Postural and Object-Oriented Experiences Advance Early Reaching, Object Exploration, and Means–End Behavior

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The effects of 3 weeks of social (control), postural, or object-oriented experiences on 9- to 21-week-old infants’ (N = 42) reaching, exploration, and means–end behaviors were assessed. Coders recorded object contacts, mouthing, fingering, attention, and affect from video. Postural and object-oriented experiences advanced reaching, haptic exploration of objects, and developing means–end behavior compared to social experience. Object-oriented experience best-advanced means–end behavior. The results suggest that the development of novel behaviors is dependent on multiple subsystems and can be similarly advanced by addressing a variety of these subsystems. They also suggest that past experiences with active object exploration can facilitate early information processing and the development of early knowledge.

Early experiences shape the development of many skills in infancy, such as early stepping (Vereijken & Thelen, 1997; Zelazo, Zelazo, Cohen, & Zelazo, 1993), reaching (Lobo, Galloway, & Savelbergh, 2004), object exploration (Needham, Barrett, & Peterman, 2002), and crawling (Adolph, Vereijken, & Denny, 1998). The goal of this project was to assess the effects of advanced parent–infant experiences on the future development of three behaviors proposed to be developmentally related: (a) reaching, (b) object exploration, and (c) means–end behavior. We predicted that altering parent–infant interactions when infants were 2–3 months of age and not yet reaching would propel infants onto different developmental trajectories in the months after the prescribed experiences ended. In the current study, parents provided just 3 weeks of advanced postural or object-oriented experiences. We assessed the effects of these experiences on future reaching, object exploration, and means–end behavior across a 12-week period.

The onset of the ability to reach at about 4 months of age is a milestone that alters daily life for infants and their parents (E. J. Gibson, 1988; Thelen et al., 1993; von Hofsten, 1991). Prior to the onset of reaching, infants in the United States spend most of their time supine on their backs engaging in face-to-face social interactions (Davis, Moon, Sachs, & Ottolini, 1998; Fogel, Messinger, Dickson, & Hsu, 1999; Mil dred, Beard, Dallwitz, & Unwin, 1995). If parents introduce objects to their infants in these months, they typically present them to infants out of reach for visual inspection (Eppler, 1995; Fogel, 1997; Fogel et al., 1999). Parents occasionally place objects in infants’ hands or mouths; however, the grasping ability required for sustained oral or manual object exploration does not emerge until after the onset of reaching (Konczak & Dichgans, 1997; Rochat, 1989). Infants move their arms often in the period before they begin to reach with and without the presence of objects or people. It is through these spontaneous movements that infants explore the biomechanics of their bodies and the forces acting upon them and gain the motor control required for later object interaction (Bhat, Heathcock, & Galloway, 2005; Thelen, 1990; von Hofsten, 1993). In effect, the period before the onset of reaching could be termed a primarily “supine, spontaneous, and social period.”

After reaching emerges, infants’ and parents’ daily activities change. Infants move their arms with more control, which allows for more purposeful interaction with objects (Bhat et al., 2005; Thelen et al., 1993). The onset of reaching also coincides with the time when infants typically begin to assume more varied postural orientations, rolling prone and supine, being
place vertical and in semireclined sitting more often, and sitting with assistance (Fogel et al., 1999; Snow, 1989). Better postural control coupled with reaching and grasping ability allows infants to independently explore objects in new ways for sustained periods through mouthing and touching (Adolph, Eppler, Marin, & Wechsler-Clearfield, 2000; J. J. Gibson, 1979). Furthermore, the onset of reaching changes the parent–infant–object dynamic. As parents observe their infants’ emerging ability to interact with objects, they begin to present repeated, daily opportunities for their infants to haptically interact with objects (Fogel, 1997; Fogel et al., 1999; Reed & Bril, 1996). Compared to the prereaching period, the period following the onset of reaching could be termed a primarily “postures, purpose, and play period.”

In our previous work, we showed that advanced general movement experiences and object-oriented experiences advanced infants’ abilities to reach for objects (Heathcock, Lobo, & Galloway, 2008; Lobo et al., 2004). Below we detail why we chose to expand on these results by assessing the effects of advanced postural and object-oriented experiences on not only reaching but also on later object exploration and means–end behavior.

The Role of Postural Experiences in the Ontogeny of Reaching

The first objective of this project was to test whether advancing the development of postural stability would advance the onset of reaching. Postural stability involves the ability to dynamically maintain the position of the body, or the center of mass, within one’s stability limits (Shumway-Cook & Woollacott, 1995). The role of parents in promoting the development of postural stability in early infancy has been documented in several cross-cultural (Bril & Sabatier, 1986; Hopkins & Westra, 1988, 1989, 1990) as well as prospective (Davis et al., 1998; Hadders-Algra, Brogren, & Forssberg, 1996) studies. Young infants lack the mobility to independently transition between positions, thus the variety of positions and postural challenges they experience is largely a function of how parents handle them. Therefore, the emergence of postural stability is dependent not only upon the evolving abilities of infants but also upon parents’ responses to these abilities.

Postural stability has been proposed as a requirement for reaching (Bertenthal & von Hofsten, 1998; Hopkins & Ronnqvist, 2002; Rochat & Goubet, 1995; Savelsbergh & van der Kamp, 1993). Developmentally, postural advancements accompanied improvements in reaching (Fallang, Saugstad, & Hadders-Algra, 2000; Fontaine & Le Bonniec, 1988; Rochat, 1992; Spencer & Thelen, 2000). Reaching also improved in real time when external postural stability was provided (Amiel-Tison, 1985; Grenier, 1981; Rochat & Goubet, 1995). If postural stability facilitates reaching, then advancing the development of postural stability should advance the emergence of reaching (Bertenthal & van Hofsten, 1998; Hopkins & Ronnqvist, 2002; Rochat & Goubet, 1995). Being placed more often in postures, such as sitting and standing, has been shown to directly advance the emergence and control of these postures (Bril & Sabatier, 1986; Hopkins & Westra, 1988, 1989, 1990; Zelazo et al., 1993). This is the first study to attempt to assess the effects of advanced postural stability on another unpracticed behavior (reaching). The postural experiences prescribed in this project were non-object-oriented experiences aimed at advancing postural stability across a variety of positions. We hypothesized that infants who received enhanced postural experience would have advanced reaching emergence and ability compared to control infants.

The Role of Object-Oriented Experiences in the Ontogeny of Reaching

The second objective of this project was to test whether providing earlier than typical object experience would advance reaching. Parents play an important role in helping their infants learn to reach around 4–5 months of age by presenting them with objects to reach for and scaffolding their early reaching attempts (Fogel, 1997; Fogel et al., 1999; Reed & Bril, 1996). Young infants cannot independently seek out objects; thus, they rely on parents to present them with opportunities to interact with objects. Therefore, as with postural stability, the emergence of reaching is dependent on the evolving abilities of infants as well as parents’ responses to these evolving abilities (Bakeman, Adamson, Konner, & Barr, 1990; Bruner, 1972; Landry & Chapieski, 1988).

Experience moving and interacting with objects has been proposed to be an important factor in the emergence of reaching (Bhat & Galloway, 2006; Fogel et al., 1999; Thelen et al., 1993). Specifically, reaching was advanced after 2 weeks of daily, object-oriented movement experiences provided 1–2 months prior to typical reach onset (Lobo et al., 2004). If experience haptically interacting with objects facilitates reaching, then advancing parent–infant interactions to incorporate objects earlier should again advance the emergence of reaching (Fogel, 1997; Fogel et al., 1999; Lobo et al., 2004; Reed & Bril, 1996). Here, we
assessed the effects on reaching behavior across a longer time span. The object-oriented experiences prescribed in this project were aimed at advancing infants’ reaching ability and haptic experience with objects in supine. We hypothesized that infants who received enhanced object experience would have advanced reaching emergence and ability compared to control infants.

The Role of Reaching Experience in the Ontogeny of Object Exploration

The third objective of this project was to test for a developmental connection between reaching and object exploration. That is, would infants in groups who reached early due to the effects of enhanced postural or object-oriented experiences also display advanced object exploration? Infants learn to extract information about the affordances and properties of objects through active object interaction (Campos et al., 2000; E. J. Gibson, 1988; J. J. Gibson, 1979). Not surprisingly, the emergences of reaching and object exploration are important milestones linked with abilities across multiple domains, including cognitive, social, and language (Bremner, 2000; E. J. Gibson, 1988, 2000; Needham, 2000; Piaget, 1952, 1954). The onset of reaching is rapidly followed by the ability to grasp objects for sustained periods (Wimmers, Savelsbergh, Beek, & Hopkins, 1998; Wimmers, Savelsbergh, van der Kamp, & Hartelman, 1998). This grasping ability coupled with increased opportunities to explore objects presented by parents may be important in transitioning infants into more frequent, purposeful, exploratory object interactions.

Although experience actively exploring objects has been viewed as necessary for infants to learn about the actions they can perform on objects (Bourgeois, Khawar, Neal, & Lockman, 2005; Case-Smith, Bigsby, & Clutter, 1998; Needham, Canton, & Holley, 2006), for infants less than 6 months of age, we know of only one study assessing reaching and exploration behaviors in combination (Needham et al., 2002). In that study, nonreaching infants given experience interacting with objects using sticky mittens with Velcro later showed greater object engagement and haptic exploration of objects. If experience actively exploring objects facilitates early knowledge about how to examine objects, then advancing the onset of reaching should advance object exploration behavior. This project aimed to determine the effect of advanced reach onset on the ontogeny of object exploration. We hypothesized that infants in groups expected to reach earlier (postural and object experience) would show more haptic exploration of objects earlier compared to control infants.

The Role of Object Experience in the Ontogeny of Means–End Behavior

The final objective of this project was to test for a connection between reaching, object exploration, and means–end behavior. That is, would infants who had been reaching and exploring objects longer also display advanced means–end behavior? By acting on objects, infants learn information about the match between their actions and external events (E. J. Gibson, 2000). For instance, by exploring a jack-in-the-box, infants learn that cranking the handle results in the sight and sounds of a toy. Such active interaction with objects has been proposed to be the vehicle by which infants gain knowledge about more complex action–environment relationships such as means–end relationships (Bremner, 2000; E. J. Gibson & Pick, 2000; Piaget, 1952, 1954; von Helmholtz, 1962). Means–end behavior involves acting on one object as the means to affect another object (Munakata, Bauer, Stackhouse, Landgraf, & Huddleston, 2002). Most means–end studies test infants older than 6 months of age with the general consensus that means–end behavior is present by 8 months of age (Funk, 2002; Lewis, Alessandri, & Sullivan, 1990; Munakata et al., 2002).

Several studies have investigated the emergence of means–end knowledge (Funk, 2002; Gowen, Goldman, Johnson-Martin, & Hussey, 1989; Menard, 2005). Visual attention paradigms have suggested that infants may possess means–end knowledge before they can demonstrate means–end behavior (Hofstadter & Reznick, 1996; Sommerville & Woodward, 2005b). It remains unclear how to reconcile the discrepancies between the behavioral and visual studies. One account for the discrepancies is the means–end deficit account, which claims that young infants may possess means–end knowledge but cannot demonstrate it because they cannot perform the tasks typically used to measure means–end behavior (Shinskey & Munakata, 2001).

To study the early emergence of means–end behavior, we designed a task in which the means were in line with infants’ skills and the end was meaningful to young infants. The requirements of the means–end tasks used in other studies are too difficult for infants younger than 6 months of age (Hood, 2001; Menard, 2005). For example, infants younger than 6 months are not able to grasp and pull a towel or to grasp and lift an enclosure while reaching for and grasping an object behind the enclosure with the opposite hand (Bojczyk & Corbetta, 2004; Corbetta, Thelen, & Johnson, 2000; Fagard, 2000). Similar to studies with older infants, our means–end task required that infants coordinate their existing
behaviors to perform in an unfamiliar task, acting on one object to affect another while demonstrating intention via interest in the “end” object (Munakata et al., 2002; Willatts, 1999). However, our task required motor, perceptual, and affect regulation abilities that young infants possess. If experience acting on objects facilitates the learning of means–end relationships, then advancing the onset of reaching and object exploration should advance emerging means–end behavior. We hypothesized that infants who had the longest duration of active object exploration, those who received object-oriented experiences prior to the onset of reaching, would show the most advanced means–end behavior.

**Method**

**Participants**

Healthy, full-term infants entered the study when they were 8–11 weeks of age and not yet reaching. Before Visit 1, 42 infants were randomly assigned to the social experience (control) group (age at Visit 1: $M = 61$ days, $SD = 5$ days, range = 54–77 days), the postural movement experience group (age at Visit 1: $M = 62$ days, $SD = 5$ days, range = 57–79 days), or the object-oriented movement experience group (age at Visit 1: $M = 61$ days, $SD = 5$ days, range = 55–74 days). Infants among groups were matched for gender. Each group contained 7 boys and 7 girls. We located families with infants through local birth announcements. Parents provided informed consent. All infants were from two-parent families. Two infants were African Americans, and the remaining infants were Caucasians.

Fourteen additional infants were excluded from the sample. Nine were excluded because of advanced reaching at Visit 1 evidenced by more than 10 object contacts during the reaching task. Excluding these infants was important because one objective of this study was to determine the effect of advanced experiences on the initial emergence and subsequent development of reaching. The remaining 5 infants were excluded because of parents’ inability to provide home experience for more than 60% of the days during the 3-week prescribed home experience period. We requested that parents provide the experiences daily yet emphasized that missing occasional days would be an acceptable reality. Parents reported in journals how much experience was provided daily and were unaware of the 60% criterion. Please see the Results section for specifics on parental reports of provision of experiences. Participants received certificates of participation and DVD recordings of their infants’ first and fifth visits as gifts upon completion of the study.

**Procedure**

The same experimenter visited families in their homes for six visits over a period of 12 weeks. Visits 1, 3, 4, 5, and 6 were separated by 3 weeks. Visits 1, 2, and 3 were separated by 1.5 weeks. We documented each session using two synchronized video recordings to provide right- and left-side views of infants for coding. A splitter was used to place both views on one screen, and a vertical interval time code generator was used to superimpose the hour, minute, second, and frame on the image.

Parents provided enhanced experiences daily only between Visits 1 and 3. Thus, parents were asked to provide the experiences for a total of 3 weeks when infants were between 2 and 3 months old. At each visit, we assessed infants’ ratings on the Alberta Infant Motor Scale (AIMS) and performance in three tasks: (a) use of arm movements to reach, (b) use of arm movements to explore objects, and (c) use of arm movements to explore a means–end task.

**Rating on the AIMS**

At each visit, we observed infants’ general motor development and rated them using the AIMS (Piper & Darrah, 1994; Piper, Pinnell, Darrah, Maguire, & Byrne, 1992). AIMS scores were used to ensure that the three groups were not different in their motor development at the initiation of the study and as an independent measure of whether the activities provided to the postural experience group actually resulted in advanced postural development. The AIMS is a valid and reliable developmental assessment tool that compares infants’ motor performance to that of a normative sample to provide percentile rankings reflecting general motor development. It consists of observation of infants’ weight bearing, posture, and antigravity movement in supine, prone, sitting with support, and standing with support.

**Task 1: Using Arm Movements to Reach**

At each visit, infants were provided opportunities to reach for an object while lying supine and sitting upright in a custom seat (Figure 1). In the seat, infants had their trunks secured but had freedom of movement of their arms. In each position, an object was held stationary in midline at the infant’s chest level for six 30-s trials. The object distance was determined at the
beginning of each session by extending the infant’s arm into midline, noting the location of the infant’s wrist, and presenting the object in this location. Trials began when infants were in a positive behavioral state and visually attending to the object (Prechtl, 1974).

Task 2: Using Arm Movements to Explore Objects

At each visit, infants were provided opportunities to use arm and hand movements to haptically explore objects while sitting upright in our seat. Infants could not reliably grasp objects for prolonged periods at the start of the study. Thus, objects were attached to infants’ wrists using Velcro bands (Figure 2). The experimental design for this task was based on Ruff (1984). Three pairs of objects varying in weight, texture, or sound-making ability were presented to infants for exploration. One object in each pair served as the familiarization object, and the other object served as the novel object. Infants had 60 s to explore each familiarization object and 45 s to explore each novel object. These times kept the familiarization period longer and novelty period shorter similar to Ruff. But the total presentation time for each pair (familiarization period plus novelty period) was shorter to increase the likelihood that the very young infants in this study could complete the entire paradigm. For the purposes of this article, we focus on global exploration of the objects by grouping the data.

At each visit, the familiarization and novelty trials were immediately preceded by the experimenter attaching the object to the wristband, raising the hand and object into the infant’s view, and then releasing the hand at the start of the trial. There was no contact between the experimenter and infant during trials. Successive objects were attached to alternating hands. The initial hand of attachment was the right for half of the infants in each group and left for the others. Within infants, the initial hand of attachment was altered at each visit.

Task 3: Using Arm Movements to Explore a Means–End Task

At each visit, infants were provided opportunities to use arm movements to explore a means–end relationship while sitting upright in our seat (Figure 3). The means–end task began with a 30-s pre-means–end period followed by two means–end periods. During the pre-means–end period, a toy was placed to the left of the infant at a distance of 1 m (see C in Figure 3). The toy was within view but out of reach of the infant and was inactive. This period allowed us to
test for changes in visual attention to the toy when it was not active or under infants’ control.

The assessment continued with two means–end periods, one 4-min period followed by a second 3- to 4-min period. The length of the second period was dependent on the behavioral state of the infant (Prechtl, 1974). During both periods, the toy remained in its position and two lever switches were presented to infants within reach, one laterally to the right and one to the left (see A in Figure 3). To test infants’ knowledge of the means–end relationship, switch–toy control was altered so one switch activated the toy during the first means–end period and the other switch activated the toy during the second means–end period. The position of the switch activating the toy during the first means–end period was counterbalanced among subjects in each group.

The lever switches were activated immediately when infants reached to displace them in any direction. One switch activated the toy (“toy activations”), which resulted in colorful plastic bugs spinning in circles to music. The other switch activated a light attached to the seat (“nonactivations”; see B in Figure 3). The light allowed coding of nonactivations and was out of the infant’s view.

A certain level of activity was required for infants to demonstrate means–end behavior. Therefore, in the early visits, we discontinued the assessment if infants produced five or less total activations of the switches within the first 2 min of the first means–end period. When an infant met this criterion, the entire assessment was completed for that visit and all subsequent visits.

Prescribed Home Experiences

Parents in each group were asked to perform the home experiences for 15 min daily throughout the first 3 weeks of the study (Visit 1 to Visit 3) in addition to their typical daily activities. After Visit 3, parents were informed that they did not need to continue performing the home experiences for the purposes of this project. Although this amount of experience seems minimal, we have seen large changes in behavior as a result of prescribed experiences of similar durations (Lobo et al., 2004). It is likely that these changes result from carryover of the prescribed activities into daily parent–child interactions.

Parents were taught to provide the experiences via demonstrations from the experimenter at Visit 1 along with illustrated instruction manuals kept by parents. At Visit 2, parents were asked to perform an independent demonstration of the experiences with their infants for the experimenter and to discuss any questions or concerns regarding the experiences. Parents tracked the frequency and duration of their performance of the experiences in daily journals.

Social experience. Parents in the social experience group were asked to position their infants in supine while encouraging face-to-face, non-object-oriented interaction for 15 min. This served as a control for the increased social interaction and associated general movement that infants in the postural and object experience groups would receive.

Postural experience. Parents in the postural experience group were asked to perform non-object-oriented activities to improve postural stability and midline hand movement ability for 15 min. Specifically, the activities involved parents assisting infants to push up in prone, to pull up supine to sitting, to maintain their heads and upper trunks upright when their lower body was moved different directions in supported sitting and standing, and to move their hands to midline for clapping play.
**Object-oriented experience.** Parents in the object-oriented experience group were asked to teach their infants to reach for midline objects and to encourage haptic exploration of objects. To teach reaching, parents spent 5 min for each hand showing the infant his or her hand, showing an object at midline, moving the hand to the object, and then allowing the infant opportunities to perform this actively. To encourage haptic exploration of objects, parents spent 5 min assisting infants to feel objects varying in characteristics such as shape, size, texture, and hardness with their hands and mouths.

**Data Analysis**

Arm movement task coders were blind to group assignment. AIMS coding was performed by a pediatric physical therapist. Coding reliability was assessed based on a comparison of agreements and disagreements from each visit. For each variable, the number of behaviors coders agreed and disagreed on was determined and percentage of reliability was calculated using the equation: \(\frac{\text{agreed}}{\text{agreed} + \text{disagreed}} \times 100\). This is a strict measure of reliability (Angulo-Kinzler & Horn, 2001; Harris & Lahey, 1978; Lobo et al., 2004). Individuals were qualified for coding once they achieved and maintained inter- and intrarater reliabilities greater than 90%.

**Variables for Rating on the AIMS**

Changes in AIMS ratings across the span of the home experience (Visit 1 to Visit 3) and across the span of the study (Visit 1 to Visit 6) were analyzed in total and for the supine, prone, sitting, and standing subscales.

**Variables for Task 1: Using Arm Movements to Reach**

The variables for this assessment were analyzed in total with secondary analyses for the supine and vertical positions because previous research suggested that early vertical reaching abilities are more advanced than supine (Carvalho, Tudella, & Savelbergh, 2007; Savelbergh & van der Kamp, 1994).

**Numbers of infants reaching.** An infant was categorized as reaching if he or she contacted the object more than five times in 3 min of supine or vertical object interaction. These criteria are based on our past reaching studies (Lobo et al., 2004) with infants demonstrating that infants who have learned to reach perform this action repeatedly and reliably across all sessions after the onset of reaching with high numbers of object contacts.

**Numbers and durations of object contacts.** Object contact occurred when any surface of the hand contacted the object. Right- and left-limb variables were summed, such that, for example, one bilateral contact was counted as two contacts. Duration of each contact was coded using the time code on the video.

**Numbers of infants reaching bilaterally and percent bilateral contact time.** Bilateral midline reaching is typically observed after the onset of unilateral midline reaching (van Hof, van der Kamp, & Savelbergh, 2002). We analyzed bilateral contact data because manipulating an object with two hands versus one allows infants to use actions not possible with just one hand to gather more information about objects’ properties (Ballesteros, Manga, & Reales, 1997; Provine & Westerman, 1979). A bilateral contact was recorded any time right- and left-handed object contacts overlapped. An infant was recorded as reaching bilaterally if this occurred more than 10 times total or more than 5 times in supine or vertical. The total time of overlap between right- and left-handed contacts was extracted from the data and analyzed to determine the percentage of time infants were interacting with the object using both hands.

**Variables for Task 2: Using Arm Movements to Explore Objects**

The percent time fingering or mouthing the exploration objects was coded and calculated. “Fingering” occurred when the opposite hand contacted the attached object. “Mouthing” occurred when the mouth or lips contacted the attached object. The time spent fingering or mouthing was totaled and then converted to a percentage of the total possible exploration time or the sum of the trial times (three 60-s trials and three 45-s trials for a total of 315 s).

**Variables for Task 3: Using Arm Movements to Explore a Means – End Task**

Our means–end task was similar to the one used by Munakata et al. (2002) in that infants acted on a switch to inflict consequences on another, more distant object in the environment that did not appear physically linked to the switch. We modeled Willatts’s (1999) use of multiple variables, including behavior with the means object and visual fixation on the end object, to assess for intentional means–end behavior. Means–end behavior in this paradigm was defined based on four criteria involving the three variables that follow.
1. **Number of toy activations and nonactivations.** Coders recorded toy and nonactivations noting the time superimposed on the video. These data provided (a) the total number of switch activations (toy activations plus nonactivations), (b) the number of toy activations, and (c) the number of nonactivations for each means–end period.

2. **Percent of toy activations and nonactivations accompanied by visual attention to the toy.** Coders determined whether infants visually attended to the toy within 5 s of each switch activation. Visual attention to the toy was not coded more than 5 s from an activation because each event of toy activity only lasted 5 s. These data were compiled to determine the percentage of toy activations and nonactivations accompanied by visual attention to the toy in each period.

3. **Percent time with positive or negative/neutral affect.** Each 5-s interval of each means–end period was coded using A System for Identifying Affect Expressions by Holistic Judgments (AFFEX), a general scale of affect for infants and children (Izard, Dougherty, & Hembree, 1989). Infants’ affect on this scale could be coded as interest, happy, sad, angry, fearful, or neutral. No periods of fearful affect were observed, so affect was grouped into positive (interest or happy) or negative (sad or angry)/neutral. These data were compiled to determine the percent of time in each period during which infants demonstrated positive or negative/neutral affect.

**Means–end behavior during one means–end period.** The means–end task challenged young infants to coordinate their visual attention and arm movements to explore the relationship between switch activations and distant toy activity while maintaining a positive affect. An infant was recorded as having demonstrated means–end behavior in a period if he or she met four criteria incorporating the three aforementioned variables: (a) infants must first actively reach to explore, so infants were required to have an average of greater than two total activations per minute during the period; (b) infants should then match their actions to the desired toy activity, so it was required that greater than two thirds of the total activations be toy activations during the period (E. J. Gibson, 1997); (c) positive affect accompanies periods of learning, so it was required that infants demonstrate positive affect greater than two thirds of the total time during the period (Lewis et al., 1990; Lewis, Hitchcock, & Sullivan, 2004); and (d) as a suggestion of whether infants were able to link their actions with the toy activity, infants were required to look at the toy within 5 s of greater than one half of the toy activations (Willatts, 1999). To demonstrate that the criteria captured behavior that was unique to toy activations, the same criteria were also applied to non-activations.

**Means–end behavior during both means–end periods.** To allow for a period of exploration after the change in the switch–toy activation relationship between periods, only the final 2 min of the second means–end period were analyzed in cases where means–end behavior occurred in the first means–end period of the visit. We analyzed toy activations as well as nonactivations to ensure that the criteria captured behavior unique to activations resulting in toy activation. The four means–end criteria remained the same.

**Secondary Variables Related to Means–End Behavior (Task 3)**

Anticipated differences in means–end behavior among groups could potentially be attributed to differential development among groups. That is, groups may not have been able to achieve the four individual means–end behavior criteria in a similar manner due to differential motor, perceptual, or affect regulation abilities. We tracked the following secondary variables to determine whether any means–end behavior differences among groups were due to more general differences in the motor, perceptual, or affective requirements of the means–end task.

1. **Numbers of infants completing the entire assessment.** Differences in means–end behavior could have been due to differential motor ability to activate the switches. This may have resulted in group differences in the numbers of infants completing the entire means–end assessment. The numbers of infants completing the entire means–end assessment were recorded for each visit.

2. **Ability to turn to visually attend to the toy location.** Differences in means–end behavior could have been due to differential motor ability to rotate one’s head to attend to the location of the toy. The ability to turn to visually attend to the toy included any instance of head rotation to attend to the toy during the means–end assessment or to the toy’s anticipated location during the reaching and exploration assessments. The numbers of infants demonstrating the motor ability to turn to visually attend to the toy location were recorded for each visit.

3. **Visual attention to the toy or switches.** Differences in means–end behavior could have been due to differential visual–perceptual performance or
object interest during the means–end task. This may have resulted in group differences in visual attention to the switch and toy (means and end) and in the coordination of toy activations with attention to the toy. The data on visual attention to the toy or switches describe infants’ looking behavior throughout the entire assessment, providing a broader picture of looking behavior than solely analyzing attention to the toy at times of switch activations. The durations infants looked at the toy during the 30-s pre–means–end period and at the toy or switches during the means–end periods at each visit were coded, summed, and converted to a percentage of the total period time.

**Statistical Analyses**

Kruskall–Wallace (KW) analysis of variance (ANOVA) was performed for most between-group comparisons. If the resultant \( \alpha \) was \( \leq .05 \), KW post hoc tests by ranks were performed. Fisher’s exact test was performed for planned between-group comparisons of nominal variables. For within-group comparisons of secondary means–end performance variables, Friedman’s ANOVA was performed because the same participants contributed to the data being compared. In all statistical analyses, \( \alpha \leq .05 \) represents significant results. When multiple results are presented within the same set of parentheses, the first \( p \) value in a set represents the three-way result and the following \( p \) values represent the results of comparisons between pairs of groups.

**Results**

There were no differences among groups in terms of age, days between visits, or amount of home experience. Infants in each group received a similar number of days of home experience (social experience: \( M = 18.0, SD = 2.7 \); postural experience: \( M = 19.1, SD = 1.7 \); object experience: \( M = 16.9, SD = 2.1 \)) and a similar number of total minutes of home experience (social experience: \( M = 304.1, SD = 146.6 \); postural experience: \( M = 263.2, SD = 64.9 \); object experience: \( M = 252.5, SD = 41.2 \)). As mentioned, provision of home experience was sufficient for inclusion in the study if it occurred on more than 60% of the days between Visit 1 and Visit 3 according to journal reports from parents. We chose this criterion based on pilot data from our previous intervention studies in which infants who received experiences less than 50% of the time did not appear different from control infants (Lobo et al., 2004). This percentage was not significantly different among groups (social experience: \( M = 87.5, SD = 11.5\% \); postural experience: \( M = 88.1, SD = 5.9\% \); object experience: \( M = 78.2, SD = 10.5\% \)).

**Rating on the AIMS**

AIMS ratings were not significantly different among the three groups at Visit 1, suggesting that infants began the study with similar levels of general motor development. Changes in AIMS ratings suggested that the postural experiences effectively advanced motor development by advancing postural stability. This was particularly the case for prone skills after the 3-week home experience period compared to both other groups and at the end of the study compared to the social experience group. The change in total AIMS rating from Visit 1 to Visit 6 was different among the groups and was significantly greater for postural experience infants than for social experience infants, \( \chi^2(2, N = 42) = 6.27, ps = .04, .02 \), respectively. The change in prone subscale rating from Visit 1 to Visit 3 was different among groups and was significantly greater for the postural experience infants than for infants in the social experience and object experience groups, \( \chi^2(2, N = 42) = 7.18, ps = .03, .02, .03 \), respectively. The change in prone subscale rating from Visit 1 to Visit 6 continued to be different among groups with a greater change for postural experience infants compared to social experience infants, \( \chi^2(2, N = 42) = 7.72, ps = .02, .01 \), respectively.

**Task 1: Using Arm Movements to Reach**

**Number of Infants Reaching**

A greater number of postural and object experience infants reached earlier than social experience infants (Table 1). More object experience infants reached than did social experience infants at Visits 3 and 4 (\( ps = .02, .01 \), respectively). More postural experience infants reached than did social experience infants at Visit 3 (\( p = .03 \)). When separating the data from the supine and vertical positions, these group differences were more evident in the vertical position earlier for both the postural and the object experience groups (Visit 2: \( ps = .08, .006 \), respectively; Visit 3: \( ps = .03, .01 \), respectively; Visit 4: \( p = .02 \) for object experience) than in the supine position (Visit 3: \( p = .02 \) for object experience; Visit 4: \( p = .05 \) for postural experience; Visit 5: \( p = .02 \) for object experience). The total number of infants reaching in
infants contacted the object more frequently than did social experience infants at Visits 2 and 4 (ps = .002, .000, respectively). Object experience infants contacted the object longer than did postural experience infants at Visits 4 and 6 (ps = .05, .001, respectively). Postural experience infants contacted the object longer than did object experience infants at Visits 2 and 3 (ps = .01, .000, respectively). Social experience infants contacted the object longer than did the postural experience infants at Visit 6 (p = .002). When separating the data from the supine and vertical positions, these group differences were more evident earlier in the vertical position, Visit 2: $\chi^2(2, N = 27) = 31.93, p = .000$; Visit 3: $\chi^2(2, N = 467) = 15.81, p = .000$; Visit 4: $\chi^2(2, N = 906) = 18.27, p = .000$, than in the supine position, Visit 3: $\chi^2(2, N = 467) = 15.81, p = .000$. The average duration of contact in each group was similar in both positions for every group for the early visits but was longer in supine for the final visit.

### Number and Duration of Object Contacts

Postural and object experience infants contacted the object more frequently at Visits 3–5 compared to social experience infants (Figure 4a). There were differences among groups for average number of contacts at Visits 3, 4, and 5, Visit 3: $\chi^2(2, N = 42) = 8.30, p = .02$; Visit 4: $\chi^2(2, N = 42) = 8.32, p = .02$; Visit 5: $\chi^2(2, N = 42) = 8.39, p = .02$. Object experience infants contacted the object more frequently than did social experience infants at Visits 3, 4, and 5 (ps = .003, .004, and .01, respectively). Postural experience infants contacted the object more frequently than did social experience infants at Visit 4 (p = .03). When separating the data from the supine and vertical positions, these group differences were more evident in the supine position earlier, Visit 2: $\chi^2(2, N = 42) = 7.58, p = .02$; Visit 3: $\chi^2(2, N = 42) = 10.15, p = .01$; Visit 5: $\chi^2(2, N = 42) = 13.34, p = .001$, than in the vertical position, Visit 4: $\chi^2(2, N = 42) = 9.84, p = .01$. Yet, the average number of contacts in each group was greater in the vertical position for every group from Visits 2 through 6.

Postural and object experience infants contacted the object for longer durations at Visits 2–4 compared to social experience infants (Figure 4b). There were differences among groups for duration per contact at Visits 2, 3, 4, and 6, Visit 2: $\chi^2(2, N = 370) = 23.47, p = .000$; Visit 3: $\chi^2(2, N = 777) = 21.99, p = .000$; Visit 4: $\chi^2(2, N = 1169) = 20.58, p = .000$; Visit 6: $\chi^2(2, N = 3042) = 13.54, p = .001$. Object experience infants contacted the object longer than did social experience infants at Visits 2 and 4 (ps = .002, .000, respectively). Object experience infants contacted the object longer than did social experience infants at Visits 2, 3, and 4 (ps = .000, .002, .001, respectively). Postural experience infants contacted the object longer than did object experience infants at Visits 2 and 3 (ps = .01, .000, respectively).

### Number of Infants Reaching Bilaterally and Percent Bilateral Contact Time

A greater number of postural and object experience infants reached bilaterally earlier than social experience infants (Table 1). More postural and object experience infants had bilateral object contacts than did social experience infants at Visits 4 and 5 (Visit 4: ps = .05, .05, respectively; Visit 5: ps = .03, .002, respectively). When separating the data from the supine and vertical positions, these group differences were more evident in the vertical position earlier for both the postural and object experience groups (Visit 4: ps = .04, .006, respectively; Visit 5: p = .02 for object experience) than in the supine position (Visit 5: p = .05 for both groups). The total number of infants reaching bilaterally in each group was greater in the vertical position for every group from Visits 2 through 6.

Postural and object experience infants spent more time bilaterally contacting the object at Visits 4 and 5 (Figure 4c). There were differences among groups at Visits 4 and 5 in terms of the percent time infants were bilaterally contacting the object, Visit 4: $\chi^2(2, N = 42) = 10.24, p = .01$; Visit 5: $\chi^2(2, N = 42) = 7.64, p = .02$. Both postural and object experience infants spent more time bilaterally contacting the object than did social experience infants at these visits (Visit 4: ps = .04, .001, respectively; Visit 5: ps = .05, .002, respectively). When separating the data from the supine and vertical positions,

### Table 1

Total Numbers of Infants Reaching Unilaterally and Bilaterally Across Visits for the SE, PE, and OE Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Numbers of infants reaching unilaterally</th>
<th>Numbers of infants reaching bilaterally</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>SE</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>PE</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>OE</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

Note. SE = social experience; PE = postural experience; OE = object experience.

*Signifies a difference from the SE group, $p \leq .05$. Each group was greater in the vertical position than the supine position for each group from Visits 2 through 6.
these group differences were more evident in the vertical position earlier, Visit 4: $\chi^2(2, N = 42) = 9.60, p = .01$; Visit 5: $\chi^2(2, N = 42) = 6.08, p = .05$, than in the supine position, Visit 5: $\chi^2(2, N = 42) = 8.97, p = .01$. The average percent time spent bilaterally contacting the object in each group was greater in the vertical position for every group from Visits 2 through 6.

**Task 2: Using Arm Movements to Explore Objects**

Postural and object experience infants spent more time haptically exploring objects at Visit 5 than did social experience infants (Figure 4d). Infants in all groups increased the time they spent haptically exploring across the study, but at Visit 5, the postural and object experience groups spent more time finger- ing and mouthing the exploration objects than did the social experience group, $\chi^2(2, N = 42) = 8.20, ps = .02, .01, .04$, respectively. By the end of the study, infants in all groups were finger- ing and mouthing the exploration objects similarly.

**Task 3: Using Arm Movements to Explore a Means–End Task**

First, we report how each group performed during both means–end periods of a visit as well as the total number of periods in which infants displayed...
Means – End behavior. We then report results from the secondary means – end variables.

**Means – End Behavior During Both Means – End Periods of a Visit**

Object experience infants demonstrated the best means – end behavior as evidenced by means – end behavior during both means – end periods of a visit. Table 2 shows the numbers of infants in each group demonstrating means – end behavior during both periods of the visit.

At Visit 6, more infants in the object experience group demonstrated means – end behavior during both periods of the visit than did infants in the social and postural experience groups (\( p = .049 \) for both comparisons). The object experience group also had the greatest total number of infants showing means – end behavior during both periods of a visit compared to the social experience group (\( p = .02 \)). This means – end behavior was unique to toy activations. No infants in any group ever met the means – end behavior criteria for nonactivations during both periods of a visit.

**Number of Periods With Means – End Behavior**

Satisfying the means – end behavior criteria during just one means – end period of a visit does not demonstrate true means – end behavior. However, it does demonstrate emerging means – end behavior because this ability must be present in order for infants to show means – end behavior in both periods. Both the object and postural experience groups displayed more individual periods of means – end behavior than the social experience group. Specifically, the object and postural experience groups had greater numbers of total periods of means – end performance than the social experience group, \( \chi^2(2, N = 42) = 6.31, ps = .04, .02, .04 \) respectively. Object experience infants had 24 and postural experience infants had 21 periods of means – end behavior, whereas social experience infants had only 12 periods across all visits.

The total numbers of periods where infants met these criteria for nonactivations were significantly lower for all groups (social experience, 1 period; postural experience, 2 periods; object experience, 0 periods) than were the number of periods where infants met these criteria for toy activations, social experience: \( \chi^2(1, N = 28) = 11.63, p = .001 \); postural experience: \( \chi^2(1, N = 28) = 16.82, p = .000 \); object experience: \( \chi^2(1, N = 28) = 20.96, p = .000 \), and were not different among groups. This suggests that the performance criteria captured behaviors unique to exploration of the switch – toy means – end relationship.

**Results for Secondary Variables Related to Means – End Behavior**

This means – end task required the coordination of motor, perceptual, and affective aspects of behavior. Results from secondary measures help to rule out whether the means – end behavior results simply reflect group differences in these requirements. Ruling out these general differences would provide further support that means – end behavior differences resulted from varying abilities of the infants in each group to coordinate these abilities to perform a challenging task.

**Motor requirements for the means – end task.** Group differences in means – end behavior were not explained by differences in motor ability. Infants in each group developed the motor requirements for the means – end performance task similarly. Motor requirements for the task involved the ability to (a) activate the switches using arm movement and (b) turn to the side to view the toy using head movement.

1. **Switch activation:** Each group activated the switches enough to have similar opportunities to display means – end behavior. Specifically, there were no significant differences among groups in the number of infants meeting the switch activation criterion more than five switch activations in the first 2 min of the first means – end period and subsequently completing the entire assessment at each visit. At least two thirds of infants in each group completed the entire assessment by Visit 3, and all infants did so by Visit 6.

In addition, each group activated the switches a similar number of times at each visit. Specifically, there were no significant differences among groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Visit 1</th>
<th>Visit 2</th>
<th>Visit 3</th>
<th>Visit 4</th>
<th>Visit 5</th>
<th>Visit 6</th>
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<td>0</td>
</tr>
<tr>
<td>PE</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>OE</td>
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<td>0</td>
<td>1</td>
<td>4(^{ab})</td>
<td>5(^{a})</td>
<td>5(^{a})</td>
</tr>
</tbody>
</table>

Note. SE = social experience; PE = postural experience; OE = object experience.

\(^{a}\)Signifies a difference from the SE group, \( p \leq .05 \). \(^{b}\)Signifies a difference from the PE group, \( p \leq .05 \).
for the number of toy activations or nonactivations except at Visit 4. Postural and object experience infants had more toy activations and nonactivations at Visit 4 than did social experience infants, toy activations: $\chi^2(1, N = 28) = 7.45, ps = .02, .01, .05$, respectively; nonactivations: $\chi^2(1, N = 28) = 8.86, ps = .01, .01, .02$, respectively.

2. Head turning to visually attend to the toy: Each group had the ability to turn their head to the side where the toy was located at each visit. There were no significant differences among groups in the numbers of infants who turned their heads toward the toy location. The majority of infants in each group demonstrated this ability at Visit 1, and all infants in each group demonstrated this ability by Visit 3.

Perceptual requirements for the means–end task. Group differences in means–end behavior were not due to general differences in visual–perceptual ability, although there were some differences among groups. That is, infants in each group developed the perceptual requirements for the means–end task similarly. These requirements were the ability to visually attend to (a) the toy during the pre-means–end period and (b) the toy or switches during the means–end periods.

Each group increased its visual attention to the toy during the pre-means–end period across visits. Each group had similar ability and interest to maintain attention to the toy during the pre-means–end period at each visit except at Visit 6. At Visit 6, the groups were different with object experience infants attending more to the toy than infants in the postural experience group, $\chi^2(2, N = 42) = 5.79, ps = .05, .02$, respectively.

Each group increased its visual attention to the toy and switches during the means–end periods across visits. Each group had similar ability and interest to maintain attention to the toy or switches during the means–end periods at each visit except at Visit 6. At Visit 6, the groups were different and the object experience group spent more time looking at the toy than did the social and postural experience groups, $\chi^2(2, N = 42) = 7.70, ps = .02, .01, .04$, respectively.

It was expected that once infants understood the switch–toy relationship, they would spend increased time looking at the toy; a focal point of the means–end behavior (Willatts, 1999). Therefore, we wanted to analyze not only how much each group attended to the toy compared to the other groups but also how much time within each group involved looking at the toy versus the switches at each visit. The social and postural experience groups spent more time looking at the switches than the toy at every visit (Figure 5a), Visit 2: social experience $\chi^2(1, N = 14) = 10.00, p = .002$, postural experience $\chi^2(1, N = 14) = 9.31, p = .002$; Visit 3: social experience $\chi^2(1, N = 14) = 6.23, p = .01$, postural experience $\chi^2(1, N = 14) = 9.31, p = .002$; Visit 4: social experience $\chi^2(1, N = 14) = 13.00, p = .000$, postural experience $\chi^2(1, N = 14) = 14.00, p = .000$; Visit 5: social experience and postural experience $\chi^2(1, N = 14) = 14.00, p = .000$. Infants in the object experience group showed this same pattern of looking until Visit 6, the visit where they demonstrated the greatest means–end performance, when they visually attended to the switches and the toy the same amount of time, $\chi^2(1, N = 14) = 10.29, p = .001$ for Visits 1–5.

Affect requirement for the means–end task. Group differences in means–end behavior were not explained by general differences in ability to regulate affect across visits. Each group met the means–end behavior affect requirement of maintaining a positive affect more than two thirds of the time in a period for the final three to four visits. Each group increased the time it maintained a positive affect across visits, and the duration of positive affect was not different among groups at each visit. Each group demonstrated more positive than negative/neutral affect from Visits 4 to 6 (Figure 5b), Visit 4: social experience, postural experience, and object experience $\chi^2(1, N = 14) = 7.14, p = .008$; Visit 5: social experience $\chi^2(1, N = 14) = 4.57, p = .03$, postural experience and object experience $\chi^2(1, N = 14) = 10.29, p = .001$; Visit 6: social experience and postural experience $\chi^2(1, N = 14) = 10.29, p = .001$, object experience $\chi^2(1, N = 14) = 14.00, p = .000$.

Motor–perceptual coupling requirement for the means–end task. Group differences in means–end behavior were explained, in part, by differences in motor–perceptual coupling abilities. Specifically, groups differed in their ability to meet the motor–perceptual coupling requirement of accompanying toy activations with visual attention to the toy. The postural and object experience groups demonstrated selective motor–perceptual coupling behavior earlier than the social experience group. Groups did not differ in the percentage of toy activations accompanied by attention to the toy at each visit. However, true means–end behavior requires that infants do not simply randomly attend to the toy with any switch activation but rather that they selectively attend to the toy more often with toy activations than with nonactivations. We term this selective
Figure 5. (a) Mean percent times each group attended to the toy or switches during the means–end periods across visits. (b) Mean percent times each group demonstrated positive or negative/neutral affect during the means–end periods across visits. (c) Mean percentages of toy activations and nonactivations for each group accompanied by attention to the toy during the means–end periods across visits.

Note. In Figure 5(a), note that the groups looked more at the switches except at Visit 6 when the object experience group looked similar amounts at the toy and switches. In Figure 5(b), note that each group increased positive affect and decreased negative/neutral affect over time without differences among groups. In Figure 5(c), note that the postural and object experience groups showed earlier selectivity of their motor–perceptual coupling than did the social experience group, attending to the toy more with toy activations than with nonactivations. Error bars reflect standard error of the mean.

*p ≤ .05.
motor—perceptual coupling. Indeed, group differences in this selective coupling emerged with greater attention to the toy with toy activations for postural experience infants by Visit 3 (Figure 5c), Visit 3: $\chi^2(1, N = 14) = 7.00, p = .01$; Visits 4 and 5: $\chi^2(1, N = 14) = 8.33, p = .004$; Visit 6: $\chi^2(1, N = 14) = 14.00, p = .000$, for object experience infants by Visit 4, Visit 4: $\chi^2(1, N = 14) = 8.33, p = .004$; Visit 5: $\chi^2(1, N = 14) = 9.308, p = .002$; Visit 6: $\chi^2(1, N = 14) = 14.00, p = .000$, and for social experience infants by Visit 5, Visit 5: $\chi^2(1, N = 14) = 10.00, p = .002$; Visit 6: $\chi^2(1, N = 14) = 7.14, p = .008$. In effect, the postural and object experience groups attended more often to the toy selectively with toy activations earlier than did the social experience group. This suggests that they had an earlier association between their actions on the switches and the activity of the toy.

**Discussion**

**Summary of the Results**

Postural and object experience infants had advanced reaching, exploration, and developing means–end behavior compared to social experience infants (Figure 6). Most of the group differences were observed after the 3-week prescribed home experience period ended at Visit 3. Differential ability to reach for and contact objects was the only change observed during the 3-week home experience period. Differences in reaching ability continued, and differences in object exploration and means–end behavior emerged weeks to months after the home experience period ended. Therefore, infants who had similar abilities at the first visit embarked on different developmental trajectories even after their prescribed home experience period ended. Specifically, postural and object experience infants had more frequent object contacts at Visits 2–5, longer contact durations at Visits 2–4, more bilateral contact time at Visits 4 and 5, more haptic object exploration at Visit 5, and greater numbers of periods of developing means–end behavior primarily at Visits 5 and 6 compared to social experience infants. The object experience group had the greatest number of infants demonstrating means–end behavior in both periods at Visit 6.

**Task 1: Postural and Object Experience Infants Had Advanced Reaching Emergence and Ability**

Postural and object experience infants had earlier onsets for reaching and advanced reaching ability compared to social experience infants. The differences in reaching ability among the three groups suggest that the emergence of reaching is dependent on multiple interacting subsystems and can be similarly advanced by experiences that affect a variety of these subsystems (Bertenthal & von Hofsten, 1998; Hopkins & Ronqvist, 2002; Thelen, 1990; Thelen et al., 1993; von Hofsten, 1993). This supports and extends our previous work showing that the emergence of reaching can also be advanced via experiences to increase arm flapping (Lobo et al., 2004).

This study is the first to demonstrate that reaching emergence can be advanced by the provision of advanced postural experiences. This builds on previous work showing that experience being placed in different postures, such as sitting or standing, can...
directly advance infants’ abilities to maintain these postures (Bril & Sabatier, 1986; Hopkins & Westra, 1988, 1989, 1990; Zelazo et al., 1993). This work was unique, however, in that the goal of the experiences was to directly advance postural stability, whereas our focus was whether this would then advance the unpracticed behavior of reaching.

To understand how postural experiences led to the emergence of reaching, we must consider factors both internal and external to the infants. Parents of postural experience infants were asked to provide infants with opportunities to improve their postural stability by placing and moving them in a variety of postures. This occurred during the supine, spontaneous, and social period when infants spend much of their time supine (Davis et al., 1998; Mildred et al., 1995). Ratings on the AIMS suggest that postural experience advanced infants’ postural stability across postures. Postural experience infants likely had improved head and trunk strength and control for visual exploration and reaching, more appropriate muscle responses to maintain balance, and increased perceptual–motor experiences in a variety of positions (Bril & Sabatier, 1986; Thelen & Spencer, 1998; Wijnroks & van Veldhoven, 2003; Witherington et al., 2002). In addition, we suspect that as parents observed their infants’ abilities to maintain different postures and to begin to reach for objects, they likely switched their parent–infant–object interactions to “postures, purpose, and play” earlier than typically reported (Fogel, 1997; Fogel et al., 1999; Reed & Bril, 1996). This switch was likely influenced by the effects of the postural experiences but was not assigned as part of the prescribed experiences. As a result, postural experience infants likely had early, increased opportunities to improve their postural stability across positions and to interact with objects throughout each day (Bertenthal & von Hofsten, 1998; Eppler, 1995). It is likely that such changes within infants combined with changes in parent handling and interaction to advance reaching ability in infants provided with postural experiences.

To understand how object-oriented experiences led to the emergence of reaching, we must again consider factors both internal and external to the infants. Parents of object experience infants were asked to provide their infants with opportunities and assistance to reach for and explore objects (Fogel, 1997; Fogel et al., 1999; Lobo et al., 2004). This occurred during the supine, spontaneous, and social period when parents primarily interact with infants face-to-face with little active object exploration (Fogel et al., 1999). Object experience infants likely had improved movement control in a midline task space, motivation to reach for objects presented, and knowledge that objects presented within reach afford haptic exploration. In addition, as parents observed their infants’ abilities to reach for, grasp, and mouth objects, they likely switched their parent–infant–object interactions to “purpose and play” earlier than typical (Fogel, 1997; Fogel et al., 1999; Reed & Bril, 1996). Consequently, object experience infants likely had increased opportunities to interact with objects on a daily basis even outside of the prescribed home experience periods (Bakeman et al., 1990; Bruner, 1972). The home experience for these infants was provided in supine, and these infants did not advance in their postural stability according to AIMS ratings as did postural experience infants. In fact, their changes in total and subscale AIMS scores were not different from social experience infants. This suggests that parents of object experience infants did not provide infants the same advanced opportunities to improve their postural stability across positions as did parents of postural experience infants.

Social experience infants did not have advanced reaching ability. By Visit 6, however, their reaching abilities were similar to infants in the two advanced experience groups. The experiences parents of these infants provided involved face-to-face interactions in supine, the type of interaction most common during the supine, spontaneous, and social period (Davis et al., 1998; Fogel et al., 1999; Mildred et al., 1995). Therefore, it was expected that reaching development in these infants would mirror typical development. In fact, social experience infants began reaching at an average of 18.25 ± 1.81 weeks of age, which is within the 4- to 5-month-old period typically reported (Thelen et al., 1993; von Hofsten, 1991). Consequently, social experience infants likely did not transition to postures, purpose, and play and have increased opportunities to interact with objects on a daily basis until after their onset of reaching at Visit 5 (Eppler, 1995; Fogel, 1997; von Hofsten, 1997).

More infants were able to contact the object more frequently with one hand as well as bilaterally earlier and throughout the study in the vertical position compared to supine. The average duration per contact was not different between the vertical and supine positions throughout the study but was greater in the supine position by the end of the study. These data support the proposal that it is easier for young infants to initiate reaches but more difficult to sustain contact with objects in a vertical position (Carvalho et al., 2007; Savelsbergh & van der Kamp, 1994). In supine, infants may find it more challenging to initiate reaches but easier to sustain contacts with objects due to the effects of gravity on the arm’s biomechanics. When the hand is farther away from the center of
Task 2: Postural and Object Experience Infants Had Advanced Haptic Exploration of Objects

Postural and object experience infants demonstrated advanced haptic exploration of objects compared to social experience infants. These results suggest that haptic exploration of objects is dependent on infants’ past experiences, the emergence of reaching, as well as ongoing daily parent–infant–object interactions (Berthier, Rosenstein, & Barto, 2005; Bourgeois et al., 2005; J. J. Gibson, 1962, 1966; Millar, 2005; Needham, 2000; Needham et al., 2002). This is the first study presenting empirical evidence for a link between the onset of reaching and later haptic object exploration across developmental time. It is important to note that increased haptic exploration of objects did not occur until the weeks after reach onset in all groups. These results are particularly interesting given that at the start of the study, infants already demonstrated the ability to bring their hands to their mouths for mouthing and to one another for fingering of the objects attached to their wrists (Rochat, 1989).

What might young infants learn from haptic exploration of objects? First, information processing via haptic exploration provides infants with knowledge about properties of objects, such as hardness, texture, and shape, which cannot be accurately detected by vision alone (Ballesteros et al., 1997; Carello, Grososfky, Reichel, Solomon, & Turvey, 1989; Case-Smith et al., 1998; Turvey, 1996). This knowledge base allows older infants to discriminate and categorize objects of varying characteristics (Booth, 2006; Bourgeois et al., 2005; Ellis & Oakes, 2006; Palmer, 1989; Ruff, 1984). Yet, infants have weeks to months of experience haptically exploring objects before this discrimination ability emerges (Case-Smith et al., 1998; Rochat, 1989). Besides knowledge about physical properties of objects, what could infants be learning from these early exploration experiences?

Even before infants are able to discriminate physical properties of objects, it has been proposed that they are able to learn what actions those objects afford (E. J. Gibson, 2000). The fact that infants did not use their available movements to explore the Velcroed objects until after the onset of reaching suggests that haptic exploration of objects may in itself be a global affordance that young infants must learn (Bourgeois et al., 2005; J. J. Gibson, 1962, 1966; Millar, 2005; Needham, 2000; Needham et al., 2002). Infants at each visit were shown the exploration objects before trials began, but they disregarded the objects at early visits before they were consistently reaching. For instance, most infants spent less than 10% of the time exploring objects haptically across the first few visits, whereas at the final visit, most infants spent about 40% of the time exploring objects haptically (Figure 4d). Object exploration in this paradigm did not require grasping as objects were Velcroed to infants’ wrists. It was as if prereaching infants did not yet realize that they could use their existing arm movements to haptically explore objects. We propose that as young infants begin to reach for, grasp, and transport objects, they learn to match these new action abilities to objects to learn that objects of certain sizes and shapes afford mouthing and fingering (Case-Smith et al., 1998; E. J. Gibson, 2000; Millar, 2005). Then, via early, frequent, active haptic exploration of a range of objects, infants learn more about how to adapt and refine their actions to more specifically match the various properties of objects (Adolph et al., 2000; Ballesteros et al., 1997; Bourgeois et al., 2005; Needham et al., 2006). For instance, infants may later learn that in addition to mouthing and fingering, objects such as rattles and spoons afford sound production and food transport. In effect, learning that some objects can be explored haptically may be the first step in the process of gaining object knowledge required for future object categorization and discrimination.

Task 3: Object and Postural Experience Infants Had Advanced Means – End Behavior

Object experience infants had the most sophisticated means – end behavior, evidenced by means – end
behavior during both periods of a visit. Postural experience infants had better developing means–end behavior than social experience infants, evidenced by a greater number of periods of means–end behavior. These results suggest that the developmental origins of means–end behavior may lie in the ongoing motor, perceptual, and cognitive experiences associated with early reaching and object exploration (Bremner, 2000; E. J. Gibson & Pick, 2000; Menard, 2005; Piaget, 1952, 1954; von Helmholtz, 1962). These results highlight the critical role action performance on objects plays in the development of means–end behavior and expand the view that early knowledge development relies primarily on perceptual and cognitive changes (Baillargeon, 1987; Johnson, Slemmer, & Amso, 2004).

Our results suggest that means–end behavior emerges after infants are able to coordinate their motor, perceptual, and affect regulation abilities. Specifically, there were no differences in the individual motor, perceptual, or affect regulation abilities among groups that can fully account for the results. This supports Willatts’s (1999) idea that intentional means–end behavior involves the coordination of multiple variables. In our task, infants had to display a greater frequency of toy activations in coordination with looking to the toy while maintaining a positive affect (Lewis et al., 1990; Munakata et al., 2002; Willatts, 1999). Infants’ abilities to coordinate these emerging abilities across domains to perform in a novel task are a hallmark of means–end behavior.

Our results support the idea that means–end knowledge is gained in part via active exploration of objects (Bremner, 2000; Piaget, 1952). E. J. Gibson (1997) suggested that infants learn by first performing exploratory activity, then observing the consequences of this activity, and finally selecting from the activities explored. She viewed trial-and-error experience as essential to learning. This type of activity is exactly what infants were required to do to explore the means–end relationship within our paradigm. To learn, infants were required to explore the switches via reaching, observe that movement of one switch resulted in distant toy activity, and then repeatedly select the behavior that resulted in that toy activity by activating that switch more frequently than the other.

Our results provide the first empirical support for the idea that the emergence of means–end behavior is in part dependent on the amount of previous object exploration. Object experience infants had increased opportunities to explore objects from Visit 1, and they demonstrated the most sophisticated means–end behavior. Postural experience infants began reaching and likely had increased opportunities to explore objects from Visit 3 and had more advanced developing means–end behavior than social experience infants. Social experience infants began reaching and likely had increased opportunities to explore objects late in the study from Visit 5 and had the poorest means–end behavior.

The results of this study provide important data on the developmental origins of the means–end behavior so often observed in older infants (Bojczyk & Corbetta, 2004; Goubet, Rochat, Maire-Leblond, & Poss, 2006; Munakata et al., 2002). Using a means–end task such as the one presented here that calls on infants to coordinate abilities they already possess to demonstrate that means–end knowledge may help avoid the performance competency issue encountered by other behavioral means–end studies (Bremner, 2000; Matthews, Ellis, & Nelson, 1996). Means–end paradigms such as ours that capitalize on infants’ existing behaviors may help researchers avoid the challenge of comparing violation of expectation paradigms with behavioral paradigms (Bremner, 2000; Hood, 2001; Munakata et al., 2002; Shinskey, Bogartz, & Poirier, 2000; Sommerville & Woodward, 2005). Future studies can build upon these results to tests for developmental connections between early associative learning and memory paradigms such as Rovee and Rovee’s (1969) mobile paradigm and later assessments of object exploration and means–end behavior.

Implications for Developmental Theory and Intervention

The developmental relationships among the three behaviors investigated in this study and the ways the prescribed experiences affected these behaviors support theories of development proposing actions as the foundation for perceptual and cognitive development (Bremner, 2000; E. J. Gibson, 2000; J. J. Gibson, 1979; Piaget, 1952; von Helmholtz, 1962). Our results also have implications for intervention for infants with developmental delay. First, the results support the premise that early intervention can advance the emergence of a behavior (Heathcock et al., 2008; Lobo et al., 2004; Ulrich, Ulrich, Angulo-Kinzler, & Yun, 2001; van Beek, Hopkins, Hoeksma, & Samsom, 1994). Postural and object experiences provided to infants with special needs may be able to advance reaching (Heathcock et al., 2008), just as experience walking supported on a treadmill can advance the emergence of walking in infants with Down syndrome (Ulrich et al., 2001). Although therapeutic interventions often begin in early infancy and frequently rely on techniques attempting to advance postural stability or object interaction, we are not aware of any prospective studies directly relating such controlled movement...
interventions to advanced behavioral outcomes in infants less than 6 months of age. Second, providing early experiences for one skill may advance development of a range of motor, perceptual, and cognitive abilities (Hack & Taylor, 2000; van Beek et al., 1994). Perhaps similar advancements across developmental domains could be achieved by advancing other early behaviors. For instance, language development may be advanced via experiences to advance early object banging or gesturing (Iverson & Fagan, 2004; Iverson & Goldin-Meadow, 2005) or later problem-solving ability could be advanced via experiences to broaden the ranges of exploratory behaviors young infants perform on various objects (Caruso, 1993). Although most therapists would agree that skill attainment generally advances development across domains, there is little empirical support for this idea in early infancy (Needham, 2000).

In summary, the behavior of infants in this study provides empirical support that (a) the development of novel behaviors is dependent on multiple subsystems and can be similarly advanced by addressing a variety of these subsystems (Bertenthal & von Hofsten, 1998; Hopkins & Ronnqvist, 2002; Thelen, 1990; von Hofsten, 1993); (b) reaching ability can be indirectly advanced via activities to improve postural stability; (c) parent–infant interactions play a critical role in early development and can be altered to advance development (Bakeman et al., 1990; Bruner, 1972; Cintas, 1995; Landry & Chapieski, 1988); (d) reaching, object exploration, and means–end behavior are developmentally related behaviors that can all be advanced via experiences aimed at advancing reaching; and (e) past experiences with active object exploration can facilitate early information processing and the development of early knowledge (Ballesteros et al., 1997; Bremner, 2000; E. J. Gibson & Pick, 2000; Needham, 2000).

References


between action processing and action production in infancy. *Cognition*, 95, 1–30.


