their children unrestricted on the floor, or constrain them in playpens or high chairs. During the taping, the experimenter remained in the background and offered minimal responses to infants or mothers. In cases when infants and mothers were separated, the experimenter focused the video camera on the infant.

Data Coding of Naturalistic Interactions

Behavioral data were scored from video using a computerized video coding system, MacSHAPA (http://www.OpenSHAPA.org) that records the frequencies and durations of specific behaviors (Sanderson et al., 1994). A primary coder coded 100% of the data; a second coder coded between 33% and 100% of the data for reliability. Interrater reliability ranged from 93.9% to 96.0% (all kappa values $p < .05$); correlation on a duration variable was $r = .98$. Disagreements between coders were resolved through discussion.

We first identified instances throughout the 1-hr video record where object episodes occurred. The onset of an object episode was determined by the infant's initial manual contact with objects. The offset of an object episode marked the video frame when the infant let go of the object or removed the hand from the object for 5 s. Transitions from one object to another in quick succession were coded as a single episode of object engagement. In the case of these multiple-object episodes, manual contact with the first object denoted the onset and the end of contact with the last object signaled offset. Time spent in object episodes indicated the total amount of time that infants spent in manual contact with objects exploring or playing with objects over the entire session (e.g., Banerjee & Tamis-LeMonda, 2007; Tamis-LeMonda & Bornstein, 1993).

Object location was coded dichotomously as distal or proximal for each object episode. Proximal object episodes denoted object retrievals within infants' arm reach. Distal object episodes required infants to locomote (by crawling/cruising/walking) to retrieve the object. A 5-s rule was imposed to determine object location—whether infants moved within 5 s prior to touching the object. Five seconds provided infants with sufficient time to travel to objects if they chose to do so. Frequencies of both proximal and distal object engagements were tallied.

Instances of carrying were computed as frequencies. Carrying began with the first frame when infants attempted to move forward while holding an object and ended when they transitioned to a stationary position or released of the object. A minimum of four consecutive steps (crawling or upright) was considered forward movement with 0.5 s or less of limbs on the floor at rest, thus, eliminating instances when infants took steps in place.

Object sharing, or ''bids'' to mothers with objects, were coded when infants extended an object toward their mothers to either show or offer the object (e.g., infant is credited with three bids if the infant is playing with tea set and hands over first cup, then spoon, then saucer to mother). Additionally, each infant bid was classified as either ''stationary'' or ''moving.'' Stationary bids were coded when infants remained in one place and extended an object toward the mother to ''show'' or ''offer.'' Moving bids required infants to bring an object over to their mothers by crawling, cruising, or walking for the purpose of sharing. From these data, the frequencies of stationary and moving bids were tallied.

Results

The association between locomotor status and infants' object interactions was tested in a series of mixed measures analyses of variance (ANOVAs). Locomotor status (crawler–crawler vs. crawler–walker) served as a between-subject variable. Age (11 and 13 months) was used as a within-subject variable. Significant main effects and interactions were followed up with pairwise comparisons using a Bonferroni-adjusted alpha level to control for experiment-wise error rates (overall $p = .05$). Preliminary analyses showed no effects for gender, so data were collapsed in further analyses.

Based on the hour of naturalistic interaction, infants spent half their time engaged with objects. Infants' time in object play increased over the 2 months, regardless of their locomotor status. Infants spent 29.77 min ($SD = 10.11$) with objects at 11 months and 34.71 min ($SD = 7.90$) at 13 months. A 2 (locomotor status) × 2 (age) ANOVA on the duration of object engagement confirmed a significant effect for age, $F(1, 48) = 10.85$, $p < .01$. There were no differences between the crawler–crawlers

(*M*s = 27.21 and 34.29 min, *SD*s = 10.05 and 7.64, at the 11- and 13-month session respectively) and crawler–walkers (*M*s = 32.55 and 35.18, *SD*s = 9.62 and 8.32, at the 11- and 13-month session respectively) on the amount of time spent with objects at either session.

How Infants Accessed Objects

The transition from crawling to walking was related to how infants accessed objects for play—that is, by engaging with things nearby or locomoting to distant objects. As illustrated in Figure 2, over age, the crawler–walker group doubled the frequency of distal object interactions from 5.29 episodes (*SD* = 3.46) at 11 months to 12.00 episodes (*SD* = 6.90) at 13 months, $t(23) = 4.65$, $p < .001$. The frequency of activities with proximal objects decreased from 40.83 episodes at 11 months (*SD* = 14.20) to 25.87 proximal episodes at 13 months (*SD* = 8.34), $t(23) = 5.14$, $p < .001$. In contrast, at both sessions, the crawler–crawler group continued to interact with proximal objects (*M*s = 38.96 and 38.84, *SD*s = 13.60 and 13.85 at 11 and 13 months, respectively) and rarely engaged with distal objects (*M*s = 2.84 and 3.92, *SD*s = 2.60 and 2.21, respectively). At 13 months, walkers were 3 times more likely to travel to objects to interact with them (*M* = 12.00) compared with crawlers (*M* = 3.92), $t(48) = 5.48$, $p < .001$. These differences were confirmed by a significant three-way interaction between locomotor status, age, and object location, $F(1, 48) = 17.56$, $p < .001$, $\eta^2 = .27$, in a mixed measures ANOVA on the frequency of object episodes.

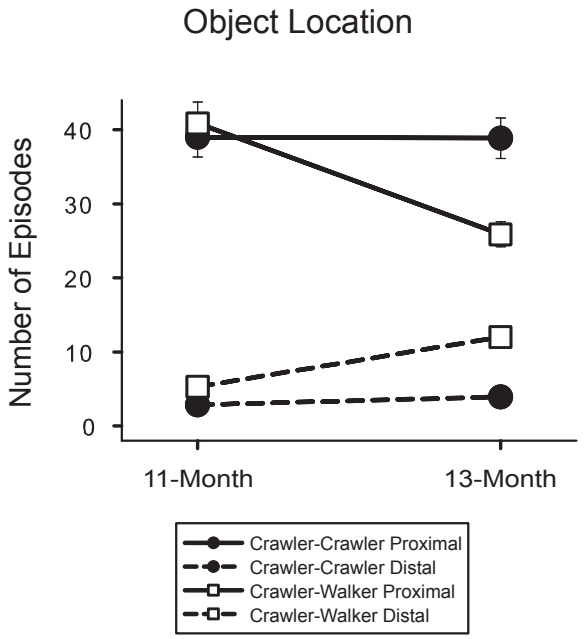

Figure 2. The average number of proximal and distal object episodes for the crawler–crawler and crawler–walker groups at 11 and 13 months of age.
Note. Error bars represent the standard error of the mean.

The findings were also reflected in the significant two-way interaction between locomotor status and object location due to the crawler–walker group engaging in a greater number of distal object episodes than the crawler–crawler group across both ages. A significant two-way interaction between age and object location was due to an increase in distal object episodes and a decrease in proximal object episodes mainly driven by the crawler–walker group.

At 11 months, the two groups also differed in their engagements with distal objects (*M*s = 5.29 and 2.85, *SD*s = 3.46 and 2.60 for crawler–walkers and crawler–crawler groups, respectively), $t(48) = 2.84$, $p < .01$. The magnitude of the difference between the two groups at 13 months ($d = 1.58$) was greater than that at 11 months ($d = 0.79$). How infants accessed objects at 11 months predicted their walking status at 13 months. In a logistic regression analysis, we tested the possibility that object activities might portend changes in locomotor status. Walking status at 13 months served as the dependent variable and the frequency of distal object episodes at 11 months served as a predictor variable. Duration of crawling experience at 11 months was treated as a control variable in the analysis to examine the independent effects of locomotor status and experience.

Frequency of distal object episodes at 11 months significantly predicted walking status at 13 months even after controlling for crawling experience at 11 months, $\chi^2(2, n = 50) = 9.47$, $p < .01$. Specifically, the analysis yielded an odds ratio of 1.29 (Wald test = 6.00, $p < .05$) indicating that the likelihood of an infant becoming a walker at 13 months was 1.29 times greater for every 1 *SD* increase in distal object engagement. Duration of crawling experience at 11 months was not a significant predictor of walking status at 13 months, nor was it correlated with frequency of distal object engagement at 11 months ($r = .10$, $p = .50$). Frequency of engagement with proximal objects at 11 months did not predict infants' locomotor status at 13 months (*p*s > .05). Thus, it appears that infants' earlier desire to access distal objects, rather than overall engagements with objects, predicted later walking.

Infants Carrying Objects

As illustrated in Figure 3, both groups increased in frequency of carrying, but the increase was far more pronounced for the crawler–walkers. The crawler–walker group increased from 6.88 instances of carrying (SD = 10.51) at 11 months, to 42.71 instances (SD = 32.45) at 13 months. The crawler–crawler group increased as well, from 1.46 instances (SD = 2.04) at 11 months to 5.08 instances of carrying (SD = 6.47) at 13 months (ps < .01). The increase in carrying for the two groups over age was confirmed in a significant age by locomotor status interaction, $F(1, 48) = 24.39$, $p < .001$, $\eta^2 = .34$.

At 11 months, the crawler–walker group (M = 5.25, SD = 5.56) and crawler–crawler group (M = 1.42, SD = 2.02) also differed in their instances of carrying, $t(48) = 3.29$, $p < .01$. This initial difference in carrying was further explored in a logistic regression analysis, which showed that the frequency of carrying at 11 months predicted infants' walking status at 13 months after controlling for 11-month crawling experience, $\chi^2(2, n = 50) = 12.88$, $p < .05$. Odds ratio for the frequency carrying revealed that the likelihood of an infant becoming a walker at 13 months was 1.29 times (Wald = 4.98, $p < .05$) greater for every 1 SD increase in the frequency of carrying. No significant correlations were found between frequency of carrying at 11 months and crawling experience at 11 months (ps > .05) perhaps because all infants were already sufficiently experienced crawlers.

Infants Using Objects in Social Exchanges With Mothers

Infants often included their mothers in their object activities. Over the 2 months, infants increased in how often they shared objects (object bids) with their mothers regardless of crawling or walking (Figure 4). At 11 months, infants averaged 8.38 object bids (SD = 12.80), sharing objects about once every 7 min. Bids doubled to an average of 15.85 (SD = 12.23) at 13 months, or once every 4 min. A 2 (locomotor status) × 2 (age) mixed measures ANOVA on the frequency of bids confirmed only a main effect for age, $F(1, 48) = 8.62$, $p < .01$. Most infants bid at least once at each of the two sessions; 92% (46 infants) at the 11-month session and 100% at the 13-month session.

Although the overall frequency of object sharing did not differ by locomotor status, the forms of object sharing differed dramatically between the crawler–crawler and crawler–walker groups when object bids were further analyzed by type of bid (stationary vs. moving). As illustrated in Figure 5, over age, the crawler–walker group increased in

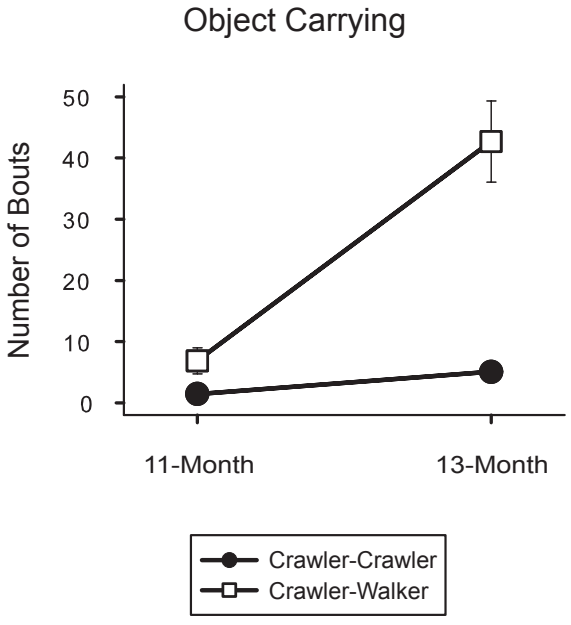

Figure 3. The average number of carrying episodes for the crawler–crawler and crawler–walker groups across age.
Note. Error bars represent the standard error of the mean.

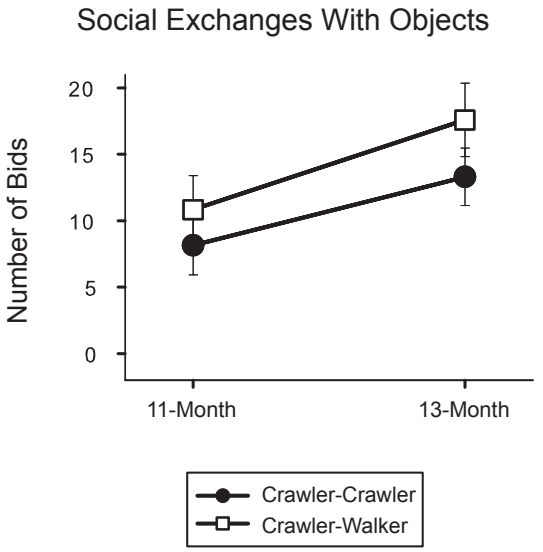

Figure 4. The average number of object bids to mothers in the crawler–crawler and crawler–walker groups at 11 and 13 months of age.
Note. Error bars represent the standard error of the mean.

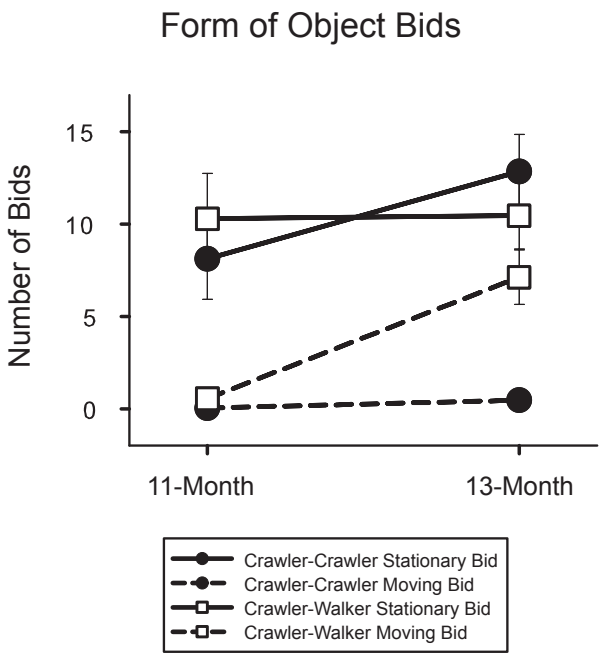

Figure 5. The average number of the two forms of object bids (stationary and moving bids) for the crawler–crawler and crawler–walker groups at 11 and 13 months. Error bars represent the standard error of the mean.

moving bids from 0.54 (*SD* = 1.47) at 11 months to 7.13 (*SD* = 7.26) at 13 months ($p < .01$), an increase of 1.26 *SD* ($d = 1.26$). However, stationary bids for this group remained unchanged (*M*s = 10.29 and 10.46, *SD*s = 12.04 and 8.90 for 11 and 13 months, respectively, $p > .01$). In contrast, for the crawler–crawler group, over age, moving bids remained infrequent (*M*s = 0.04 and 0.46, *SD*s = 0.20 and 1.39 at 11 and 13 months, respectively) and infants continued to bid to their mothers, while stationary ($M = 8.12$, $SD = 11.20$ at 11 months; $M = 12.85$, $SD = 10.25$ at 13 months; $p > .05$). A mixed measures ANOVA on the frequency of bids confirmed a significant three-way interaction between locomotor status, age, and object bid type, $F(1, 48) = 6.72$, $p < .05$, $\eta^2 = .12$. Averaged across age, both groups exhibited more stationary bids with objects ($M = 20.86$, $SD = 16.24$) than moving bids ($M = 3.94$, $SD = 6.61$) as revealed in a significant main effect for bid type, $F(1, 48) = 63.89$, $p < .001$, $\eta^2 = .57$.

Although at 11 months, the crawler–walker group displayed more moving bids ($M = 0.54$, $SD = 1.47$) than the crawler–crawler group ($M = 0.04$, $SD = 0.20$), variability was high and the difference was only marginally significant ($p = .09$). A logistic regression analysis followed to examine the potential of the total amount and form of infants' object sharing in predicting walking status at 13 months. The number of total and stationary bids at 11 months did not significantly predict walking status after controlling for crawling experience. The odds ratios for total bids ($\beta = 1.02$, Wald = .42, $p = .52$) and stationary ($\beta = 1.03$, Wald = .23, $p = .61$) were not significant. The odds ratio for moving bids was marginally significant ($\beta = 8.51$, Wald = 3.50, $p = .06$). No significant correlations were found between the two forms of object bids and crawling experience at 11 months (*p*s > .05).

The marginally significant effect for moving bids at 11 months in predicting walking status at 13 months may be due to the low number of infants displaying moving bids at 11 months. Of the 50 infants, at 11 months, only 7 shared objects with their mothers after traveling to them with the object at least once. However, of these 7 infants, 6 became walkers by 13 months, $\chi^2(1, n = 50) = 4.64$, $p < .05$, providing tentative support for the idea that infants who already share objects over distances show earlier onsets of walking.

Discussion

We investigated infants' spontaneous object interactions during an hour of naturalistic observation in their homes. We focused on the time infants spent interacting with objects, the location of objects accessed, infants' carrying of objects, and whether infants used objects in social interactions with their mothers. Of particular interest was whether changes in infants' locomotor status and object interactions are functionally related. With our longitudinal design, all infants were experienced crawlers at 11 months, but by 13 months, half were novice walkers. Thus, infants naturally fell into two groups, crawler–crawlers and crawler–walkers, enabling comparison of associations between infants' transition to walking and object activities in infants of the same age. We also examined whether infants' earlier activities with objects predicted later walking status.

Age-Related Changes in Object Interactions

At both ages, infants spent an impressive amount of time in contact with objects, and frequently shared objects with their mothers. During the hour-long observation, infants spent over half the time engaged with objects, and they shared objects with mothers once every few minutes. Infants who remained crawlers and those who

became walkers by 13 months showed similar increases in the time spent with objects and how often they shared them. These age-related changes may be due to improvements in infants' abilities to regulate and focus attention on objects (Butterworth & Cochran, 1980), share intentions with others about objects (Tamis-LeMonda & Adolph, 2005), and represent everyday experiences through object play (McCune, 1993).

Infants' Object Activities and Locomotion

Infants' object activities and locomotor status were functionally related. The development of walking was associated with qualitative changes in how infants accessed and engaged with objects and how they used objects in social interactions with their mothers. Reciprocally, infants' earlier object activities—retrieving distal objects, carrying objects, and approaching mothers to share objects—predicted walking status at 13 months.

Infants' walking status at 13 months was associated with the locations from which infants accessed objects for play. Over the 2 months, the crawler–walker group shifted from primarily engaging with proximal objects to engaging with distal objects for over a third of their object interaction time. In contrast, the crawler–crawler group continued to engage with whatever objects happened to be nearby. This finding indicates that walkers explore their environment differently than crawlers. Rather than staying put and engaging with items within the vicinity, traveling to and contacting objects at different locations may provide walkers new ways to learn about the ''movability'' of one's own body and detached objects relative to the permanent aspects of the environment (Gibson, 1988).

The development of walking was also associated with qualitative changes in the ways infants engaged with objects and how they used objects in social interactions. Over the 2 months, almost all infants (90%) increased in how often they transported objects, even crawlers. In fact, the crawler–crawler group increased their carrying bouts by over 200%. This result is quite surprising as crawlers were using their hands to move and to carry objects. The crawler–walkers increased their carrying bouts by over 500% over the 2-month period. At 13 months, walkers displayed 9 times more carrying bouts than crawlers. Although balance is adversely affected by load carriage (e.g., Garciaguirre et al., 2007), these novice walkers were willing to potentially compromise their balance in favor of locomoting with objects.

Walkers' frequent carrying of objects paralleled changes in the way they shared objects with their mothers. By 13 months, walking infants were more likely than the crawlers to share objects by locomoting to their mothers (moving bids), even though the two groups did not differ in how often they shared objects overall. At 13 months, almost all of the walkers shared objects by moving to their mothers (n = 23 infants, 96% of the crawler–walker group) at least once as compared to only 6 crawlers (23% of the crawler–crawler group). In fact, 44% of walkers' bids were characterized as moving bids compared to only 3% of crawlers' bids at 13 months. Despite the developmental increase in carrying bouts for crawlers, their carrying did not result in a higher frequency of moving bids. At 13 months, walkers who were likely to carry objects were also likely to offer them to their mothers after traveling, $r(24) = .48$, $p < .05$. However, carrying bouts were not related to the frequency of moving bids for 13-month-old crawlers ($p > .05$). Thus, even though crawlers also carried objects, these carrying episodes did not readily translate into bids to mothers.

What might explain these differences in infants' engagement with distal objects, carrying of objects, and moving bids? One possibility is that walking provides infants with an elevated vantage point and frees the hands from having to support the body. Because walkers were upright, they could see objects at distal locations and therefore moved to access them. While moving upright, walkers also had their hands free to carry objects to their mothers for the purpose of sharing. Although crawlers also increased in their carrying, the coordination of carrying and sharing may have been more difficult and less efficient for them than it was for walkers. In order to execute a moving bid, infants had to locate their mother and travel to her while transporting the object. For crawlers, this meant switching from a quadrupedal posture to a sitting posture to first locate and then extend the object to mothers. Perhaps because of the extra difficulties, crawlers continued to bid while stationary.

Reciprocally, the motivation to access distal objects, carry objects around, and share objects with mother may both precede and motivate walking. Infants who were more likely to travel to distal objects and carry objects at 11 months were also more likely to have begun walking by 13 months, lending support to this hypothesis. Additionally, of the 7 infants who had instances of moving bids at 11 months, 6 infants began to walk before 13 months. Even seemingly small differences among infants in their tendencies to access distal objects,

carry objects, and approach caregivers with objects at the end of the 1st year foretold later walking status, which in turn facilitated various aspects of walkers' object activities at 13 months. These results highlight bidirectional influences between locomotor status and infants' activities with objects and people.

Of course, a number of alternative, third variables might explain the current findings. Perhaps infants in the crawler–walker group were given more opportunities to explore their environments by their mothers, which in turn led to earlier walking onsets and greater object activities. However, both groups of infants were unrestrained for the majority of the observation time at both ages, and all infants could travel around their home and interact with objects at will.

Locomotor experience can likewise be discounted as an explanation for walking infants' advantage in object activities. By 13 months, crawlers had 4 times more crawling experience as walkers had walking experience. Therefore, it would be reasonable to assume that the more experienced crawlers would be more likely to travel to distal objects, carry objects, and locomote toward mothers to share objects than walkers. Novice walkers might be expected to decrease their object activities until walking improved, due to the burden of learning a new locomotor skill (Adolph et al., 2003). This was not the case. An infant with only 2 days of walking experience at 13 months carried objects 35 times and had eight moving bids over the course of the hour. The numbers of carrying and moving bids for this infant were comparable to the overall average for walkers ($M = 42.58$ frequency of carrying, $M = 7.13$ frequency of moving bids for walkers at 13 months).

Another possibility is that the crawler–walker group was developmentally more advanced than the crawler–crawler group. However, if this were the case, walkers should have displayed greater gains than crawlers across all measures of object engagement. Walkers should have spent more time engaged with *both* distal and proximal objects and display more object bids to their mothers overall. They did not. In fact, walkers' engagements with proximal objects decreased, as did their stationary bids (though not significantly). Moreover, developmental gains in overall social bidding were equivalent in the two groups of infants.

We reasoned that opportunity, experience, and general abilities are unlikely explanations for the associations between infants' locomotion and object interactions. Instead, findings indicate a reciprocal, functional relation between the two domains: early motivations to engage with objects portend walking. Walking, in turn, offers infants new opportunities for learning about the environment through object and social interactions. These changes may also have implications for the ways that caregivers respond to infants, thereby, inciting further changes in infants' social environments. Thus, the joint study of infants' locomotion and object activities provides a valuable test of developmental cascades, by highlighting how emerging skills can have system-wide consequences for infants' functioning in their natural, everyday environments.

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