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Assessing motivation to move and its relationship to motor development in infancy

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ABSTRACT

Motivation to move has typically been a post hoc explanation for infants' discovery of new patterns of behavior. As a first step to studying motivation to move directly, we qualitatively assessed motivation to move and measured its relationship to motor development in infancy. We observed 27 infants longitudinally from ages 7 to 12 months. Every 3 weeks we assessed infants' motor motivation based on persistence, activity level, activity preference, and stimulus strength needed to elicit movement. We documented the onset of sitting, pulling-to-stand, crawling and cruising, as well as infants' overall motor development as measured with the Alberta Infant Motor Scale (AIMS). Motor motivation increased over the course of the study and we identified two distinct motivation profiles. *Strongly motivated* infants had earlier onsets for all four motor milestones than *weakly motivated* infants (all *p*-values <0.05). Infants' motivation to move score was positively correlated with their AIMS percentile at the same and subsequent sessions. These findings provide empirical evidence for a *motivational cascade* whereby motivation to move and motor development enjoy a reciprocal relationship. These findings have important clinical implications for children with motor delay, suggesting that evaluation of motivation could be included as part of the assessment procedure so that both treatment and expectations can be tailored appropriately.

1. Introduction

For over a century developmental theorists have argued that motivation to move prompts the discovery of new patterns of behavior (Trettien, 1900). For example, von Hofsten (2007) argued that motivations drive action and that understanding that action is the foundation for cognitive development. Adolph and colleagues, (Adolph, Vereijken, & Denny, 1998; Vereijken & Adolph, 1999) speculated that motivational differences may explain why some infants suffer the discomfort of belly crawling, while others wait until they have the strength to locomote on hands and knees before they move independently. On Thelen's Dynamic Systems account, motivation is one of several crucial components that must coalesce for a new behavior to appear (Thelen, 2005). Motivation may prompt instability in a system, so that infants can leave their current stable posture for a new unstable one.

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As in the theoretical discussions of development described above, the concept of motivation to move is also important from a clinical perspective. Practitioners who work with children, especially those with motor impairments, must incorporate strategies for keeping the children motivated into a therapeutic plan (Winders, 2001). For example, Winders (1997) created a dichotomous motivation profile for children with Down syndrome. *Motor Driven* children are motivated to move: they take risks when learning new movements, prefer to be moving and exploring rather than being held, move quickly, and resist stationary positions. In contrast, *Observers* are cautious, like to stay in stationary positions or be held, and they move at slow speeds. Despite the acknowledgment of children's motivation to move as an important factor for whether therapy is effective, it has not yet been systematically studied or related to prognoses or longer-term developmental outcomes.

Despite the centrality to developmental theory of the concept of motivation to move, motivation as an impetus for change has primarily served as a post hoc explanation. Whether as an explanation for how infants learn to reach (Thelen, 2005), transition from crawling to walking (von Hofsten, 2007), or invent creative strategies for using novel tools (Berger, Adolph, & Lobo, 2005), motivation to move has yet to be measured directly. *Mastery motivation*, a broad intrinsic psychological drive to explore or master the environment or task, is well-studied (Morgan, Harmon & Maslin-Cole,1990; McCall, 1995; Messer, 1995), and even has a subscale relating specifically to movement (the *Gross Motor Persistence* subscale; Morgan et al., 2009, p. 45). However, most of the items on that subscale attempt to capture infants' feelings about motor mastery, such as asking parents to rate whether their infant "tries to do it well" when learning a new motor skill, rather than focusing on a variety of aspects of movement and what the infants actually do. Other subscale items designed to capture infants' persistence refer to time on or attention to a single motor task, but "persistence on a task" would not sufficiently capture the motivation to move of infants who demonstrate frequent and variable movement without it being continually directed to the same outcome. Although the various accounts of motivation to move offer clear predictions about the developmental trajectory of motivation to move and the relationship between motivation to move and motor development, they have yet to be tested. Thus, the general aim of this study was to launch a formal study of motivation to move as a variable in its own right, rather than just as an explanation for other behavior.

Our first objective was to test the feasibility of capturing motor motivation. To do this, we designed a motivation to move scale to document variability of motivation. Qualitative measures of infant movement have successfully been used to evaluate neuromotor function in typically developing infants, as well as dysfunction in premature and other high-risk infants (e.g., Einspieler, Prechtl, Ferrari, Cioni, & Bos, 1997; Heineman, Bos, & Hadders-Algra, 2008; Prechtl, 1990; Prechtl & Hopkins, 1986). Following the rich tradition of qualitative motor assessment in infancy, we made subjective judgments about infants' movement, such as how often they changed body position during the observation, as well as the intensity of the stimulation required to evoke movement (Pollitt, Huang, & Jahari, 1999).

One component of Thelen's (2005) explanation for how infants learn to solve problems of motor control was that their motivation to move would increase with each small victory. She described a motivational cascade whereby motivation prompts action, which, when successful, in turn prompted further motivation. On this account, we would expect to observe increasing motivation over time as infants gain physical strength or they achieve more of their goals. Therefore, the second objective of this study was to longitudinally examine the developmental trajectory of motor motivation in infancy, which we did by observing infants every 3 weeks from ages 7 to 12 months to document the nature of motivation to move over locomotor transitions. Additionally, on Thelen's (2005) description of a motivational cascade, motivation to move provides the initial conditions for changes in motor skill whereby as motor skills are acquired, infants' own motivation level for the next developmental milestone emerges. As a result, we would predict that the higher infants' motivation to move, the earlier they acquire their motor milestones. Our third objective, therefore, was to examine the relationship between motor motivation and overall motor development and test whether individual differences in motivation to move were related to the timing of the acquisition of motor milestones.

2. Methods

2.1. Participants

Twenty-seven infants (17 male; 10 female) participated in this study from the time they were 7 months old until they were 12 months. We chose this age range because of the dramatic changes in infants' locomotor abilities that occur during this time span, particularly the prelocomotor to locomotor transition, and because the time frame was long enough to provide observations pre- and post-milestone onsets. No infants could crawl on hands-and-knees when the study began. By the time the study ended, all infants could crawl, pull to a stand, and cruise (independently holding on to a surface of support with their hands) and 7 infants had begun to walk. The trade-off for making observations at close intervals and being able to document variability before, during, and after the onset of motor milestones was having to end the study before all of the infants had begun to walk independently. Many parents would have found participation beyond 5 months to be a hardship, so we chose a time frame that sacrificed being able to capture walking, but still allowed us to capture crawling, pulling-to-stand, and cruising. All infants were screened for normal motor development using the Alberta Infant Motor Scale (AIMS; Piper & Darrah, 1994), described in more detail below.

Families were recruited to participate in the study by posting fliers about the research around the university and at health care centers. Participants were also recruited via a "snowball" technique where participants were asked to mention the research to friends or contacts via word of mouth. All infants were born at full term and were in good health. All families but one were urban, Caucasian, and of middle to upper-middle socio-economic status. Mothers' average age at the start of the study was 33 years; fathers' average age was 35 years. Average education for both mothers and fathers was 17 years. Families received disks with the movies from each observation session and a children's book as thank you gifts.

2.2. Procedures

Based on best practices in the temperament literature (Carnicero, Pérez-López, Salinas, & Martínez-Fuentes, 2000; Rothbart & Bates, 1998; Rothbart & Hwang, 2002; Wachs, 1990), we used complementary sources of information that capitalize on the strengths of both parental report and experimenter observation to document motor motivation in infancy over several months and to measure whether and how motivation is related to typical motor development.

2.2.1. Naturalistic observation

Infants were videotaped for 20–30 min in their own homes every 3 weeks from 7 months of age until 12 months (7 observations × 27 infants = 189 total sessions). Observations were structured so that they took place in a designated play space delineated by a play mat or an area rug. The space contained toys that an experimenter brought to each session, as well as some of the infants' own toys. Parents were told that researchers were documenting infants' motor development and were instructed to behave naturally with their baby as they would if the researcher were not there, but parents were also instructed to encourage their infants if they did not appear to be performing to their ability spontaneously (e.g., Heineman et al., 2008).

2.2.2. Motivation to move scale

From the videotapes of each session, a primary coder (OA) formed a global estimate of infants' motivation to move based on 5 factors: the proportion of the session spent in motion, persistence to move relative to difficulty or lack of motor control, frequency of changes in position, strength of external stimulus needed to elicit movement, and preference for high or low energy activities. High energy activities were defined as vigorous movements that involved big movements of the body, large weight shifts, and the use of multiple body parts. In contrast, low energy activities were defined as limited movements that involved small weight shifts and using one or few body parts. These criteria were partly based on established, qualitative classification systems for movement and activity in infancy (e.g., Rothbart, 1981; Rothbart, Derryberry, & Hershey, 2000). Unlike previous activity level coding schemes, however, additional criteria were adapted from guidelines for therapeutic assessment designed to capture the intensity of the "motivator" needed to facilitate the therapy (Winders, 1997). Together, the combined criteria went beyond typical measures of activity level to recognize motivation to move as a construct that is related to, but not the same as, motor activity.

In early infancy, when activity level is used to measure temperament, observations are made across infants' positive and negative emotional states (Rothbart, 2007). However, since the focus of our study was motor development and not temperament, we did not observe infants when they were stressed. The session was child-driven in that we were interested in the extent to which caregivers had to prompt and encourage infants to elicit movement, rather than have all caregivers carry out the same instructions (Einspieler et al., 1997; Piper & Darrah, 1994).

2.2.2.1. Scoring criteria. Taking into account the entire observational period, infants were classified on a scale from 1 to 5, where 1 indicated very low motivation to move and 5 indicated very high motivation to move (see Appendix for final set of coding criteria):

1. Very low motivation to move. Infants demonstrate low levels of motor activity, rarely change positions, and mostly remain stationary (i.e., lying, sitting still). When movement does occur it takes longer to initiate, and has low levels of intensity and duration. Even high external encouragement to move results in little to no movement.
2. Low motivation to move. Movement occurs infrequently, intensity is low-to-average, and preferred activities require little energy. Infants change position from time to time when they are highly stimulated to do so.
3. Moderate motivation to move. Infants move and change position with moderate frequency and will move to reach a goal. The duration of movement depends on context. No preference for high or low energy activities.
4. High motivation to move. Infants change position often and do not need clear stimulation to move. Infants seem to prefer moving over staying still, but may stop to play or hold a position if something captures their interest. Infants prefer high energy activities (i.e., climbing).
5. Very high motivation to move. Infants move for the sake of moving and movements are quick, frequent, and have high intensity. Play can seem secondary. Infants prefer high energy activities. No external encouragement is needed to elicit movement.

Coders were instructed to first observe the entire segment and form an overall estimate using the above 1–5 scale. Then, the observation was watched again, this time with a focus on the five factors (see Appendix A). If the estimate adequately described the separate factors the score was used for the analysis (75% of the observations yielded a match). If there was a mismatch between the overall initial estimate and the rating of the individual factors (25% of the cases), the coder observed the session once again in order to decide on the appropriate overall final score.

Infants were given a separate motivation to move score for each session, yielding a total of 7 motor motivation scores per child over the course of the study.

2.2.2.2. Reliability. Establishing the reliability of the scale involved a number of steps. First, the primary coder and an additional coder, both pediatric physical therapists, watched together a sample of the observations from the current study and discussed scoring criteria and primary outcome measures. The coders were blind to each other's scoring and their responses were compared. Several iterations of this process occurred before the final set of coding criteria was established. Disagreements were resolved by watching the video together, discussing the score in question, and fine-tuning the scoring criteria, resulting in the scoring criteria presented above.

In the second step to ensure reliability on this new measure, a third coder, a research assistant uninvolved in establishing the coding guidelines, tested the scoring criteria on a different, independent data set of 30 observations from 10 infants. Participants were infants between the ages of 5 and 13 months of age who took part in a different longitudinal study. Infants were assessed for motivation to move three times between the ages of 7 and 11 months. Observations were coded for motivation to move scores independently by the primary coder and the third coder. Calculation of the proportion of trials that the two coders were in agreement yielded an inter-rater reliability of 90% (Kappa = 0.54, $p < 0.00$).

The primary coder (OA) scored all observations, while the second coder independently scored 29 randomly chosen observations (15% of the entire primary data set). The proportion of trials that the two coders were in agreement was 84% (Kappa = 0.79, $p < 0.00$). Together, the Kappa coefficient for the 59 observations, which served for establishing the reliability of the scale, and in which the agreement between the primary coder (OA) and the other coders was tested, was $K = 0.75$, $p < 0.00$.

2.2.3. Parental report

To obtain an independent measure of infants' motor development and to corroborate what experimenters observed during the home visits, parents completed a survey about their infants' motor habits during wakefulness at each session. Parents reported how much their child moved in the 2 weeks prior to the home visit. Infants received a grade of *1* if movement was minimal, *2* if they moved to reach a target, and *3* if they were in constant motion.

2.2.4. AIMS

Trained pediatric physical therapists rated videotapes using the Alberta Infant Motor Scale (AIMS; Piper & Darrah, 1994) for each home observation of each infant. The AIMS is an assessment tool used to identify motor delay, evaluate motor performance, and measure changes in motor performance over time from birth to 18 months or independent walking. The scale was normed on a cross-sectional, random sample of over 2000 Canadian infants (Piper & Darrah, 1994). The AIMS has high inter-rater and test-retest reliability and validity (Darrah, Piper, et al., 1998; Darrah, Redfern, et al., 1998) and has been cross-culturally validated and used successfully (e.g. Jeng, Yau, Chen, & Hsiao, 2000; Manacero & Nunes, 2008; Syrengelas et al., 2010). 58 separate items covering supine (9 items), prone (21 items), sitting (12 items), and standing (16 items) postures make up the scale. Each item comprises 3 movement components: weight-bearing, postural alignment, and antigravity movement. Each observed skill earns the infant 1-point and the sum of the points observed in one session represents the infant's raw score for the session. The AIMS raw scores can be converted into age-based percentile ranks (Piper & Darrah, 1994).

A primary coder watched 100% of the videotaped sessions to calculate infants' AIMS scores at each observation session. A second coder independently scored infants' AIMS scores for 22% of the sessions. Agreement on the AIMS scores was 87%.

2.2.5. Motor milestone checklist

Parents were given an illustrated checklist of motor milestones based on Scher and Cohen's (2005) motor diary. They were instructed to use the checklist to monitor changes in their infants' motor skills between observation sessions. Parents recorded the date on the checklist of the first day that infants met the criteria for each of 13 milestones from rolling to cruising. For the purposes of this study, we focused on sitting, pulling-to-stand with support, hands-and-knees crawling and cruising because they are major milestones and easy for parents to observe (WHO, 2006). The onset of sitting was when the infant could get into a sitting position independently and hold the position for 1 min. The onset of pulling-to-stand was when infants could use furniture or another object as support to pull themselves up and maintain the position without falling for 1 min. The onset of crawling was when infants could execute 2 full cycles of forward movement on hands and knees with their belly off the ground. The onset of cruising was when infants could support an upright posture by holding onto a surface of support with their hands and execute 2 full cycles of movement using hands and feet. With only one exception, onset date was also the first day of performing the skill continuously. One child pulled-to-stand and then did not do it again for one week. His onset date for pulling-to-stand was calculated as the average between the first day he demonstrated the skill and the day he started performing the skill continuously. Because the purpose of onset date is to capture experience, using the first day that infants performed the skill would not be an accurate reflection of experience if they did not subsequently perform it from then on. However, on the same rationale, using the first day of continuous performance underestimates experience. Averaging the two dates brings us closer to capturing the events that the infant actually experienced.

Table 1
Age of onset and correlation with Motivation to Move score for each milestone. Ages are reported as months: days. $N = 27$.

	Onset age			
	Range	Mean	Standard deviation	Pearson *r*
Motor milestone				
Independent sitting	5:28–11:13	8:28	1:12	−0.43*
Pulling to stand	5:28–11:27	8:20	1:8	−0.57**
Hands-and-knees crawling	5:28–11	8:16	1:9	−0.59**
Cruising	7:18–12:18	9:24	1:4	−0.57**

* $p < 0.05$.
** $p < 0.01$.

3. Results

3.1. Motor milestone onsets

Age of motor milestone onset was based on parents' checklist diaries and corroborated via video coding. Over the course of the study, all infants learned to sit independently, pull-to-stand using an object for assistance, crawl on hands and knees, and cruise. All infants reached their milestones within the normal age range (see Table 1).

3.2. Changes in motivation to move over time

A repeated measures ANOVA on the motivation to move score over the course of the 7 observations revealed significant differences in motivation across session, $F(6, 144) = 3.61$, $p < .01$. As expected, motivation to move tended to increase over the course of the study. A series of post hoc pairwise comparisons revealed that motivation to move was significantly lower in session 1 than in sessions 5, 6, and 7; significantly lower in session 2 than in sessions 6 and 7; and significantly lower in session 3 than in session 7 (all p values <0.05; see Fig. 1).

3.3. Relationship between motivation to move and motor development

To address the question of whether motivation to move was related to infants' motor development, we carried out correlations between infants' motivation to move and the three measures of their motor development—parental reports of motor activity, AIMS percentile, and age of onset of motor milestones. Pearson correlations between infants' motor motivation score and parental report of motor activity at each of the 7 sessions revealed positive relationships at 4 of the 7 observations (see Table 2, column 2). Pearson correlations between infants' AIMS percentile at each session and their score on the motivation to move scale at the same session revealed significant positive relationships at each time point, except for session 5 which was marginal (see Table 2, column 3). The higher infants' motivation to move, the more advanced their motor development, as measured by the AIMS. Pearson correlations between infants' age of onset for sitting, pulling-to-stand, hands-and-knees crawling, and cruising and their motivation to move score averaged over all 7 sessions revealed significant negative relationships for all 4 milestones (see Table 1, last column). The higher infants' motivation to move, the younger they were when they reached their motor milestone.

Fig. 1. Infants' motivation to move scores over the course of the study. Error bars represent standard errors.

Table 2
Pearson correlations between Motivation to Move score and measures of motor development at each observation session ($n = 27$).

Observation session	Parent report	AIMS
1	0.24	0.44*
2	0.49*	0.55**
3	0.62**	0.69**
4	0.39	0.52**
5	0.55*	0.36[a]
6	0.34	0.42*
7	0.45*	0.41*

* $p < 0.05$.
** $p < 0.01$.
[a] $p = 0.06$.

In addition, we examined the influence of the onset of motor milestones on the trajectory of motivation to move. To do this, we normalized the onset of pulling-to-stand and crawling for each infant and analyzed changes in motivation to move score relative to onsets. Repeated measures ANOVAs on motivation to move score over 5 sessions (the one preceding the milestone onset, the first session where milestone is observed, 3 sessions post milestone onset) revealed an effect of milestone onset on motivation to move, $F(1, 26) = 8.49$, $p < 0.01$ and $F(1, 14) = 8.74$, $p = 0.01$, respectively (see Fig. 2). A series of post hoc pairwise comparisons revealed a significant increase in motivation to move from the session prior to milestone onset to the session immediately after the onset session (pulling-to-stand) or the 2nd and 3rd sessions after the onset session (crawling), all p's ≤ 0.05. Given the multiple comparisons, when applying a more stringent criterion, the significant increase ($p < 0.01$) occurred from the session prior to the milestone to the third session post the onset for both pulling-to-stand and crawling.

3.4. Motivational cascade

To test explicitly for a motivational cascade, we examined the relationship between motivation to move and motor development at different time points. Because the starting time point of the study was somewhat arbitrary, we tested for cascades starting both with a motivation score (Fig. 3A) and with a motor development score (Fig. 3B) at Time 1. Our rationale was that as one event followed another, correlations between motivation and motor development should remain strong because new milestones were providing new sources of motivation and ongoing motivation was spurring new skill acquisition. Regardless of whether we started our analysis with a motivation or motor score at the first time point, we found significant correlations throughout the duration of the study.

3.5. Individual differences

Our third objective was to examine the implications of individual differences in motivation to move. To do so, we took an exploratory approach by testing whether differences in motor development were related to different motivation patterns

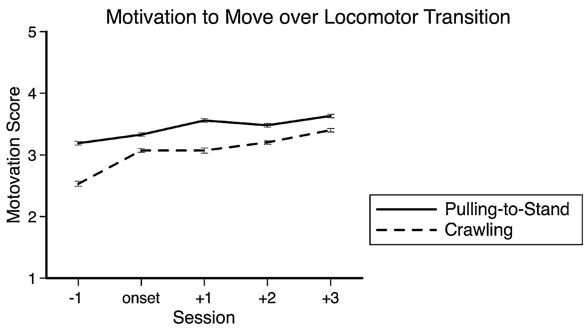

Fig. 2. Infants' motivation to move scores for pulling-to-stand (solid line) and crawling (dashed line) at the observations prior to, at, and post-onset. Error bars represent standard errors.

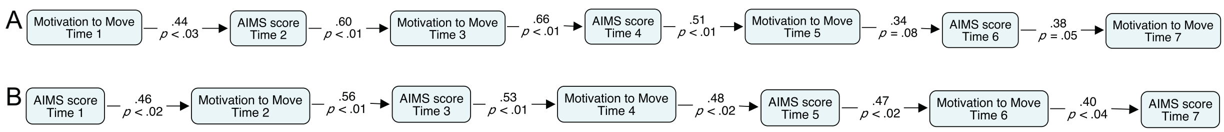

Fig. 3. Correlations and p values for the relationship between motivation to move scores and AIMS scores at subsequent time points over the duration of the study. Arrows represent time between observations. For all correlations, $n = 27$.

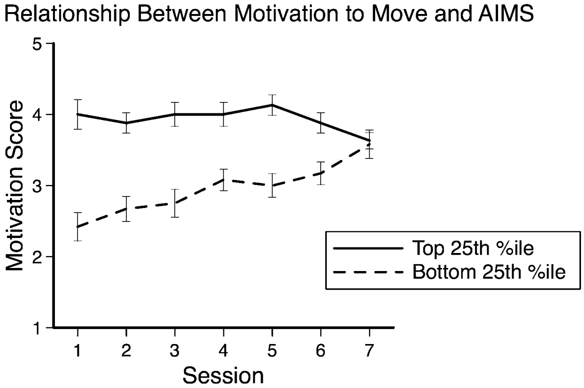

Fig. 4. Infants' motivation to move scores over the course of the study for those in the top 25th percentile of the AIMS (solid line; $n=8$) and for those in the bottom 25th percentile of the AIMS (dashed line; $n=12$). Error bars represent standard errors.

(van Geert & van Dijk, 2002). After finding significant correlations between motivation to move and the motor development measures, we felt it fitting to examine inter-individual variability (Siegler, 2002). We identified infants at the extremes of the distribution of AIMS percentile scores at each individual session, as well as averaged over all sessions for a single total score. We grouped infants by percentile on the AIMS with those scoring in the upper 25th percentile as "early" in developmental timing and those scoring in the lower 25th percentile as "late" in developmental timing. As only one infant showed a fluctuation in group across the 7 sessions, we used the total AIMS percentile scores for analyses. A 7 (test session as a within-subjects factor) × 2 (group as a between-subjects factor) mixed factors ANOVA on motivation to move score revealed a main effect for group, $F(6, 108)=2.96$, $p<0.01$, and an interaction between session and group, $F(1, 18)=925.16$, $p<0.01$, but no main effect for test session (see Fig. 4). Infants who scored higher on the AIMS had higher motivation to move scores than infants who scored lower on the AIMS. The significant interaction was driven by an increase in motivation scores by the lower scoring group across sessions and a decrease in motivation scores by the higher scoring group from sessions 6 to 7. Post hoc independent samples t-tests between the two groups at each session revealed that the higher scoring AIMS group always had significantly higher motivation scores (all p's <0.04) until the last session.

Although there was variability in infants' scores on motivation to move and on motor ability, for the most part individual trajectories parallel the results at the group level. Specifically, 63% of the sample ($n=17$) demonstrated an increase in motivation to move over the course of the study. Among those infants who followed the overall pattern of increasing motivation to move scores, trajectories varied. For example, some infants showed steady, gradual increases (see Fig. 5A), others showed sudden increases (see Fig. 5B), and others showed fluctuations within the overall increase. Among infants whose trajectories did not reflect the group average, one showed no change in motivation to move (3.7%), 5 demonstrated fluctuations in motivation to move scores over the observation sessions (18.5%, see Fig. 5E), 2 infants' motivation to move scores decreased over the course of the study (7.4%, see Fig. 5F), and 2 others showed an increase at the beginning of the study followed by a slight, stable decrease (7.4%).

Because the correlational analyses could not speak to the direction of causality, we decided to explore the data further to see whether we could learn anything about the influence of motor motivation on motor development and vice versa. Our first step was to temporally separate motivation from motor development. We did this by conducting a median split on the average age of crawling onset. We chose crawling because it is typically the first form of independent locomotion. We defined early crawlers as those whose onset date fell below the median ($n=12$) and late crawlers as those whose onset date fell above the median ($n=12$). We did not include 3 infants whose crawling onset was at the median in these analyses. We conducted independent-samples t-tests on infants' motor motivation at the first 3 sessions of the study, all of which occurred prior to the onset of crawling. In other words, we tested whether there was a sequential effect of motivation—did infants' motivation to move at earlier time points influence the achievement of a motor skill at a later time point? We found significant differences in motivation to move scores between early and late crawlers at all three sessions prior to crawling. At all three sessions, infants who were early crawlers had higher motivation scores than infants who were late crawlers, $t(22)=2.45$, 3.54, and 3.03 at sessions 1–3, respectively (see Fig. 6).

To further explore this idea that early motor motivation may influence later development of motor skills, we ran another series of t-tests to examine the effect of individual differences on early motor motivation. We ran a median split on motor motivation scores at the 1st session of the study, before any of the 4 motor skills of interest had been acquired by any of the participants. Infants with scores of 1 or 2 on the motivation to move scale were categorized as having low motor motivation ($n=8$). Infants with scores of 4 or 5 on the motivation to move scale were categorized as having high motor motivation ($n=7$). Infants with scores of 3 at the first observation session were not included in these analyses. Independent samples t-tests on age of onset for sitting, pulling-to-stand, crawling, and cruising revealed that infants with high motivation scores had earlier onsets on all milestones than infants with low motivation scores, $t(13)=2.39$, 2.98, 2.25, 2.50, respectively, all p values <0.05 (see Fig. 7).

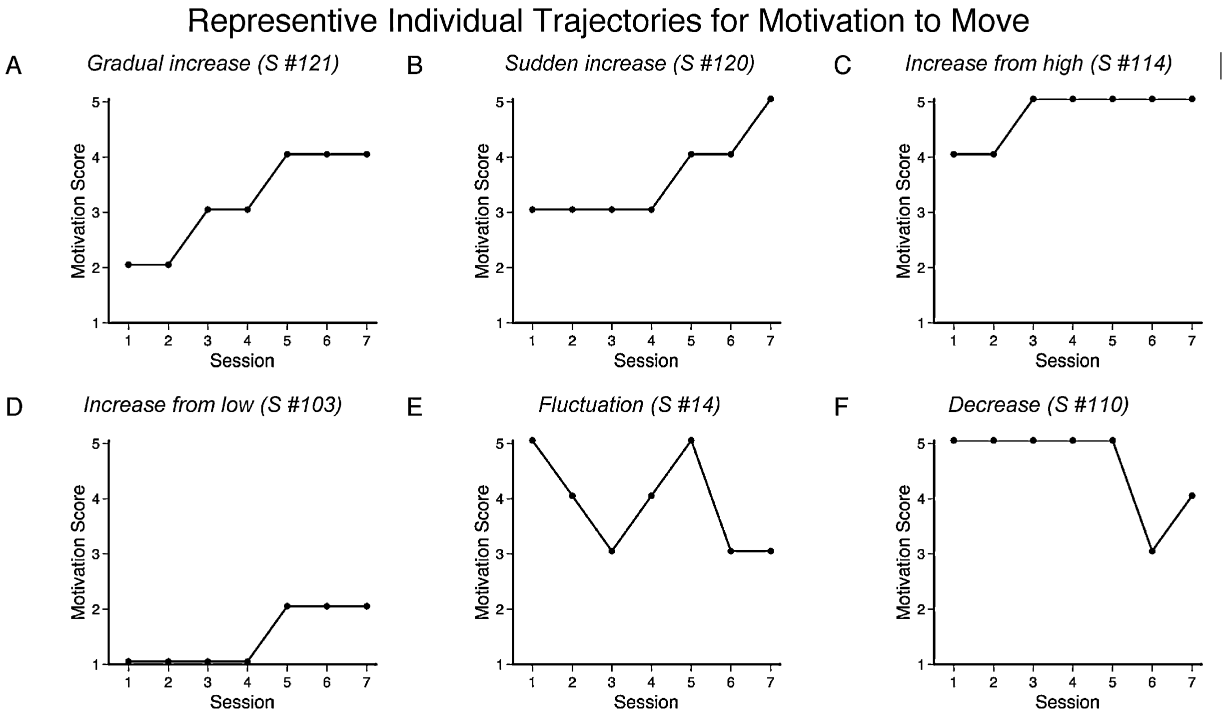

Fig. 5. Exemplars of individual motivation to move trajectories over the course of the study. Infants' scores typically increased (A–D), but on occasion infants scores fluctuated (E) or decreased (F) over the 7 observation sessions.

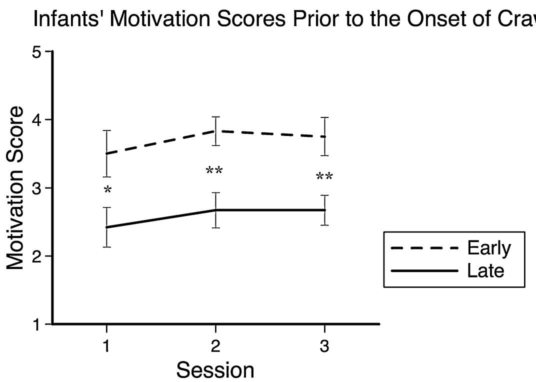

Fig. 6. Infants' motivation to move scores for early crawlers (dashed line) and late crawlers (solid line) at three observation sessions prior to the onset of crawling. Error bars represent standard errors. *p <0.05; **p <0.01.

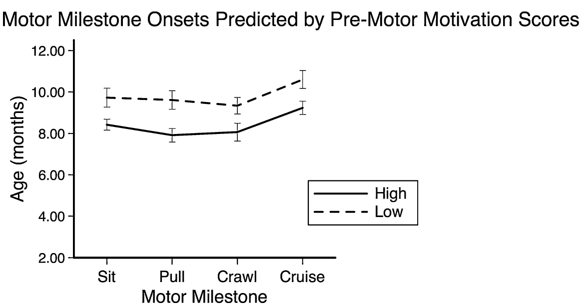

Fig. 7. Age of onset for sitting, pulling-to-stand, crawling, and cruising for infants with high motor motivation scores (solid line) and infants with low motor motivation scores (dashed line) at the first observation session. Error bars represent standard errors.

4. Discussion

A classic puzzle is why children give up successful locomotor postures that they perform expertly, such as crawling, in favor of inexperienced postures, such as cruising or walking (Shirley, 1931). Although recent work has shown that in the specific case of the transition from crawling to walking there is little cost to attempting a new locomotor strategy (Adolph et al., 2012), many more developmental theories have used motivation to move as a post hoc explanation for the achievement of various other motor milestones (e.g., Adolph et al., 1998; Thelen, 2005; von Hofsten, 2007). We took the first steps in measuring a variable that had not been measured before. Our first objective was to document motivation to move, including whether it was feasible as a course of study. The first challenge we faced in designing the motivation to move measure was in operationalizing the *intended* motor behavior, rather than only the actual, observable motor behavior. This seems to be a challenge in several areas of research that attempt to capture motivation. Research on mastery motivation in infancy, for example, has focused on mastery of a concrete problem, such as solving a puzzle, understanding a new toy, or practicing a specific motor skill, and on persistence during play or other social behavior (see Morgan et al., 2009, for a review).

Another potential limitation of the motivation to move measure was researchers' global assessment, which involved a subjective component. However, subjectivity per se is not grounds for methodological invalidation. In the tradition of classic motor development assessment, the present instrument provides detailed, reliable, qualitative descriptions of different levels of motivation to move. To bring in an element of the "tried and true" to an otherwise novel assessment tool, we included measures of motor activity, motor intensity, and general motivation previously included in other assessments (e.g., Eaton, Enns, & Presse, 1987; Pollitt et al., 1999). We also introduced new criteria better designed to capture behaviors uniquely associated with the construct of motivation to move. As is customary with initial studies designed to get the lay of the land, our measure was descriptive. We believe that three findings lend impetus to the future establishment of a more formal, quantitative motivation to move measurement tool: 1) significant relationships between the motivation to move measure and independent measures of motor development, 2) significant relationships between the motivation to move measure and measures of motor development at independent time points, and 3) reliability between coders.

Our second objective was to longitudinally examine the developmental trajectory of motivation to move during the first year of life. As predicted, we found that infants' motivation to move increased with age. More specifically, we discovered variability in the trajectory of motivation to move at the level of the individual and as evidenced by the decreasing difference in motivation between the top and bottom quartiles of the AIMS over time. The convergence of motivation could reflect the possibility of a motivation ceiling. Just as walking represents a kind of ceiling on the AIMS (Piper & Darrah, 1994), because virtually all babies learn to walk, there may be a limit to the amount of motivation that individual infants can demonstrate or that we could measure with our preliminary assessment. Because all infants achieved their milestones within the normal age range, we are not suggesting that infants in the lower percentiles on the AIMS showed any kind of developmental delay, but we do propose that infants achieve the same developmental outcome via a variety of ways. Previous research has shown that variability in body size, environment, or energy level influence motor development (e.g., Adolph et al., 1998; Mulligan, Specker, Buckley, O'Connor, & Ho, 1998; Thelen, Corbetta, & Spencer, 1996). Likewise, variability in infants' motivation to move seems to be another influence on the timing of the onset of infants' motor milestones.

Our third objective was to examine the relationship between motivation to move and motor development. We demonstrated that, in general, the higher infants' motivation to move, the more advanced their motor development, regardless of measure. More specifically, when we compared motivation score across sessions between infants in the top and bottom quartiles on the AIMS, we found that infants' motivation to move was related to their overall motor performance. Despite confirmation that motivation to move and motor development were related, the preliminary analysis could not speak to direction of causation. Did a naturally high motivation to move prompt earlier motor achievements? Did high motor skill prompt motivation to move? Or was it some combination of the two? To gain further insight into the direction of the relationship, we attempted to tease apart motivation to move and motor development. One way we did this was by examining the effect of the onset of a motor milestone on the trajectory of infants' motivation to move scores. We observed significant increases in motivation only a session or two after the onsets of pulling-to-stand and crawling. We did not see an immediate increase in motivation at the first session in which motor skills were observed, suggesting that motivation to move may increase after infants have explored their newly acquired skills and in response to feedback from their new experiences, rather than merely from increased motor activity made possible by the new skill.

Other ways we examined the temporal relationship between motivation to move and motor development were by dividing the sample into early and late crawlers and testing for differences in motivation in the sessions preceding the onset of crawling and by dividing the sample into high and low scorers on the motivation scale at the beginning of the study and testing for differences in age of onset of motor milestones later in the study. Both of these strategies tested whether motivation at one time point was related to motor skill at another time point. Indeed, we found that the earliest crawlers in this sample already had higher motivation to move scores than the latest crawlers weeks prior to crawling onset. Similarly, infants with the highest motivation to move scores at the very first observation session, prior to the onset of any of the four motor milestones of interest, achieved all four skills before the infants with the lowest motivation to move scores at the first session.

As a first attempt to address the measurement of motivation to move, this study lays the groundwork for a new set of research questions. We identified two trajectories simply by examining the extremes of the sample. Subsequent studies should investigate inter-individual variability in trajectories of motivation to move by focusing on how and why motivation to move changes over time (Chen & Siegler, 2000; Lavelli, Pantoja, Hsu, Messinger, & Fogel, 2005; Oakes & Plumert, 2002). A microgenetic approach that timed measurement of motivation to move with the onset of specific motor milestones could reveal differences in infants' reactions to the acquisition of motor skills. Such a design would be important for understanding the reciprocal process by which motivation to move and motor development influence each other. In addition, future work will certainly have to tease apart intention from action and we can turn to the mastery motivation literature for possibilities of how to do that. For example, on the *Gross Motor Persistence* subscale (Morgan et al., 2009, p. 45), most of the items attempt to capture infants' feelings about motor mastery, such as asking parents to rate whether their infant "tries to do it well" when learning a new motor skill, rather than focusing on what infants actually do. The next phase of motivation to move research would be to capture that aspect of motivation.

We were encouraged that parent reports on infants' motor development during the 2 weeks preceding an observation were correlated with infants' motivation to move on 4 of the 7 time points. Given that parents were describing infants' behavior in the time leading up to, but not including, the observation and that parents were working with a somewhat crude 3-point scale, we were satisfied that what the researchers documented during the observation session was an accurate representation of infants' motor ability. While our first attempt to study the relationship between motivation to move and motor skill is promising, it is clear that this relationship is more complex than infants simply being excited to move once they acquire motor skills. Differences in infants' motivation to move were apparent from the first session (before the onset of the 4 motor milestones of interest for this study), but because this was a naturalistic observation, we cannot tell whether the relationship between motivation and motor development was mediated by other factors. For example, caregivers' reactions to infants who are highly motivated to move might facilitate motor development by providing them with experiences that strengthen motor skill (Crockenberg & Acredolo, 1983) or infants who are motivated to move might receive more practice than infants who show little interest in moving, which, in turn, prepares them for the next motor skill (e.g., Adolph et al., 1998; Metcalfe et al., 2004; Zelazo, Zelazo, & Kolb, 1972). We may have enough evidence to support the existence of a motivational cascade, though perhaps not yet enough to identify the individual converging streams. Future studies may determine whether there is a direct relationship between motivation to move and motor development, a mediated relationship, or, most likely, some combination of the two.

Motivation to move continued to increase as motor milestones were achieved and for the duration of the study we found significant correlations between motivation to move scores and AIMS scores at different time points. This finding suggests the importance of reconceptualizing the way we think about the relationship between social-emotional development and motor development. Previous studies have typically documented motor activity as a sub-category of behavior with the intent of describing temperament, rather than as a primary outcome in its own right (Thomas and Chess, 1977; Rothbart, 2007). Other work has demonstrated that the acquisition of new motor skills creates opportunities for new emotional responses and social interactions (Biringen, Emde, Campos, & Appelbaum, 1995; Campos, Kermoian, & Zumbahlen, 1992). However, recent research has repeatedly shown that change in one developmental domain influences changes in other developmental domains (e.g., Berger, 2010; Campos et al., 2000; Needham, 2000; Scher, 2005) and that artificial divisions between domains may be overly simplistic (Henderson & Wachs, 2007).

These findings have important theoretical and methodological implications for intervention. While variation in individual differences is commonly used in the developmental psychopathology literature to examine the relationship between early markers and later adverse outcomes (Rapport, Kofler, & Himmerich, 2006), this study emphasizes the importance of taking into account the naturally occurring variability within typical and atypical development. These findings also have implications for the execution of a therapeutic plan. We recommend putting into formal practice what most practitioners know from clinical experience: that infants' motivation to move can affect the effectiveness of treatment. Motivation is rated high in importance by physical therapists when considering factors influencing the acquisition of motor abilities (Bartlett & Palisano, 2002), children who are motivated to move are more likely to participate willingly and completely in an intervention (Larin, 2000), and clinicians recommend that children's motivation be taken into account as part of the "goal-setting process" during treatment (Winders, 1997; 2001). And yet, despite the consensus regarding the importance of motivation, there is not enough explicit "clinical reasoning" about factors that may influence motor outcomes, such as motivation (Bartlett & Palisano, 2002). The onus is on the clinician to facilitate movement and design individual plans that take into account variations in starting levels of motivation and the motivators that would be most effective in increasing motivation to move, if necessary. With this preliminary success in measuring motivation to move, the next step is the development of a new, formal evaluation of motivation to move that could be included as an explicit part of the assessment procedure so that both treatment and expectations can be standardized and tailored appropriately according to clinical recommendations.

One could imagine a situation in which infants' motivation to expand their possibilities for action and acquire new skills competes with their satisfaction with the status quo—to be content with the safety and familiarity of their expert postures. This may be where motivation to move, or the "pleasure of moving" (von Hofsten, 2007, p. 55) becomes important. Almost four decades ago, Clara Mears identified the notion of *peragration* to describe the play of movement, a joy in movement for the sake of movement, observed in infant rhesus monkeys (Mears & Harlow, 1975). Starting when the monkeys were 9 weeks old,[1] they were observed daily for 12 weeks as they encountered "playrooms" outfitted with climbing platforms, swinging rings,

[1] 9-21 weeks in rhesus monkeys is roughly equivalent to between 1 and 2 years of human life, so comparisons with human infants are appropriate.

ladders, toys, and other monkeys. Peragration occurred more frequently than either locomotion or exploratory behavior; could involve social interaction, but usually did not; and typically involved props, but did not have to. Strikingly, even when the monkeys were moved to playrooms devoid of special equipment, they persisted in peragration (Mears, 1978). They unexpectedly used walls as "bouncing boards" and a small protrusion from the wall as a handhold to launch themselves almost 200 cm off the ground. Peragration was conceptualized as distinct from locomotion and as a foundation for later social play. In fact, peragration may tip the scales in favor of movement so that motivation and peragration combined prompt the discovery of new patterns of behavior and facilitate development. In other words, it would be maladaptive for a novice to focus on an outcome that is difficult to achieve because of the frustration it would raise. However, it would be adaptive to take pleasure in the discovery process itself. Motivation to move does not attempt to describe infants' interactions with the whole environment, but instead aims to focus on infants' movement per se. Infants' motivation to learn about their own abilities and their joy in discovering new actions prompts them to try out many different behaviors (von Hofsten, 2007). The movement itself, not an external reward, can be sufficient for infants to explore the possibilities of movement.

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Appendix A.

Coding criteria for motivation to move score.

Factors/score	Persistence to move relative to difficulty	Frequency of changes in position	Proportion of session spent in motion	Strength of stimulus to elicit movement	Preference for high or low energy activities
1	Rarely attempts a new or challenging motor skill, if so gives up easily	Rarely changes positions	Remains stationary almost entire observation, when moves does so slowly	High external encouragement to move results in little to no movement	Prefers stationary and very low energy motor skills (i.e., lying supine and sitting still)
2	Very few attempts to try a new or challenging motor skill, if so usually gives up easily	Changes positions infrequently; usually to a preferred position	Prefer to be stationary, can move but intensity is low-to-average.	Needs high external stimulation in order to move	Prefers activities requiring little energy
3	Attempts to initiate a new or challenging motor skill, can try several times before giving up or succeeding	Changes position from time to time depending on context	Engaged both in motion and stationary without preference, depending on context	Needs moderate external encouragement to move; can move spontaneously to reach a goal	Engages in both high and low energy activities. (High: crawling, climbing, squatting, walking, PTS; Moderate: kneeling, four point kneeling, standing with assistance)
4	Makes multiple attempts to initiate a new or challenging motor skill, shows persistence	Changes position often	Prefers moving over staying still, movements are quick. Spends more time in motion than stationary	Does not need clear stimulation to move; can move for the sake of moving or for external stimulus	Prefers high energy activities
5	Repeatedly tries new or challenging motor skills, usually until achieving	Changes positions almost constantly	Prefers to move, rarely staying still; movements are very quick	Moves for the sake of moving; no external stimulation needed to elicit movement	Almost exclusively high energy activities

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