Enhanced Handling and Positioning in Early Infancy Advances Development Throughout the First Year

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Behaviors emerge, in part, from the interplay of infant abilities and caregiver–infant interactions. Cross-cultural and developmental studies suggest caregiver handling and positioning influence infant development. In this prospective, longitudinal study, the effects of 3 weeks of enhanced handling and positioning experiences provided to 14 infants versus control experiences provided to 14 infants at 2 months of age were assessed with follow-up through 15 months of age. Behaviors in prone were immediately advanced. Short-term advancements occurred in multiple behaviors, including prone, head control, reaching, and sitting behaviors. Longer term advancements, up to 12 months after the experience period, occurred in object transfer, crawling and walking behaviors. This suggests broad and long-lasting changes can arise via brief periods of change in caregiver–infant interactions.

The role of daily experience in the typical development of early behaviors is of interest to several disciplines. For developmental psychology and early education, studies that quantify the effects of daily experiences provide an empirical test of key theoretical principles of how infants gain the foundational skills for increasingly complex behaviors. For example, this study tests the notion of embodied development, which states that developmental abilities do not emerge de novo but emerge from a rich history of exploration and daily interactions between caregivers, young infants, and the physical environment (Adolph & Berger, 2006; Lockman, 2001). For pediatric rehabilitation, studies that quantify the effect of caregiver–infant interactions provide an important foundation for new assessment and intervention strategies and highlight the potential benefits of family-centered interventions (Bamm & Rosenbaum, 2008). The general purpose of this project was to determine if a relatively short period of caregiver–infant interactions would impact longer term changes in development.

Specifically, we aimed to determine the developmental consequences of a 3-week caregiver-provided enhanced handling and positioning program. These activities were “enhanced” because they involved behaviors that are not typical of daily life for young infants born into Western cultures. These behaviors included supported sitting and standing, encouragement of independent head and trunk control, and emphasis on prone positioning (Kuo, Liao, Chen, Hsieh, & Hwang, 2008). Our previous research suggested that enhancing caregiver–infant interactions immediately advances the emergence of reaching, as well as object exploration and problem-solving development weeks to months after stopping the enhanced experiences (Lobo & Galloway, 2008; Lobo, Galloway, & Savelsbergh, 2004). The current study focused on quantifying even longer term changes through the onset of walking around 1 year of age. This study is the first to use a prospective experimental design to assess the effects of early, prescribed changes in caregiver handling and positioning practices on infant motor development into the 2nd year of life. We hypothesized 2-month-old infants provided enhanced handling and positioning experiences would display more advanced development throughout the 1st year of life.

Our hypothesis is supported by cross-cultural studies suggesting that differences in handling and positioning can affect infant development. “Handling” is those behaviors that occur when caregivers...
are in physical contact with young infants. Differences in handling practices across cultures have been associated with differences in the development of adaptive behaviors, motor behaviors, early communication, and cognitive development (Adolph, Karasik, & Tamis-LeMonda, 2010; Bril & Sabatier, 1986; Hopkins & Westra, 1988). For instance, in areas of Kenya, Nigeria, and West India, formal handling techniques to encourage sitting and walking from birth have resulted in infants sitting and walking months earlier than those in Western cultures. Non-Western caregivers using similar formal handling techniques have infants with better head control at 1 month and advanced sitting and standing at 6 months of age compared to infants born to mothers not using such practices (Hopkins & Westra, 1989).

Young, immobile infants also spend considerable time being placed in positions by caregivers. Descriptive studies suggest that greater experience in multiple positions in the months after birth is associated with better development in the 1st year for healthy infants and those born preterm and at risk for delays (Fetters & Huang, 2007). Reduced experience in the months after birth in the prone position, a position that is especially challenging for young infants and that most caregivers avoid or utilize very little, is associated with delayed development in certain skills in the 1st year of life (Kuo et al., 2008; Majnemer, 2007). Therefore, theoretical and cross-cultural work suggests that caregivers facilitate infants’ development through their everyday handling and positioning interactions. This prospective, longitudinal, multiple-group study specifically tested this proposal. Our goal was to build upon these findings from across cultures and within Western cultures to create an enhanced handling and positioning program aimed at advancing future development.

**Process by Which Handling and Positioning Were Expected to Affect Developmental Change**

We expected a relatively brief period of enhanced handling and positioning would have longer lasting effects for two reasons. First, the altered handling and positioning activities were expected to advance infants’ foundational abilities that are developmentally linked to future skills. For instance, being placed in a range of positions allows infants to experience a variety of possibilities for action, views of the world, levels of arousal and social interaction, and postural and strength requirements (Fogel, Messinger, Dickson, & Hsu, 1999). These opportunities were expected to lead to corresponding changes in infants’ potential to perceive, act, and attend within their world. Second, we expected caregivers would adapt to their infants’ emerging abilities and continue advancing their interactions even outside of and after the home experience period. A cycle would occur in which changes in caregivers or infants would in turn create change in the other (Bronfenbrenner, 1979). For instance, our work and others’ suggest that once caregivers observe their infants attempting to reach for objects, they begin to present objects to infants more often within reach so infants have greater opportunities daily for object exploration (Fogel, 1997; Lobo & Galloway, 2008; Reed & Bril, 1996). This ongoing cycle of change supports the emergence of novel behaviors in development and the maintenance of gains when development is advanced through early intervention (Gottlieb, 1983; Ramey & Ramey, 1998). The present study aimed to accelerate this cycle by educating caregivers to use handling and positioning techniques to facilitate developmental advancements that were expected to continue well into the future.

We expected the handling and positioning experiences to have broad developmental effects because they aimed at enhancing early perceptual-motor experiences across a variety of postures and activities. Some literature suggests that the effects of early experiences are specific. For instance, task-specific activities focused on advancing target skills, like sitting or stepping, can advance the onset of those target skills (Vereijken & Thelen, 1997; Zelazo, Zelazo, Cohen, & Zelazo, 1993). Similarly, perception of traversibility of slopes has been demonstrated to be dependent upon specific experience with each mode of locomotion, such as creeping on hands and knees and walking (Adolph, Tamis-LeMonda, Ishak, Karasik, & Lobo, 2008). On the contrary, other studies have suggested that the effects of experiences can be much broader. For instance, sitting ability has been shown to advance knowledge about object properties (Soska, Adolph, & Johnson, 2010). Early experiences to advance reach onset also advance future object exploration and means–end problem-solving ability (Lobo & Galloway, 2008). And early experiences in prone advance the future ability to crawl on hands and knees (Adolph, Vereijken, & Denny, 1998). The present study aimed to utilize a variety of early experiences in order to advance the development of those skills practiced as well as to advance the development of future related skills.
Method

Participants

Twenty-eight families with infants born full-term were recruited from the local community at 2 months of age. Inclusion criteria were typical development and no medical diagnoses. Twenty-six of the infants were Caucasian and 2 were African American. Caregivers provided informed consent. Three additional families were excluded from the study because they did not meet the minimum experience performance criterion (see below for details).

Experience Groups

Infants were randomly assigned to either the social experience (control) group or the handling and positioning experience (experimental) group. Infants were matched for gender so each group had seven males and seven females.

Experiences were provided to infants by caregivers 15 min daily the first 3 weeks of the 60-week study when infants were in an awake and alert state. Caregivers were informed they could perform the experiences in shorter segments throughout the day if necessary to ensure infants remained in a positive behavioral state during the activities. Caregivers received an illustrated manual and training from an experimenter at the first study visit (see Figure 1). They were given a diary to chronicle the frequency, duration, and content of their sessions. There was a minimum experience performance criterion of 60% of the days for inclusion in the study. Each participant’s diary was examined after the prescribed home experience period and anyone not meeting the 60% criterion was excluded from the study at that point. The same experimenter, a licensed pediatric physical therapist, trained all families and conducted the visits.

At the second study visit caregivers were offered the opportunity to ask questions, were asked to demonstrate the home experiences without referring to the manual, and were offered any suggestions to improve the provision of the activities if they deviated from the instructions. After the end of the experience period (third study visit), caregivers were no longer required to perform the activities with their infants.

Social Experience (Control)

Caregivers in the control group were asked to place their infants in supine and engage them in face-to-face interaction for 15 min daily (see Figure 2a for related image and online supporting information Appendix S1 for more detail). The aim of these experiences was to control for the social interaction and associated general movements that infants in the experimental group would receive. Therefore, the social experiences chosen were typical for this developmental period and incorporated the social and supine general movement components of the experimental experiences. Caregivers were asked to use minimal physical interaction and no objects during these interactions and to use their face and voice to encourage infants to attend to them. We did not choose more advanced social experiences because it was likely that such experiences would accelerate development in other ways.

Handling and Positioning Experience (Experimental)

Caregivers in the experimental group were asked to perform advanced handling and positioning activities with their infants 15 min daily. The specific activities involved caregivers encouraging and assisting infants: (a) by placing them in prone on the floor or caregiver while encouraging them to push up to lift their head, (b) by pulling them up and lowering them down slowly between sitting and supine while assisting them to keep their head in line with their body, (c) by supporting them in sitting and standing while swaying them slowly in different directions while encouraging them to weight bear and to reorient their body upright with respect to gravity, and (d) by moving their hands to midline for play to encourage a shift from lateral to more midline arm placement (see Figure 2b–g for related images and online supporting information Appendix S1 for more detail).
Appendix S2 for more detail). These activities provided enhanced perceptual-motor experience across positions in order to promote abilities including strength, postural control, and midline hand behavior. These activities also involved a fair amount of social interaction between caregivers and infants.

Procedure

Assessments in the Home

The same experimenter, a licensed pediatric physical therapist, visited families in their homes for 6 visits across the first 3 months of the study. The average age of infants at each visit was 9, 10.5, 12, 15, 18, and 21 weeks of age (see Figure 1 for assessment schedule). There were no differences in the ages of infants in each group at the start of the study or at subsequent visits (age in weeks: Visit 1: control 8.7 ± 0.9, experimental 8.9 ± 0.7; Visit 2: control 10.3 ± 0.9, experimental 10.6 ± 0.8; Visit 3: control 11.8 ± 0.8, experimental 11.9 ± 0.7; Visit 4: control 14.8 ± 0.7, experimental 14.9 ± 0.9; Visit 5: control 17.9 ± 0.8, experimental 17.9 ± 0.9; Visit 6: control 20.6 ± 0.8, experimental 20.8 ± 1.0). Visits were documented via video recordings so coders blind to group assignment and not present for visits could code the assessments described below. The visits were conducted when infants were in an awake and alert state. The first and second visits also included training activities for caregivers as aforementioned.

Alberta Infant Motor Scale (AIMS). At every home visit, infants’ general motor ability was assessed using the AIMS. This is a valid and reliable assessment tool that compares young infants’ motor performance with a normative sample. It consists of observation of infants’ weight bearing, posture, and antigravity movement in four positions/subscales: supine, prone, sitting, and standing (Piper, Pinnell, Darrah, Maguire, & Byrne, 1992). Each subscale consists of a series of behaviors infants may be observed to progress through developmentally. For instance, in prone, infants may progress through pushing up on their arms with their elbows behind their shoulders, then with their elbows in line with their shoulders, and then may demonstrate the ability to lift their heads higher and shift their weight. Infants receive a score of 1 for behaviors they are
observed performing and a 0 for more advanced items they were not observed performing. Therefore, each point received reflects an infant’s ability to behave at a new level within each position.

Reaching. At every home visit, infants’ reaching ability was assessed in supine and seated in a custom chair. In each position, infants were given one 3-min trial to interact with a stationary, midline toy held an arm’s length away at chest level.

Caregiver Questionnaire

Caregivers were provided written questionnaires at the start of the study and at the final home visit at 5 months of age. The questionnaires assessed infants’ sleeping position and if and how caregivers reportedly changed the ways they interacted with their infants as a result of participation in this study (see online supporting information Appendix S2).

Follow-up Developmental Assessment

From the end of the home assessments at 5 months of age until the onset of independent walking between 10 and 15 months of age, infants were followed using a reliable and valid Parent Milestone Report Form (Adolph, Robinson, Young, & Gill-Alvarez, 2008; Bodnarchuk & Eaton, 2004). Caregivers were asked to track their infant’s development on behaviors from reaching through creeping on hands and knees and walking. Once weekly they documented whether they observed their infant performing each of the behaviors. Then at the end of each month, an experimenter blind to group assignment collected these data from the caregiver by phone and recorded them.

Variables

Assessments in the Home

Alberta Infant Motor Scale. A trained experimenter who did not perform the home visits and was blind to group assignment and the details of the study scored the AIMS assessments from video. A second scorer, also blind to group assignment and not present at visits, scored 20% of the assessments to ensure interrater reliability with the primary scorer. The number of item scores agreed and disagreed on was determined and the percentage of reliability was calculated using the equation: \[\text{percentage of reliability} = \frac{\text{agreed}}{\text{agreed} + \text{disagreed}} \times 100\]. Interrater reliability between the two scorers was 94%. Infants received a score for each subscale (supine, prone, sitting, and standing) as well as a total score (sum of the four subscale scores). We analyzed scores at Visit 1 to ensure groups were similar at the start of the study. We analyzed changes in AIMS scores for infants in each group during the 3-week experience period (2–3 months of age) and throughout the home assessment period (through 5 months of age) to assess the immediate and short-term effects of the home experiences.

Reaching. Two trained experimenters blind to group assignment coded the number of times infants contacted the midline object from the reaching assessment videos. Each time the infant’s hand came in contact with the object, a contact was coded. From these data, we calculated the visit of reach onset for each infant, or the first visit when the infant contacted the midline object more than 10 times total (total contacts supine and seated in the chair) and the number of object contacts for all subsequent visits remained greater than this value.

Coding reliability was assessed for 20% of the coded data across age using the equation described above. Intrarater reliabilities were 95% and 96% for each coder. Interrater reliability was 92% between coders.

Caregiver Questionnaire

Caregiver responses were categorized for statistical analyses by two experimenters blind to group assignment. Interrater agreement for categorization was Kappa = 1.00 (p < .001). Sleeping position was categorized into supine, prone, or sidelying. Study participation was categorized as either having an effect or having no effect on caregiver–infant interactions. For those who reported participation did affect their interactions, the ways in which their interactions were affected were categorized as increased social interaction (responses such as “looking,” “attention,” or “talking”), increased handling and positioning interaction (responses such as “postures,” “strength,” or “continued with experience activities”), or increased play with objects (responses such as “toys,” “reach,” or “hold”). All responses fell into one of these three categories.

Follow-up Developmental Assessment

The weekly milestone tracking was used to determine the week of each milestone’s onset in relation to the week the infant had his or her first study visit. When infants were first observed performing a behavior 3 weeks consecutively, the onset of the behavior was defined as the first of these weeks. For
instance, if an infant was observed by his or her
caregiver transferring objects from hand to hand at
15, 16, and 17 weeks after the week of the infant’s
first visit, the onset of this behavior was recorded as
happening at 15 weeks after the first visit. To pro-
vide readers with a better perspective of develop-
mental time, these results are reported both in terms
of weeks from the first visit as well in terms of
infants’ ages in months.

Data Analysis

Mann–Whitney $U$ nonparametric tests were used
to compare the two groups for all variables. Median
followed by minimum and maximum values in
parentheses and effect size using Cohen’s corre-
lation coefficient ($r$) are reported for all comparisons,
with $r = 0.10$ representing a small effect, $r = 0.30$
representing a medium effect, and $r = 0.50$ repre-
senting a large effect (Cohen, 1992). One-tailed tests
were utilized for variables we hypothesized would
be different as a result of the experiences, such as
change in AIMS score after enhanced experience.
Two-tailed tests were used for the remainder of the
variables, such as age at the first visit. Only results
with significance values $\leq 0.05$ are reported. To bet-
ter describe these significant group changes, we also
report individual counts of behaviors. To test the
robustness of the findings, all analyses were
also performed using parametric independent sam-
ple t tests with Levene’s test for equality of vari-
ces. The parametric and nonparametric findings
were consistent but the nonparametric findings are
reported here because many of the variables are
ordinal and our sample sizes are modest.

Results

Groups Began the Study at a Similar Age and
Developmental Level

Infants were similar at the start of the study. All
infants were born full-term and there was no differ-
ence in weight at birth between groups. Infants in
each group started the study at the same age:control
$Mdn$ 8.4 (7.7, 11.0), experimental $Mdn$ 8.7 (8.1,
11.2) weeks old, $U = 72.50$, ns, $r = -0.22$. There was
no reported difference in sleeping position of
infants ($U = 82.50$, ns, $r = -0.22$). The majority of
infants in each group slept in supine. Sleep position
differences between groups could have been an
important confound because motor development in
the 1st year of life may be delayed in infants who
sleep supine compared to infants who sleep prone
(Davis, Moon, Sachs, & Ottolini, 1998).

At the start of the study, the control and experi-
mental groups had similar total AIMS scores:control
$Mdn$ 9 (8, 13), experimental $Mdn$ 9 (7, 13); and
similar scores for the supine:control $Mdn$ 3 (2, 5),
experimental $Mdn$ 3 (2, 5); sitting:control $Mdn$ 1 (1,
2), experimental $Mdn$ 1 (1, 2); and standing:control
$Mdn$ 2 (1, 2), experimental $Mdn$ 2 (2, 2); AIMS
subscales (total $U = 60.50$, ns, $r = -0.35$; supine
$U = 92.00$, ns, $r = -0.06$; sitting $U = 98.00$, ns,
$r = .00$; standing $U = 77.00$, ns, $r = -0.34$). Control
infants did have better prone subscale scores at this
visit, about 1 point higher: control $Mdn$ 3 (2, 6),
experimental $Mdn$ 2 (1, 6) ($U = 53.50$, $p \leq .05$,
$r = -0.41$). Because the difference was in favor of
our control group and we believed our experiences
would advance development for the experimental
group beyond this difference, this small difference
at the start of the study was acceptable. Infants’
median total AIMS scores were at the 50th percen-
tile for both groups at the start of the study.

Groups Had Similar Amounts of Home Experience

During the 3-week home experience period, both
groups had a similar number of days of experi-
ence: control $Mdn$ 17.5 (14, 25), experimental $Mdn$
18.5 (17, 23) days ($U = 63.00$, ns, $r = -0.31$) and sim-
ilar total minutes of experience: control $Mdn$ 267.5
(210, 795), experimental $Mdn$ 268 (182.5, 403) total
minutes; control $Mdn$ 15 (13.4, 31.8), experimental
$Mdn$ 13.8 (10.3, 19.19) min/day ($U = 81.50$, ns,
$r = -0.14$).

Immediate Effects of the Experiences: Advancements in
Prone Abilities

At the end of the 3-week home experience period when infants were 3 months old, infants in the
experimental group were already making develop-
mental advances compared to control infants (see
Figure 3). From 2 to 3 months of age they had
greater increases in their AIMS prone subscale
scores: control $Mdn$ 1 (0, 4), experimental $Mdn$
2 (0, 5) points change ($U = 47.50$, $p \leq .01$, $r = -0.45$).
This manifested from greater advancements in their
ability to push up on their forearms and extended
arms, to shift their weight for early mobility, and to
raise one arm to reach for objects and people in the
prone position. After the home experience, control
infants’ median total AIMS score was at the 65th
percentile, while experimental infants’ median
score increased to the 80th percentile.
Short-Term Effects of the Experiences: Advancements in Global Motor Abilities, Hand Movement, Object Interaction, and Head Righting

After the 3-week home experience period, caregivers were no longer asked to perform the home activities, yet experimental infants continued to demonstrate advancements. Specifically, from 3 to 5 months of age, experimental infants demonstrated advanced midline hand movement ability, object interaction abilities, head righting abilities, and global motor development. They began to rest their hands in midline rather than lateral in supine, an item on the AIMS, earlier than control infants (at 3 months: 8 of 14 control infants; 12 of 14 experimental infants, $U = 70.00$, $p \leq .05$, $r = -0.31$; at 4 months: 10 of 14 control infants; all 14 experimental infants, $U = 70.00$, $p \leq .05$, $r = -0.40$). Next, they reached for objects earlier in the reaching assessment: control Mdn 18 (12, 21), experimental Mdn 13.5 (10.5, 21) weeks of age ($U = 59.00$, $p \leq .05$, $r = -0.34$). Control infants were reaching in the middle of the typical age expected (3–5 months of age) by about 4.2 months of age, while experimental infants were reaching at the early end by about 3.1 months of age (Thelen, Corbetta, & Spencer, 1996). At the first visit no infants were reachers. At the second and third visits (around 2.5 and then 3 months old), no control infants and 4 experimental infants were reachers (Visit 2: $U = 28.00$, $p \leq .05$, $r = 0.4$; Visit 3: $U = 28.00$, $p \leq .05$, $r = 0.4$). At the fourth visit (around 3.75 months old), 6 control and 9 experimental infants were reachers. At the fifth visit (around 4.5 months old), 10 control and 12 experimental infants were reachers. At the last home visit (around 5.25 months old), 13 control and all 14 experimental infants were reachers. After reach onset, experimental infants were able to right their heads earlier by keeping it in line with their trunk when pulled by the hands from supine to sitting, another item on the AIMS (at 4 months: 5 of 14 control infants, 10 of 14 experimental infants, $U = 63.00$, $p \leq .05$, $r = -0.35$; at 5 months: 9 of 14 control infants, 13 of 14 experimental infants, $U = 70.00$, $p \leq .05$, $r = -0.34$).

Infants in the experimental group were making greater global motor developmental advances compared to control infants (see Figure 4). Through 5 months of age they had greater increases in their AIMS total scores, prone subscale scores, and sitting subscale scores—points change total: control Mdn 8 (5, 12), experimental Mdn 11 (8, 18) ($U = 45.50$, $p \leq .01$, $r = -0.46$); prone: control Mdn 3 (2, 6), experimental Mdn 5 (3, 9) ($U = 42.50$, $p \leq .01$, $r = -0.45$); sitting: control Mdn 2 (0, 4), experimental Mdn 3 (1, 7) ($U = 62.00$, $p \leq .05$, $r = -0.34$). At 5 months of age, control infants’ median total AIMS scores were at the 30th percentile, while experimental infants’ scores were at the 50th percentile.

Figure 3. Immediate changes in development for each group during the experience period represented by changes in total and subscale scores on the Alberta Infant Motor Scale (AIMS). Note. The time frame represents 3 weeks between 2 and 3 months of age in this box plot.

* $p \leq .05$.

Figure 4. Short-term changes in development for each group during the home assessment period represented by changes in total and subscale scores on the Alberta Infant Motor Scale (AIMS).

Note. The time frame represents 3 months from 2 to 5 months of age in this box plot.

* $p \leq .05$. 

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Longer-Term Effects of the Experiences: Advancements in Object Manipulation and Locomotor Abilities

In the 7–12 months following the 3-week home experience period, experimental infants continued to show important advances in object manipulation and locomotion abilities (see Figure 5). Infants in the experimental group transferred objects from one hand to the other 2.5 weeks earlier, explored their environment by creeping or crawling on their hands and knees 5 weeks earlier, walked supported sideways holding on to furniture or forward holding on to an adult’s hands 2.5 weeks earlier, and walked alone less than 10 ft 6 weeks earlier—weeks from the first study visit object transfer: control Mdn 15.5 (10, 24), experimental Mdn 13 (4, 18) (U = 57.50, p ≤ .05, r = 0.35); creeping on hands and knees: control Mdn 29 (16, 35), experimental Mdn 24 (11, 38) (U = 58.00, p ≤ .05, r = 0.30); walking with support: control Mdn 33 (28, 46), experimental Mdn 30.5 (24, 43) (U = 60.00, p ≤ .05, r = 0.33); walking independently: control Mdn 45 (37, 67), experimental Mdn 39 (31, 55) (U = 57.50, p ≤ .05, r = 0.35).

Transferring objects from hand to hand typically emerges between 5 and 6 months of age and was defined in the parent report form as when the “baby can pass a small toy, cookie, or other object from hand to hand.” This behavior emerged in control and experimental infants within the typical range at 5.5 months of age and 5.3 months of age, respectively. Creeping on hands and knees typically emerges around 8–10 months of age and was defined in the parent report form as crawling more than 10 ft using only the hands and knees for support, with the back straight, the knees under the hips, and the elbows under the shoulders. This behavior emerged for control infants within the typical range at 8.7 months of age and for experimental infants a bit earlier at 7.5 months of age. Walking with support typically emerges between 10 and 11 months of age and was defined in the parent report form as the infant supporting his or her own weight and taking several steps but receiving assistance to balance by holding furniture and stepping sideways or holding an adult’s hands and stepping forward. This behavior emerged for control infants just before the typical range at 9.7 months of age and for experimental infants a bit earlier at 9.1 months of age. Walking independently typically emerges around 12 months of age and was defined in the parent report form as the infant taking at least one step alone with each foot without the support of others or objects (Haywood & Getchell, 2009; Long & Cintas, 1995; Piek, 2006). This behavior emerged for control infants at the typical age of 12.4 months and for experimental infants a bit earlier at 11 months.

The Experiences Elicited Different Changes in Caregiver-Infant Interactions

A similar majority of caregivers in each group reported on the parent questionnaire that participation in the study did affect the way they interacted with their infants (12 of 14 control infants, all 14 experimental infants). However, the specific ways caregivers reported their interactions were affected were quite different between groups (U = 175.00, p < .01, r = 0.78). Thirteen of the 14 experimental caregivers reported that they handled or positioned their infants differently. In contrast, 10 of the control caregivers who reported their interactions with their infants were affected reported that they played more socially with their infants. The remaining families in each group reported greater increase in interest playing with toys.

Discussion

Infants who received enhanced handling and positioning experiences at 2 months of age showed advanced abilities that began immediately and continued through 12 months after the experiences. Behaviors in prone were immediately advanced,
followed by advancements in prone, head control, midline hand control, reaching, and sitting behaviors. Longer term advancements occurred in object transfer, creeping on hands and knees, and walking behaviors.

How did a relatively short period of advanced experience lead to such lasting and widespread advancements in infants’ motor abilities? How did infants improve not only on tasks experienced, such as hands to midline and head righting, but also on other tasks, such as reaching and transferring objects? To answer these questions, we first discuss the interrelation of the skills advanced. Second, we discuss some key changes in infants, caregivers, and caregiver-infant interactions that likely created and maintained this advanced developmental trajectory.

Skills Advanced Share Common Thread

Infants in the experimental group were advanced in skills ranging from floor play to object manipulation and locomotion. Although these skills may at first glance seem very different, they all share a common thread. These skills do not emerge de novo but from a rich history of perceptual-motor experience (Kamm, Thelen, & Jensen, 1990). All are also important vehicles for exploration and the development of embodied cognition (Adolph & Berger, 2006; Lockman, 2001). Behavioral development in infancy can often be linked to previous experience with seemingly unrelated activities. For instance, a certain level of experience and control in prone and supine precedes the onset of independent sitting (Green, Mulcahy, & Pountney, 1995). Prone experience is connected to the development of creeping on hands and knees as it allows infants to coordinate the co-occurrences of head orienting, reaching, and kicking (Goldfield, 1989). Therefore, advancements in development so far after our experience period ended were likely related to experimental infants’ enriched perceptual-motor history. We now discuss some mechanisms through which these experiences may have advanced development.

Changes Within Infants

The likely consequence of experimental infants’ early experiences was enhanced priming of their perception-action and cognitive systems. Below we describe some ways experience may have advanced the development of experimental infants’ perception-action and cognitive systems.

First, infants in the experimental group likely developed advanced postural control. Postural control is important for each of the skills we measured and develops as a result of movement and experience in a variety of positions (Bertenthal & Von Hofsten, 1998; Chen, Metcalfe, Chang, Jeka, & Clark, 2008). For instance, the postural control required to manipulate objects develops, in part, from earlier experiences maintaining balance in reaction to perturbations from spontaneous arm movements (Thelen & Spencer, 1998). The postural control required to manipulate objects while sitting or standing is not present when infants begin to independently assume these positions but develops through exploratory play in various positions (van der Fits, Klip, van Eykern, & Hadders-Algra, 1999).

As experimental infants explored their perception-action possibilities across positions they likely constructed a range of complex anticipatory reactions to maintain balance and body alignment (Metcalfe & Clark, 2000).

Second, experimental infants may have physiologically primed their neuromuscular systems to be better prepared for action. The experimental group was exposed to various positions and movement experiences that required head, trunk and limb muscles to work against gravity, which is known to increase muscular strength (Kleyweg, Vandermeche, & Schmitz, 1991). Experiencing movements across positions also likely taught them to coordinate their muscular forces along with inertial forces from distant joints and gravity to produce smooth, functionally adaptive movements (Galloway & Koshland, 2002). In addition, the neuromuscular activity associated with the handling and positioning experiences may have guided the pruning and strengthening of neuronal connections, the pruning and strengthening of one neuronal innervation per muscle fiber, and the development of the corticospinal system, all processes shaped by perception-action experience (Eyre, Taylor, Villagra, Smith, & Miller, 2001; Ijkema-Paassen & Gramsbergen, 2005; Martin, Choy, Pullman, & Meng, 2004). Consequently, experimental infants may have accelerated these processes so their neuromuscular systems were physiologically better equipped to execute actions across a variety of positions.

Third, experimental infants may have primed their perceptual systems to better process sensory information. Many perceptual systems are not mature at birth but develop, in part, as a result of experience. Each position an infant is held or placed in allows for different actions and accompanying perceptual experiences. For instance, more
kicking behavior occurs in supine and more hand-to-mouth behavior occurs in sidelying (Geerdink, Hopkins, Beek, & Heriza, 1996; Rocha & Tudella, 2008). Changing head position with respect to gravity also provides a variety of visual and vestibular experiences (Shumway-Cook, 1992). Experience is important in the development of the visual and vestibular systems as infants must learn to keep their heads stable in order to receive reliable perceptual information (Pozzo, Levik, & Berthoz, 1995). Experience is also crucial for infants to learn how to accurately perceive information from these systems. For instance, when infants begin to assume a standing position, this novel upright experience allows them to adapt their otolithic responses and sensitivities so they can detect movement of the body in planes not previously experienced through crawling and rolling (Bril & Ledebt, 1998). Therefore, experimental infants likely had enhanced ability to detect and process perceptual information across positions.

Changes in Caregivers and Caregiver–Infant Interactions

The interplay between caregivers’ perceptions and actions and infants’ abilities underlies the developmental process and was a focus of this study. Even in the first months of life, typical development involves a cooperative process of communication and interaction between caregivers and infants as infants facilitate and regulate their own learning in conjunction with guidance from more experienced caregivers. Caregivers who are more sensitive at reading infants’ cues and adapting their interactions to match infants’ abilities and needs have infants with better social-emotional and cognitive development at 1–2 years of age (Forcada-Guex, Pierrehumbert, Borghini, Moessinger, & Muller-Nix, 2006; Treyvaud et al., 2009).

The changes we observed in infants’ abilities most likely resulted from an interaction between changes in infants’ abilities and in caregivers’ perceptions and interactions. Interestingly, caregivers in the two groups reported different effects of participation in the study on their everyday interactions with their infants. Control group caregivers reported greater social play and improved visual attention for their infants, while experimental group caregivers reported greater handling and positioning play and improved strength and postural control for their infants. These reports suggest that the changes in infants’ developmental abilities were not simply the result of 15 min of isolated experience across 3 weeks in time but that they were also the result of changes in caregivers’ perceptions and the everyday play interactions between caregivers and infants that extended well beyond the prescribed experience period.

Significance of the Findings

The findings of this study have important implications for developmental psychology and early childhood education. First, they provide comprehensive support for the proposal that caregiver handling and positioning behaviors can instill broad and long-lasting developmental changes. Second, they provide additional empirical support for the proposal that behaviors emerge, evolve, and become increasing adaptive as a function of a complex history of experiences dependent upon the interplay of infant abilities, caregiver–infant interactions, and environment. Third, they help us better understand the complex process of development and provide the foundation for more specific hypothesis testing. For instance, many basic questions remain, such as what are the cues caregivers respond to as they provide more advanced opportunities for their infants in development; what sources typically inform and guide caregivers’ perceptions about how to handle, position, and play with their infants; and how does attainment of novel behaviors such as reaching, sitting, crawling, or walking affect daily interactions between caregivers and infants and the structuring of their environment.

The findings of this study also have important implications for medical professionals and early educators working with populations with special needs. The findings support that caregivers, their interactions with infants, and the environment they cocreate with infants are all critical components of the developmental process and are important components of early assessment and intervention programs (Wilder & Granlund, 2003). The findings suggest early interventions should be jointly aimed at educating caregivers and enabling infants (Cotnoir-Bichelman, Thompson, McKerchar, & Haremza, 2006). Therefore, the results support the notion that a key component of early intervention should be focused caregiver education targeted toward advancing foundational abilities at developmentally appropriate times (Mahoney, Robinson, & Perales, 2004).

Although the results of this study provide important insights into development, limitations in the design leave several questions open for future investigation. First, participants enrolled in the study by showing motivation to respond to recruit-


**Supporting Information**

Additional supporting information may be found in the online version of this article:

- **Appendix S1.** Social Experience Manual.
- **Appendix S2.** Handling Positioning Manual.

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