Scaffolding or interference: How do parent behaviors shape infants’ object exploration skills

by

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Reaching skills allow infants to explore their environment actively from birth. These skills progress from simple touches to more complex actions like grasping and manipulating objects. Reaching skills not only enable exploration, but they also contribute to the development of other motor skills. Therefore, nurturing reaching skills during infancy is critical. Parental scaffolding, which involves providing or removing support during tasks, is examined in the context of infant object exploration. While some argue that scaffolding may hinder development by interrupting infants' exploration, others suggest it may enhance learning opportunities. The current study aims to investigate the impact of parental resetting on infants' reaching skill development during a reaching task. Data from 84 parent-infant dyads were analyzed, and parental resetting behavior was categorized into low or high resetting groups. We found that infants in the high parental resetting group showed a shorter latency to first contact objects, increased maturity of manual object exploration, and higher scores on the Early Motor Questionnaire (EMQ). The current study's results shed light on whether parental resetting scaffold or disrupt the development of independent reaching skills during infancy.

Keywords: parent-infant interactions, manual exploration, scaffolding, resetting.

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1.0 Scaffolding or interference: How do parent behaviors shape infants' object exploration skills?

The acquisition of motor skills during infancy can have profound cascading impacts throughout many domains of an individual's development (Adolph & Hoch, 2019). For example, 3-month-old infants who have self-initiated reaching experiences develop a stronger preference for faces over objects compared to 3-month-old infants who do not have these active reaching experiences (Libertus & Needham, 2011). Reaching behaviors are among the earliest emerging motor skills (White et al., 1964), which is critical given their role in shaping how infants learn about themselves, their environment, and the agency they possess within their environment (Sommerville et al., 2005). In addition, there are demonstrated effects of parent scaffolding on child development during parent-infant interactions in other domains of infant development. For instance, research on child language development has shown that the quality and quantity of parent talk contributes to individuals' vocabulary at different points of development (Rowe, 2012). However, there is a lack of research demonstrating similar impacts of parent scaffolding on infant reaching behavior. The current study will aim to fill this gap in the literature by examining the impact of parent behavior on infants' object exploration skills.

1.1.1 Reaching Skills

The development of reaching skills allows infants to manually explore their environment through active perceptual observation from birth. Typically, children's reaching skills mature over time, allowing them to interact with their environment differently. For example, it has been shown that from birth to 3 months of age, infants' clutching frequency increases while their clutching duration decreases (Ferronato et al., 2023). Increasing clutching frequency while decreasing clutching duration leads to infants having more interactions with their environment. Infants perform manual exploration through a variety of behaviors including touching, grasping, lifting, and performing actions — shaking, rotating, banging — with objects in their environment. While these exploratory behaviors are tools that infants use to learn and acquire knowledge, some reaching skills can be considered more complex than others (Libertus & Needham, 2010). For instance, a touch typically precedes a grasp; a grasp precedes a lift; and a lift precedes an action. Therefore, an action is the most complex behavior, while a touch is the least complex behavior. Higher levels of manual exploration indicate that infants are engaged in a more advanced form of manual exploration. Furthermore, reaching behaviors are an important method that infants use to interact with their environment before they develop postural and locomotive skills. Evidence suggests that reaching skills are not only a critical tool for infants' exploration, but that reaching skills also drive the development of other motor skills, such as sitting (Harbourne et al., 2013). Thus, it is important that parents nurture reaching skills during infancy to enable infants' engagement in more complex and independent exploration of their environment.

1.1.2 Parent-Infant Interactions

An important factor influencing motor development during infancy is the interactions that occur between infants and their parents. For instance, mother-child bonding has been shown to have a greater impact on infant motor development than socioeconomic status (Chaves et al., 2021). Research on parent-child interactions is especially significant because there is likely a bidirectional causality between the actions of the parent and infant in relation to parent scaffolding.

A study by Neale and Whitebread (2019) found that mothers engaged in contingent scaffolding — providing or removing support in response to the child — such that they were more likely to remove support when their child successfully performed an action than they were to provide support when their child was struggling to perform an action. Regardless of directionality, it is imperative that parents understand and nurture the development of infants' reaching skills, as such skills play a critical role in infants' knowledge acquisition and learning processes.

1.1.3 Parental Scaffolding

In addition to understanding the mechanisms involved in infants' manual engagement with objects, it is also necessary to recognize the influence that parental behaviors have on infants' reaching skill development. One way in which parents interact with infants is through scaffolding. Parental scaffolding is when a parent facilitates their child's learning process by providing or removing support (Neale & Whitebread, 2019; Needham et al., 2015). Regardless of whether the scaffolding lends or withdraws support, it only remains an effective form of scaffolding when it is applied in appropriate amounts (i.e., not taking over the task or being completely removed from the task). Furthermore, it has been suggested that parents' propensity to scaffold is fairly consistent over time (Neale & Whitebread, 2019). Although the intention of parental scaffolding is to facilitate learning processes, there is dissention regarding the influence of scaffolding on infant object exploration. For instance, scaffolding with "sticky mittens" — Velcro-covered gloves that stick to Velcro-covered toys — has been argued to be ineffective because it eliminates haptic touch (van den Berg & Gredeback, 2021). Therefore, the impact of parental scaffolding on infants' development of motor behaviors warrants more exploration.

1.1.4 Active Play

Parent behaviors play a key role in creating an environment that promotes active exploration. For instance, a study conducted by Libertus and Needham (2010) found that 2-3 month old infants who were allowed to actively explore a toy without parental interference exhibited more reaching, grasping, and action behaviors. This evidence supports the notion that allowing an infant to actively explore independently may allow for an increase in the duration of their manual exploration of an object. Additionally, this finding suggests that parental scaffolding may inhibit the development of more advanced behaviors. Alternatively, it is plausible that parental scaffolding could increase an infant's object exploration because taking the object away from the infant effectively resets the reaching task. Research has suggested that repeated parent-initiated demonstrations of object manipulations can positively impact infants' manual object exploration. For example, repeatedly demonstrating a task has been shown to provide infants with more opportunities to practice obtaining an object, thereby potentially increasing manual object exploration (Clearfield, 2019). Despite the important role that parent-infant interactions play in infant motor development, an unsatisfactory amount of research exists on the topic (Rocha et al., 2020).

1.1.5 The Current Study

The current study investigates the impact of parental resetting on infants' object exploration behavior. We explored this topic by examining whether parental resetting during a reaching task has an impact on infants' reaching success. To accomplish this goal, we categorized parents into two groups based on their tendency to interrupt the reaching task during a structured play session (low or high levels of task resetting). We hypothesized that infants would be faster to contact an object and engage in more mature manual object exploration when parents show high levels of resetting. We theorized that parental resetting provides a more interactive form of play that encourages reaching attempts and increases infants' manual object exploration maturity. An alternative hypothesis was that lower levels of parental resetting would create an environment that promoted active play and subsequently related to infants contacting the object faster and more frequently. We also hypothesized that the influence of parental resetting behavior would result in lasting changes to infant motor development – lasting at least until 10 months of age. Finally, given the impact of infant age on their motor behaviors (Smith & Libertus, 2022) we also hypothesized that slightly older infants would show more advanced motor skills including shorter latency to contact, more manual exploration, and more advanced motor skills at a follow-up visit independent of resetting. Results from this research further our understanding of whether interruptive parental behaviors scaffold or disrupt the development of independent reaching skills during infancy.

2.0 Methods

2.1.1 Participants

A total of 103 parent-infant dyads were observed in two separate online studies completed with the Online BabyLab at the University of Pittsburgh (see Table 1 for participant characteristics). From this initial group, 19 parent-infant dyads were excluded for low birthweight (*n* =2), infant was greater than 4 months of age at older at study onset (*n* = 3), no reaching behavior coded (*n* = 6), parent or sibling interfered with the task (*n* = 8). The final sample for the current study included 84 parent-infant dyads. Infant participants joined either research study around 3.5 months of age (*M* = 106.85 days, *SD* =10.81 days) and were followed longitudinally for 8 weeks with one behavioral observation each week. Study 1 included 52 parent-infant dyads who completed longitudinal online observations between 2014 and 2018. Study 2 included 35 parent-infant dyads who completed longitudinal online observations between 2018 and 2023. At the time of assessment, all families resided in the United States, with the majority living in Pennsylvania (54% in Study 1, 69% in Study 2). Children had no known developmental disorders and a birth weight of at least 2500 grams (see Table 2). Parents recruited prior to January 2020 were compensated $20 for completing all 8 visits. The majority of infants (83%) completed all eight visits, but due to technical issues, missed visits, or the parent or sibling interfering with the task, video records were incomplete for 10 dyads. All dyads completed at least 5 codable observations. For the 10 dyads with missing observations, we used multiple imputation to replace the missing observations.

Table 1: Participant characteristics

	Study 1 (*N* = 55)	Study 2 (*N* = 48)
Infant Gender (%)		
Female	31 (56%)	21 (44%)
Male	24 (44%)	27 (56%)
Infant Race/Ethnicity (%)		
White	45 (82%)	37 (77%)
Mixed/Multi-racial	5 (9%)	6 (13%)
Asian	4 (7%)	1 (2%)
Black	1 (2%)	0 (0%)
Latin/Hispanic	2 (4%)	2 (4%)
Did not report	0 (0%)	4 (8%)
Annual Household Income, Mean (SD)	Not Collected	10.21 (2.51)[a]
Household Education, Mean (SD)	7.96 (1.45)[b]	7.41 (1.60)[c]

Notes: [a]Can be interpreted as an average annual household income falling between $90-99.9K and ranging between $60K and greater than or equal to $150K when accounting for standard deviation. [b]Can be interpreted as both adults having the equivalent of a 4-year college degree or professional degree. [c]Can be interpreted as both adults having the equivalent of some college (degrees from 2-year colleges or skilled training) or a professional degree.

Table 2: Resetting group characteristics

	High Resetting Group (*n* = 39)	Low Resetting Group (*n* = 45)
Infant Gender (%)		
Female	16 (41%)	28 (62%)
Male	23 (59%)	17 (38%)
Infant Race/Ethnicity(%)		
White	33 (85%)	37 (82%)
Mixed/Multi-racial	4 (10%)	4 (9%)
Asian	2 (5%)	3 (7%)
Latin/Hispanic	4 (10%)	0 (0%)
Did not report	0 (0%)	1 (2%)
Infant Birth Weight (grams), Mean (SD)	3564 (486)	3590 (557)
Annual Household Income, Mean (SD)	9.50 (3.24)[a]	10.67 (1.62)[b]
Household Education, Mean (SD)	7.41 (1.70)[c]	8.22 (1.18)[d]*
Infant Age at Study Onset, Mean (SD)	106 (11.3)	103 (13.6)

Notes: * $p < .05$. [a]Can be interpreted as an average annual household income falling between $80-89.9K and ranging between $50K and greater than or equal to $150K when accounting for standard deviation. [b]Can be interpreted as an average annual household income falling between $90-99.9K and ranging between $80K and greater than or equal to $150K when accounting for standard deviation. [c]Can be interpreted as both adults having the equivalent of a 4-year college degree or professional degree. [d]Can be interpreted as both adults having a professional degree or doctoral degree.

2.1.2 Procedures

Informed consent was obtained from all parents prior to participation in any study procedures and all assessments and procedures were approved by the Institutional Review Board at the University of Pittsburgh. Families joined online video calls with a researcher from the Online BabyLab via Zoom, Skype, or Facetime on a weekly basis for a total of eight weeks. During the calls, parent-infant dyads completed a 1-minute task designed to observe the child's manual exploration skills (Reaching Task, see below). Additionally, dyads completed a 1-minute sitting task, but this task was not included in the current study's analyses. At an additional follow-up visit when the child was around 10-11 months of age, parents were asked to complete an online survey about their child's motor development (EMQ, see below) administered via the Qualtrics survey platform.

2.1.3 Measures

2.1.3.1 Observational Measure: Reaching Task

To assess manual exploration skills, all children completed weekly 1-minute reaching assessments during their longitudinal observations. For this task, parents were instructed to place their child on their lap, in a stable child-seat at a table, or on a flat surface. Parents positioned the camera documenting the interaction (i.e., phone or laptop computer) in front of the child providing a frontal view of the child's face and hands. Parents were then asked to place a spoon from their own home within reach of the child and to encourage the child to reach for the spoon. Parents were asked to let their child explore the spoon freely, but they were allowed to tap the spoon to draw attention to the spoon if needed. Critically, the amount of encouragement or attention drawn to the spoon was not specified by the experiment. The task was recorded for offline data analysis.

2.1.3.2 Parent-report Measure: Early Motor Questionnaire (EMQ)

In addition to the observation of infants' behavior, parents were asked to complete the Early Motor Questionnaire (Libertus & Landa, 2013) to assess infants' motor development. The EMQ is a 127-item parent-report measure covering Gross Motor (GM, 48 items), Fine Motor (FM, 48 items), and Perception-Action skills (PA, 31 items). Each item is rated on a 5-point scale ranging from -2 to +2 (resulting in total scores ranging from -254 to +254). The EMQ provides a good estimation of infants' motor skills and has been validated against gold-standard observational measures (Libertus et al., 2013). Parents completed the EMQ when their child was between 10-11 months of age and raw EMQ scores were converted into age-independent t-scores, allowing for comparison to expected scores for developmental age (population mean of 50, standard deviation of 10; Smith & Libertus, 2022).

2.1.4 Data Preparation and Coding

To address the main goals of the research, we developed a detailed coding scheme that quantified both parent and child behavior during the longitudinal observations of infants' manual exploration. Parent-infant dyad behaviors were coded using frame-by-frame video coding software (Datavyu) to capture details in parent and child behaviors as they unfold. Coding was completed sequentially with multiple coding passes for each video, allowing coders to focus on one behavior at a time. All passes were time-locked and allowed for a combination of behaviors across passes.

The following three coding passes were completed: parental resetting, infants' latency to first contact, and infants' manual exploration.

2.1.4.1 Pass 1: Parental Resetting

During the first coding pass, instances when parents "reset" the task were identified. Resetting was defined as any instances when the parent replaced the spoon on the table after intentionally removing the spoon from either the child's contact, or from a reachable position on the table. Instances where the parent removed the spoon during the reaching task created a new starting point or "reset" of the task and are distinct from attention-getting behaviors such as tapping, spinning, and flipping of the spoon to re-direct the child's attention. Instances when the spoon was beyond the child's reach (e.g., knocked onto the ground) were not counted as "resetting". To create a universal definition of "reset" for all participants, the initial trial start was not counted as a reset (see Appendix A). Inter-rater reliability was calculated for 25% of videos using a Pearson correlation and showed sufficient agreement between raters (r = .76).

2.1.4.2 Pass 2: Latency to First Contact

During the second coding pass, infants' latency to first contact was identified. To determine infants' latency to first contact, we defined the beginning of a potential latency to first contact period as the moment when the parent was no longer in contact with the spoon after resetting it. If the parent placed the spoon on the table, but the infant contacted the spoon before the parent could release it, we coded the latency period as being 0.001 seconds (the minimum amount of time that can be coded in a duration cell in Datavyu). Infants' latency to first contact was coded as "LT" if the first contact was a touch, "LG" if the first contact was a grasp, or "LL" if the first contact was a lift/action. If a child never made contact with the toy during a valid trial, the latency to first contact was recorded as 60 seconds (the total duration of a visit; Willatts, 1979. The coding manual that was referenced during this portion of the data pass can also be found in Appendix A. Inter-rater reliability was calculated for 25% of videos using a Pearson correlation and showed good agreement between raters (r = .86).

2.1.4.3 Pass 3: Manual Object Exploration

During the third coding pass, we identified instances and durations of infants' manual object exploration. Any contact between the child's hand and the spoon lasting at least 2 seconds was coded as an instance of manual exploration. Requiring the contact time to last at least 2 seconds avoided the coding of behaviors that were not intentional or exploratory in nature. This code was further sub-divided into four hierarchical categories defined as a touch (T, any object contact), grasp (G, fingers curled around the object), lift (L, object completely lifted off the table), or action (A, object lifted and manipulated by shaking, rotating, or banging). Instances where the child was not afforded an opportunity to engage with the spoon were marked (Colomer et al., 2022) and were excluded from the calculation of duration proportions (see Appendix B). Proportions were calculated for the proportion of time infants spent in a simple touch (not including higher maturity behaviors), the proportion of time infants spent in a grasp (Libertus & Needham, 2010), and the proportion of total time infants were in contact with the object (any manual exploration behavior). Frequency was calculated for infants' grasping as well. Both approaches (duration and frequency) provide complimentary ways to assess infants' level of manual exploration (Ferronato et al., 2023). Inter-rater reliability was calculated for 35% of videos using a Pearson correlation and showed sufficient agreement between raters (r = .81).

3.0 Results

3.1.1.1 Preliminary Analyses

Prior to our main analyses, preliminary Pearson correlation analyses were used to explore whether there is any relation between parental resetting, infants' manual exploration skills, EMQ scores, and age at study onset. Rather than using individual measures obtained during each of the eight study observations, this broad overview analysis used summary measures that combined information across all observations using either averages or growth rates (i.e., slopes). For resetting behavior and latency to first contact, we calculated averages across all eight observations. For manual exploration behaviors (simple touching, grasping, and total contact), we calculated linear slopes across all observations. Slopes quantify the change or "growth" in manual exploration ability over time into a single number. All preliminary correlation results are summarized in Table 3. Results indicate a significant negative correlation between mean parental resetting behavior and infants' mean latency to first contact (r = -.45, p = .001), suggesting that more parental resetting was associated with infants' exhibiting a shorter latency to first contact. Mean parental resetting behavior showed no significant correlation with growth rates (i.e., slopes) of infants' simple touching behavior, grasping behavior, or total contact (all ps > .05, see Table 3). Lastly, analyses showed that mean parental resetting was not significantly correlated with gross motor, fine motor, perception-action, or global motor scores on the EMQ (p > .05).

Table 3: Pearson correlation of resetting, manual exploration, EMQ scores, and age at visit onset

	Mean Parental Resetting Frequency	Mean Latency to First Contact	Growth of Touching Proportion	Growth of Grasping Proportion	Growth of Grasping Frequency	Growth of Total Contact Proportion	Gross Motor Score	Fine Motor Score	Perception-Action Score	Global Motor Score	Infant Age at Study Onset
Mean Parental Resetting Frequency	—										
Mean Latency to First Contact	-0.453 ***	—									
Growth of Touching Proportion	-0.121	0.294 **	—								
Growth of Grasping Proportion	-0.113	-0.342 **	-0.357 ***	—							
Growth of Grasping Frequency	-0.048	-0.298 **	-0.056	0.696 ***	—						
Growth of Total Contact Proportion	-0.172	-0.240 *	0.044	0.918 ***	0.720 ***	—					
Gross Motor Score	-0.015	-0.306 *	-0.047	0.329 **	0.321 *	0.334 **	—				
Fine Motor Score	0.210	-0.274 *	-0.166	0.241	0.192	0.187	0.640 ***	—			
Perception-Action Score	0.064	-0.238	-0.189	0.137	-0.006	0.065	0.480 ***	0.668 ***	—		
Global Motor Score	0.104	-0.322 *	-0.149	0.287 *	0.218	0.243	0.849 ***	0.911 ***	0.798 ***	—	
Infant Age at Study Onset	0.069	-0.309 **	-0.215 *	0.406 ***	0.397 ***	0.343 **	0.178	0.355 **	0.263 *	0.310 *	—

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

In addition to examining correlations among the measures collected for the current study, we also examined whether there are any correlations with infant age at study onset. Infant age was not correlated with mean parental resetting behavior (r = .07, p = .533) indicating that parental resetting did not differ systematically between slightly older and younger infants in our sample. In contrast, we observed significant negative correlations between infant age and their mean latency to first contact (r = -.31, p = .004) suggesting that older infants showed shorter latency to first contact. Infants' age at study onset was also positively correlated with the growth of both grasping (r = .41, p < .001) and total contact proportions (r = .34, p = .001). This indicates that the older infants in our sample showed significantly faster growth in grasping proportion, grasping frequency, and total contact proportion with the object than younger infants. In contrast, we found that infants' age at visit onset showed a significant negative correlation with growth rates of infants' simple touching behaviors (r = .-.22, p = .05). This result may indicate that older infants reduced their simple touching behaviors over time as these were replaced by more advanced exploration behaviors.

3.1.1.2 Parental Resetting

To examine the impact of parental resetting behaviors on infant motor development, parents were sorted into either a *low* or a *high* resetting group depending on their resetting frequency. Group membership was determined by conducting a k-means cluster analysis including parental resetting frequency at visit 1-8 (see Figure 1). After establishing resetting groups, we conducted independent samples t-tests between the two groups to determine if the groups differed on any of our demographic variable. Results only revealed a significant difference in household education such that parents in the low resetting group had a significantly greater household education compared to parents in the high resetting group (see Table 2). To statistically control for the effects of household education, we included household education as a covariate in subsequent analyses when possible (i.e., using ANCOVA).

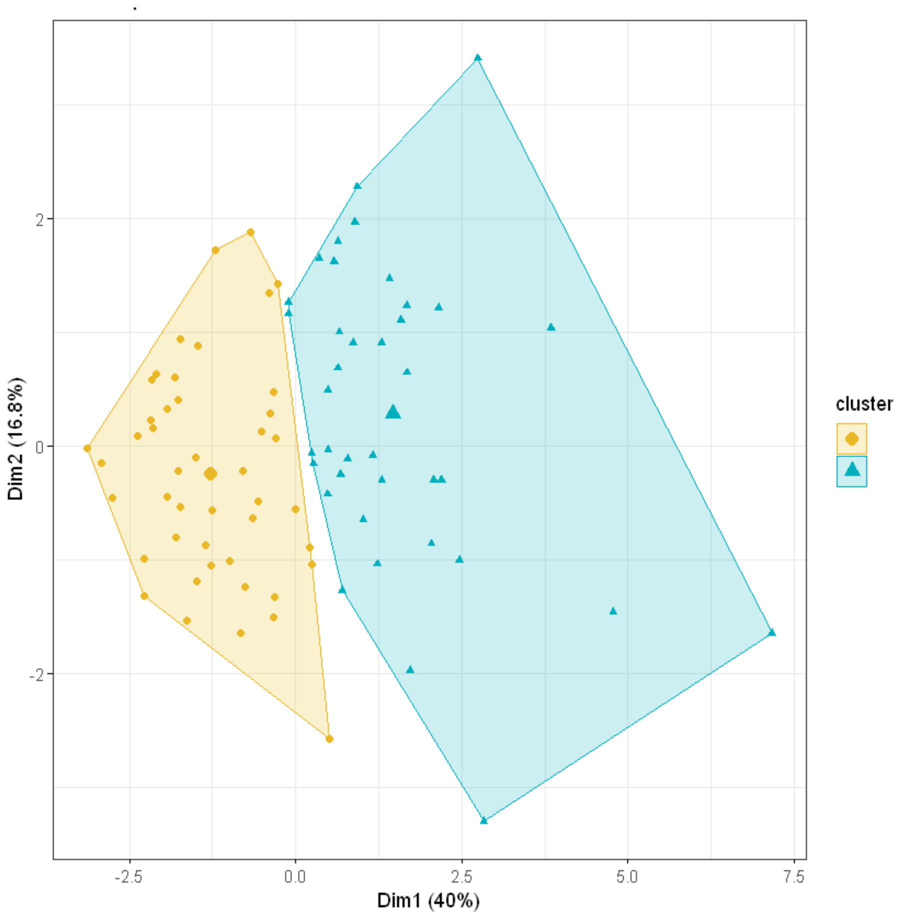

Figure 1: Cluster analysis of parental resetting.

To verify whether our categorization into low and high resetting groups created two groups that indeed differed in resetting behavior, we conducted a repeated-measures Analysis of Covariance (ANCOVA) on parental resetting frequency with Resetting Group (2, high vs. low) as the between-subjects factor, Visit (8) as the within-subjects factor, and Household Education as a covariate. Mauchly's test of sphericity indicated that the assumption of sphericity had been violated (W = .44, $p < .001$). Therefore, we used a Huynh-Feldt correction and found a significant main effect of Resetting Group, $F(1, 81) = 97.68$, $p < .001$, $\eta^2 = .175$, but no main effect of Visit $F(6.11, 494.53) = 0.94$, $p = .479$, $\eta^2 = .006$, and no significant effect for the Household Education, $F(1, 81) = 0.40$, $p = .531$, $\eta^2 = .001$. However, the main effect of Group was qualified by a significant Resetting Group by Visit interaction, $F(6.11, 494.53) = 4.86$, $p < .001$, $\eta^2 = .029$ (see Figure 2a). The significant interaction between Group and Visit suggests that parental resetting behavior was changing over the 8 study observations for one of the two resetting groups but not the other. To further probe this interaction effect, we performed a series of t-tests to explore group differences in resetting behavior separately for each of the eight study visits. Results reveal that parental resetting was significantly different between high and low resetting groups at all eight visits (*ps* < .05, see Table 4). Visual inspection of the data (see Figure 2a) suggests that resetting behavior *increases* slightly across visits for the low-resetting group but *declines* slightly over time for the high-resetting group. Thus, the two groups become more similar in their resetting behavior as our study visits progress. This pattern suggests that we should explore resetting behavior during the earlier visits (1-4) separately from resetting behavior during the later visits (5-8). Splitting our data into visits 1-4 and visit 5-8 reduces the overall number of statistical comparison while still allowing us to examine whether an effect of visit on infant or parent behavior exists. In summary, the ANCOVA analysis confirms that our grouping variable captures differences in parental resetting behavior and that these differences vary across at least the first four compared to the last four study visits. Therefore, we will include both resetting-group and study visit as factors in all subsequent analyses. In separate analyses, we will explore differences across early (1-4) and late (5-8) study visits separately to determine if there is a broader effect study visit.

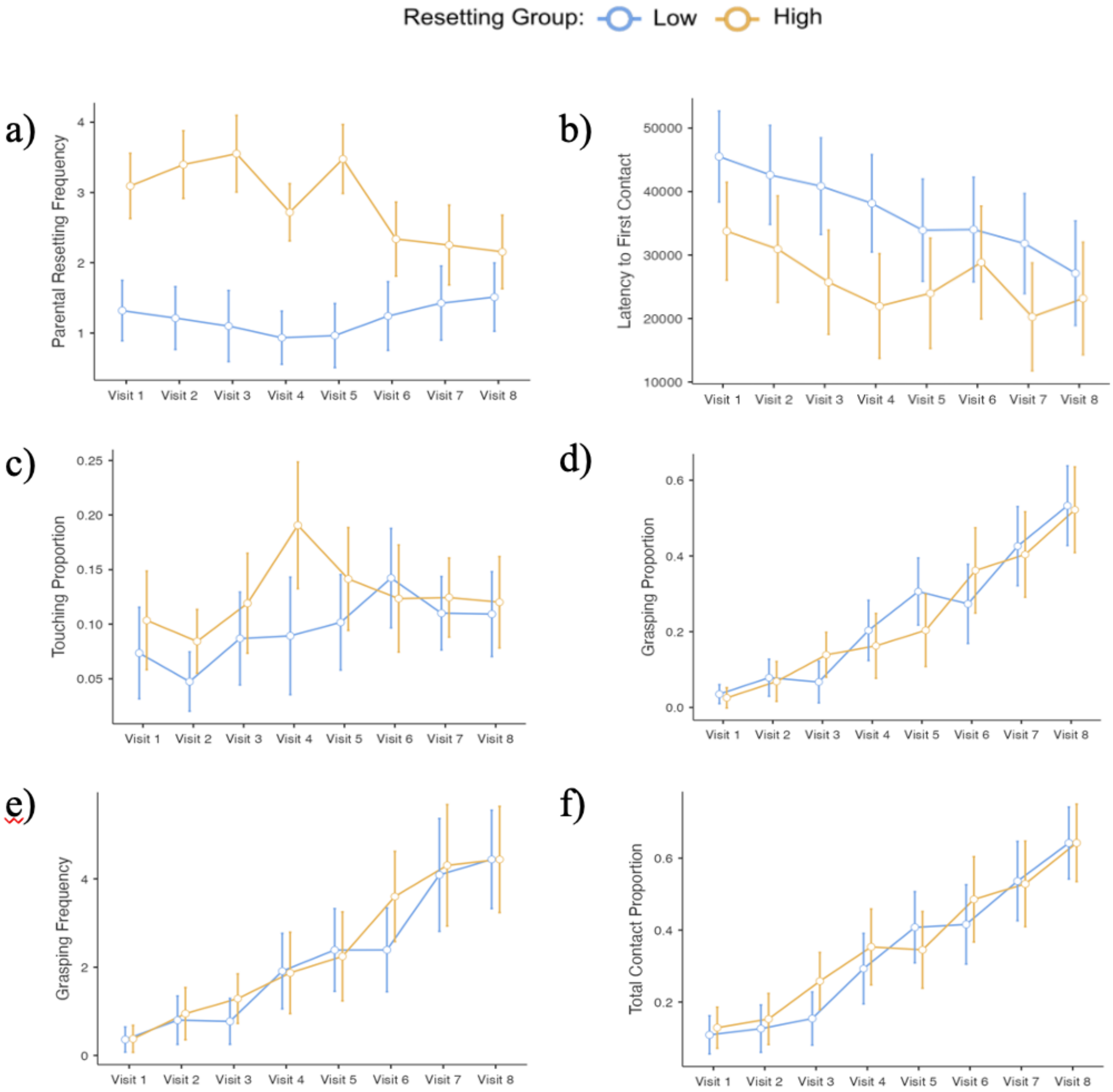

Figure 2: Mean parental resetting frequency (a), mean latency to first contact (b), touching proportion (c), grasping proportion (d), grasping frequency (e), and total contact proportion (f).

Note: Vertical bars represent 95% confidence intervals.

Table 4: Parental resetting between high and low parental resetting groups

Visit	High Resetting Group Mean (*SD*)	Low Resetting Group Mean (*SD*)	Difference (*t-test*)
1	3.13 *(1.63)*	1.29 *(1.22)*	*t(82) = 5.92, p < .001*
2	3.38 *(1.71)*	1.22 *(1.22)*	*t(82) = 6.73, p < .001*
3	3.51 *(2.01)*	1.13 *(1.31)*	*t(82) = 6.51, p < .001*
4	2.77 *(1.56)*	0.89 *(0.91)*	*t(82) = 6.84, p < .001*
5	3.44 *(1.89)*	1.00 *(1.07)*	*t(82) = 7.40, p < .001*
6	2.31 *(1.88)*	1.27 *(1.34)*	*t(82) = 2.95, p = .002*
7	2.36 *(2.06)*	1.33 *(1.48)*	*t(82) = 2.65, p = .005*
8	2.21 *(1.73)*	1.47 *(1.49)*	*t(82) = 2.10, p = .019*

3.1.1.3 Latency to First Contact

We conducted a repeated-measures ANCOVA on infants' latency to first contact with Resetting Group (2, high vs. low) as the between-subjects factor, Visit (8) as the within-subjects factor, and Household Education as covariate. The ANCOVA revealed a significant main effect of Resetting Group, $F(1, 81) = 13.12$, $p < .001$, $\eta^2 = .030$, no main effect of Visit, $F(6.33, 512.47) = 1.13$, $p = .341$, $\eta^2 = .008$, no effect of Household Education Level, $F(1, 81) = 2.28$, $p = .135$, $\eta^2 = .005$, and no Resetting Group by Visit interaction, $F(6.33, 512.47) = 0.62$, $p < .724$, $\eta^2 = .004$ (see Figure 2b). These results support our first hypothesis by demonstrating that infants with parents who engage in high levels of resetting show a shorter latency to contact objects compared to infants with parents who were less likely to engage in resetting. Further, the results demonstrate that this difference holds across all eight study visits.

We further explored the impact of parent resetting on infants' latency to first contact by conducting t-tests comparing infants' mean latency to first contact in earlier visits (visits 1-4) and later visits (visits 5-8) between resetting groups. Analyses showed that infants in the high resetting group ($M = 27.74$, $SD = 16.73$) had a significantly shorter latency to first contact than infants in the low resetting group (*M* = 42.06, *SD* = 16.70) across visits 1-4. The difference between the means was statistically significant, $t(82) = 3.92$, $p < .001$ (see Figure 3a). Similarly, we found that infants in the high resetting group (*M* = 23.09, *SD* = 14.42) had a significantly shorter latency to first contact than infants in the low resetting group (*M* = 32.53, *SD* = 15.81) across visits 5-8 (see Figure 3b). The difference between the means was statistically significant, $t(82) = 2.84$, $p = .006$ (see Table 5 for a summary). These analyses confirm our ANCOVA findings that infants with parents that frequently reset the task have a significantly shorter latency to first contact using a more powerful two-visit (early vs late) approach.

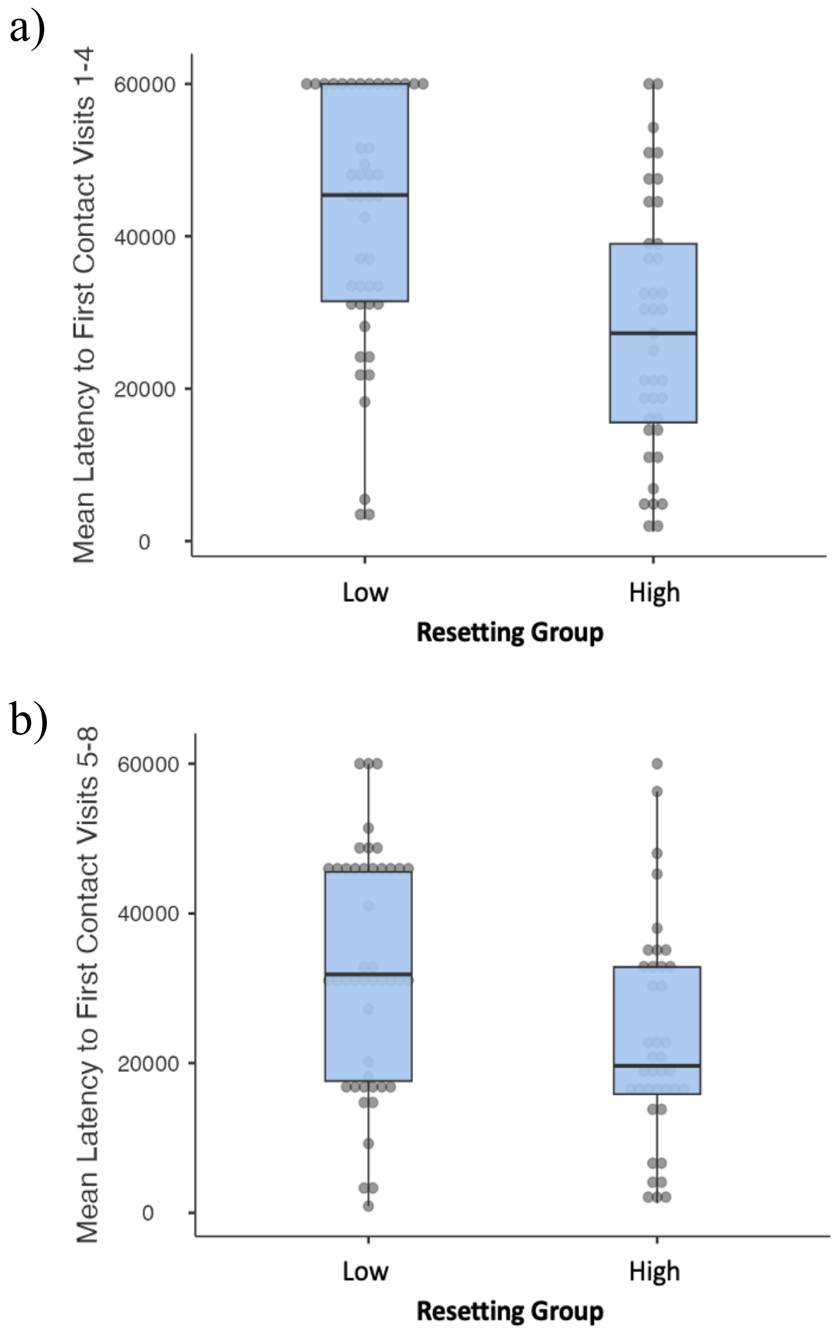

Figure 3: Infants' latency to first contact between high and low parental resetting groups during visits 1-4 (a) and visits 5-8 (b).

Table 5: Infants' latency to first contact between high and low resetting groups

	High Resetting Group Mean (*SD*)	Low Resetting Group Mean (*SD*)	Difference (t-test)
Mean Latency to First Contact Visits 1-4 (sec)	27.74 *(16.73)*	42.06 *(16.70)*	$t(82) = 3.92$, $p < .001$
Mean Latency to First Contact Visits 5-8 (sec)	23.09 *(14.42)*	32.53 *(15.81)*	$t(82) = 2.84$, $p = .006$

3.1.1.4 Manual Object Exploration

We conducted separate repeated-measures ANCOVAs on infants' simple touching proportion, grasping proportion, grasping frequency, and total contact proportion with Resetting Group (2, high vs. low) as the between-subjects factor, Visit (8) as the within-subjects factor, and Household Education as a covariate. The ANCOVA with simple touching proportion as the dependent variable revealed a significant main effect of Resetting Group, $F(1, 81) = 3.99$, $p < .049$, $\eta^2 = .009$, no main effect of Visit, $F(5.77, 467.10) = 1.35$, $p = .235$, $\eta^2 = .010$, no effect of Household Education, $F(1, 81) = 0.41$, $p = .525$, $\eta^2 = .001$, and no Resetting Group by Visit interaction, $F(5.77, 467.10) = 1.39$, $p < .221$, $\eta^2 = .010$, (see Figure 2c). This analysis supports our hypothesis that infants in the high resetting group would exhibit more simple touching behavior than compared to infants in the low resetting group. In contrast, ANCOVAs exploring more advanced exploration behaviors such as grasping proportion, grasping frequency, and total contact proportion showed no significant between-group or within-group differences (all *ps* > .05, see Figure 2d-f).

We conducted a series of t-tests to further explore the differences in infants' growth of simple touching proportion comparing between early and late study visits. Results reveal significant differences in infants' growth of simple touching behavior (i.e., slopes) between high and low resetting groups for early visits, $t(82) = -2.22$, $p = .029$, but not for late visits. Specifically, for visits 1-4, we observed a slightly greater increase in simple touching behaviors in the high resetting group (*M* = 4.60e-3, *SD* = 9.92e-3) compared to in the low resetting group (*M* = 7.49e-4, *SD* = 5.69e-3; see Table 6 for statistics and Figure 4 for visual representation).

Table 6: Manual exploration growth between high and low resetting groups

	High Resetting Group Mean (*SD*)	Low Resetting Group Mean (*SD*)	Difference (*t-test*)
Touch Proportion Visits 1-4	4.60e-3 *(9.92e-3)*	7.49e-4 (5.69e-3)	*t(82) = -2.22, p = .029*
Touch Proportion Visits 5-8	-9.22e-4 *(0.01)*	-3.25e-4 *(6.48e-3)*	*t(82) = .30, p = .764*
Grasp Proportion Visits 1-4	6.98e-3 *(9.48e-3)*	*6.52e-3 (.01)*	*t(82) = -.19, p = .854*
Grasp Proportion Visits 5-8	.01 *(.02)*	.01 *(.01)*	*t(82) = -.48, p = .629*
Grasp Frequency Visits 1-4	.07 *(.11)*	.06 *(.14)*	*t(82) = -.45, p = .651*
Grasp Frequency Visits 5-8	.11 *(.20)*	.10 *(.17)*	*t(82) = -.10, p = .917*
Total Contact Proportion Visits 1-4	.01 *(.01)*	7.27e-3 *(.01)*	*t(82) = -1.53, p = .129*
Total Contact Proportion Visits 5-8	.01 *(.02)*	.01 *(.01)*	*t(82) = -.31, p = .760*

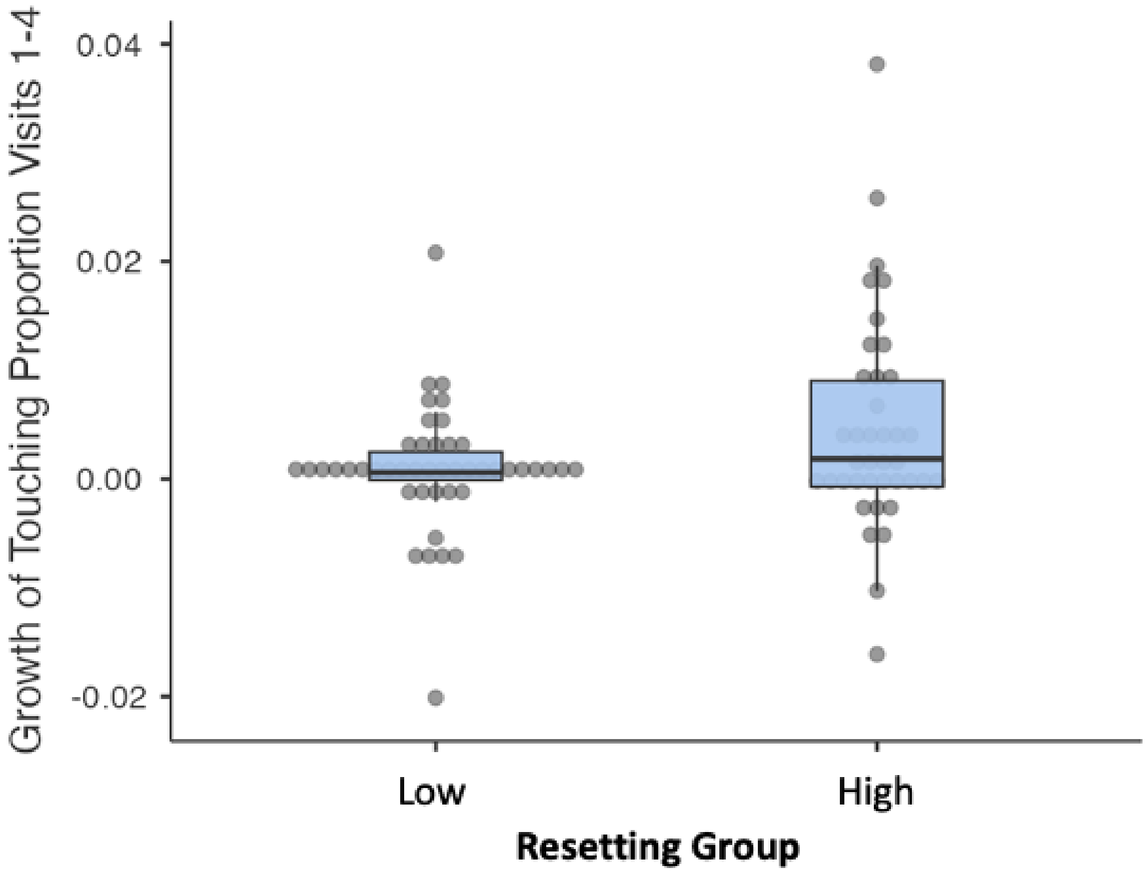

Figure 4: Infants' growth in simple touching behavior between high and low parental resetting groups.

3.1.1.5 EMQ

Finally, we assessed the impact of parental resetting behavior on infant's subsequent global motor, gross motor, fine motor, and perception-action skills at 10- to 11-months of age. We conducted separate ANCOVAs of infants' gross motor, fine motor, perception-action, and gross motor scores with Group (2, high vs. low) as the between-subjects factor, and Household Education as a covariate. For infants' fine motor scores, ANCOVA results revealed a significant main effect of Resetting Group, $F(1, 59) = 6.92$, $p = .011$, $\eta^2 = .102$, but no effect of Household Education, $F(1, 59) = 1.60$, $p = .210$, $\eta^2 = .024$. For infants' perception-action scores, ANCOVA results revealed a significant main effect of Resetting Group, $F(1, 59) = 5.12$, $p = .027$, $\eta^2 = .075$, and a significant effect of Household Education, $F(1, 59) = 4.25$, $p = .044$, $\eta^2 = .062$. Finally, for infants' gross motor and global motor scores, ANCOVA analyses showed non-significant effects of Resetting Group and Household Education ($p > .05$, see Table 7 for statistics and Figure 5a-b for visual representation). These findings suggest that higher levels of parental resetting between 3- to 5-months of age are associated with infants' subsequent fine motor and perception action skills at 10-11 months of age and infants in households with a lower education scored higher on the perception-action domain of the EMQ at 10 months than infants in households with a higher education.

Table 7: EMQ scores between high and low resetting groups

	High Resetting Group Mean (*SD*)	Low Resetting Group Mean (*SD*)	Difference (ANCOVA) Group; Household Education
Gross Motor Score	50.7 *(3.73)*	50.3 *(2.78)*	$F(1, 59) = 0.08$, $p = .782$, $\eta^2 = .001$; $F(1, 59) = 1.76$, $p = .190$, $\eta^2 = .029$
Fine Motor Score	55.1 *(4.38)*	52.4 *(4.63)*	$F(1, 59) = 6.92$, $p = .011$, $\eta^2 = .102$; $F(1, 59) = 1.60$, $p = .210$, $\eta^2 = .024$
Perception-Action Score	49.0 *(4.13)*	47.1 *(4.35)*	$F(1, 59) = 5.12$, $p = .027$, $\eta^2 = .075$; $F(1, 59) = 4.25$, $p = .044$, $\eta^2 = .062$
Global Motor Score	51.7 *(3.74)*	50.2 *(3.09)*	$F(1, 59) = 3.95$, $p = .051$, $\eta^2 = .062$; $F(1, 59) = 1.26$, $p = .267$, $\eta^2 = .020$

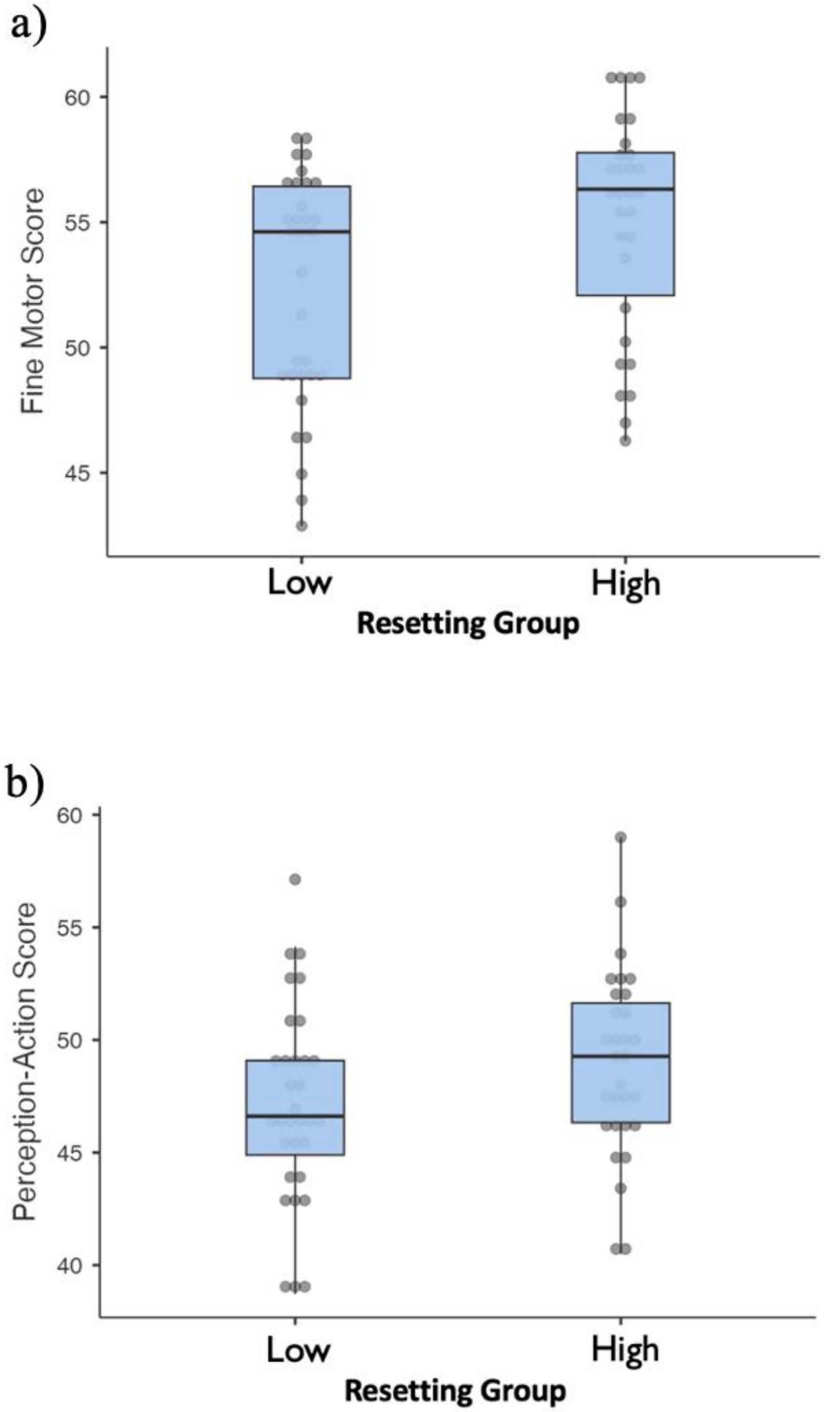

Figure 5: Infants' EMQ fine motor scores (a) and perception-action scores (b) between high and low parental resetting groups

4.0 Discussion

The current study investigated a previously unexplored parental behavior, *resetting*, to explore its impact on infant development of manual exploration skills. Confirming our hypothesis, we found that infants were faster to contact an object and engaged in more mature manual object exploration when parents show high levels of resetting. These findings suggest that parental resetting may be used as a potential motor intervention strategy that promotes early manual exploration behaviors. Specifically, our findings suggest that increased parental resetting behavior may shorten infants' latency to first contact when engaging with an object. Shorter latency to first contact – in turn – showed a significant positive correlation with infants' subsequent fine motor and perception-action skills around 10 months of age. Together, these findings suggest that parental resetting behavior may initiate a developmental cascade that has both immediate (latency to contact and touching proportion) and delayed (overall fine motor and perception-action skills) effects on infant motor development.

Our finding that parental resetting was associated with infants having a shorter latency to first contact strongly suggests that parental resetting promotes infant development of manual exploration skills. Latency to first contact has been interpreted as a measure of infants' planning such that shorter latency to first contact indicates more advanced visuomotor skills (McCarty et al., 1999; Willatts, 1979). Additionally, a shorter latency to first contact shows a change in planning and anticipatory behaviors in the context of infants' grasping behaviors. For example, infants develop an increased ability to pre-shape their hands as they approach differently sized or shaped objects (Barrett et al., 2008) and a faster speed of hand approach as they reach for objects as they get older (Corbetta et al., 2000). As such, the shorter latency to first contact that we observed in infants in the high resetting group was not just the pathway through which resetting promoted infant development of manual exploration skills. Rather, a shorter latency to first contact is in and of itself indicative of more mature manual exploration skills, especially within the perception-action domain.

We also found that parental resetting had a significant effect on infants' subsequent motor development as assessed on the EMQ. This influence showed a medium to large effect for both fine motor and perception-action skills. Previous research using the EMQ has indicated that the majority of variability in EMQ scores can be explained by the child's age – about 85% of variability (Smith & Libertus, 2022). Our findings add to these results and indicate that parental resetting behavior may also contribute to children's motor development. Additionally, our finding that household education was a significant factor explaining infant's perception-action skills as measured on the EMQ. However, we observed that relatively lower household education scores resulted in higher perception-action scores. Thus, our findings counter previous results linking greater parental education to more effective childcare practices (Saccani et al., 2013). In contrast, our results suggest that infants growing up in lower education households do not necessarily receive less effective childcare practices than infants in high education households – at least not when it comes to parental engagement practices such as resetting behaviors. This observation warrants future research and suggests that parental engagement might buffer the effects of lower-resource households. However, this prediction was not tested in the current sample as we did not have access to income information for the entire sample. Future research should examine the impact of family income on parental resetting behaviors and its longer-term impact on motor development.

Overall, parental resetting appears to have a significant association with infants' fine motor and perception-action development. Parental resetting may create a ripple effect such that it influences latency to first contact which then impacts the maturity of infants' manual object exploration. Furthermore, resetting could have a cascading impact (Iverson, 2021) such that it ultimately contributes to infants learning about their environment, themselves, and the agency they possess within their environment. For instance, cascading effects from resetting could potentially be seen in many domains of development including but not limited to other motor skill development (Harbourne et al., 2013), language development (Gonzalez et al., 2019), and cognitive development (Zuccarini et al., 2020). The current study's findings suggest that parental resetting does not interfere with infants' manual object exploration skills. Rather, parental resetting supports normal child development in the progression from reflexive grasping to purposeful object exploration and may have a longer-lasting positive influence on infants' development of fine motor and perception-action skills.

However, when interpreting the results of the current study it is important to recognize that there are some limitations. Although a naturalistic non-randomized study design allowed for us to evaluate parent behaviors as they naturally occurred, we were unable to determine causality in our results. Infant behavior has been shown to impact parent behavior (Neale & Whitebread, 2019) so it is likely that the relation between infant behavior and parental resetting behavior was bidirectional. Now that we have evidence that parents naturally have different propensities to reset, it would be beneficial to investigate the effect of resetting using a randomized-controlled study design. For example, future research could randomly assign parent-infant dyads to either a no resetting, moderate resetting, or high resetting group to determine the directionality in the relationship between parental resetting and infants' development of manual exploration skills.

Another potential limitation of our study is that we did not assess parental engagement overall. Parental engagement has been shown to encourage infants' motor development (Parfitt et al., 2014), so we cannot be certain that parental resetting is impactful because of the specific nature of the behavior or merely because it is a form of parental engagement. In the future, it would be beneficial to evaluate parental engagement more broadly (e.g., assess parent talk). In doing so, a better understanding could be gained of the reason parental resetting facilitates infants' motor development.

Future research can also use the current study as a framework for exploring whether parents with a high propensity to reset are more anxious about their child's development. There is evidence that parent anxiety can shape the environment in which parent-child interactions are occurring for parents of older children (Turner et al., 2003). Regarding impacts of anxious behaviors on infant development, research has found that anxious parents are less satisfied in their parenting quality and are more eager to find new parenting methods (Khomaeny & Kusumaputeri, 2022). Therefore, gaining a better understanding of whether anxious parents have a higher tendency to scaffold infant behavior could help us improve care for parents with anxiety and ultimately improve parenting quality. Thus, a new resetting-based parenting intervention could be very appealing to parents that are anxious about their child's development and could potentially contribute to them feeling more competent in their parenting abilities.

The current study provides encouraging evidence for a resetting-focused parenting intervention. Since many parents worry about their children not being on a normal trajectory regarding motor development (Porter & Ispa, 2013), a new, low-cost intervention could be an effective resource for parents to use with their child. The current study supports that a resetting-based intervention could be used as a form of scaffolding that promotes infants' early manual exploration skills as well as their subsequent fine motor and perception-action skills.

Appendix A Reset-Latency Coding Manual

<table>
<tr><th colspan="3">Reset Coding</th></tr>
<tr><td colspan="3">- Reset definition: the parent removes the spoon from the child’s contact, or from a reachable position (e.g., on the table or the child’s chest), and places the spoon onto the table
- Behaviors that are not a reset: tapping, spinning, flipping, and reorienting the spoon
- If the spoon starts off the table (parent or infant’s is holding the spoon), ignore the first reset, but then code as normal</td></tr>
<tr><th>Column Name</th><th>Code</th><th>Description of Code</th></tr>
<tr><td>Reset</td><td>R</td><td>Each “R” point-cell represents a time the parent resets the reaching task. The cell’s onset/offset should be the moment the parent releases the spoon</td></tr>
<tr><th colspan="3">Latency Coding</th></tr>
<tr><td colspan="3">- Latency definition: the period from when the parent releases the spoon to the infant’s first contact with the spoon
- Onset: the moment parent is no longer in contact with the object after resetting it
- Offset: the infant’s first contact (this should match the onset of the manual exploration column code)
- If the infant contacts the spoon before the parent can finalize a reset, code the latency duration as 0.001 seconds (with the offset matching the onset of the manual exploration column code)
- If the parent completes a reset by initiating contact between the spoon and the infant, do not code this as a latency, but still code it as a reset
- If the parent introduces another spoon, code resets and latencies for both objects</td></tr>
<tr><th>Column Name</th><th>Code</th><th>Description of Code</th></tr>
<tr><td rowspan="3">Latency</td><td>LT</td><td>Used when the first contact after a reset is a touch</td></tr>
<tr><td>LG</td><td>Used when the first contact after a reset is a grasp</td></tr>
<tr><td>LL</td><td>Used when the first contact after a reset is a lift/action</td></tr>
<tr><td colspan="3">How to install the script to add the Latency and Reset columns:
- Download the script
- Download the Datavyu file
Go the “Script” at the top of computer and select the downloaded file</td></tr>
</table>

Appendix B Manual Exploration Manual

NOTE: *The following codes are mutually exclusive and should cover all observable behaviors. Therefore,* ***one code needs to be active at all times.***

Brief contact rules: If a contact with an object is **shorter** than 5 JOG presses (200ms), do **NOT** code as contact. This same rule applies in transitioning types of contact: if the child is Grasping an object and we get 5 or less JOG presses of a Lift but then regress to a grasp again, keep the coding at Grasp (no new cell).

The contact types below are hierarchical, but discrete. If a continuous contact matures from a Touch to a higher listed contact type (Grasp, Lift, or Action) for more than 5 JOG presses, **begin a new cell.**

<type>	**Code**	**Description**
Negative Time	**X**	*There is interference by a parent, experimenter, pet, or another toy that causes any length of time in the video to be not codable or breaks the experiment. This includes time where the parent is retrieving a dropped object in the REA task or time when the child is out-of-frame in the video.*
No contact	**0**	*Child is not touching an object.*
Touch	**T**	*Child is touching the object. A touch is any contact between hand and object. Child does* **not** *have control over object's motion; child may poke, skim fingers across the surface, or have passive contact with the object (not touching with fingers, but hand has contact below the wrist), but object does not move in response to child's touch.*
Grasp	**G**	*At least one of the child's fingers are curved around the object or a corner of the object OR the object is at least partially lifted off the supporting surface OR the child otherwise has control over the object's motion.*
Lift	**L**	*Object is entirely lifted off the surface and supported by the child's hand alone.*
Action	**A**	*The child achieves a lift and uses the object to perform an action such as shaking, rotating, or banging it**

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