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Unintentional training? Consequences of naturalistic parent-guided positioning

Ran An and Klaus Libertus *

Department of Psychology, University of Pittsburgh, Pittsburgh, PA, United States

EDITED BY
Jordan Ashton Booker,
University of Missouri, United States

REVIEWED BY
David Ian Anderson,
San Francisco State University, United States
Ryoko Kalmar,
Mimasaka University, Japan

*CORRESPONDENCE
Klaus Libertus
klaus.libertus@gmail.com

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Introduction: Early motor skills are an essential part of healthy development. Previous research has demonstrated that intentional interventions may facilitate the emergence of key motor milestones such as grasping, sitting, crawling, or walking. However, less is known about the impact of less formal and intense practice opportunities on infant motor development. The current study fills this gap by examining the effects of brief, parent-guided postural positioning for the assessment of their infant's motor behavior. Critically, the parent-guided positioning lasted mere minutes and was not designed as an intervention.

Methods: A sample of 81 parent-infant dyads participated in a longitudinal remote observation study conducted entirely via video conference. Dyads were divided into a "observed" and an "unobserved" group. The "observed" group experienced a total of 8 parent-guided positioning observations lasting a combined 16 min over an 8-week period just about 2 min of positioning experiences per week. The "unobserved" group was not observed and did not experience parent-guided positioning.

Results: Comparing infant development between the groups at 6 and 10 months of age, results reveal higher scores in both motor and language domains for infants in "observed" group.

Discussion: These results demonstrate even brief engagement in new motor skills, or the indirect influence these engagements have on parenting behavior, may have cascading effects on concurrent and subsequent development.

KEYWORDS

infancy, motor development, language development, home observations, parent-guided activities, training, sitting, reaching

Introduction

The acquisition of new motor skills during infancy is a key part of healthy development as motor abilities enable the child to interact with the physical and social world in new ways (Gibson and Pick, 2000). Prior research offers several examples of the importance of motor skills across developmental domains. For example, the emergence of independent sitting frees up infants' hands to allow for advanced visual-manual exploration (e.g., Marcinowski et al., 2019; Soska et al., 2010). Engaging in independent sitting also provides infants with an improved vantage point during face-to-face exchanges that facilitates the development of joint attention (Franchak et al., 2018). Several research studies have demonstrated that the onset of crawling and walking skills have far reaching implications by providing children with new opportunities to explore previously inaccessible places and objects (e.g., Adolph et al., 2012; Adolph and Tamis-LeMonda, 2014; Campos et al., 2000; Rheingold and Eckerman, 1970). Finally, emerging sitting and locomotor skills have been associated with children's language development (He et al., 2015; Libertus and Violi, 2016; Walle and Campos, 2014). Consequently, identifying factors that influence early motor development may be important for our understanding of broader developmental processes taking place during infancy. The current study contributes to this larger research area by examining the effects of parent-guided motor experience on children's early motor development.

Developmental cascades

Development is a dynamic and interconnected process. Developmental cascades offer one the potential mechanisms linking motor skills to other areas of development, and refer to the cumulative consequences of behaviors, events, or interactions initiated earlier in development that then propagate over time, resulting in lasting changes (Masten and Cicchetti, 2010). Empirical evidence supports this notion. For example, a systematic review of 43 studies concluded that children's motor development may significantly affect their development of social, cognitive, and language skills (Leonard and Hill, 2014). Similarly, a growing number of studies have provided evidence for developmental cascades following the attainment of specific motor milestones (Libertus and Hauf, 2017). Therefore, motor skills are fundamental to development across domains and the examination of factors influencing early motor development merits attention.

Several early emerging motor skills have been identified as initiating developmental cascades that may influence subsequent development across domains. For example, sitting and walking have been reported to predict the development of spatial skills such as spatial memory, spatial processing, and spatial language (Oudgenoeg-Paz et al., 2015). Similarly, progress in reaching skills has resulted in the advancement of children's object exploration and problem-solving abilities (Lobo and Galloway, 2008). Several research studies have examined the effects of crawling on infant development and have identified associations between infants' crawling skills and their spatial abilities such as mental rotation or search (e.g., Bai and Bertenthal, 1992; Campos et al., 2000; Clearfield, 2004; Schwarzer et al., 2012). Further, it has been noted that crawling experiences influence infants' social and emotional development (Bertenthal et al., 1984, 1994). Longitudinal research reports that motor exploration activity at 5 months of age seems to indirectly impact children's academic achievement 14 years later (Bornstein et al., 2013). The acquisition of walking has been linked to significant increases in vocabulary size in 10–13-month-old infants as well (He et al., 2015; Walle and Campos, 2014). Finally, the emergence of sitting skills at 3 months of age has been linked to infants' receptive vocabulary size at 10 and 14 months of age (Libertus and Violi, 2016). Together, these findings support the notion of developmental cascades and suggest that early emerging motor skills such as grasping, sitting, crawling, and walking can have important implication for concurrent and subsequent development. Attainment and mastery of new motor skills during the infancy period have a clear impact on the psychology of the developing child (Campos et al., 2000). Identifying factors that influence early motor development has both theoretical and practical implications and more research in this area is warranted.

Factors influencing motor development: explicit training

Early emerging motor skills are highly malleable readily responding to training or intervention paradigms. The impact of formal training or intervention is well-established. For example, a classic study dating back to the 1970s provided evidence that brief but consistent daily training of the stepping reflex led to a persistence of the reflex and to an earlier onset of walking (Zelazo et al., 1972). Similarly, research has demonstrated that children with developmental disorders benefit from formal motor interventions (e.g., Morgan et al., 2014; Reus et al., 2013; Ulrich et al., 2008). However, evidence also exists suggesting that informal parent-guided motor training in the home context may also shape motor development. For example, brief training using so-called "sticky mittens" has been reported to encourage grasping behaviors in early infancy (Libertus and Needham, 2010; Needham et al., 2002). These findings have been replicated in infants at a high risk for ASD (Libertus and Landa, 2014) and preterm infants (Nascimento et al., 2019). In addition to encouraging grasping behaviors, parent-guided in-home motor training has been found to increase infants' subsequent object exploration behaviors (Needham et al., 2017). Finally, longitudinal findings suggest that the effects of parent-guided training using sticky mittens can last up to 1 year following training (Libertus et al., 2016; Wiesen et al., 2016). Taken together, these studies suggest that even low-dosage, parent-guided activities may promote motor skill development.

However, not all studies have supported the notion that parent-guided training for early motor skills is effective. A review of studies using the "sticky mittens" paradigm concluded that the reported results do not provide sufficient evidence to support the notion that parent-guided experiences during infancy facilitate the emergence of motor skills (van den Berg and Gredeback, 2020). Empirical findings from the same group confirmed this conclusion and suggested that reaching and grasping behaviors were not affected by parent-guided training using "sticky mittens" (van den Berg et al., 2022). In addition, another study observed no effect of parent-guided training using "sticky mittens" on infants' toy contact and grasping activity (Williams et al., 2015). Consequently, there has been renewed interest in the question of whether *any* experience provided by a parent positively impacts early motor development (Corbetta et al., 2016; van den Berg and Gredeback, 2021). The impact of parent-guided motor enrichment needs to be revisited along with consideration of the long-term implications of early motor experience. However, it should be noted that the criticism regarding parent-guided training is aimed specifically at the "sticky mittens" training paradigm and does not exclude the possibility that other—more structured and involved—training procedures may encourage early motor development.

Factors influencing motor development: daily practices

Beyond structured and interventional training procedures, studies have provided evidence that "everyday" experiences may significantly influence infants' early motor development. Everyday experiences can be shaped by cultural factors and practices, which may set-up children from one culture to attain some motor skills earlier than children raised in a different cultural context (e.g., Cintas, 1995; Super, 1976). Cross-cultural work offers a fascinating lens on the impact of daily practices on infant motor development (Karasik et al., 2018), but cannot control for a range of additional factors that are likely impacting child development in addition to daily practices and experiences (Cintas, 1995). Studies altering daily practices within one culture can avoid such potential confounds. For example, Lobo and Galloway (2012) conducted a naturalistic training study in which parents were asked to engage in a brief (15 min daily for 3 weeks), parent-guided motor intervention. The intervention consisted of asking parents to place their 2-month-old child in challenging postures, such as prone on their tummy, for short periods each day. The results revealed both the immediate and long-term effects of this simple intervention and suggest that even brief motor experience can promote motor skills in infants.

In addition to naturalistic training experiences, mere observation may also influence the development of motor skills. Boonzaaijer et al. (2019) reported that remote observations of infant motor skills influenced subsequent behavior of both the children and their parents. After completing remote observation sessions, parents reported that they became more aware of their children's motor development, claimed to have a better understanding of their children's motor development, and reported encouraging behaviors to facilitate their children's motor development. These findings suggest that parent-guided or initiated experiences may have far-reaching consequences for infant development. However, given the mixed evidence regarding the effectiveness of explicit training interventions and the limited number of studies examining the effect of naturalistic observations, the question whether brief motor experience can influence motor development merits closer examination.

The current study

The current study used a longitudinal design to examine the effects of brief parent-guided motor experiences on infant motor development. We asked parents to place their children in specific postures or contexts so that the current motor skills of the child could be observed. Based on previous findings (see Boonzaaijer et al., 2019; Lobo and Galloway, 2012), we hypothesized that mere participation in motor observations would encourage motor development. For the purposes of the current study, we refer to the motor observations as "unintentional training." Furthermore, we hypothesized that infants' early motor skills would predict their subsequent language learning (e.g., Libertus and Violi, 2016).

Methods

Participants

A total of 98 parent-child dyads participated in the current longitudinal study and were followed from either 3- or 6-months of age until 10-months of age. For the current study, behavioral observations taken at 6 months of age and parent-report measures taken at 10 months of age were used. No other observations from the larger longitudinal study were used in the current research. Participants were recruited via local and social media advertisements and 17 dyads were excluded prior to analysis because of premature birth (1), low birth weight (2), non-U.S. residence (6), or missing demographic information (8). The final sample consisted of 81 dyads divided into two groups using a quasi-experimental design based on age at enrollment (see Figure 1).

One group of participants was enrolled in the study when the child was around 3 months of age and completed up to 8 weekly observations of the infants' sitting and reaching skills (observed group; $n_T = 37$). The second group was enrolled in the study slightly later, at 6 months of age, and therefore did not complete any weekly observations (unobserved group; $n_U = 44$). Both groups were observed remotely when the child was around 6 months of age and completed a language development assessment when the child was around 10 months of age (MacArthur-Bates Communicative Development Inventories, see Measures section). Propensity score matching was used to reduce potential bias in this non-random sample, resulting in the removal of seven cases from the unobserved group ($n_{U\_matched} = 37$). Table 1 shows the demographic information of both the groups before and after matching. All participants were invited to continue assessments beyond the current study period as part of the larger longitudinal research project.

Procedure

Parents completed an online informed consent form before participating in this study, and a local Institutional Review Board approved all the study procedures. Infant behavior was observed at the family's home via video chat (e.g., FaceTime, Skype, or Zoom) and recorded for offline coding. Using this approach, the "observed group" completed up to eight weekly observations between 3 and 5 months of age—participation in these longitudinal observations (see Measures below) may have provided "non-intentional training" for participants in this group. Both the observed and unobserved groups completed one remote observation session when the child was ∼6 months of age. For the "unobserved group," the observation at 6 months of age was their first and only remote observation. Finally, parents in both groups completed two online questionnaires about their children's motor skills (at 6 months) and receptive language skills (at 10 months). Unfortunately, there was missing data throughout the study procedure—as is common in research with small children. Observations were missed due to parents failing to complete a questionnaire measure or due to children failing to complete an observational assessment. Figure 1 provides a detailed overview of where and how many observations are missing in our dataset. Participants with missing observations were excluded from statistical analyses of that particular measure—but were included in all other statistical analyses where observations were available.

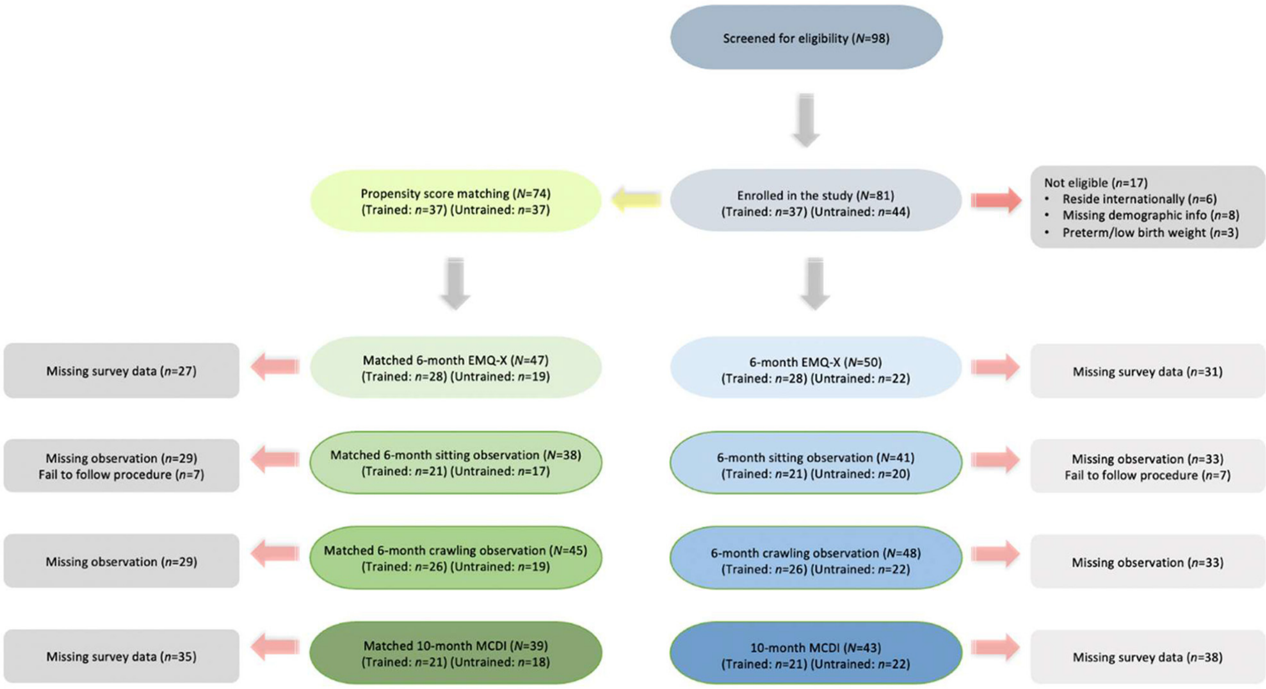

FIGURE 1
Breakdown of participant recruitment. The left-hand side represents participants after propensity score matching, whereas the right-hand side represents participants before propensity score matching. EMQ refers to the Early Motor Questionnaire assessing infant motor development and MCDI refers to the MacArthur-Bates Communicative Development Inventory assessing children's language development. Cases with missing data were excluded from analyses (where applicable).

TABLE 1 Participant demographics and comparison between observed and unobserved groups (after matching).

Variable	Observed[a]	Unobserved before matching	Unobserved after matching	Group comparison: *T*-test before matching (*p*-value)	Group comparison: *T*-test after matching (*p*-value)
Total sample	37 (17 female)	44 (26 female)	37 (20 female)	–	–
Child age at 6-month observation (months)	6.26 (0.21)	6.28 (0.23)	6.27 (0.25)	0.825	0.874
Parent education	9.92 (2.3)	9.52 (2.32)	9.68 (1.93)	0.444	0.624
Mother age (years)	32.54 (4.21)	31.86 (4.25)	32.16 (4.47)	0.475	0.709
Birthweight	3472.66 (408.08)	3497.04 (432.78)	3503.08 (448.04)	0.795	0.761
Family income	10 (2.96)	9.61 (3.03)	9.97 (2.85)	0.565	0.968
Caucasian	31	36	30	–	–

Parental education and family income were measured using a 1–14 scale, with 1 being the lowest and 14 being the highest. Birth weight was measured in grams (g). Age is reported in months for children and years for parents. Values in parentheses represent standard deviations.
[a]Observed group remains unchanged before and after propensity score matching process.

Measures

Remote observation measures

We assessed children's motor skills using 1-min naturalistic observations via video chat. Children in the observed group completed up to eight observations of their sitting and reaching skills between 3 and 5 months of age. At 6 months of age, children in both the observed and unobserved groups completed observations of their sitting and crawling skills (see Figure 2). Due to the observation schedule of the larger longitudinal study, we did not assess children's reaching skills at 6 months. Sitting and reaching tasks were adapted from a previous study (Libertus and Violi, 2016).

Sitting task

We observed the children's independent sitting skills while they were placed on a flat surface without external support for 1 min. Parents were instructed to place their child on a flat surface, let go of any support but remain vigilant to catch the child should they lose balance. Researchers used a baby doll to model these instructions during the video call. Trained observers,

FIGURE 2
Examples of reaching, sitting, and crawling tasks (left to right). Examples of the reaching **(a)**, sitting **(b)**, and crawling **(c)** observations completed remotely via video chats. Photographs were obtained with permission from the parents.

blinded to participant group, used frame-by-frame video-coding software (Datavyu Team, 2014) to classify four types of postures: parent-supported position, flat or pike sitting, tripod sitting with hands for support, and independent sitting with arms raised (Figure 3). Durations for each posture were calculated, but tripods and independent sitting were combined for data analysis (as done in Libertus and Violi, 2016). Finally, we calculated the sitting proportion score by dividing successful sitting by the total duration of all the coded sitting postures (excluding parent-supported sitting). Seven parents supported their children more than 90% of the time and were excluded from the analysis. Based on these proportion scores, we also categorized children as "sitters" (sitting >50% of the time) or "non-sitters." Two separate observers coded all videos and established high internal reliability (>90% agreement). Disagreements between observers were resolved via video review and discussion. Observers were blind to the child's group assignment.

Crawling task

Children's emerging crawling skills were assessed at 6 months using a 1-min observation with the child placed in a prone position on a flat surface without support. Parents were instructed to place their child in a prone position on a flat surface and then remove any support. Parents were allowed to give verbal encouragement or place a favorite toy beyond reach of the child to encourage crawling behavior. All parents provided verbal encouragement and also placed a toy beyond reach on at least one of the remote observations. Researchers used a baby doll to model these instructions during the video call. Crawling behavior was coded in real time from video recordings by dividing the session into three 20-s segments. Trained observers, blinded to participant group, rated crawling proficiency during each segment on a 6-point scale ranging from 0 (the child remained in a static prone position) to 5 (the child was in a crawling posture and completed at least five crawl strokes with either arm). For crawling bouts extending across two segments, the highest observed was assigned to both segments. The average scores of the three segments were calculated and analyzed. Two separate observers coded all videos and established high inter-rater reliability (>90% agreement). Disagreements were resolved through discussions and video review. Observers were blind to the child's group assignment.

Questionnaire measures

Motor skills

Infant motor skills were assessed using the Early Motor Questionnaire (EMQ, Libertus and Landa, 2013; Smith and Libertus, 2022) when the child was ∼6 months of age. The EMQ is a popular parent-report measure that has been validated against two gold-standard observational motor assessments (i.e., the Mullen Scales of Early Learning, and the Peabody Motor Development Scales 2, Libertus and Landa, 2013) and provides separate scores for gross motor (GM), fine motor (FM), and perception-action (PA) skills. To further probe the development of motor skills assessed using observational measures, we calculated three composite scores from EMQ items focused on sitting, reaching, and crawling skills. Internal consistency was high for each of these skill-specific composites (sitting: six items, $\alpha = 0.86$; crawling: eight items, $\alpha = 0.87$; reaching: 31 items, $\alpha = 0.82$).

Language skills

We assessed infants' receptive language development at 10 months of age using the widely used MacArthur-Bates Communicative Development Inventories (MCDI, Fenson et al., 2006). This parent-report measure included sections asking about the child's comprehension of early understanding of familiar words and phrases (31 items), as well as a 396-item vocabulary checklist. Because of the young age of our participants, we focused on receptive language only and combined familiar words and phrases

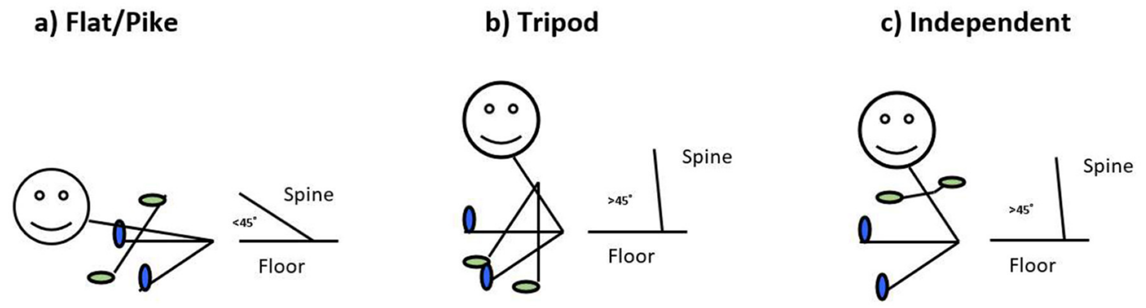

FIGURE 3
Examples of sitting postures. Postures were coded during the 1-min sitting task. A flat posture uses hands for support and has an upper body bend low for additional support **(a)**. A tripod posture uses one or both hands for support but maintains the upper body above a 45-degree angle relative to the floor **(b)**. Finally, an independent sitting posture was coded when the child was sitting without the support of their hands (on the floor or self) with the upper body upright **(c)**.

with vocabulary checklist items, resulting in a maximum possible score of 427 (see also Libertus and Violi, 2016).

Results

Normality of all variables was checked using Shapiro–Wilk tests, and appropriate statistical analyses were selected depending on the outcome of these tests.

Propensity score matching

Propensity score matching was used to reduce potential bias from non-random group assignments (Zhao et al., 2021). Propensity scores were calculated using the R package *matchit* (Ho et al., 2011) and included infants' birth weight, sex, race, parent education, family income, and mother's age. This process resulted in two matched groups of 37 infants each, using the nearest-neighbor method. For completeness, all analyses were performed using both original and matched samples.

Immediate effects on motor skills

The first aim of the current study was to examine whether parent-guided motor experiences provided in the observed group would encourage infants' immediate motor skill development. We hypothesized that infants in the observed group would show more advanced motor skills than would unobserved infants. Analyses of parental reports and observational measures confirmed this hypothesis. Table 2 provides a summary of the descriptive and inferential statistics for both the full sample and matched samples. First, we completed these analyses on the full sample, without propensity score matching. Parent-reported motor skills, as assessed using the EMQ, revealed that infants in the observed group received higher parental ratings than unobserved infants on overall gross motor skills, $t_{(48)} = 2.03$, $p = 0.047$, $d = 0.58$, and sitting-related items $X^2{}_{(1)} = 5.76$, $p = 0.016$. There were no significant between-group differences on any of the remaining EMQ measures (Table 2). Results of the behavioral observations complement and confirm these parent findings. Children in the observed group showed a trend toward longer independent sitting durations than those in the unobserved group, $X^2{}_{(1)} = 3.06$, $p = 0.08$ (see Figure 4). While only the duration of sitting showed a trend, there were more children in the observed group classified as "sitters" (16 of 21) than in the unobserved group (9 of 20), $X^2{}_{(1)} = 4.19$, $p = 0.041$. Together, these results suggest more developed sitting skills in the observed compared to the unobserved group—at least during our observation at 6-months of age. In contrast, there were no significant differences in infants' crawling behavior ($p = 0.77$, see Figure 5), but the overall crawling levels were low across all children.

We repeated the same analysis on the reduced sample using propensity score matching. Overall, the patterns of the results for the matched sample are identical to those obtained for the full sample. However, in contrast to the full-sample analysis, we also observed significantly higher scores on the reaching-related item composite of the EMQ, $t_{(45)} = 2.01$, $p = 0.051$, $d = 0.60$. Similarly, behavioral observations revealed significantly longer sitting durations and more children classified as "sitters" in the observed and matched unobserved groups. Again, the only difference between the two sets of analyses was that the between-group difference in sitting duration reached statistical significance, $X^2{}_{(1)} = 4.8$, $p = 0.028$. We conclude that children in the observed group showed more developed gross motor skills, especially sitting skills, than those in the unobserved group.

Later effects on language skills

The second aim of this study was to examine whether early motor experiences would have a cascading effect on infants' language development at 10 months of age. We hypothesized that infants in the observed group would show larger receptive vocabularies than those in the unobserved group would. These results confirmed this hypothesis. Infants in the observed group showed larger receptive vocabulary scores (combined scores of early words, phrases, and vocabulary checklist items) than infants in the unobserved group (see Figure 6). Furthermore, this pattern

TABLE 2 Descriptive statistics of EMQ scores between the two groups.

Measure	Sample	Observed		Unobserved		Comparison
		M (SD)	n	M (SD)	n	Statistic
Total EMQ	Full sample	−110.32 (30.42)	28	−121.73 (20.24)	22	$t_{(48)} = 1.51, p = 0.14$
	Matched			−126.26 (17.79)	19	$t_{(45)} = 2.05, p = 0.046$
GM	Full sample	−44.36 (10.91)	28	−49.95 (7.76)	22	$t_{(48)} = 2.03, p = 0.047$
	Matched			−52.05 (5.56)	19	$t_{(45)} = 2.83\ p = 0.007$
FM	Full sample	−37.71 (13.17)	28	−39.45 (9.11)	22	$t_{(48)} = 0.53, p = 0.60$
	Matched			−41.21 (8.32)	19	$t_{(45)} = 1.02, p = 0.31$
PA	Full sample	−28.25 (10.76)	28	−32.32 (7.71)	22	$\chi^2 = 1.16, p = 0.28$
	Matched			−33.00 (7.45)	19	$\chi^2 = 1.48, p = 0.22$
Sitting items	Full sample	−1.21 (4.98)	28	−4.36 (3.75)	22	$\chi^2 = 5.76, p = 0.016$
	Matched			−5.21 (3.24)	19	$\chi^2 = 8.00, p = 0.005$
Crawling items	Full sample	−8.32 (6.40)	28	−9.55 (4.45)	22	$\chi^2 = 0.13, p = 0.72$
	Matched			−10.74 (2.58)	19	$\chi^2 = 0.96, p = 0.33$
Reaching items	Full sample	5.68 (13.35)	28	0.95 (10.6)	22	$t_{(48)} = 1.36, p = 0.18$
	Matched			−1.42 (9.29)	19	$t_{(45)} = 2.01, p = 0.051$

M, Mean; SD, Standard Deviation. A total of 31 participants did not complete the parent report measure at 6 months of age.

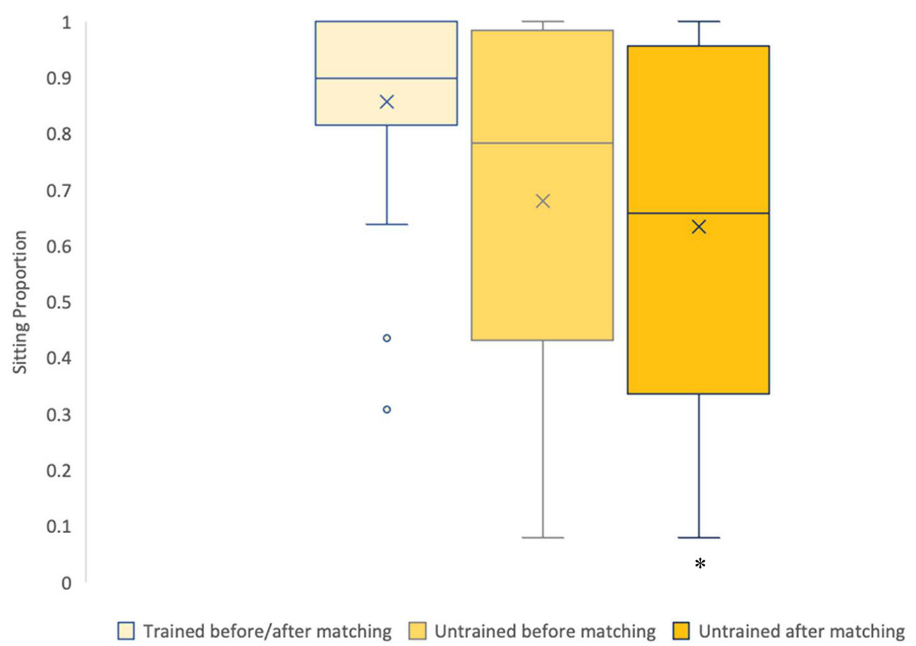

FIGURE 4
Sitting proportion for the Observed and Unobserved group before and after matching. This graph shows the average sitting proportions (sum of tripods and independent sitting) of children in the observed and unobserved groups. The proportions were derived by dividing the total durations of flat, tripod, independent sitting, and supported sitting. The observed group obtained a significantly higher sitting proportion than the unobserved group, both before and after matching. Thirty-three participants did not complete the sitting observation at 6 months of age, while seven were excluded because of failure to follow the study procedures. [X]Indicates the mean. *Significant difference between the two groups ($p < 0.05$).

of results holds both before $X^2{}_{(1)} = 5.79$, $p = 0.016$, and after $X^2{}_{(1)} = 6.72$, $p = 0.01$, propensity score matching. These results suggest that even brief parental encouragement of early motor skills can have cascading effects on the infants' subsequent language development.

Discussion

The current study examined the impact of short parent-facilitated motor experiences on infants' motor skills and subsequent language development. Our findings lead to three key

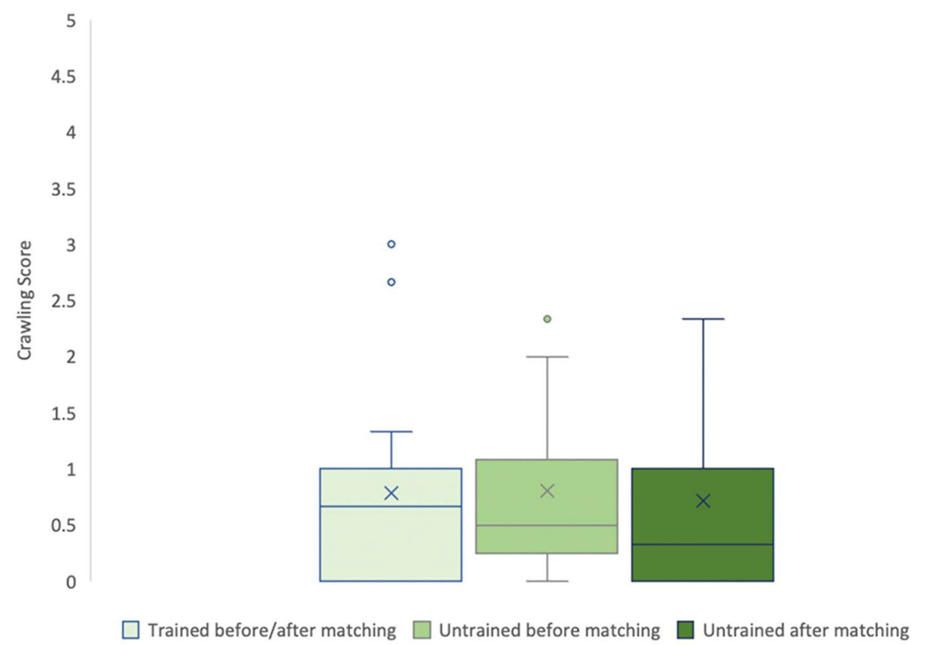

FIGURE 5
Crawling score for the Observed and Unobserved group before and after matching. This graph displays the average crawling scores of children in the observed and unobserved groups. The scores ranged from 0 (child lying in a prone position) to 5 (body raised in a crawling posture and completing at least five crawl strokes with either arm). No significant difference was found between the two groups in terms of crawling scores before and after the matching. A total of 33 participants did not complete the crawling observation at 6 months of age. X Indicates the mean.

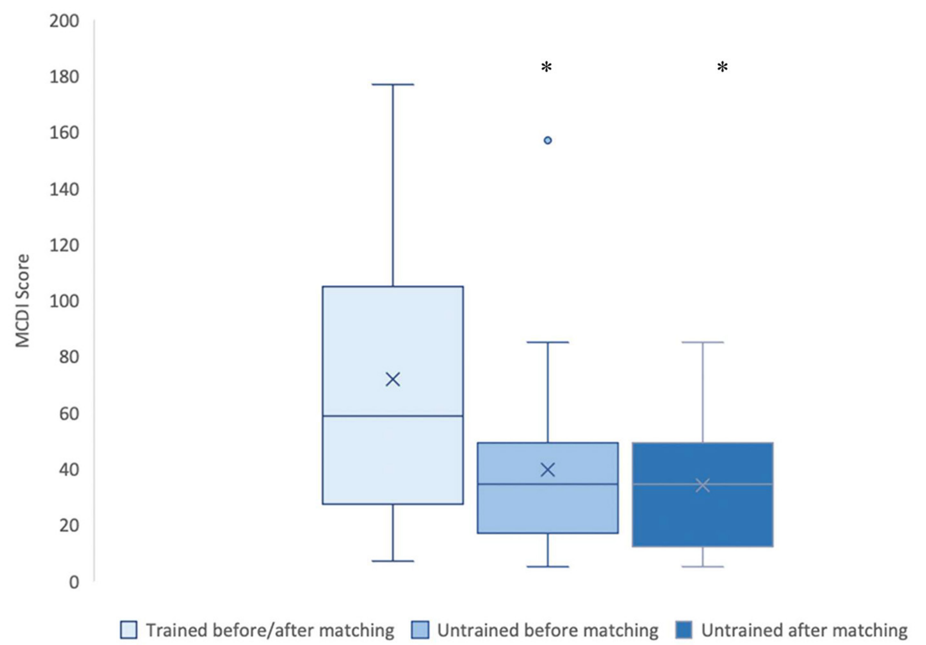

FIGURE 6
MCDI score for the Observed and Unobserved group before and after matching. This graph displays the average MacArthur-Bates Communicative Development Inventory (MCDI) raw scores for observed and unobserved groups. The observed group scored significantly higher than the unobserved group, both before and after matching. A total of 38 participants did not complete the MCDI at 10 months of age. X Indicates the mean. *Significant difference between the two groups ($p < 0.05$).

conclusions. First, just minutes of parent-guided motor stimulation over a period of 8 weeks encourages infants' subsequent motor development. Asking parents to engage their child in sitting and reaching behaviors for 1 min each week starting at around 3 months of age facilitated mastery of the same skills at 6 months. Second, parent-guided motor stimulation in early infancy may initiate a developmental cascade that facilitates subsequent language development (specifically receptive language skills at 10 months of age). Third, mere participation in observational research can have unintended and lasting effects on early childhood development. Together, the findings reported here encourage future applications of parent-guided training protocols, but caution researchers that seemingly "innocuous" observations may inadvertently alter developmental trajectories.

Effectiveness of parent-guided experiences

Formal training studies have indicated that the parent-guided stimulation of motor skills can promote early motor development. However, training studies are designed explicitly to induce changes in motor skills and include scripted training procedures that last weeks to months. For example, the "sticky mittens" procedure by Needham et al. (2002) asks parents to engage their child in structured training for at least 10 min each day for a 2-week period (resulting in 140 min of training). Other studies have adapted this training procedure to high-risk populations and have often used longer training durations (for review see Righetto Greco et al., 2022). More frequently, studies used longer training protocols. For example, Lobo and Galloway (2012) asked parents to engage their child with advanced postures and handling for 15 min each day for a period of 3 weeks (a total of 315 min of training). Together, these studies demonstrated that prolonged and intensive motor stimulation, as part of rigorous training protocols, can promote the development of motor skills in children. The current study expands upon these findings by using a drastically shorter training period of only *16 min of* parent-guided motor stimulation (or only 8 min per motor skill we observed). Furthermore, in the current study, parent-guided engagement was *not* designed to promote a specific skill. Rather, parents were merely asked to place their children in a context that allowed for naturalistic observations of their current motor skill level. However, even this brief observation of motor skills resulted in changes in the infants' early motor development. Therefore, the results reported herein provide strong evidence supporting the effectiveness of parent-guided stimulation. However, we do not know what exactly causes the effects we observe—was it the experiences themselves or did participation in the observation sessions change parent behavior outside of our study?

Changes in parent behavior and daily experiences

Dose-response relationships are frequently observed in motor training research. The infants in the current study experienced challenging postures that may have enhanced their head and postural control skills (Lobo and Galloway, 2012), but at such a low dosage (a mere 16 min) that it is likely not sufficient to stimulate substantial motor skill growth. Therefore, we suspect that the relation between parent-guided stimulation and infant motor development is *indirect* rather than direct. Parental behaviors happening outside of the study procedure may have caused the observed effects. By participating in the study and closely observing their children, parents likely changed their perceptions of the child, their beliefs about child development, and even their daily behaviors (e.g., Boonzaaijer et al., 2019). In fact, participation in the study and repeated observation of their children's motor skills may have biased the parents to view their child as more capable—which in turn could change their everyday behaviors and interactions with the child. The impact of indirect effects may be critical even for studies using explicit training paradigms. Therefore, studies that have failed to replicate the effects of parent-guided training (Williams et al., 2015) should be carefully re-examined for potential factors that may have blocked or limited this indirect pathway of everyday parental behavior. Factors to consider include differences in the wording of study instructions, or even broader cultural differences regarding compliance with procedures provided by authority figures. The question of whether and to what degree parents' behaviors are affected by participation in research studies remains unknown and should be examined systematically in future research.

Motor stimulation and developmental cascades

The pattern of results observed in the current study agrees with other studies showing that motor experiences early in life have the potential to alter infants' future behavior and exploration, thereby initiating a developmental cascade that supports future motor skill acquisition (Lobo and Galloway, 2013). The impact of such developmental cascades seems to extend beyond the motor domain, and evidence suggests that children's acquisition of new motor skills may facilitate concurrent (He et al., 2015; Walle and Campos, 2014), and subsequent language development (LeBarton and Landa, 2019; Longobardi et al., 2014; Oudgenoeg-Paz et al., 2012). Specifically, previous studies have indicated that infants who master independent sitting skills earlier show more advanced language development at 10 and 14 months of age (Libertus and Violi, 2016). The current findings support these results and agree with recent theories predicting such motor-language associations (Iverson, 2021). The emergence of new motor abilities in infancy appears to initiate a developmental cascade that facilitates subsequent language learning.

Broader implications: focusing on parents

The findings reported here demonstrate the importance of parent-focused programs that promote best practices and provide sound advice to new parents. That a mere minutes of parent-guided motor experience can change children's developmental trajectories across domains shows that parents play a critical role in children's development. However, the exact mechanism underlying these changes remain unclear. On the one hand, children may engage in more exploration and self-exploration following a brief practice of new motor skills (e.g., Lobo and Galloway, 2013). However, parents might have provided additional learning opportunities in response to observing their children's independent sitting behaviors during the sitting task (Kretch et al., 2022) or may have started interacting with their child more socially (Lobo and Galloway, 2012). Changes in parents' behavior would stimulate children's motor and cognitive development (Koziol et al., 2022). In addition, previous findings have suggested that parents are receptive to advice from trusted sources. Parents often turn to social networks, including friends, families, pediatricians, and increasingly social media, for support when it comes to parenting and health information (Elkin et al., 2020; Moon et al., 2019). Hence, parents may change their perceptions or beliefs about parenting following their interactions with researchers. Parents may have realized new ways to encourage their children's development or simply started to pay more attention to their children's emerging motor skills (e.g., Boonzaaijer et al., 2019). These unconscious changes may result in greater encouragement of motor skills during everyday interactions with children. Accordingly, children whose parents emphasize and provide opportunities for the development of motor skills are likely to have more advanced motor outcomes than their counterparts (Karasik and Kuchirko, 2022; Super, 1976; Vierhaus et al., 2011). Therefore, changes in parents' behaviors, perceptions, and beliefs could result in significant changes in children's developmental outcomes. To promote children's development, it is essential to ensure that parents receive adequate support and resources.

Limitations and future directions

This study offers interesting findings regarding the impact of parent-guided experience on infant development. However, the home environment was not measured in the current study and should be carefully considered in future studies. Furthermore, parents' views, beliefs, and knowledge of child development should be quantified in future work to determine their effect on child development and outcomes. Parental beliefs and views may change in response to study participation and could at least partially explain the results obtained. Along the same lines, families from more diverse backgrounds and cultures will need to be examined in future research to determine whether the patterns observed here can be generalized to other families.

Conclusions

The current study highlights the malleability of early motor development, demonstrating that parent behaviors can have a significant impact on infants' motor development, and that motor skills have domain-crossing influences on other domains such as language learning. Our findings advance the theoretical understanding of the developmental process and have practical implications for parent-guided intervention. Finally, our findings demonstrate that repeated observations—even if just mere minutes in total duration—may have unintended training effects that should be considered in future research.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of Pittsburgh Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

RA: Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. KL: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that this research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflict of interest.

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