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The social foundation of executive function

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Abstract

In this study, we propose that infant social cognition may 'bootstrap' the successive development of domain-general cognition in line with the cultural intelligence hypothesis. Using a longitudinal design, 6-month-old infants (N = 118) were assessed on two basic social cognitive tasks targeting the abilities to share attention with others and understanding other peoples' actions. At 10 months, we measured the quality of the child's social learning environment, indexed by parent's abilities to provide scaffolding behaviors during a problem-solving task. Eight months later, the children were followed up with a cognitive test-battery, including tasks of inhibitory control and working memory. Our results showed that better infant social action understanding interacted with better parental scaffolding skills in predicting simple inhibitory control in toddlerhood. This suggests that infants' who are better at understanding other's actions are also better equipped to make the most of existing social learning opportunities, which in turn may benefit future non-social cognitive outcomes.

KEYWORDS

executive function, infants, scaffolding, social-cognition

1 | INTRODUCTION

Humans have evolved superior cognitive skills compared to other primates (Roth & Dicke, 2005). The *cultural intelligence hypothesis* proposes that the complexity of humans' social environment fosters uniquely social cognitive capacities (Dunbar & Shultz, 2007; van Schaik & Burkhart, 2011; also see McNally, Brown, & Jackson, 2012) that 'bootstrap' the development of more general cognitive abilities (Herrmann, Call, Hernández-Lloreda, Hare, & Tomasello, 2007; Wobber, Herrmann, Hare, Wrangham, & Tomasello, 2014). Accordingly, what distinguish humans from other animals are skills within the social domain, such as the ability to teach and learn from each other, rather than any general cognitive skills (e.g., Tomasello, 2009a, 2009b).

Circumstantial evidence for the cultural intelligence hypothesis exists. Rudimentary cognitive abilities for processing social information are present shortly after birth (Farroni, Csibra, Simion, & Johnson, 2002; Goren, Sarty, & Wu, 1975). Important social cognitive skills, such as the ability to form *internal models* (i.e., the capability to predict and interpret other peoples' actions based on previous experiences; see Gredebäck, Lindskog, Juvrud, Green, & Marciszko, 2018) and *gaze following* (i.e., the ability to share attention with others based on their gaze direction) are evident before 6 months of age (Butterworth & Jarret, 1991; Gredebäck, Lindskog, et al., 2018). These abilities are critical for successful social interactions (Southgate & Vernetti, 2014) and transfer of social knowledge (Morales et al., 2000). Individual difference data also show that infant social cognition is predictive of future social-cognitive outcomes (Aschersleben, Hofer, & Jovanovic, 2008; Wellman, Phillips, Dunphy-Lelii, & LaLonde, 2004). Additionally, we know that including social stimuli in experimental learning tasks enhances infants' performance (Wu, Gopnik, Richardson, & Kirkham, 2011). This evidence speaks to the potential importance of the social domain

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for child cognitive development. Moreover cross-species comparisons reveal that children as young as 2–2.5 years of age have social cognitive skills superior to those of other primate species, while performance on physical-cognitive tasks (i.e., tasks assessing skills related to understanding quantity and causality) are comparable across species at this age (Herrmann et al., 2007; Wobber et al., 2014). Together these findings suggest that social cognitive skills in early childhood may be the driving force behind the ontogeny of humans' superior general cognitive skills.

So far, no study has provided robust support for the cultural intelligence hypothesis by showing that individual differences in preverbal infants' social cognition potentiate learning from the social environment and thus predicts later domain-general cognitive function. The present study was designed to test this hypothesis. We did this by following a large sample of children (N = 118) and their families from 6 to 18 months of age. At 6 months, we administered eye tracking based tests of two basic aspects of infant social cognition – *internal models* and *gaze following*. As an index of the quality of the child's social learning environment we used a structured observation assessment of *parental scaffolding behaviors* (i.e., parental behaviors that support children's autonomy and goals and enables them to achieve higher levels of problem-solving; Whipple, Bernier, & Mageau, 2011) during a parent–child interaction at 10 months. Eight months later, the children were followed up with a cognitive test-battery assessing executive functions, specifically *simple* and *complex inhibition* and *working memory*.

In this study, we operationalize children's cognitive development as executive function (EF). EF refers to domain-general cognitive abilities important for goal-directed behaviors that have been strongly linked to intelligence (Diamond, 2013). Early developing executive functions, such as being able to delay a response (i.e., *simple inhibition*), hold information in mind (i.e., *working memory*), and rely on one's working memory to inhibit a habitual motor response (i.e., *complex inhibition*) are suggested to emerge by the end of the first or second year of life (Garon, Bryson, & Smith, 2008). In this study, we assessed both working memory as well as simple and complex forms of inhibition. Crucially for the hypothesis being tested, there is abundant evidence that EF development is sensitive to the influence of the social environment (Carlson, 2009), particularly parental scaffolding behaviors (Bernier, Carlson, & Whipple, 2010).

We tested two hypotheses. The *first* predicts that better infant ability to follow gaze and to form internal models would be associated with better EF at 18 months. However, the *quality* of the social learning environment (here indexed by parental scaffolding ability) is also likely to matter. Therefore, we suggest that children who are better at understanding social signals are better equipped to make the most of existing scaffolding opportunities. Consequently, the *second hypothesis* states that if scaffolding opportunities are optimal (i.e., a parent with good scaffolding skills) *and* the child is skilled at understanding the socially conveyed information, then the child's cognitive development should benefit greatly. In statistical terms, we expected that the longitudinal relationships described in the first prediction would be moderated by parental scaffolding skills.

Research Highlights

- This longitudinal study investigated associations between infants' social cognitive skills, the quality of their social learning environment, and child non-social cognitive outcome in toddlerhood.
- We found that our two social cognitive measures were uncorrelated at 6 months, as were our three non-social executive function measures at 18 months.
- We report that individual differences in infants' social understanding potentiate learning from the social environment and predicts later inhibitory control skills.
- This work highlights the role of the social domain for children's non-social cognitive development.

2 | METHODS

2.1 | Participants and study design

Overall, 118 children (50% female) participated in the present study as part of an ongoing longitudinal project. Ages at the three measurement points included in this study were: 6 months (M = 185 days; SD = 7), 10 months (M = 302 days; SD = 9), and 18 months (M = 544 days; SD = 12). The participants were recruited from the sample of a population-based study in Uppsala, Sweden, investigating perinatal maternal health (Wesström, Skalkidou, Manconi, Fulda, & Sundström-Poromaa, 2014). The targeted sample size (≈120) was set prior to enrollment and based on practical convenience. At the first visit, 62% of the mothers and 52% of the children's other parents held a university degree, and all but one child lived with both parents.

The study was approved by the local ethics review committee (EPN) in Uppsala, Sweden, and conducted in full compliance with the Helsinki Declaration. The study required parental written consent for participating prior to the start of the study and at each subsequent visit. Participating families received a gift voucher (≈30 €) at each visit as compensation for participation.

2.2 | Measures

Infant social cognition was assessed using eye tracking measures of *Internal Models* and *Gaze Following* at 6 months.[1] The quality of the child's learning environment was based on structured observations of *Parental Scaffolding* at 10 months, and child *EF* was assessed at 18 months. See Figure 1 for an illustration of the tasks.

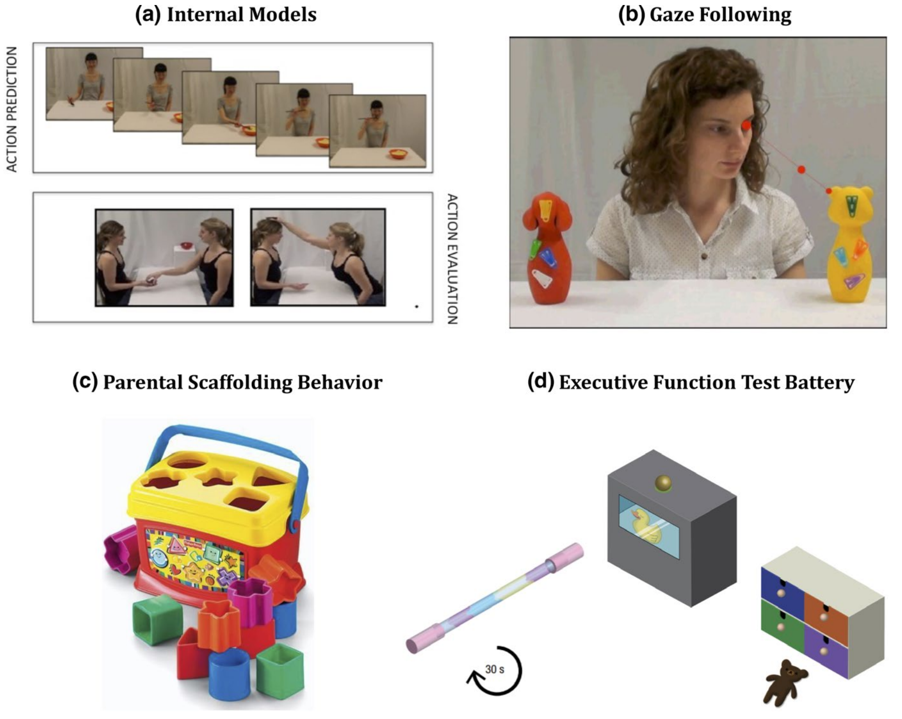

FIGURE 1 Illustration of the test battery at 6, 10, and 18 months. (a) *Internal Models*: A combined measure of infants' ability to predict (top) and evaluate other people's actions (bottom; left = appropriate trial; right = inappropriate trial); (b) *Gaze Following*: Measure of infants' first look to the correct (gazed-cued) versus incorrect object. (c) *Parental Scaffolding*: Parental scaffolding behaviors were coded from video recordings of parent–child interactions during play with a challenging shape-sorting toy; and (d) Child *EF* was assessed on three standard tasks and coded from video recordings: The Prohibition task (left; *Simple Inhibition*), the Tricky-Box task (middle; *Complex Inhibition*); and a Hide-and-Seek task (right; *Working Memory*)

2.2.1 | General eye tracking procedure

Infants' eye-movements were recorded by a Tobii TX300 (set to 60 Hz; Tobii Technology AB). Experimental stimuli were presented on a 23-inch monitor from a 60-cm viewing distance. Data collection was preceded by a 5-point calibration. See Supplemental Material for a detailed description of the pre-processing of the eye tracking data.

Internal models

Following Gredebäck, Lindskog, et al. (2018), this is a combined measure of infants' *action prediction* and *action evaluation* scores (r = .41, p < .000). The measure was constructed by first reversing the action prediction variable and then averaging standardized scores from the two tasks. The *action prediction* and *action evaluation* tasks are described briefly below (see Gredebäck, Lindskog, et al., 2018 for detailed task information). Positive values on this measure indicate that the participant was faster at predicting goal-related actions (i.e., action prediction) and/or reacted with more surprise when events unfolded in an inappropriate way (i.e., action evaluation).

Action prediction

The *Action Prediction* task (based on Green, Li, Lockman, & Gredebäck, 2016) consisted of six trials assessing the infants' ability to predict that a spoon will go to an actor's mouth during an eating action. We calculated an action prediction score based on the average saccadic reaction time over trials at which infants made a fixation to the mouth relative to when the spoon left the bowl. Negative values indicate that infants fixated within the mouth-AOI before the spoon arrived at the AOI and was defined as a predictive gaze shift. To be included in the analysis, the infant needed to provide at least two valid trials. Infants on average contributed 3.5 (out of 6) valid trials at 6 months.

Action evaluation

The *Action Evaluation* task (modeled on Gredebäck & Melinder, 2010) consisted of 12 trials, with six appropriate and six inappropriate actions, that is, a 'giver' gave a 'receiver' an object (block) in their outstretched upraised palm (give-me gesture; appropriate trial) or put it on top of the head of the 'receiver' (inappropriate trial). For each trial, we defined a baseline period (1,000 ms) and an analysis period (3,000 ms) relative to when the 'giver' grasped a block in the bowl, and we measured the change in pupil size between baseline and analysis period. The outcome measure was calculated as the difference between the mean change in pupil size during inappropriate and appropriate trials leading to a total of six trials. Positive values indicate larger pupil dilatation on inappropriate trials (i.e., surprise). To be included in the analyses, the children had to contribute at least two trials and on average they contributed with 3.5 trials.

Gaze Following

The *Gaze Following* task consisted of six trials and stimuli were taken from the gaze direction condition used in previous studies (e.g., Gredebäck, Astor, & Fawcett, 2018). Each trial started with a scene showing a female actor who was seated centrally behind a table and her face was facing downwards (2 s). Two colorful toys were positioned evenly spaced on either side of the table in front of her. Following a beeping sound, the actress raised her head and looked at the camera and then turned her head and gazed toward one of the two toys (6 s). We calculated a difference score of first looks to gazed-cued object (i.e., number of correct first looks minus number of incorrect first looks) and this served as our outcome measure. To be included in the analysis, the infant needed to provide at least two valid trials. The mean number of valid trials was 5.95 (out of 6) at 6 months.

Parental scaffolding

The assessment and coding of *Parental Scaffolding* were based on work by Whipple et al. (2011). Parent–infant dyads were presented with a challenging shape-sorting toy and were instructed to explore the toy together; then the experimenter left the room for 4 min. Based on video recordings, parental scaffolding behavior was coded on four scales (intervene according to child's need, encourage the child, takes the child's perspective, and follow the child's pace) ranging from 1 (not supportive) to 5 (extremely supportive). The scales were significantly correlated (*rs* = .66–.89) and averaged into a parental scaffolding score (Cronbach's α = .94). Interrater reliability, established by intra-class correlation for a randomly selected subset of 27 interactions, was satisfactory (ICC = 0.68).

Executive functioning

Executive functioning was assessed with three tasks targeting *simple inhibition*, *complex inhibition*, and *working memory* (see Gottwald, Achermann, Marciszko, Lindskog, & Gredebäck, 2016 for additional details) During these assessments the child was placed in a high chair or on his/her parent's lap at a table in front of the experimenter.

Simple inhibition

Simple inhibition was assessed with the Prohibition task (Friedman, Miyake, Robinson, & Hewitt, 2011). The experimenter presented an attractive toy (a colorful and glittering wand) by holding it in front of her. She then made eye contact with the child, shook her head and said: 'now, ("child's name"), you are *not* allowed to touch this' while simultaneously placing the toy on the table within the child's reach. The experimenter then looked down with a neutral face. After 30 s, or earlier if the child had already touched the toy, the experimenter looked up and said: 'It's OK, you can touch it now'. The outcome variable was the latency to touching the toy, with a maximum of 30 s. Interrater reliability, based on a randomly selected subset of 20 cases, was excellent (ICC = 1.0).

Complex inhibition

Complex inhibition was assessed with a version of the tricky-box task (modeled on Garon, Smith, & Bryson, 2014). The child was presented with a black box with a plexiglas window openable only by pulling a knob attached to the top. Following a warm-up phase, when the child got to practice opening the window, the child was shown an attractive toy (color-changing plastic duck). In the subsequent four test trials, the toy was placed behind the window inside the box. Then the experimenter pushed the box forward and asked the infant to get the toy. If the infant reached only for the window, the experimenter waited for 10 s and then pointed to the knob and said, 'You have to pull here!' If the infant still did not pull the knob, the experimenter opened the window by pulling the knob and took out the toy and gave it to the infant.

The participants' performance on each trial were coded from videos in the following manner: reaching directly for the knob (2 points); reaching for the window first, but then self-correcting and reaching for the knob (1 point); not reaching for the knob within 10s (0 points). The mean score overall test trials was used as the outcome variable in the analyses. Interrater reliability, established by Cohen's Kappa on a randomly selected subset of 20 cases, was excellent (*Kappa* = 0.98).

Working memory

Working memory was assessed with a hide-and-seek task (Garon et al., 2008). A small table chest of four differently colored drawers was used as hiding locations. After two warm-up trials, in which a toy was hidden and the child searched for it without time delay, four test trials were performed. On each trial, the experimenter hid the toy in one of the drawers, in full view of the infant, while simultaneously saying: 'Now I am hiding it here.' She then covered the chest with a cloth. After 5 s the experimenter pushed the chest forward and asked the infant to search for the toy. If the infant did not find the toy, the experimenter said, 'Where is it?' to motivate further search. The infant could search for the toy a maximum of four times before the experimenter started a new trial. The toy was hidden in a new location on each trial in a fixed order. The test trials were coded from videos for successful searches in the following manner: The child received a score of 4, 3, 2, or 1 according to whether they were successful on the first, second, third, or fourth attempt, respectively. Children who did not succeed after four attempts were given a score of 0. The mean score over all test trials was calculated and used as the outcome measure. Interrater reliability, based on a randomly selected subset of 20 cases, was excellent (*Kappa* = 0.96).

2.3 | Statistical analyses

All analyses were performed in SPSS version 24. Data were examined for non-normality to render parametric statistics valid. Graphical inspections of Q-Q plots, histograms, and values of skewness and kurtosis (see Table 1) indicated acceptable distributions for all outcome measures. Missing data were handled by using the expectation-maximization (EM) algorithm to support analysis with the full sample of 118 child-parent dyads. This technique is superior to approaches such as deletion, mean-substation, and prior imputation approaches (e.g., Baraldi & Enders, 2010). The EM technique is recommended to be used to minimize bias and improve power when data are missing at random (e.g., Scheffer, 2002), which was the case according to Little's MCAR test (p > .05).

We investigated the role of infant social cognition in EF assessed at 18 months (Hypothesis 1), by correlating gaze following and internal models with the three EF measures. Furthermore,

TABLE 1 Descriptive data for all variables at 6 months, 10 months, and 18 months

	M	*Md*	*SD*	*Skewness*	*Kurtosis*
Social cognition 6 months					
Internal models	0.00	−0.19	0.84	0.16	−0.19
Gaze following	0.54	0.00	1.94	0.14	0.67
Social learning environment 10 months					
Parental scaffolding	2.78	2.75	0.75	−0.06	−0.71
Executive functions 18 months					
Simple inhibition	6.07	1.34	9.80	1.65	1.50
Complex inhibition	0.92	0.97	0.54	0.22	−0.60
Working memory	2.81	2.75	0.59	0.22	−0.10

we ran regression analyses through the SPSS macro PROCESS v 3.0 (Hayes, 2018) to study interaction effects between each infant social cognitive measure and parental scaffolding abilities in predicting toddler EF (Hypothesis 2). The number of bootstrap resamples was set to 1,000 with 95% confidence intervals. Gaze following and internal models were entered as predictor variables in a series of OLS regression models together with the moderator variable (parental scaffolding). Each of the three EF measures was used as an outcome variable in separate models. Significant interaction effects were followed up examining conditional effects (simple slopes analyses) of the regression slopes at the 16th, 50th, and 84th percentiles of the moderator. All hypothesis-related analyses were adjusted for multiple statistical testing using the false discovery rate-method (Benjamini & Hochberg, 1995).

3 | RESULTS

Table 1 shows descriptive data (*M*, *Md*, *SD*, *skewness*, and *kurtosis*) for child social-cognitive outcomes at 6 months, parental scaffolding behavior at 10 months, and child executive function at 18 months.

Intercorrelations of all variables are presented in Table 2. Gaze following and internal models were uncorrelated, as were the three EF measures. Parental scaffolding was correlated with simple inhibition (r = .20, CI = 0.02 to 0.38, p = .031), but unrelated to the other two EF measures as well as to gaze following and internal models.

3.1 | Hypothesis testing

3.1.1 | Testing hypothesis 1

We examined if infant ability to follow gaze and to form internal models would be positively associated with EF at 18 months. Our results showed that internal models (r = .23, CI = 0.01–0.43, p = .031) and gaze following (r = .20, CI = 0.05–0.36, p = .047) at 6 months were significantly correlated with simple inhibition, but not with the other two EF measures at 18 months (see Table 2).

3.1.2 | Testing hypothesis 2

We investigated if the association between social cognitive abilities and EF would be moderated by parental scaffolding skills. Table 3 presents the results of the interaction effects between social cognitive functions and parental scaffolding. For simple inhibition, the interaction between internal models and parental scaffolding was positive and statistically significant and accounted for 6% of the variance (R^2 Δ = .06, p = .008). The significant interaction effect is illustrated in Figure 2. No other interactions effects were significant.

TABLE 2 Intercorrelations among social cognitive variables, parental scaffolding, and child EF, N = 118

	1	2	3	4	5	6
1. Internal models	–	−0.03	0.12	0.23*	0.05	−0.02
2. Gaze following		–	0.02	0.20*	0.02	0.07
3. Parental scaffolding			–	0.20*	0.01	0.01
4. Simple inhibition				–	−0.04	0.00
5. Complex inhibition					–	0.13
6. Working memory						–

*p < .05.

TABLE 3 Regression models of interaction effects between infant social cognitive functions at 6 months and parental scaffolding at 10 months in the prediction of executive functions at 18 months, *N* = 118

	Executive functions								
	Simple inhibition			Complex inhibition			Working memory		
	b	*SE*	95% CI	*b*	*SE*	95% CI	*b*	*SE*	95% CI
Internal models									
Internal models	2.26*	1.03	0.22 to 4.29	0.03	0.06	−0.09 to 0.15	−0.01	0.07	−0.15 to 0.12
Parental scaffolding	2.32*	1.15	0.05 to 4.59	0.00	0.07	−0.13 to 0.14	0.01	0.07	−0.14 to 0.16
Internal models × parental scaffolding	3.99*	1.47	1.08 to 6.90	−0.03	0.09	−0.20 to 0.14	0.06	0.10	−0.13 to 0.25
Gaze following									
Gaze following	0.99*	0.46	0.09 to 1.89	0.01	0.03	−0.04 to 0.06	0.02	0.03	−0.03 to 0.08
Parental scaffolding	2.56*	1.18	0.23 to 4.89	0.01	0.07	−0.12 to 0.14	0.01	0.07	−0.14 to 0.16
Gaze following × parental scaffolding	−0.03	0.68	−1.36 to 1.31	−0.04	0.04	−0.11 to 0.04	−0.02	0.04	−0.11 to 0.06

Note: b = Unstandardized coefficient, *SE* = standard error of b.
*$p < .05$.

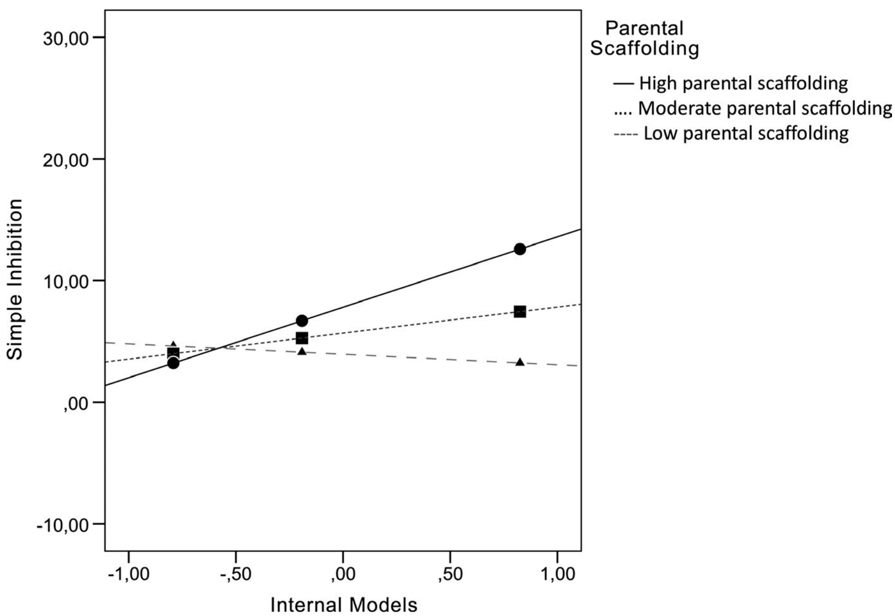

FIGURE 2 The conditional effect of internal models at 6 months on simple inhibition at 18 months as a function of parental scaffolding. The simple slopes at and above moderate level of parental scaffolding are significantly different from zero

Conditional effects of internal models at values of the moderator showed that the regression slope at low values (16th percentile) of parental scaffolding was not significant (b = 2.00, 95% CI = −3.98–2.26, t = −0.55, SE = 1.58, p = .586) whereas the regression slope at moderate (50th percentile; b = 2.75, 95% CI = 0.09–4.17, t = 2.07, SE = 1.03, p = .041) and high values (84th percentile; b = 5.79, 95% CI = 2.59–8.99, t = 3.58, SE = 1.61, $p < .001$) of parental scaffolding were significant different from zero. In other words, the level of internal model functioning is less important for the development of simple inhibitory ability when parental scaffolding ability is low. In contrast, when parental scaffolding ability is moderate to high, the level of internal models predicts simple inhibition, with better internal models predicting better inhibitory control.

4 | DISCUSSION

In this longitudinal study, we examined individual differences in preverbal infants' social cognition, the quality of their social learning environment, and their subsequent cognitive development. Our study showed that infants who were better at sharing attention through gaze following and forming internal models of other people's actions at 6 months exhibit better cognitive outcomes at

18 months, specifically the ability to delay a response, that is, simple inhibition. This suggests that early emerging social cognitive abilities that help infants to follow and understand other people's goal-related actions provide a mechanism for the development of inhibitory control.

Our results also revealed that the relationship between internal models and simple inhibition was moderated by the quality of the child's social learning environment, here indexed by parental scaffolding behaviors. Thus, infants with a better social understanding appear to be better equipped to make use of existing learning opportunities in social interactions. As suggested by previous work (van Schaik & Burkart, 2011), learning through high-quality social interactions is more beneficial for cognitive development than individual explorations. High-quality parental scaffolding behaviors involves providing the child with optimal adjustment of support, respecting the child's pace, and ensuring that the child plays an active role during tasks, which enables the child to perform beyond their current ability (Bernier et al., 2010). This set of parenting behaviors possibly leads to more frequent opportunities for the child to learn and may over time, through day-to-day interactions, provide a mechanism for the development of child self-regulatory (i.e., executive function) abilities (Carlson, 2009). Previous work has shown that parental scaffolding behavior assessed at 15 months predicts EF at 18 months of age (Bernier et al., 2010), but to date, no previous study has investigated the role of parental scaffolding for later EF development in children as young as 10 months of age.

The results from this study provide support for the idea that social cognitive skills in early childhood may be a driving force behind the development of domain-general cognitive skills, in line with the cultural intelligence hypothesis (e.g., Dunbar & Shultz, 2007; van Schaik & Burkhart, 2011). The cultural intelligence hypothesis proposes that human's unique cognitive achievements are rooted in species-unique social cognitive abilities that also make humans predisposed to teach and learn from each other (e.g., Tomasello, 2009a, 2009b). Thus, humans' special aptitudes are suggested to be within the social domain. Previous cross-species comparisons between 2 and 2.5-year-old children and chimpanzees have provided support for this idea by showing species differences in the social cognitive, but not in the physical-cognitive domain (Herrmann et al., 2007; Herrmann, Hernández-Lloreda, Call, Hare, & Tomasello, 2010). Our study expands the aforementioned work by showing that individual differences in human infants early emerging social cognitive skills is predictive of future cognitive outcomes within the non-social domain.

However, our results must be viewed with some caution as we only found significant associations between infant social cognitive skills and parental scaffolding behavior in relation to simple response inhibition, but not to the other two EF outcomes (i.e., complex inhibition and working memory) at 18 months. This lack of associations may be attributed to differences in developmental demands between the EF measures, with the development of simple inhibition preceding the development of complex inhibition and working memory. The development of EF is generally seen as a hierarchical process where simpler skills lay the foundation for more complex abilities. Simple forms of inhibition, such as delaying the impulse of reaching for something interesting, develops around the latter half of the first year of life. More complex skills, such as updating information (i.e., working memory) and coordinating updating of information and response inhibition (i.e., complex inhibition), become apparent around 15–24 months of age (e.g., Garon et al., 2008). Thus, this could mean that by the time of our EF assessment at 18 months, simple inhibition is a relatively established ability compared to the other two EF measures that are still under rapid development. Indeed, the lack of correlations between the three EF tasks in our study suggest a developmental dissociation between these measures when assessed in early toddlerhood (but see Wiebeet al., 2011 for evidence of a unitary EF structure at age 3 years).

One alternative hypothesis is that the simple inhibition task, which involves obeying the instruction not to touch an interesting toy, involves higher linguistic demands than the other two EF tasks, and better social cognitive abilities lead to better language comprehension (e.g., Tomasello, 1988). However, the lack of significant correlations between linguistic understanding and performance on the EF tasks (rs = −.13 to 0.13, ps = 0.21 to 0.52) render this hypothesis implausible (see Table S3). In any case, future work should attempt to determine if associations between infant social cognitive skills and more complex EF skills may be found at a slightly older age in childhood.

It was somewhat surprising that gaze following was associated with simple inhibition only when assessed at 6 months, as our supplemental analysis showed no such association at 10 months (see Supplemental Material). However, this is in keeping with findings from other preliminary analyses on the same study sample that gaze following, in general, has different patterns of correlation with other variables at 6 and 10 months and thus likely involves different underlying mechanisms (Astor et al., 2019). Similarly, we found no association between our two social cognitive measures (i.e., gaze following and internal models). Again, this suggests that the measures may involve underlying dissociable skills.

Finally, it is important to mention that other early developmental sources of EF, not controlled for in this study, have been proposed. For example, several authors have suggested that low-level visual attention control, such as selective or sustained attention, might be one important precursor (e.g., Garon et al., 2008; Johansson, Marciszko, Gredebäck, Nyström, & Bohlin, 2015; Posner & Rothbart, 2000). Another proposal highlights the potential role of early prospective motor control for subsequent EF development (e.g., Gottwald et al., 2016; Ridler et al., 2006). An interesting future line of work would be to examine concurrent links between social cognition, visual attention control, and prospective motor skills in infancy and their subsequent predictability of EF development. Such work would not only be of relevance from a theoretical standpoint but could also inform the development of new interventions targeting EF in early development.

In conclusion, in this longitudinal study, we report associations between two basic social cognitive skills in infancy (i.e., gaze following and internal models) and simple inhibitory control in toddlerhood.

We further show that high-quality parental scaffolding skills moderates the association between internal models and inhibitory control. Thus, the present findings implicate the child's social cognitive skills and highlight the role of the social learning environment for the later development of non-social cognitive skills.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

CM, BK, ML, MF, and GG contributed to the study design. CM, LF, and ML contributed to the recruitment of participants and acquisition of data. CM and LF performed the data analysis, and all authors contributed to the interpretation of the results. CM and LF drafted the first versions of the manuscript, and all authors provided critical revisions. CM and LF contributed equally to this work and share first authorship. All authors approved the final version of the manuscript for submission.

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ENDNOTE

[1] Prior to any data analysis, the initial aim was to study the social cognitive predictors, *Internal Models* and *Gaze Following*, at 6 and 10 months of age. However, the construction of the conceptual predictor *Internal Models* was not feasible at 10 months due to a lack of correlation between action prediction and action evaluation at this age ($p < .05$). This was attributed to questionable validity of the tasks at this age as described in Gredebäck et al. (2018). First, 87% of the infants predicted the action in the action prediction task, indicating a ceiling effect. Second, action evaluation data indicated that infants at 10 months no longer reacted with surprise to the displayed irrational actions as they did at 6 months. A true developmental decrease in surprise is not expected between these ages, but an explanation may rather be that the current stimuli were too decontextualized for older infants to be surprised (Gredebäck et al., 2018). Therefore, we focused our main analyses on the social cognitive predictors assessed at 6 months. However, for transparency, descriptive data of the eye tracking measures and gaze following results using the 10-month data are presented in Tables S1 and S2.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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