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Reaching experience increases face preference in 3-month-old infants

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Abstract

The developing infant learns about the physical and the social world by engaging with objects and with people. In the study reported here, we investigated the relationship between infants' interactions with the physical and the social world. Three-month-old infants were trained for 2 weeks and experienced either actively manipulating objects themselves or passively having objects touched to their hands. Following active or passive experiences, spontaneous orienting towards faces and objects was compared between the trained groups and untrained 3- and 5-month-olds. It is known that the onset of reaching behavior increases infants' interest in objects. However, we report that active, self-produced reaching experiences also increase infants' spontaneous orienting towards faces, while passive experiences do not affect orienting behavior. Regression analyses provide evidence for a link between manual engagement and the development of orienting towards faces. Implications of orienting towards faces for the development of triadic interactions, joint attention, and social cognition in general are discussed.

Introduction

The first 2 to 3 months of life are a time of rapid developmental change. Between 6 and 8 weeks of age, infants start to engage in dyadic social interactions with their caregivers (Schaffer, 1984). Starting at 3 months of age, objects are incorporated into these interactions and sensitivity to triadic interactions emerges (Striano & Stahl, 2005; Striano, Stahl, Cleveland & Hoehl, 2007). Triadic interactions are thought to be important for future social and cognitive development and may form the basis for joint attention appearing around 9 months of age (Amano, Kezuka & Yamamoto, 2004; Striano & Reid, 2006; Tomasello, Carpenter, Call, Behne & Moll, 2005). However, we know little about why infants start to engage in triadic exchanges and what influences infants' dynamic interactions with objects and people. Important influences are likely to come from infants' active exploration of the environment (Gibson, 1988). Intentional, self-produced actions are evident in the first months of life or even prior to birth (e.g. Myowa-Yamakoshi & Takeshita, 2006; van der Meer, 1997; van der Meer, van der Weel & Lee, 1995; von Hofsten, 1984; Zoia, Blason, D'Ottavio, Bulgheroni, Pezzetta, Scabar & Castiello, 2007) and provide ideal opportunities for learning because their outcomes are dependent on the specific nature of the action itself. In this article, we present new empirical findings to support the notion that young infants' engagement with objects and people is shaped by their own exploratory actions.

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Exploration and development

Several theoretical positions emphasize the role of active exploration for cognitive, perceptual, and social development (e.g. Bushnell & Boudreau, 1993; Gibson, 1988; Woodward, 2009). In particular, Eleanor Gibson (1988) presented a model of development with three distinct phases of exploratory activity where the emergence of new motor skills drives the transition from one phase to the next. According to Gibson's model, infants' active exploration of their environment (including objects and people) shapes learning. Consequently, even simple actions such as orienting towards faces or reaching for toys have important implications for development. By repeatedly acting on objects, infants provide themselves with opportunities to learn about object properties (such as texture, hardness, weight), object boundaries, categories, and their own abilities to act (e.g. Bourgeois, Khawar, Neal & Lockman, 2005; Needham, 2000). Similarly, by repeatedly orienting towards faces, infants provide themselves with opportunities to learn about distinctive features of individual faces, emotional information present in faces, and contingent social interactions provided by faces (e.g. Kelly, Quinn, Slater, Lee, Ge & Pascalis, 2007; Nelson, 2001; Pascalis, Scott, Kelly, Shannon, Nicholson, Coleman & Nelson, 2005; Schwarzer, Zauner & Korell, 2003; Striano & Reid, 2006). Infants' learning about people and about objects has traditionally been investigated separately. However, there are interesting connections between infants' learning in these two domains.

Gibson (1988) predicted increased attention towards objects following improved exploration skills. Empirical findings support this prediction: 3–6-month-old infants show more interest in objects following the onset of reaching and self-sitting behavior (Fogel, Dedo & McEwen, 1992; Fogel, Messinger, Dickson & Hsu, 1999). Others have shown that object manipulation skills between 3.5 and 5.5 months of age predict visual attention towards multimodal object-manipulation events but not towards multimodal social-interaction events (Eppler, 1995). Finally, infants' 3D object completion skills are facilitated by self-sitting and manual-exploration experiences (Soska, Adolph & Johnson, 2010). These studies indicate that there is a relation between motor experiences and infants' perception of the physical world.

At the same time, there is a relation between motor experiences and infants' perception of the social world. Infants' own reaching actions inform their understanding of observed actions (Sommerville, Woodward & Needham, 2005), and infants learn about actions by observing others (Hauf, 2007). Thus, motor experiences influence both infants' interest in the physical and in the social world. Also demonstrating this point, following the onset of upright locomotion, infants show more sophisticated interactions with objects *and* initiate more interactions with their mothers (Clearfield, 2011; Clear-field, Osborne & Mullen, 2008). Indeed, to engage in triadic interactions, joint attention, and complex play, infants have to pay attention to people *and* objects. This may be difficult to manage for a young infant with limited attentional resources. Several studies indicate that infants exhibit a strong preference for the social world – especially faces – early in development.

Development of face preferences

Starting at birth, infants prefer looking at faces or face-like arrangements to looking at other patterns (e.g. Fantz, 1963; Goren, Sarty & Wu, 1975; Johnson, Dziurawiec, Ellis & Morton, 1991a; Valenza, Simion, Cassia & Umilta, 1996). This face preference declines over the first months of life before it rebounds, creating a nonlinear developmental trajectory (Fantz, 1961; Johnson *et al*., 1991a). Different mechanisms may underlie neonatal and later emerging face preferences with a transitional period around 2–5 months (Morton & Johnson, 1991). Similarly, eye-tracking findings indicate that visual attention in 3-month-olds is primarily influenced by perceptual saliency and only by 9 months of age attention is guided by an explicit 'face model' (Frank, Vul & Johnson, 2009). However, face preference is not absent between 2 and 5 months, and Turati and colleagues report a reliable preference for natural faces over faces with rearranged features in 3-month-olds (Turati, Valenza, Leo & Simion, 2005). Rather, stimulus and procedural parameters seem to strongly influence infants' preferences during this time (for a systematic review see Maurer, 1985).

To date, studies on infants' face preferences have focused on the perceptual features present in the faces or on influences of prior visual experiences (Pascalis & Kelly, 2009; Pascalis *et al*., 2005; Sangrigoli & de Schonen, 2004). However, the influences of infants' own motor experiences and emerging exploration skills on their face-preference behavior remain unknown. Developmental data supporting such an ecological approach to face perception (Zebrowitz, 2006) are needed in order to fully understand the full range of processes shaping social development.

The current study

The current study investigates the relationship between infants' own motor experiences and their visual preferences for faces or objects by experimentally manipulating motor experiences. Two groups of 3-month-old infants were provided with similar object-focused training interventions. One group of infants was enabled to actively manipulate objects with the help of 'sticky mittens' (Needham, Barrett & Peterman, 2002). A second group of infants experienced passive object exploration (i.e. a toy was moved by the parent and touched to the infant's palm by the parent) but was matched to the first group in terms of total training duration, exposure to the training materials (Table 1), manual contact with the training materials, and parental engagement. Critically, both groups experienced the same amount of sitting experiences and interactions with objects, with their parents, and with the experimenter during the training period, but only one group was allowed to actively interact with the objects. Following training, both groups were tested on a spontaneous preference task comparing infants' interest in unknown faces to their interest in novel, unknown toys. Both training groups were compared to an age-matched, non-reaching and non-sitting control group and an older comparison group.

Method

Participants

Participant details are shown in Table 1. Fifty-five non-reaching and non-sitting 3-month-old infants were divided into three different groups: An 'Active Training' (AT, $N = 18$) group, a 'Passive Training' (PT, $N = 18$) group, and an untrained 3-month-old comparison (NT3, $N = 19$) group. Additionally, we included an older untrained comparison group of 5-month-old infants (NT5, $N = 23$). All participants were born within 3 weeks of their due date. However, because postmen-strual age is a better predictor for motor development than chronological age (van der Fits, Klip, van Eykern, & Hadders-Algra, 1999), age of all participants was adjusted for prematurity based on parent report (i.e. a 13-week-old born 1 week early was recorded as a 12-week-old). Three infants did not complete the spontaneous visual-preference task due to fussiness ($n_{AT} = 1$, $n_{NT3} = 2$) and three different infants from the untrained 3-month-old group did not complete the manual-exploration assessment due to fussiness ($n = 1$) or technical difficulties with the recording equipment ($n = 2$).

Stimuli

Two sets of training stimuli were created. For the Active Training group, the set consisted of a pair of infant mittens and six Duplo® toy blocks with Velcro® attached to both mittens and blocks. While wearing the mittens, infants were able to independently 'pick up' a block by touching it (see also Needham *et al*., 2002). For the Passive Training group, the same mittens but different toy blocks without Velcro® were used. Tape was used to match the visual appearance to the blocks without Velcro® to the blocks with Velcro®.

Spontaneous visual preference behavior was assessed during observation of a face and a toy presented side-by-side for 10 seconds. Face–toy pairs were constructed from four full-color photographs of neutral faces (two female, all Caucasian) taken from the NimStim stimulus set (Tottenham, Tanaka, Leon, McCarry, Nurse, Hare, Marcus, Westerlund, Casey & Nelson, 2009) and four full-color photographs of commercially available infant toys (two balls, a stacker, a grasping ring). Faces and toys were similar in size and 3.8–6.4 cm apart. Manual-exploration behavior was assessed using a colorful toy rattle (0.8 × 6.4 × 11.5 cm, H × W × D) as target object.

Procedure

Infants in the Active and Passive training groups received 10 minutes of object-focused training each day for a period of 2 weeks. This training duration is based on published reports using the same paradigm (Libertus & Needham, 2010b; Needham *et al*., 2002). During training, mittens were placed on the infant's hands and a set of toy blocks was placed in front of the infant. In the Active Training group, parents provided one demonstration of the mittens each day by guiding the infant's hand to a block and making it stick to the mitten. The toy was then removed from the mitten and the infant was encouraged to independently reach for the toy again. Upon successful contact, infants were allowed to explore the toy for about 10 seconds before the toy was placed back on the table and the sequence was repeated. In the Passive Training group, infants were passive observers and parents provided visual and tactile stimulation by moving the toys across the infant's visual field and touching them to the inside of infant's palms (while wearing the mittens) according to a script based on the object movements commonly produced by the infants in the Active Training group. The training procedures were designed to ensure similar overall levels of object exposure, parent engagement, sitting experiences, and manual object contact (either through the Velcro® blocks sticking to the mitten or through the parent touching the blocks to the mitten) in the two training groups. Parents in both groups completed a daily log and training compliance was additionally monitored on 3–4 in-home observations of the parents administering the training. During in-home visits, parents could also ask questions about the procedure and received another demonstration if necessary.

Following 2 weeks of training, infants' face preference was assessed by presenting eight face–toy pairs sequentially on a computer screen while recording eye-gaze with a remote eye-tracker (Tobii 1750). Prior to testing, a nine-point calibration procedure was performed. Face preference was defined as the difference between the proportions of time infants looked at the face versus the toy (%face − %toy, with %face + %toy = 100%). A score of zero indicates no preference, positive scores indicate a face preference, and negative scores indicate a toy preference. Face orienting was defined as face preference during the 1000–2000 ms time windows following stimulus onset (white bars in Figure 1 and shaded area in Figure 2). This time window was chosen to capture infants' first choice while providing them with enough time to disengage from the preceding fixation stimulus (see Hood & Atkinson, 1993). Face-preference calculations were based on fixation duration while face-orienting calculations were based on total gaze duration (raw eye-gaze data).

In addition, all 3-month-old infants completed a four-step reaching assessment where a toy was first placed beyond reach (Step I), within reach but far (Step II), close to the hand (Step III), and inserted into the hand (Step IV). Each step lasted approximately 30 seconds and this reaching assessment was always completed following the face-preference task to avoid short-term influences from the motor experiences. Influences of the different training procedures on reaching and grasping behavior in these infants using the four-step reaching assessment are reported elsewhere (Libertus & Needham, 2010b). Briefly, there were no between-group differences in spontaneous exploration behavior on the four-step reaching assessment prior to training. Following training, infants in the Active-Training group showed less attention to the experimenter, more grasping behavior, and more looking episodes to the toy (but not more interest in the toy overall) (for details see Figure 3 in Libertus & Needham, 2010b). The present report focuses on changes in visual preferences following training, and the relation between infants' visual preferences and their overall manual contact with objects. For the current report, manual engagement was defined as *any* manual toy contact during Steps II and III of the four-step reaching assessment – including intentional and accidental (e.g. brushing the object with the side of the hand) toy contacts. Manual object contact assesses the opportunities for learning infants provide for themselves (object contact can – but doesn't have to – culminate in exploration). As defined here, manual object engagement is part of the typical motor repertoire of a 3-month-old infant and not a proxy for developmental status or maturation.

During manual object engagement, looking and touching behaviors were coded frame-by-frame by trained observers using custom-built software (Libertus, 2008). To assess reliability and validity of the frame-by-frame coding program, looking and touching behavior after training were also coded in real time off videotapes by different observers using an established coding protocol (Needham *et al*., 2002). Correlations between the two coding methods were high ($r = .94$). Frame-by-frame coding results were used for the reported manual engagement scores.

Results

Face preference

Using the overall face-preference score as dependent variable, results revealed that only infants in the Active Training group and untrained 5-month-olds showed a significant face preference (see solid bars in Figure 1 and total time-course in Figure 2). Within-group analyses showed a significant face preference in untrained 5-month-olds ($t(22) = 4.98$, $p < .001$, 95% CI [19.28, 46.80]) with 20 out of 23 infants looking longer at the face than the toy ($p < .001$, binomial procedure), and in the Active Training group ($t(16) = 2.61$, $p = .019$, [4.54, 43.95]) with 11 out of 17 infants looking longer at the face ($p = .094$, binomial procedure). In contrast, the Passive Training group ($t(17) = .207$, $p = .839$, [−16.35, 19.91]) and untrained 3-month-olds ($t(16) = 878$, $p = .393$, [−9.18, 22.15]) showed no preference for either face or toy and only nine out of 18 infants (PT) and nine out of 17 infants (NT3), respectively, looked longer at the face (both $p = .185$, binomial procedure).

A 2 (Gender) × 3 (Group) analysis of variance (ANOVA) on overall face-preference scores confirmed these results and revealed a significant effect of group ($F(3, 67) = 3.436$, $p = .022$, $\eta^2 = .131$) but no effects of gender ($F(1, 67) = .895$, $p = .348$, $\eta^2 = .011$) and no interaction ($F(3, 67) = .067$, $p = .977$, $\eta^2 = .003$). Planned comparisons were performed to test whether the untrained 5-month-olds showed a stronger face preference than each of the 3-month-old groups. Untrained 5-month-olds showed a stronger face preference than untrained 3-month-olds ($t(39) = -2.420$, $p_{one\text{-}tailed} = .009$; [−49.88, −4.79]) and than infants in the Passive Training group ($t(38) = -2.774$, $p_{one\text{-}tailed} = .004$; [−52.71, −8.60]). However, untrained 5-month-olds did not show a stronger face preference when compared to the Active Training group ($t(38) = -.807$, $p_{one\text{-}tailed} = .212$; [−31.40, 13.33]).

Face orienting

Using the face-orienting scores as dependent variable, results parallel the findings of the face-preference scores (see Figure 1, white bars and area between dotted lines in Figure 2).

Within-group analyses revealed a significant face-orienting response in untrained 5-month-olds ($t(22) = 3.25$, $p = .004$, 95% CI = [9.63, 45.93]) with 19 out of 23 infants first orienting to the face ($p = .001$, binomial procedure), and the Active Training group ($t(16) = 2.65$, $p = .018$, [6.19, 56.04]) with 12 out of 17 infants first orienting to the face ($p = .047$, binomial procedure). Again, the Passive Training group ($t(17) = -.362$, $p = .722$, [−21.41, 15.14]) and untrained 3-month-olds ($t(16) = -1.226$, $p = .238$, [−39.24, 10.48]) did not consistently orient to either face or toy and only seven out of 18 infants (PT; $p = .121$, binomial procedure) and seven out of 17 infants (NT3; $p = .148$, binomial procedure), respectively, first oriented to the face.

A 2 (Gender) × 3 (Group) ANOVA on face-orienting scores confirmed these results and revealed a significant effect of group ($F(3, 67) = 4.883$, $p = .004$, $\eta^2 = .174$) but no effects of gender ($F(1, 67) = 1.779$, $p = .187$, $\eta^2 = .021$) and no interaction ($F(3, 67) = .302$, $p = .824$, $\eta^2 = .011$). Planned comparisons showed a stronger face-orienting response in untrained 5-month-olds compared to untrained 3-month-olds ($t(39) = -3.104$, $p_{one\text{-}tailed} = .002$; [−73.08, −15.88]) and compared to the Passive Training group ($t(38) = -2.161$, $p_{one\text{-}tailed} = .02$; [−58.29, −2.32]). Again, untrained 5-month-olds did not show a stronger face-orienting response when compared to the Active Training group ($t(38) = .198$, $p_{one\text{-}tailed} = .422$; [−25.56, 31.18]).

Regression model

To determine the impact of motor experiences on face-orienting behavior in 3-month-old infants above and beyond other potentially influential factors, we conducted a multiple-regression analysis with three predictor variables/groups: (1) demographic and maturational factors (i.e. gender, parent education, and birth-weight, see Broekman, Chan, Chong, Quek, Fung, Low, Ooi, Gluckman, Meaney, Wong & Saw, 2009; Tong, Baghurst & McMichael, 2006); (2) constraints on orienting behavior (i.e. the number of gaze shifts produced by the infant, see Butcher, Kalverboer & Geuze, 2000; Johnson, Posner & Rothbart, 1991b); and (3) manual object engagement (i.e. *any* manual toy contact during the reaching assessment).

Systematic between-group differences in motor behavior could bias our regression model. Previous results have shown that infants who experienced Active Training show more *intentional* object contact and more *purposeful* reaching and grasping behavior (Libertus & Needham, 2010b; Needham *et al*., 2002). Based on these results, we predicted no between-group differences on *overall* (intentional and accidental) manual object contacts. A 2 (Gender) × 3 (Group) ANOVA on the proportion of manual object engagement duration confirmed this prediction and revealed no differences between the Active Training, Passive Training, and untrained 3-month-olds groups ($F(2, 46) = 2.243$, $p = .118$, $\eta^2 = .084$). Therefore, overall manual object engagement was used as motor predictor variable in the regression model.

The full regression model explained a significant proportion of variation in 3-month-olds' orienting towards faces ($F(5, 41) = 4.873$, $p = .001$, $R^2_{Adj}=.296$). Controlling for all other variables in the model, manual object engagement uniquely explained a significant amount (7.3%) of variation in infants' face-orienting behavior ($F(1, 41) = 4.752$, $p = .035$, $\beta = .276$, $R^2_{Change}=.073$). Thus, in a carefully age-matched population of 3-month-old infants, overall manual object engagement was a significant predictor for face-orienting behavior above and beyond influences from demographic and maturational constraints. More manual object engagement was associated with a stronger orienting response towards faces in 3-month-old infants (Figure 3).

Discussion

The goal of this study was to explore how motor experience shapes infants' spontaneous interest in objects and faces. Manual exploration activity provides infants with new opportunities for action within the physical *and* social worlds. Consequently, ecological perspectives of social cognition predict connections between motor and social development (Zebrowitz, 2006). Our results provide empirical support for this prediction and for the first time show that self-produced reaching experience strengthens a spontaneous preference for faces over objects in 3-month-old infants. Further, individual differences in infants' overall manual object engagement predict orienting towards faces above and beyond demographic and maturational factors.

Why would self-produced reaching experience affect infants' face preferences? Three processes associated with self-produced action experience may support a subsequent increase in orienting towards faces: First, through action experiences, infants acquire a new understanding of *themselves* as agents who can act on the world. Second, action experiences may change infants' understanding of *others* as intentional and goal-directed agents (e.g. Sommerville, Hildebrand & Crane, 2008; Woodward, 2009). And third, motor experience may shape the development of a motor resonance system that is involved in the understanding of observed actions (e.g. Cross, Hamilton & Grafton, 2006; Gallese, Rochat, Cossu & Sinigaglia, 2009; Lepage & Theoret, 2007). Indeed, several studies now provide evidence that some form of motor resonance is present in infants around 6–8 months of age (e.g. Nyström, Ljunghammar, Rosander & von Hofsten, 2011; Shimada & Hiraki, 2006) and that motor resonance supports infants' understanding and prediction of observed actions (Southgate, Johnson, El Karoui & Csibra, 2010; Southgate, Johnson, Osborne & Csibra, 2009). Together or in isolation, these three processes make the social world more predictable, change infants' understanding of the social affordances offered by faces, and open up opportunities for triadic engagement with others.

Regardless of its underlying mechanism, a connection between motor experiences and orienting to faces has far-reaching theoretical and practical implications. Attending to faces provides infants with exposure to social partners, which may have cascading effects on future social development (Johnson, 2005). If motor development fosters infants' interest and orienting towards faces, then motor development may indirectly set the stage for development of more complex social skills such as triadic interactions, gaze following, joint attention, social referencing, and shared intentionality which all require coordination between agents and objects (Bakeman & Adamson, 1984; Gaffan, Martins, Healy & Murray, 2010; Striano *et al*., 2007; Tomasello & Carpenter, 2007). To engage in triadic attention, 3-month-old infants first need to focus on an adult's face (head and eye position) and then learn to shift their attention to the actual effectors (i.e. the hands) producing the adult's action (Amano *et al*., 2004).

Conversely, when motor skills are delayed or impaired, social interactions could also be negatively affected. Support for this notion comes from studies on children with autism. Children with autism show motor deficits such as poor motor coordination, abnormal object exploration, or impaired play skills (e.g. Brian, Bryson, Garon, Roberts, Smith, Szatmari & Zwaigenbaum, 2008; Landa, 2008; Landa & Garrett-Mayer, 2006; Williams, 2003), as well as infrequent orienting towards people (e.g. Kikuchi, Senju, Tojo, Osanai & Hasegawa, 2009; Osterling, Dawson & Munson, 2002; Pierce, Conant, Hazin, Stoner & Desmond, 2010). Consequently, motor deficits could be a risk factor for abnormal social development. In contrast to genetic or demographic risk factors, motor deficits can be targeted directly in interventions. Motor enrichment, for example, has been shown to reverse behavioral abnormalities associated with autism in a rat model (Schneider, Turczak & Przewlocki, 2006). Thus, procedures that foster voluntary motor control (such as ‘sticky mittens’) may provide useful intervention strategies. Future research will have to test this hypothesis.

The present findings together with previous reports indicate that active motor experience can influence cognitive, perceptual, and social behavior (e.g. Clearfield, 2011; Held & Hein, 1963; Needham *et al*., 2002; Sommerville *et al*., 2005; Soska *et al*., 2010). Consequently, focusing only on processes taking place within one of these domains means that important linkages between domains will be missed. Our results call for further studies that will move the field towards a more integrated view of development as a dynamic, domain-crossing process (Needham & Libertus, 2011).

Alternative explanations

This report is the first to show a direct relation between infants’ preference for faces and their own, active motor experiences. Our findings are in agreement with ecological (Gibson, 1988; Zebrowitz, 2006) and embodied (Needham & Libertus, 2011) theories of development. However, there may be a number of alternative explanations for our results that we will consider in the following.

First, the interactions between parents and infants *during training* may have been different in the Active compared to the Passive Training group. For example, parents in the Active Training group may have been more excited and showed more exaggerated facial expressions during training. To minimize such differences, written directions were provided to both groups and members from our lab observed trained infants 3–4 times in their home during training to ensure compliance with our instructions (for details see Libertus & Needham, 2010b). Additionally, parents completed a daily log about the training sessions which indicated that training durations were similar across both groups (see Table 1) and that infants in both groups were mostly sitting on their parent’s lap during training (equating for posture and self-sitting experiences). Our use of four independent groups further argues against influences of the training situation and procedure. Parent engagement during training should have affected both the Active and Passive Training groups. However we observed no differences between the Passive Training group and untrained 3-month-olds, suggesting that differences in interactions during training cannot explain our results.

Second, parents in the Active Training group may have interacted differently with their children *outside* the training sessions. A change in the dynamics of the parent–infant dyad due to infants’ success in reaching is indeed possible and has been reported previously with regard to locomotion (e.g. Biringen, Emde, Campos & Appelbaum, 1995; Campos, Anderson, Barbu-Roth, Hubbard, Hertenstein & Witherington, 2000). Therefore, changes in parent–infant interaction (or even the whole ‘family system’, see Campos *et al*., 2000) occur naturally with infants’ increasing motor skills and may also influence infants’ face-preference behavior. A longitudinal investigation of reaching and grasping behavior on the same infants from the Active, Passive, and untrained groups revealed an increase in reaching and grasping over the training period in the Active Training group (Libertus & Needham, 2010b). Consequently, infants in the Active Training group may show more spontaneous exploration behavior outside the training sessions. This change is part and parcel of our training and not a confound but a direct consequence of the Active Training procedure.

Third, infants in the Active Training group may have been overly familiar with and therefore less interested in toys. We made efforts to avoid direct, low-level influences of the training by using different toys during training and the spontaneous preference assessment. To avoid short-term influences (e.g. priming) there was no training or motor task immediately prior the spontaneous preference assessment. Further, infants’ overall behavior following training is not consistent with a short-term influences interpretation, because infants do not become less interested in toys in general: When sitting across from an experimenter, with a toy lying on the table (a 'live' version of the face-versus-toy choice), infants in the Active Training group show more visual interest in the toy and more looking episodes towards the toy (Libertus & Needham, 2010b; Needham *et al*., 2002). Lastly, infants in the Passive Training group received the same amount of exposure to the training toys but did not show a significant preference for faces over toys. It is possible that the Active Training experience changed infants' visual preferences because these infants started to make use of distance information when interacting with objects and realized that a toy on the computer screen was beyond their reach and could not be interacted with. Such changes have been reported following the onset of independent reaching (Fetters & Todd, 1987) and therefore would be a direct consequence of the reaching experiences, in line with our interpretation.

Fourth, the lack of a face preference in our sample of untrained 3-month-old infants raises concerns about the validity of our task. Several studies have reported a preference for faces in newborns (e.g. Fantz, 1963; Goren *et al*., 1975; Johnson *et al*., 1991a; Turati, 2004; Valenza *et al*., 1996) and in 3-month-old infants (e.g. Kagan, Henker, Hentov, Levine & Lewis, 1966; Turati *et al*., 2005). However, a lack of a face preference has also been reported at these ages (e.g. Keller & Boigs, 1991; Maurer, 1985) and eye-tracking evidence indicates that 3-month-olds do not consistently look at faces in complex scenes (Frank *et al*., 2009). The use of different experimental measures (preferential looking vs. tracking of moving stimuli vs. eye tracking) makes direct comparisons difficult. Our results indicate that when given a 10-second choice between realistic photographs of an unknown face and an unknown object, 3-month-olds do *not* show a spontaneous face preference. We have since replicated these findings in another sample of 20 untrained 3-month-olds (Libertus & Needham, 2010a, in preparation). Our findings do not conflict with others that show a face preference in 3-month-old infants using a different paradigm or different competing stimuli (such as a face with rearranged features, see Turati *et al*., 2005). Rather, our results shed some light on the developmental processes that shape spontaneous preferences in the absence of familiarization, habituation, or priming influences during a period of transition in the development of face preferences.

Few studies have investigated the relation between motor and social development, and these studies indicate that improved manual exploration skills increased infants' interest in objects but not in people (Eppler, 1995; Fogel *et al*., 1992). However, social development does not regress or pause when new motor milestones are reached. Quite the opposite: once infants begin to engage in independent reaching, their social interactions also become more complex (Striano & Reid, 2006). Piaget (1954) proposed a connection between infants' own actions and their perceptual development. There is no reason why a perception–action relation should not extend to social perception as well. Our results show that infants' motor experiences also affect their engagement with the social world. This connection may be important for future social development as interest in faces and objects is necessary for triadic exchanges and offers new opportunities for social interactions and sharing games. Our results indicate a new direction for research on the development of social cognition skills in infancy. The current report and future research will help to elucidate the interesting consequences brought about by the emergence of new motor abilities.

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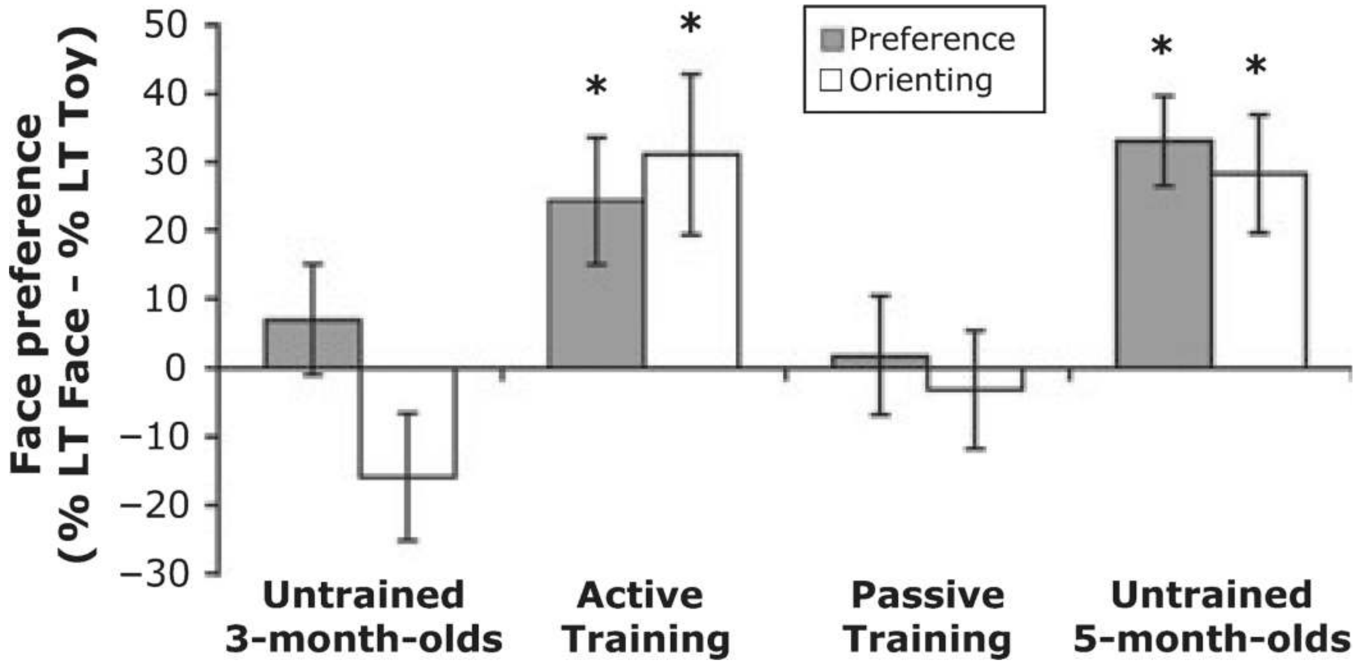

Figure 1.

Face-preference (solid bars) and face-orienting (white bars) scores following Active or Passive Training and for untrained infants. Only the Active Training group and untrained 5-month-old infants showed a significant preference and orienting towards faces. Error bars are SEM, *p < .05.

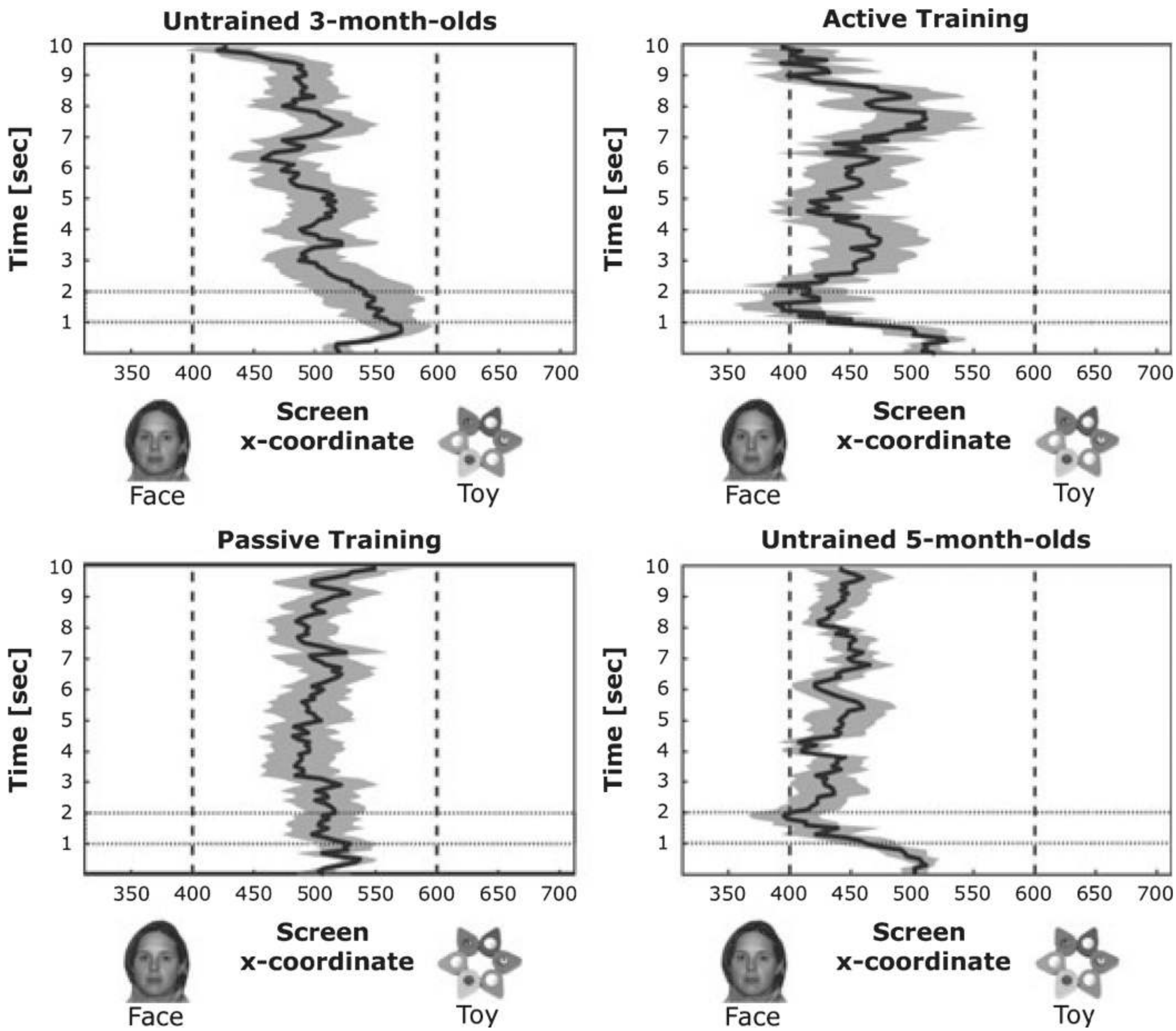

Figure 2.

Time-course of the spontaneous visual preference task. Horizontal eye-gaze (x-axis) is plotted against time elapsed (in sec.) since stimulus onset (y-axis). The dashed lines indicate approximate onset of face and toy area respectively. Dotted lines mark the 2nd second of stimulus presentation. Gray shaded area represents SEM.

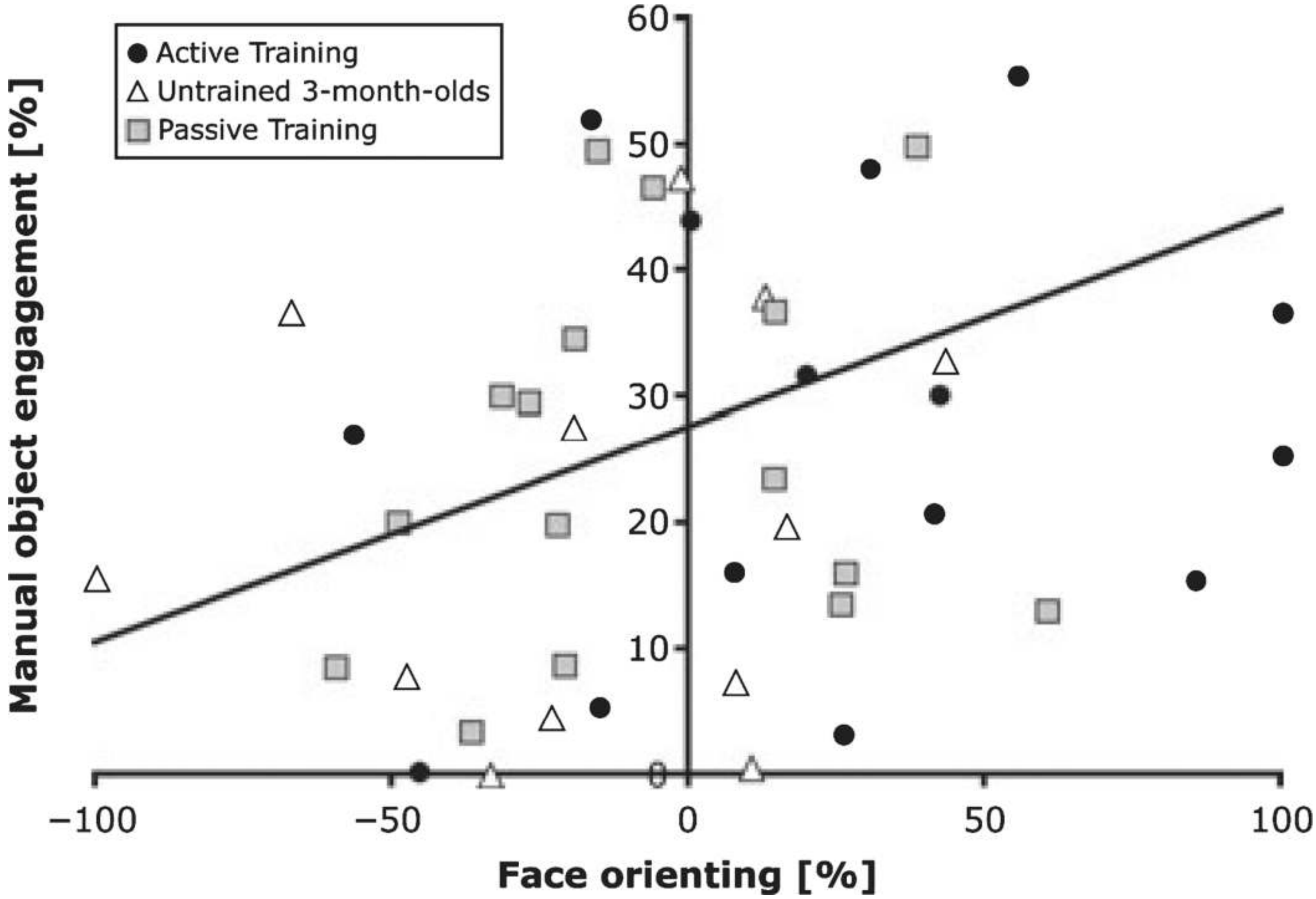

Figure 3.
Relationship between manual object engagement and orienting towards faces in 3-month-old infants. Across all 3-month-old groups, infants who engaged in more manual object engagement also showed a stronger orienting response towards faces.

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Table 1

Participant details of training and comparison groups

Group	N	#F	Age at training onset	Training duration	# of home visits	Age at test (after training)	Parent edu.	Birth weight
Active Training	18	9	10.90 (1.75)	125 (23.70)	3.80 (0.38)	12.92 (1.77)	9.38 (2.99)	3621 (578)
Passive Training	18	10	10.90 (1.52)	144 (23.70)	3.80 (0.33)	12.93 (1.55)	9.94 (2.24)	3544 (470)
Untrained 3-month-olds	19	8	–	–	–	12.61 (2.17)	10.05 (1.61)	3280 (377)
Untrained 5-month-olds	23	11	–	–	–	19.70 (1.93)	9.60 (1.30)	3418 (515)

Note: The total number of participants in each group (*N*) and the number of females per group (#F) are indicated. All other values are group averages with standard deviations given in parentheses. Age is reported in weeks, birth weight in gram, training duration in minutes. 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).