

## Encouragement is Nothing Without Control: Factors Influencing the Development of Reaching and Face Preference

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Four parent-guided training procedures aimed at facilitating independent reaching were compared in 36 three-month-old infants recruited for this study and 36 infants taken from previously published reports. Training procedures systematically varied whether parental encouragement to act on external objects was provided, and whether self-produced experiences of moving an object were present. Reaching behavior was assessed before and after training, and face preference was measured after training by recording infants' eye gaze in a visual-preference task. Results showed that simultaneous experiences of parental encouragement and self-produced object motion encouraged successful reaching and face preference. Neither experience in isolation was effective, indicating that both external encouragement and self-produced action experiences are necessary to facilitate successful reaching. However, experiences with self-produced object motion increased infants' face preference. This result provides evidence for a developmental link between self-produced motor experiences and the emergence of face preference in three-month-old infants.

**Keywords:** infancy, motor development, motor learning, embodiment, social cognition, perception

During the first year, infants acquire a number of key motor skills that are necessary to interact with their environment. Attainment of skills such as postural control, reaching, or locomotion bring about new opportunities for exploration, social interaction, and learning and therefore have a significant impact on development (Gibson, 1988). Indeed, several studies suggest that motor skills can catalyze change across developmental domains. For example, infants' independent object exploration is associated with their 3D object completion skills (Soska, Adolph, & Johnson, 2010), crawling is associated with spatial abilities such as mental rotation or spatial search (Bai & Bertenthal, 1992; Campos et al., 2000; Clearfield, 2004; Schwarzer, Freitag, Buckel, & Lofruth, 2012), and the transition from crawling to walking changes infants' engagement with objects and with their own mothers as well as the verbal feedback provided by their mother (Karasik, Tamis-LeMonda, & Adolph, 2011, 2013).

While motor experiences seem to propel development in domains such as perception, cognition, and social interaction, it remains unclear why this is the case. Do developmental changes emerge as a consequence of the motor experiences themselves, merely co-occur with new motor skills as a result of overall maturational processes,

or are they the product of the social interactions that often accompany motor experiences such as parental encouragement, praise, or object sharing bids by the child (e.g., Karasik et al., 2013)? To answer this question and to study the effect of motor experiences on development, experimental manipulation of motor experiences are necessary. The work of Needham and colleagues exemplifies this approach by providing young infants with scaffolded reaching experiences to selectively study the effect of these actions (Libertus & Needham, 2010, 2011; Needham, Barrett, & Peterman, 2002). Building on this work, the current study manipulates specific components of the training experience to investigate how factors such as social context or object manipulation opportunities influence infants' learning from early reaching and object exploration experiences.

### Reaching Onset and its Consequences

Reaching is one of the most consequential motor milestones acquired early in life because it allows infants to independently act on their environment (Bertenthal & Clifton, 1998). Reaching emerges very early in development, with jerky 'pre reaching' swipes toward objects present even in newborns (Campos et al., 2008; von Hofsten, 1982) and open-handed reaches emerging around four months of age (Pomerleau & Malcuit, 1980; von Hofsten & Ronnqvist, 1988). Further, reaching

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Experience (ME) condition, parents attached a toy to their child's hand—providing experiences of control over the object—but did not encourage their child to act on the toy. Data from the Active Training (AT) and Passive Training (PT) procedures reported in Libertus and Needham (2010, 2011) were used as comparison groups.

Because three-month-old infants are not yet reaching independently, we hypothesized that the experiences of the EE group would be similar to those of the PT group (i.e., neither group experienced reaching or manual control over objects) and would not encourage successful reaching or face preference behavior. In contrast, the ME condition would likely provide similar self-produced action experiences as the AT condition (because toys are attached to the infants' hand) and we predicted a similar increase in face preference in this group. However, because parents did not encourage their child to act on the toy, we predicted that ME training would not affect infants' reaching behavior.

## Methods

### Participants

A total of 36 full-term three-month-old infants participated in this experiment and completed the EE training ( $n = 18$ ) or the ME training ( $n = 18$ ). For comparison purposes, data from an additional 36 infants who completed the PT ( $n = 18$ ) or the AT ( $n = 18$ ) training procedures was obtained from previously published reports (Libertus & Needham, 2010, 2011) and analyzed along with data collected for the current study. These two groups provide a critical comparison for the EE and ME procedures as the AT group experienced both parental encouragement and control over object whereas the PT group experienced neither. In fact, by design the EE and ME procedures are diluted versions of the AT procedure—each with an emphasis on a different aspect of the AT procedure.

Participant details are provided in Table 1 (with participants taken from published reports marked with an \*). An additional six infants were recruited but excluded from the final sample due to fussiness resulting in failure to complete the study ( $n = 3$ ), equipment failure ( $n = 2$ ),

and in response to violations of statistical assumptions ( $n = 1$ ).

Participants were recruited from public birth records. Parents received travel reimbursement and a small gift for their participation. The Institutional Review Board approved the research protocol and a parent or legal guardian provided informed consent before testing.

### Procedure

All participants completed two weeks of daily, parent-guided, 10 min training sessions (average total training duration over two weeks per parent report:  $M = 120.43$  min,  $SD = 30.56$ ) using one of four different training procedures (see below). To assess manual exploration skills, participants completed a four-step reaching assessment on two occasions—one time before training and one time after training (approximately 2 weeks later,  $M = 2.13$  weeks,  $SD = 0.37$ ). Further, participants completed a two-choice visual preference task assessing their preference for faces over objects (both presented side-by-side on a single computer screen) once after the two weeks of training. Infants in the AT and PT groups were additionally visited and tested on the four-step reaching assessment in their homes on four occasions during the training period (for more details see Libertus & Needham, 2010).

The four training procedures reported here differed along several dimensions. For example, in the AT and PT procedures infants wore Velcro mittens during the training and were seated on their parent's lap (facing away from the parent). In contrast, in the EE and ME procedures no mittens were used and infants sat across, face-to-face with their parents (to facilitate engagement in the EE condition). Most critically, the four procedures were designed to systematically differ on whether object attainment was facilitated and whether parents encouraged acting on objects.

**Active Training (AT).** Object attainment was facilitated through the use of Velcro mittens and toys. Parents encouraged infants to reach for toys and infants experienced successful reaching when the toys stuck to the mittens. Previous research demonstrates that this

**Table 1 Participant Characteristics**

Group	n	#F	Race	Age Pre	TD	Age Post	PE	BW
EE	18	9	12C, 3B, 1A, 2M	10.51 (1.40)	109 (25.85)	13.09 (1.87)	8.17 (2.53)	3667 (687)
ME	18	7	15C, 3B	10.87 (1.03)	101 (31.17)	13.33 (1.82)	9.23 (1.79)	3417 (585)
AT*	18	9	15C, 1A, 2M	10.90 (1.75)	125 (24.70)	12.92 (1.77)	9.38 (2.99)	3621 (578)
PT*	18	10	14C, 1B, 1A, 2M	10.90 (1.52)	144 (23.70)	12.93 (1.55)	9.94 (2.24)	3544 (470)

Abbreviations: EE = Encouragement-Experience group; ME = Movement-Experience group; AT = Active Training; PT = Passive Training; TD = Training Duration (minutes); PE = Parent Education; BW = Birth Weight (grams).

*Note.* The total number of participants in each group (n) and the number of females per group (#F) are group totals. All other values are group averages with standard deviations given in parentheses. Age is reported in weeks. Parents' education level was assessed on a scale from 0 (no High School degree) to 6 (Post-doctoral Training) for each parent and summed (max. 12). Race abbreviations: C = Caucasian, B = Black or African American, A = Asian, M = More than one race. \* = data previously reported in Libertus and Needham (2010, 2011).

procedure encourages successful reaching (for detailed procedure see Needham et al., 2002).

**Passive Training (PT).** Object attainment was *not* facilitated, and parents *did not* encourage infants to act on the toys. In the PT condition, parents moved toys across their child's visual field and touched them to the Velcro mittens on their child's hands, but toys did not stick to the mittens. Infants were passive observers in this condition and not allowed to act on the toys on their own. This procedure did not facilitate reaching in previous research (for detailed procedure see Libertus & Needham, 2010).

**Encouragement Experience (EE).** Object attainment was *not* facilitated, but parents actively encouraged infants to act on the toy. Specifically, parents placed a wrist rattle (closed to form a graspable loop) beyond reach in front of the infant and drew attention to the rattle. Next, parents lifted the rattle to the infant's eye level, commented on the rattle (e.g., its color, shape, or sounds), and moved it next to the infant's hands while encouraging the infant to touch the rattle. After about one minute (regardless of the infant's reaching success), the rattle was placed back in the beyond-reach position and the sequence was repeated. Parents were asked to refrain from helping their child and infants had to engage in independent reaching to obtain the toy (see Figure 1a).

**Movement Experience (ME).** Object attainment was facilitated by a parent attaching a toy to the child's hand, but parents *did not* encourage their child to act on the toy. Specifically, parents placed a wrist rattle (open, lying flat on the table) beyond reach in front of the infant while engaging with the infant. During this time, parents were

asked not to look at or talk about the rattle. Next, parents lifted the rattle and secured it around the infant's palm using attached Velcro straps. While the toy was attached to the infant's hand, parents continued to talk to the infant but did not refer to, point at, or draw attention to the rattle. After approximately one minute (regardless of the infant's activity), the rattle was placed back in the beyond-reach position and the sequence was repeated. Parents were asked not to talk about or draw attention to the rattle during this procedure. Infants always obtained the object, regardless of their own reaching behavior (see Figure 1b).

Compliance, fidelity, and total training durations were assessed via parent-completed daily logs (all groups), biweekly home-visits and training observations (AT and PT groups), or biweekly phone calls to the parent and daily recording of the training sessions by the parent (EE and ME groups). To record their training sessions, parents in the EE and ME groups were provided a small Flip camera and tripod. For each family, one to two random training sessions were reviewed and in all reviewed sessions parents completed the EE or ME training as instructed (i.e., EE parents did not put the toy into the child's hand, and ME parents did not point to or talk about the toy).

## Measures

**Reaching Assessment.** To assess reaching behavior, infants were seated on a caregiver's lap and a colorful toy rattle (not used during training) was presented sequentially beyond reach (Step 1), within reach but far from the hand (Step 2), next to the hand (Step 3),



**Figure 1** — Training procedures. **a)** Encouragement Experience (EE): Parent draws attention to toy but does not help infant grasp toy. **b)** Movement Experience (ME): Parent does not talk about toy or draw attention to toy but attaches it to the infant's hand.

and placed into the child's hand (Step 4, see Figure 2a). Each step lasted approximately 30 s and the far and next to hand steps (2 and 3) were combined for analyses as both allow for successful reaching actions. Behavior was coded from video recordings by trained observers with frame-by-frame coding software using the same definitions as in Libertus and Needham (2010). In particular, successful reaching was defined as an arm movement toward the toy that results in contact with the object and a partial or complete lift of the object off the table. In this measure, the reach and grasp phase were combined as both behaviors are performed toward the same goal—exploring the toy. The entire duration of a successful reaching unit was quantified, starting with the infant moving his hands away from the body toward the toy while looking at the toy (successful reach onset), continued while the infant was grasping the toy, and ended when the infant released the toy onto the table or floor (successful reach offset). Please note that grasping behaviors continued to be counted while the infant engaged in higher-level actions such as lifting, shaking, or mouthing the toy (as long as contact with the hand and the toy continued). These behaviors were coded frame-by-frame, with one frame every 100ms. Summing scores across frames resulted in our final duration measure (assuming that a behavior continued for the entire 100ms duration of a frame).

Data from 38% of participants in the EE and ME groups were coded by two independent observers and correlation of successful reaching durations between the two observers was high ( $r = .88$ ). During the reaching assessment, the experimenter was seated across from the infant but looked down and did not make eye contact to avoid distracting the child. This may affect the child's interest in the experimenter and may make the toy more interesting in this context.

**Face-Preference Task.** Face preference was assessed using a remote eye tracking system (Tobii 1750) sampling eye gaze at 50 Hz. Infants were seated in a reclined infant seat or on their parent's lap at a distance of approximately 60 cm from a 17-inch computer screen (1024 × 768 pixel resolution, 33.4 × 25.4 degrees of visual angle).

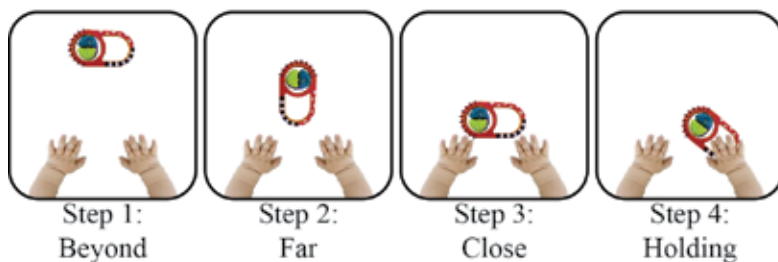
Four face-toy pairs were constructed from four realistic photographs of neutral faces (two female, all Caucasian) and four photographs of infant toys (Figure 2b). Faces and toys were 3.8–6.4 cm apart, similar in size and luminance, and have been used in previous studies (DeNicola, Holt, Lambert, & Cashon, 2013; Libertus & Needham, 2011). Face images were selected from the NimStim stimulus set (Tottenham et al., 2009). Three infants (one each from the EE, ME, AT group) failed to complete the face-preference task due to fussiness. The faces used in the face preference task were shown with gaze straight ahead, the face and toy were presented simultaneously, both were novel for the infant, and both were clearly beyond reach.

## Analysis

Manual exploration behavior was assessed analogous to Libertus and Needham (2010) as the proportion of time (behavior duration out of 60 s trial duration) infants spent looking at the experimenter (Step 1), as the proportion of time infants engaged in successful reaching (Step 2 and 3), and as the number of toy looking episodes (Step 4). Please note that looking at the toy in Step 4 was quantified as frequencies while all other behaviors were quantified as durations (to determine overall engagement). Duration measures do not distinguish between one long action and many short actions being added together but provide a good overall measure of infants' engagement (Steps 1–3). In contrast, the number of looks (frequency) used in Step 4 provides is sensitive to this difference and provides an estimate for how often the infant's gaze shifted toward the toy. This frequency should increase during triadic interactions where gaze shifts repeatedly between the object and the person.

An analysis of change was conducted to determine between-group differences after two weeks of training by using Analysis of Covariance (ANCOVA) with pretraining behavior included as covariate and Group (4) and Sex (2) as between-subjects factors. Significant effects of Group were followed up by post hoc comparisons. Due to unequal error variances (Levene's Test), data for Step 1 were log-transformed before analysis. Within-groups analyses comparing behavior before and after training

### a) Four-Step Reaching Assessment



### b) Face-Preference Task



**Figure 2** — Stimuli used in the experiment. **a)** Four-step reaching assessment (Steps 2 and 3 were combined for analyses). **b)** Face-preference task.



were performed separately for each group using paired  $t$  tests.

Face preference was assessed as in previous studies by calculating the proportion of looking at the face or toy (with %face + %toy = 100%) and by deriving a single face-preference score (FP = %face - %toy) for each participant. Positive FP values indicate a face preference, negative values a toy preference, and 0 indicates no preference (Libertus & Needham, 2011). For each group, FP scores were then compared with 0 using single-sample  $t$  tests (two-tailed). The relation between face preference and successful reaching behavior was assessed in the ME and EE groups using correlation.

## Results

### Reaching Assessment

**Between-Group Analyses.** Comparisons using ANCOVAs with pretraining behavior as covariate did not reveal any significant effects of Group or Sex for Step 1 or Step 4 (all  $p > .121$ ). In contrast, a significant effect of Group was observed on successful reaching during combined Steps 2 and 3,  $F(3,63) = 3.103$ ,  $p = .033$ . There were no effects of Sex and no interactions (all  $p > .120$ ). Post hoc comparisons showed significantly more successful reaching in the AT group ( $M_{AT} = 29.93$ ,  $SD_{AT} = 27.42$ ) compared with the PT group ( $M_{PT} = 11.80$ ,  $SD_{PT} = 14.69$ ,  $p = .019$ ,  $d = .82$ ), and compared with the

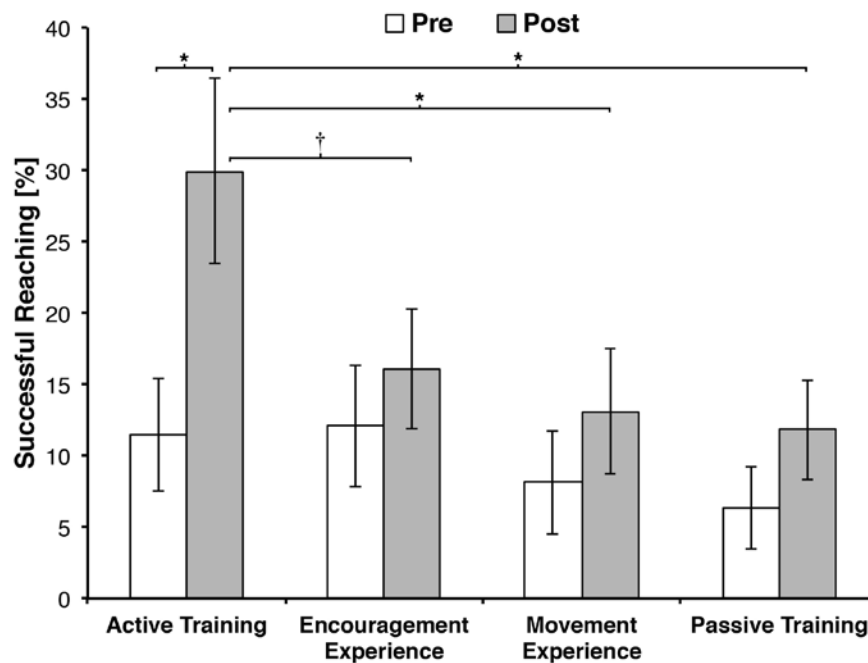
ME group ( $M_{ME} = 13.10$ ,  $SD_{ME} = 18.53$ ,  $p = .038$ ,  $d = .72$ ). Differences between the AT and the EE group were marginal but failed to reach statistical significance ( $M_{EE} = 16.07$ ,  $SD_{EE} = 17.39$ ,  $p = .081$ ,  $d = .60$ ). There were no differences between the any of the other groups (all  $p > .437$ ). These results are summarized in Figure 3.

**Within-Group Analyses.** Comparing behavior before and after training revealed that the infants in the AT group showed a marginally significant decline in looking at the experimenter (Step 1),  $t(17) = 2.082$ ,  $p = .053$ , a significant increase in reaching and grasping behavior (Steps 2 and 3),  $t(17) = 3.857$ ,  $p = .001$  (Figure 3), and a significant increase in toy looking episodes (Step 4),  $t(17) = -2.257$ ,  $p = .037$ . Within-group analyses were not significant for any of the remaining groups (all  $p > .090$ ).

Collectively, within- and between-group analyses suggest that only the AT procedure had a significant impact on infants' engagement with toys and leads to an increase in reaching and grasping behavior. The PT, EE, and ME procedures did not influence infants' reaching behavior.

### Face Preference Task

Preliminary analyses revealed no effect of Sex on face preference scores ( $p > .706$ ) and the data were collapsed across Sex for all analyses. Within group analyses revealed a significant face preference in the AT group ( $M_{AT} = 24.24$ ,  $SD_{AT} = 38.32$ ),  $t(16) = 2.609$ ,  $p = .019$ , 95%



**Figure 3** — Average successful reaching duration as proportion of total trial duration. Data for the Active and Passive Training groups are taken from Libertus & Needham (2010). Error bars represent SEM, \*  $p < .05$ . †  $p = .08$ .

CI [4.54, 43.95], with 11 out of 17 infants looking longer at the face than at the toy ( $p = .094$ , binomial procedure). No face preference was present in the PT group ( $M_{PT} = 1.78$ ,  $SD_{PT} = 36.46$ ),  $t(17) = .207$ ,  $p = .839$ ,  $[-16.35, 19.91]$ , with 9 out of 18 infants looking longer at the face than at the toy ( $p = .185$ ). Analogous analyses for the EE and ME groups revealed a significant face preference in the ME group ( $M_{ME} = 19.01$ ,  $SD_{ME} = 25.20$ ),  $t(16) = 3.110$ ,  $p = .007$ ,  $[6.05, 31.97]$ , with 13 out of 17 infants looking longer at the face than at the toy ( $p = .018$ ), but no face preference in the EE group ( $M_{EE} = 15.27$ ,  $SD_{EE} = 43.42$ ),  $t(16) = 1.450$ ,  $p = .166$ ,  $[-7.06, 37.59]$ , with 11 out of 17 infants looking longer at the face than at the toy ( $p = .094$ ). Together, these findings suggest that both the AT and the ME procedure encouraged face preference in three-month-old infants.

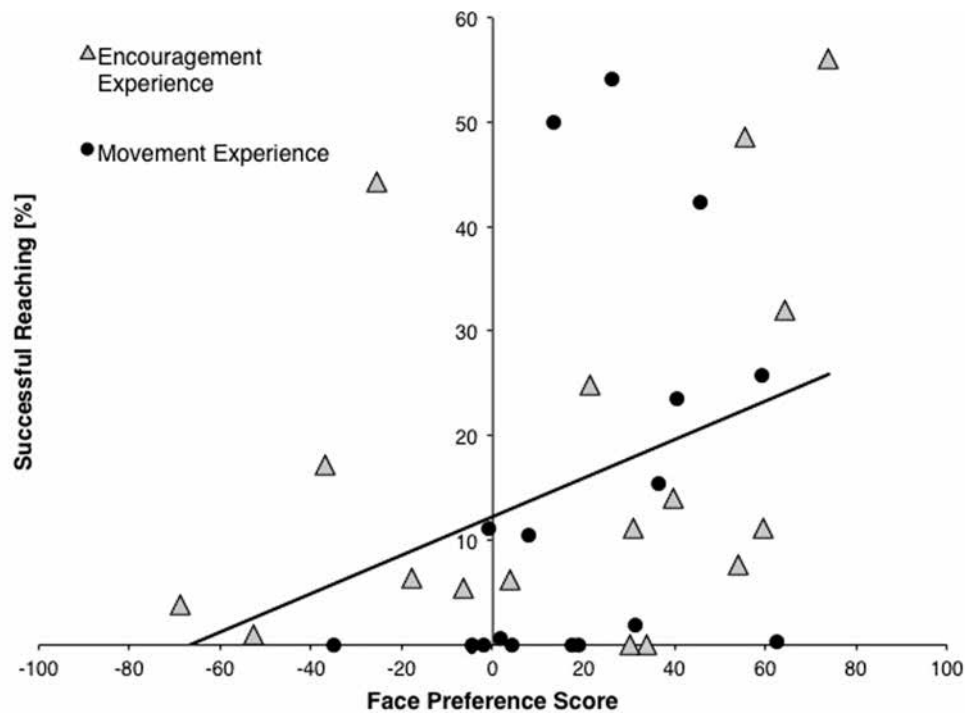
### Relation Between Reaching and Face Preference

Libertus and Needham (2011) noted a significant relation between successful reaching and face preference in three-month-olds: Infants showing more successful reaching tended to show higher face-preference scores. Here, we examine the same relation in the EE and ME groups using correlation analyses. While face preference showed a positive correlation with successful reaching in both groups ( $r(16)_{EE} = .387$ ;  $r(16)_{ME} = .363$ ) these

results failed to reach significance, possibly due to the small sample and large variance within groups ( $p > .122$ ). However, the correlation results were significant for both groups combined, suggesting a developmental link between successful reaching and face preference in three-month-old infants ( $r(34)_{EE/ME} = .356$ ,  $p = .039$ ; see Figure 4).

## Discussion

The results reported here confirm our initial hypotheses and show that neither parental encouragement to reach for objects nor self-produced experiences of moving an object attached to the hand are effective on their own in encouraging independent reaching behavior in three-month-old infants. Rather, a combination of both experiences (as in the AT training) seems necessary. At the same time, both EE and ME groups showed some increases in successful reaching and in face preference. Given the large within-group variation, only infants in the ME group showed a significant preference for faces over toys. Together with the findings reported by Libertus and Needham (2011), these results suggest that active, self-produced motor experiences—either facilitated through sticky mittens or through parental assistance—and the development of a preference for faces are connected in early infancy. A connection between motor experiences and social attention provides empirical evidence for



**Figure 4** — Scatterplot showing relation between successful reaching (see Figure 3) and face preference (see Figure 5) in the EE (triangles) and ME (circles) groups.

ecological and embodied perspectives on social cognition (Smith & Gasser, 2005; Zebrowitz, 2006).

### Variability in Training Success

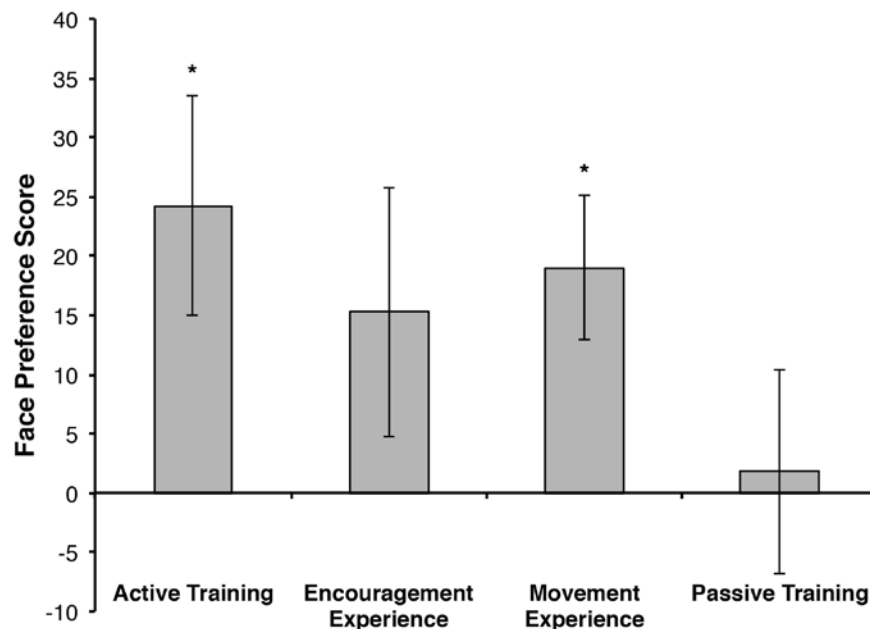
Figure 5 indicates that there is large variation of face preference scores in both the EE and ME groups. This considerable variability suggests that the EE and ME training may have been effective for some infants but not for others. In particular, those infants in the EE group who started to engage in successful reaching early experienced both parental encouragement and controlling object motion—similar to infants in the AT group. As long as parents followed our instructions, which our assessments of training fidelity suggest was the case, infants in the ME group did not experience this kind of parental encouragement.

Further, the large variability in our results suggests that some infants are more ready to learn from encouragement or self-produced object-motion experiences than others. Thus, while both experiences in combination seem most efficient, scaffolded reaching experiences using ‘sticky mittens’ are *not* the only way to encourage successful reaching in three-month-old infants. Rather, the benefit of Active Training in comparison with the EE or ME conditions seems to be that more infants are able to benefit from the AT procedure while the other procedures affect only a subset of infants who were closer to making this transition from the beginning of the study.

### Learning From Contingent Feedback

The results reported here call to mind the ‘kitten carousel’ findings by Held and Hein (Held & Hein, 1963) and demonstrate the importance of self-guided and self-initiated motor experiences for learning and development in three-month-old human infants. Repeated external encouragement to act on a toy (EE group) or experiences of passively obtaining a toy (ME group) did not encourage independent reaching in most infants. Rather, it seems critical that infants experienced outcomes that are contingent upon their own, self-produced motor actions. Such experiences were likely scarce in the EE and ME conditions—offering some explanation for why these training methods were less effective than the Active Training.

Previous studies have shown that three-month-old infants are sensitive to triadic exchanges and gaze cues (Farroni, Massaccesi, Pividori, & Johnson, 2004; Striano & Stahl, 2005; Striano et al., 2007). However, it is not known whether three-month-olds are also able to learn from such exchanges. Results of the EE group suggest that some three-month-old infants may not yet have the ability to learn from triadic exchanges, or notice the triadic bid but lack the motor skills necessary to respond to it. It is likely that these infants need additional experiences, such as experiences of contingent feedback from their own movements (i.e., visual stimulation from their own hands) or from a caregiver. Indeed, studies suggest that auditory feedback that is contingent on infants’ arm



**Figure 5** — Average face-preference scores. Data for the Active and Passive Training groups are taken from Libertus & Needham (2011). Error bars are *SEM*, \*  $p < .05$ .



movements does encourage reaching activity (Darcheville et al., 2004; Lee & Newell, 2013). Infants in the EE group likely experienced only few successful reaching episodes that would trigger contingent feedback from the parent. And while infants in the ME group produced arm and toy movements, these actions were not paired with parental encouragement. Out of the four procedures used here, only the AT procedure increases the likelihood of successful reaching experiences that could be paired with contingent parental feedback.

### Effectance—Motivation to Act

In addition to responding to contingent parental feedback, it is also well known that infants readily learn from the outcomes of their own, self-produced actions and adjust their behavior to reproduce interesting events (e.g., DeCasper & Carstens, 1981; Piaget, 1953; Rovee & Rovee, 1969). Once infants realize that their own actions result in predictable, observable outcomes, infants come to develop a sense of their own ‘effectance’—a drive toward competence that encourages infants to act on their environment (Lamb, 1981; Watson, 1985; White, 1959). In a reaching context, effectance can be seen as motivating the infant to persistently attempt to reach for objects.

Due to the lack of independent reaching at age three months, the EE and PT procedure likely did not increase infants’ sense of effectance. In contrast, both AT and ME conditions would have encouraged the development of effectance in three-month-olds. Nonetheless, infants in the ME condition failed to show the same increase in successful reaching as infants in the AT condition. The lack of parental encouragement can partially explain these differences. In addition, infants in the ME group might have actually learned that no reaching is necessary on their part to obtain an object because their parents always helped them. In a sense, the experiences of the ME condition (although not aversive) may have encouraged a state akin to ‘learned helplessness’ (Maier & Seligman, 1976) and reduced infants’ motivation to act. Instead of learning to reach, infants in the ME condition may have learned to wait for external help. Therefore, the success of ‘sticky mittens’ may stem from a combination of scaffolded reaching experiences, contingent parental encouragement, experiences of success that motivate future actions, and the necessity to act independently to obtain an object. In addition to these factors, learning by observation may also play a role as infants acquire independent reaching.

### Doing Facilitates Effective Observation

Learning from our own actions is important, but learning by observation is equally important for knowledge acquisition. Studies suggest that infants’ understanding of observed actions is facilitated by first-hand experiences with similar actions (Kanakogi & Itakura, 2010; Lepage & Theoret, 2007; van Elk, van Schie, Hunnius, Vesper,

& Bekkering, 2008). In particular, scaffolded reaching experiences have been shown to facilitate infants’ action perception and understanding (Gerson & Woodward, 2013; Skerry et al., 2013; Sommerville et al., 2005). Following first-hand reaching experiences, external encouragement and parent-guided demonstrations may have become more meaningful and effective for the infant. By facilitating action understanding, the synergies between self-produced reaching experience and action observation may have been a critical factor contributing to the effectiveness of the AT procedure. Even though infants in all four groups tested here saw their parents lift and manipulate toys, it is possible that only infants in the AT group were able to learn from these observations.

### Cascading Effects of Reaching Experiences

Once infants engage in independent reaching, new opportunities to learn about objects, object properties, and the relation between objects and surfaces arise (Bourgeois, Khawar, Neal, & Lockman, 2005; Lederman & Klatzky, 2009; Needham, 2000). Further, reaching experiences influence development well beyond the motor domain itself and seem to facilitate infants’ social preferences, their perception of actions and goals, and their perception of intentions (Gerson & Woodward, 2013; Libertus & Needham, 2011; Rakison & Krogh, 2012; Skerry et al., 2013; Sommerville et al., 2005). Are these social cognition skills affected by the motor aspects of reaching behaviors or by their social components such as parental engagement and object sharing?

Our results of the PT and EE procedures suggest that parental engagement and encouragement alone were not sufficient to encourage motor or social development. However, first-hand experiences with moving an object in the ME procedure did facilitate face preference, suggesting that motor experiences may facilitate social development. Other studies support this idea by suggesting that motor experiences facilitate infants’ social, emotional, and language development (Clearfield, 2011; Iverson, 2010; Karasik et al., 2011). Of course, it is possible that infants in the ME group tried to engage their parent in triadic attention and object sharing bids once the toy was attached to their hand. Although parents were asked not to talk about or look at the toy, they may have responded to triadic attention bids by smiling and encouraging their child. Therefore, due to the naturalistic parent-child interactions used here our results cannot rule out that parents’ engagement during the ME procedure contributed to infants’ social learning. Further, changes in infants’ motor behaviors during the training may have changed how parents’ interact with their child (Karasik et al., 2013)—which is also likely to affect infants’ future social development. Therefore, the changes we observe in infants’ face preferences following scaffolded reaching experiences may be the result of a developmental cascade beginning with successful reaching behaviors that in turn

lead to new opportunities for sharing objects and triadic coordination of attention during play (Karasik et al., 2013; Soska et al., 2010).

## Clinical Implications

The findings reported here have some interesting clinical implications as they suggest that scaffolded reaching experiences could be used as an intervention strategy for children at risk for motor delays. For example, infants born preterm are at increased risk for future motor and learning delays (van Haastert, de Vries, Helders, & Jongmans, 2006). Early intervention can be quite effective and may facilitate cognitive, and to a limited degree also motor development, in preterm infants (Spittle, Orton, Anderson, Boyd, & Doyle, 2012). Our results suggest that scaffolded reaching experiences can encourage successful reaching and the application of this method in preterm infants should be investigated in future studies (Heathcock, Lobo, & Galloway, 2008).

Similarly, delayed motor skills have also been noted in Autism Spectrum Disorders (ASD) and may precede and predict social impairments in this population (Bhat, Galloway, & Landa, 2012; Flanagan, Landa, Bhat, & Bauman, 2012; Leonard, Elsabbagh, Hill, & the BASIS team, 2013; Nickel, Thatcher, Keller, Wozniak, & Iversen, 2013). The connection between motor and social development suggested here is intriguing, as social deficits are a hallmark of ASD (Landa, 2008). Future studies should investigate whether successful reaching experiences would facilitate social development in these infants at high familial risk for ASD (see Lloyd, MacDonald, & Lord, 2013).

## Conclusion

The results reported here suggest that with regard to early motor experiences, the whole is more than the sum of its parts. Scaffolded reaching experiences using 'sticky mittens' have been shown to encourage independent reaching and face preference (Libertus & Needham, 2010, 2011; Needham et al., 2002). The current report shows that external encouragement to act on an object or self-produced experiences with moving objects in isolation were not sufficient to affect development in a similar way. Nonetheless, self-produced experiences with moving objects, even if infants did not have to obtain the object themselves, encouraged a preference for faces in three-month-old infants. This result suggests a developmental link between infants' own motor experiences and face preferences in early infancy. Future studies are necessary to determine if a connection between reaching behaviors and face preference occurs naturally during development or is evoked solely in the context of training paradigms as used here. Finally, the results reported here support a view of early development that is complex and crosses traditional domain boundaries. To better understand developmental processes, researchers should focus on

the mutual influences among 'cognitive', 'motor', and 'social' phenomena.

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