Beliefs about the development of mental life

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0.1 Abstract

In a series of large-scale studies we assessed how US adults conceptualize the development of the human mind over the first five years of life. Exploratory factor analysis identified four categories of mental capacities that anchored participants' representations of the developing human mind: *bodily sensations*, *negative affect*, *social connection*, and *cognition and control*. Participants perceived that these four aspects of mental life were present to different degrees at birth, followed different developmental trajectories, and were driven by different developmental mechanisms (e.g., biological "preprogramming," physical maturation, passive observation, social learning). These studies reveal the lay theories that govern US adults' understanding of the development of the human mind, illuminating the cognitive architecture that supports some of the most important social interactions: caregiving relationships with infants and children.

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Frustration, compassion, worry, humor, imagination, love—such experiences are fundamental parts of human life. But few people would assert that these capacities are fully developed at birth. In any given interaction with a child, adults come face to face with a being whose experience of the world is like their own, but different; whose mind is capable of some of the thoughts and feelings that an adult's mind is, but perhaps not all of them. When an adult interacts with the same child over time, they witness innumerable changes in that child's mental life: A sleepy newborn gradually becomes a child who experiences complex emotions and original ideas and develops personal memories and intricate plans. This familiar but remarkable transformation requires adults to make inferences about a given child's developing mental capacities in order to interpret that child's behaviors and respond appropriately.

In this paper, we examine how adults conceptualize the developing minds of infants and children. We draw on techniques developed in studies of mind perception, in which researchers use large datasets and modern statistical methods to reveal conceptual representations of "the mind," broadly construed. In a groundbreaking study, Gray et al. asked participants to compare the mental capacities of a range of humans, animals, technologies, and other entities, and argued that participants' judgments revealed a fundamental distinction between "agency" (e.g., capacities for self-control, moral reasoning, memory, and planning) and "experience" (e.g., capacities for hunger, fear, pain, and pleasure) (Gray, Gray, and Wegner 2007). More recently, Weisman et al. used a similar empirical approach to argue that people's conceptions of mental life are anchored by three fundamental components: "body" (physiological sensations such as hunger and pain), "heart" (social-emotional abilities such as embarrassment and pride), and "mind" (perceptual-cognitive capacities such as vision and memory (Weisman, Dweck, and Markman 2017b)); see (Malle 2019) for a similar three-factor solution.

However, the burgeoning field of mind perception has largely neglected the question of how the mind emerges over development. In many studies, infants and children have simply not been included as targets for mental capacity attributions; instead, participants have been asked to reason about human adults alongside a range of non-human entities, including other animals, technologies, and supernatural beings. Even studies that have probed participants' mental capacity attributions to infants and children have generally treated them as beings distinct from adults, rather than as snapshots of a single mind as it emerges and changes over time. For example, Gray et al.'s early work on mind perception suggested that a five-month-old infant is an entity that is generally considered to have experience but not agency—in contrast to, say, a five-year-old child (considered to have experience as well as limited agency), a human adult (considered to have maximal experience and agency), or a robot (considered to have agency but not experience) (Gray, Gray, and Wegner 2007). Likewise, Weisman et al.'s studies characterized infants and young children—along with, e.g., chimpanzees, elephants, and dolphins—as entities that are perceived to be fully capable of physiological sensations but more limited in their perceptual-cognitive capacities and social-emotional abilities; this is in contrast to human adults, who are perceived to be fully capable across these domains (Weisman, Dweck, and Markman 2017b).

Although such findings can be reinterpreted as providing preliminary evidence that people consider the minds of infants and children to differ from the minds of adults, they do not address how people conceptualize the development of the mind in early life.

Of course, infants and young children are far from unusual social partners. Caregiving relationships are at the core of human existence; for many people, infants and young children are among the most frequent and highly valued minds that we encounter. Caring for a young child involves making countless decisions under uncertainty: Why is my child crying, smiling, shouting, or biting? Can they understand what I am saying? Does my child love me? As in other domains of reasoning (Gerstenberg and Tenenbaum 2017; Gopnik and Wellman 1994; Wellman and Gelman 1992), people likely draw on folk beliefs and intuitive theories about how the mind develops to predict, explain, and respond to children's behavior and development, with consequences for the well-being of children in their care.

In the current studies we set out to investigate this important and understudied aspect of mind perception: how ordinary people reason about the development of human mental life. In three studies, we assessed US adults' folk beliefs about children's developing abilities for physiological sensation, perception, cognition, emotion, self-regulation, social interaction, and other aspects of "mental life," broadly construed. We focused on development between birth and age five years—a time of particularly dramatic maturation in perceptual acuity, emotional experience, cognitive ability, executive function, social engagement, and many other domains.

1 Results

1.1 Study 1

We began with an expansive exploration of US adults' attributions of mental life to infants and young children of different ages. Drawing inspiration from previous work on mind perception (Gray, Gray, and Wegner 2007; Weisman, Dweck, and Markman 2017b, 2017a, 2018) as well as standard assessments of infant temperament and behavior (Putnam, Gartstein, and Rothbart 2006; Rothbart 1978), we included a wide range of 60 capacities in this initial exploration, from basic physiological sensations, to capacities for perception, cognition, and emotion, to abilities for self-regulation and social interaction. We asked participants ($n = 301$) to assess these capacities at three different ages (at birth, 9 months, and 5 years), with the goal of characterizing the conceptual structure underlying participants' reasoning about the development of mental life: What do people perceive to be the fundamental components of mental life, as they pertain to a developing human child?

We designed Study 1 to explore the correlational structure of participants' responses, as a window into the underlying conceptual structure that might support their reasoning about the development of mental life. Our primary analysis for this preregistered study was an exploratory factor analysis (EFA) of participants' capacity ratings. This analysis allowed us to examine which capacities tend to "hang together" in participants' assessments of the mental lives of infants and young children. For example, when a participant indicated that newborns are highly capable of feeling scared, what other capacities did they tend to attribute to newborns? Following previous work on mind perception, we argue that the suites of capacities revealed by applying dimensionality reduction (in our case, EFA) to this covariance structure offer a meaningful approximation of the latent conceptual structure underlying participants' reasoning about the developing human mind.

A 4-factor solution (as suggested by parallel analysis) accounted for 72% of the total variance in participants' capacity attributions. See Figure 1 for all factor loadings after oblique transformation.

The first factor corresponded primarily to capacities related to thinking, reasoning, agency, and executive function—a suite of capacities that we will refer to as *cognition and control*. It was the dominant factor for such items as "planning," "having self-control," "thinking before they act," "having goals," "reasoning about things," "controlling their emotions," "telling right from wrong," and "understanding what somebody else is thinking," and accounted for 38% of the shared variance in the rotated 4-factor solution and 27% of the total variance in participants' capacity attributions.

The second factor corresponded primarily to social abilities and emotional experiences, particularly those with positive valence—a suite of capacities that we will refer to as *social connection*. It was the dominant factor for such items as "feeling excited," "finding something funny," "loving somebody," "learning from other people," "feeling happy," "feeling loved," "recognizing somebody else," and "getting pleasure from music," and accounted for 33% of the shared variance in the rotated 4-factor solution and 24% of the total variance in participants' capacity attributions.

The third factor corresponded primarily to physiological sensations related to biological needs—a suite of capacities that we will refer to as *bodily sensations*. It was the dominant factor for such items as "getting hungry," "feeling pain," "feeling tired," "feeling thirsty," "feeling too hot or too cold," "feeling physically uncomfortable," "hearing sounds," and "being comforted by physical touch," and accounted for 19% of the shared variance in the rotated 4-factor solution and 14% of the total variance in participants' capacity attributions.

Finally, the fourth factor corresponded to negatively-valenced sensations and emotions—a suite of capacities that we will refer to as *negative affect*. It was the dominant factor for the items "feeling helpless," "feeling overwhelmed," "feeling frustrated," "feeling annoyed," and "feeling neglected"; the items "feeling distressed," "feeling confused," "feeling worried," and "feeling lonely" also loaded relatively strongly on this factor (albeit slightly more strongly on other factors). This factor accounted for 10% of the shared variance in the rotated 4-factor solution and 7% of the total variance in participants' capacity attributions.

How robust are these findings? The factors we have called *bodily sensations*, *social connection*, and *cognition and control* each had strong factor loadings (≥ 0.60) for many individual items ($n = 8$-16) and each accounted for a substantial amount of the total variance in participants' capacity attributions (14-27%), indicating three robustly distinct and interpretable factors. In contrast, the fourth factor—*negative affect*—had more moderate loadings even for its strongest-loading items (all loadings < 0.46) and accounted for only 7% of the total variance. Nonetheless, we consider the general domain of *negative affect* to be of particular theoretical and clinical interest.

It is worth noting that a handful of items loaded relatively strongly on two factors (loadings ≥ 0.40), suggesting that these factors are not entirely distinct. The item "feeling distressed," for instance, loaded roughly equally strongly on both *bodily sensations* and *negative affect*—perhaps reflecting the idea that "distress" might be experienced both as a physical sensation (like pain) and an affective state (like frustration). Likewise, "seeing" loaded equally strongly on both *bodily sensations* and *social connection*—perhaps reflecting an understanding of vision as both a sensory ability and a critical part of many social interactions (eye contact). The relatively large degree of overlap between *cognition and control* and *social connection*, in particular, might indicate that participants believed these two constructs to be more strongly connected than other aspects of life; in fact, these two factors were the most strongly correlated of all pairs of factors ($\phi = 0.65$). (The next strongest correlation was between *bodily sensations* and *social connection*: $\phi = 0.59$. All other inter-factor correlations: $\phi \leq 0.50$.)

What does it mean that these four factors emerged? At a most basic level, our results reflect sets of intercorrelated capacities: When a participant judged that a child of a certain age was highly capable of planning, they also tended to judge that that child was capable of having self control, thinking before they act, and the other capacities with strong factor loadings on the *cognition and control* factor; and likewise for the suites of capacities that define the other factors revealed by EFA. Therefore, we take these factors to reflect latent constructs—fundamental components of mental life relevant to reasoning about human children (Weisman, Dweck, and Markman 2017b). Moreover, because each participant was asked to reason not just about some class of target characters (e.g., "chimpanzees," "robots"), but about the human child over development, we further propose that part of what contributed to the differentiation of these four factors was participants' perceptions of development: the extent to which different capacities are present at birth, the rate at which different capacities develop, and the mechanisms that drive this development. In Studies 2 and 3, we explore these possibilities in greater depth.

1.2 Study 2

In Study 2 ($n = 304$), we replicated the conceptual structure identified by Study 1 and then used it to chart how different aspects of mental life are perceived to change over development: What kinds of abilities do people believe are present at birth, and to what degree? To what extent are capacities for *bodily sensations*, *negative affect*, *social connection*, and *cognition and control* perceived to change over childhood, and what is the shape of this perceived developmental trajectory?

The design of Study 2 was nearly identical to Study 1, except that instead of assessing 60 capacities for 3 target ages, each participant assessed 20 capacities for 13 target ages. Capacities were chosen to represent the four domains of mental life identified through EFA in Study 1: *Bodily sensations* was represented by the items "getting hungry," "feeling pain," "feeling tired," "feeling physically uncomfortable," and "hearing sounds"; *negative affect* was represented by "feeling distressed," "feeling lonely," "feeling frustrated," "feeling helpless," and "feeling overwhelmed"; *social connection* was represented by "feeling excited," "finding something funny," "loving somebody," "learning from other people," and "feeling happy"; and *cognition and control* was represented by "planning," "having self-control," "reasoning about things," "controlling their emotions," and "telling right from wrong." Target ages were based on the developmental milestone ages identified by the CDC (Centers for Disease Control and Prevention 2021) and on the American Academy of

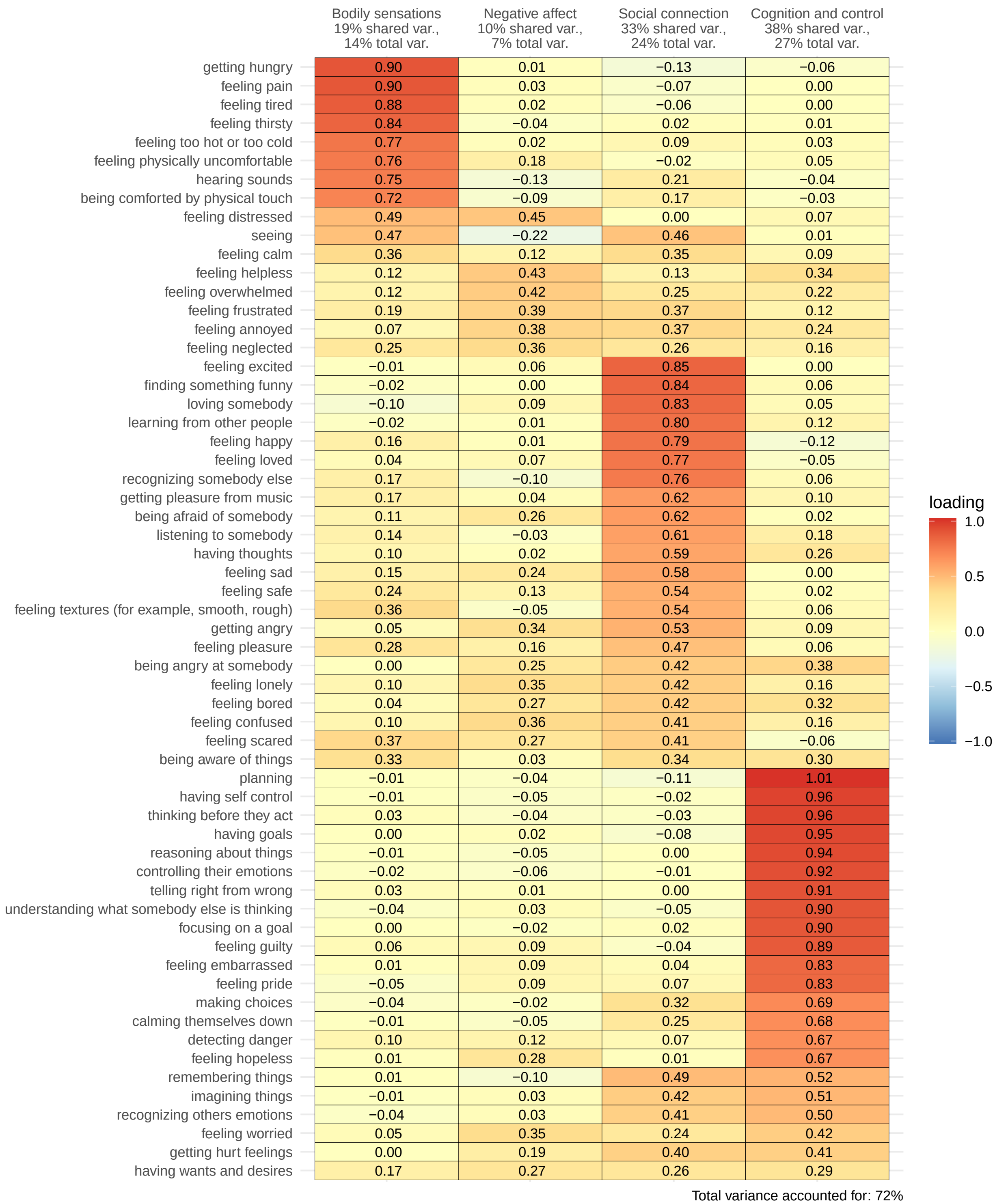

Figure 1: Factor loadings from an exploratory factor analysis of participants' capacity attributions to newborns, 9-month-old infants, and 5-year-old children in Study 1.

Pediatrics' recommendations for pediatrician visits (American Academy of Pediatrics 2018): birth, 4 days, 1 month, 2 months, 4 months, 6 months, 9 months, 12 months, 18 months, 2 years, 3 years, 4 years, and 5 years. This design allowed us to chart perceived developmental trajectories with a high degree of precision without undue burden to participants.

In terms of the covariance structure of participants' capacity ratings, a preregistered EFA yielded four factors very similar to the four factors from Study 1 (see Supplemental Materials), with all capacity items loading strongly on the factors that they were selected to represent. Minimally, these results suggest that our selection of mental capacities for this study captured the essential meaning of the four factors revealed in Study 1. Beyond this, we consider these results to be a somewhat independent conceptual replication of Study 1 results and validation of our interpretation of these factors. After all, given that Study 2 featured only 20 of the 60 capacities featured in Study 1, it certainly could have been the case that this analysis would suggest retaining fewer factors (as often occurs with fewer variables). Conversely, given that Study 2 featured 13 within-subjects observations for each capacity compared to the 3 in Study 1, this analysis could have surfaced more than four factors (as often occurs with more observations). Finally, if we had misinterpreted the fundamental semantic content that distinguished the factors in Study 1 and selected inappropriate capacities to represent these factors, the Study 2 analysis could have identified more capacities with cross-loadings. Instead, we believe the results of this analysis offer some validation of the four factors we have called *bodily sensations*, *negative affect*, *social connection*, and *cognition and control*.

Regressing participants' item-level responses onto target age, domain, and interactions between them (via a multilevel generalized additive model; see Methods) confirmed both of our preregistered hypotheses: On average, participants rated older children as more capable, but perceptions of the development of children's capacities differed dramatically across domains. On one extreme, participants attributed some, but relatively little, capacity for *cognition and control* to newborns (median score for newborns: 1.00 out of 100 points, $M =$ 8.24, $sd = 18.61$), but reported that such capacities increase dramatically over the target age range (average smoothing term, analogous to a slope in linear regression: $F = 3396.88$, $p < 0.001$, $edf = 8.13$). Compared to these attributions of *cognition and control*, participants attributed substantially greater capacities to newborns in the domains of *social connection* (median score for newborns: 45.00 out of 100 points, $M =$ 46.06, $sd = 37.30$; increase in log-odds relative to *cognition and control*: $\beta = 3.13$, $p < 0.001$) and *negative affect* (median score for newborns: 63.50 out of 100 points, $M = 56.24$, $sd = 38.04$; increase in log-odds: β $= 3.05$, $p < 0.001$) and, accordingly, reported relatively small increases over the target age range in both domains (average smoothing terms for *social connection*: $F = 2351.32$, $p < 0.001$, $edf = 8.63$; for *negative affect*: $F = 1535.93$, $p < 0.001$, $edf = 8.13$). At the other extreme, in the domain of *bodily sensations* participants attributed nearly maximal capacity to newborns (median score for newborns: 100.00 out of 100 points, $M = 86.42$, $sd = 24.28$; increase in log-odds relative to *cognition and control*: $\beta = 4.82$, $p < 0.001$) and a significant but small increase in capacities for *bodily sensations* over the target age range (average smoothing term: $F = 364.84$, $p < 0.001$, $edf = 6.07$). See Figure 2, Panel A.

Visual inspection of Figure 2, Panel A clearly illustrates that the shape of perceived growth in children's capacities varied substantially across domains. In the domain of *bodily sensations*, participants perceived hardly any growth over the target age range, and what growth they did perceive occurred in the first year of life. Participants perceived development in the domains of *negative affect* and *social connection* to be quite non-linear, characterized by rapid development over the first 1-2 years of life, at which point the curves level off dramatically. In contrast, participants perceived dramatic development in the domain of *cognition and control*, but perceived this development to unfold fairly steadily across the full age range.

We speculate that these differences in perceptions of growth in children's capacities emerge from intuitive theories of development that specify different mechanisms or drivers of development for different domains. For example, if participants believe that development in the domain of *bodily sensations* is primarily driven by innate biological forces, they might assume that most of this development is complete before birth, leaving little room for change over the target ages assessed (see (Berent, Platt, and Sandoboe 2019) for empirical evidence in line with this speculation). In contrast, in a domain where participants believe development depends on observation, exploration, or social learning, they might think that children need time in the world to change and grow, yielding lower estimates of capacities at birth and slower estimates of rates of change; or, in a domain where participants believe that development occurs through explicitly teaching the child something, they might perceive that development proceeds nonlinearly, such that large changes occur following specific milestones (e.g., entry to preschool). We explore this possibility in Study 3.

1.3 Study 3

Study 3 was designed with two goals in mind: First, we aimed to provide a more direct assessment of the differences in perceived developmental trajectories surfaced by Study 2. Second, we aimed to probe the lay theories that might underlie the differentiation of the four factors surfaced by Studies 1-2 and the perceived developmental trajectories surfaced by Study 2 (and the current study).

1.3.1 Perceived developmental trajectories

In Study 2, participants focused on one target age at a time, assessing a variety of capacities for that age before proceeding to the next target age (from youngest to oldest). This design was intended to encourage participants to focus primarily on providing a holistic assessment of mental life at a given target age; the trajectories connecting target ages were likely not the participants' primary concern in the moment of responding. In Study 3, we flipped the design to focus participants' attention on development more explicitly: Participants were asked to provide judgments of a single capacity for the full range of target ages (arranged from youngest to oldest) on the same "trial," before proceeding to the next capacity. In addition to signaling more strongly to participants that we were interested in their perceptions of development, this approach gave participants the opportunity to view and adjust all of their responses for a given target capacity simultaneously, charting out their perceptions of the full developmental trajectory from birth to age 5 years. In order to accommodate the addition of questions probing lay theories of development (see next section), participants assessed only 8 capacities: "getting hungry" and "feeling pain" (representing the domain of *bodily sensations*); "feeling distressed" and "feeling helpless" (*negative affect*); "learning from other people" and "feeling happy" (*social connection*); and "controlling their emotions" and "reasoning about things" (*cognition and control*).

The results of Study 3 yielded a very similar picture of US adults' understanding of the development of human mental life; see Figure 2, Panel B. As in Study 2, participants perceived that newborns have very little capacity for *cognition and control* (median score for newborns: 0.00 out of 100 points, $M = 4.49$, $sd = 12.69$), but reported that such capacities increase dramatically over the target age range (average smoothing term: $F = 1782.20$, $p < 0.001$, $edf = 8.45$). Again, participants attributed substantially greater capacities to newborns in the domains of *social connection* (median score for newborns: 10.00 out of 100 points, $M = 30.16$, $sd = 35.74$; increase in log-odds: $\beta = 3.15$, $p < 0.001$) and *negative affect* (median score for newborns: 60.00 out of 100 points, $M = 55.10$, $sd = 42.02$; increase in log-odds: $\beta = 3.49$, $p < 0.001$); in Study 3, as in Study 2, participants reported relatively small increases over the target age range in the domain of *negative affect* (average smoothing term: $F = 748.53$, $p < 0.001$, $edf = 8.45$), but in this case they reported quite dramatic increases in the domain of *social connection* ($F = 1744.70$, $p < 0.001$, $edf = 8.85$). Finally, as in Study 2, in the domain of *bodily sensations* participants attributed nearly maximal capacity to newborns (median score for newborns: 100.00 out of 100 points, $M = 89.21$, $sd = 23.20$; increase in log-odds relative to *cognition and control*: $\beta = 6.00$, $p < 0.001$) and a significant but small increase in capacities for *bodily sensations* over the target age range (average smoothing term: $F = 175.99$, $p < 0.001$, $edf = 8.13$). See Figure 2, Panel B.

Visual inspection of Figure 2, Panel B makes it clear that the shape of these perceived developmental trajectories varied substantially across domains, echoing quite precisely the results of our post-hoc exploratory analyses in Study 2. In the domain of *bodily sensations*, participants perceived hardly any growth over the target age range, and what growth they did perceive was understood to occur rapidly in the first year of life. In the domains of *negative affect* and *social connection*, participants perceived much more growth over the target age range, and in both cases most of this growth was understood to occur during the first two years of life; again, this was especially pronounced in the domain of *social connection*. Finally, participants perceived development in the domain of *cognition and control* to be much more gradual and, by extension, more linear across the target age range.

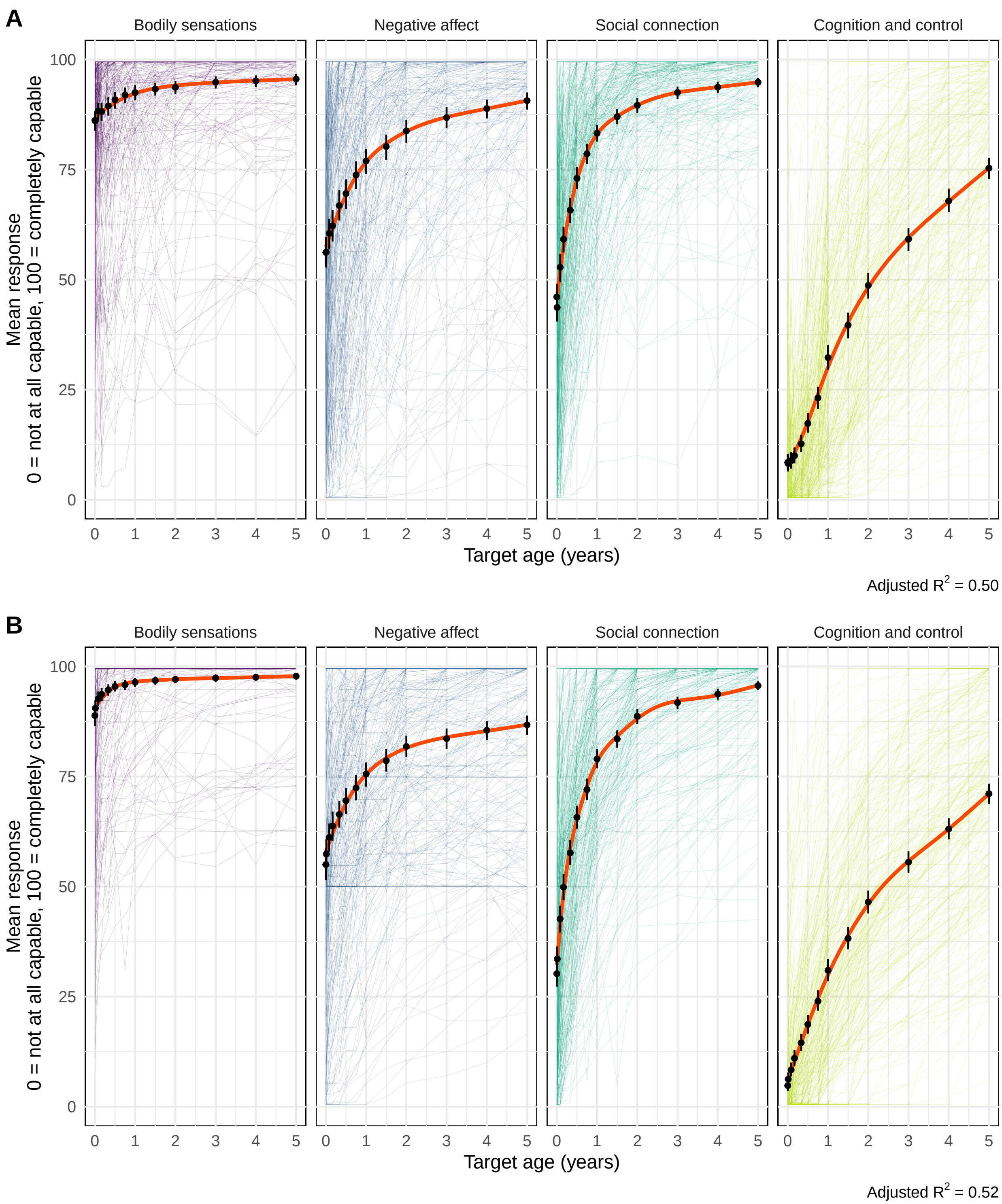

Figure 2: Perceived developmental trajectories for four domains of mental life (Studies 2-3). Lighter lines represent individual participants' responses, black points correspond to mean responses across the sample, error bars are bootstrapped 95% confidence intervals, and thick red lines are predictions from our generalized additive models (beta regressions). In Study 2 (Panel A), participants assessed 5 capacities within each domain, and assessed all capacities for a given target age before moving on to the next target age. In Study 3 (Panel B), participants assessed 2 capacities within each domain, and assessed a single capacity for all target ages before moving on to the next capacity.

See Supplemental Materials for the full results of this analysis.

1.3.2 Lay theories of development

Why do people believe certain aspects of mental life, but not others, to be present at birth? What do people perceive to be driving the development of capacities for *bodily sensations*, *negative affect*, *social connection*, and *cognition and control*? As a first step in what we hope to be a longer line of work addressing such questions, we asked participants to assess the importance of a variety of possible developmental mechanisms for each of the capacities included in this study. We theorized that when people perceive that a capacity is substantially present at birth, they believe that the capacity is innate, and, conversely, that when people perceive that a capacity develops slowly over years, they believe the capacity is in some sense learned. (See (Wang 2019; Berent, Platt, and Sandoboe 2019; Berent, Feldman Barrett, and Platt 2020) for in-depth investigations of ordinary people's intuitions about the innateness of cognitive abilities, motor abilities, and emotion.)

We assessed a wide range of potential developmental mechanisms for children's capacities, and gave participants opportunities to endorse nuanced, even internally inconsistent theories of development, by having them assess each of these developmental mechanisms for each capacity independently in addition to selecting the "most important" mechanism via forced choice.

A variety of dimensionality reduction techniques (see Supplemental Materials) converged to suggest that participants perceived the ten developmental mechanisms we included in this study as falling into two general categories (with some indications of two sub-groups within each of these general categories). First, there were what we will call "intrinsic" mechanisms, including those whose influence occurs prior to a child's birth ("the child is biologically 'preprogrammed' to have this ability," "the child has experiences in the womb that give them this ability") and those whose influence continues into infancy and childhood ("the child's body grows and matures [for example, muscles get stronger, child gets taller]," "the child's senses improve [for example, vision gets sharper, hearing improves]"). Participants clearly distinguished these intrinsic mechanisms from what we will call "extrinsic" mechanisms, which included both passive forms of learning ("the child observes the objects and the physical world around him or her," "the child observes the people around him or her," "the child interacts with the people around him or her") and more active forms of learning ("people explicitly teach the child how to do this," and "the child actively experiments with how to do this"). One mechanism—"the child's brain changes (for example, brain grows bigger, more or fewer connections between neurons)"—was difficult to categorize as "intrinsic" or "extrinsic," with different analyses suggesting different conclusions; indeed, on its face this item is more ambiguous and could refer both to intrinsic maturational processes and to the effects of external experiences influencing brain circuitry. This item was eliminated from the analyses that follow (but included in the visualizations presented in Figure 3).

A multilevel linear regression suggested that, collapsing across domains, intrinsic and extrinsic mechanisms were rated as equally important (median score for intrinsic mechanisms: 2.78 on a scale from 0-6, $M = 2.81$, $sd = 1.00$; median score for extrinsic mechanisms: 3.35 on a scale from 0-6, $M = 3.38$, $sd = 0.97$; comparison: $\beta = 0.13$, 95% CI: [-0.07, 0.33], $p = 0.215$), but that the difference between intrinsic and extrinsic mechanisms varied across domains (interaction terms: $|\beta|$ ranged from 0.16-0.50, all $p < 0.001$).

For capacities in the domain of *bodily sensations*, participants rated intrinsic mechanisms as much more important drivers of development than extrinsic mechanisms (median of participant-level mean differences: -1.77 out of a maximum difference of $\pm$ 6 points, M_{diff} = -1.67, $sd = 1.18$; comparison to 0 in separate multilevel regression model: β = -0.36, 95% CI: [-0.63, -0.08], $p = 0.010$). In the domain of *negative affect*, participants rated intrinsic and extrinsic mechanisms as equally important (median of participant-level mean differences: 0.35, $M_{diff} = 0.32$, $sd = 1.23$; comparison to 0 in separate multilevel regression model: $\beta = 0.07$, 95% CI: [-0.19, 0.34], $p = 0.584$). In the domain of *social connection*, participants rated extrinsic mechanisms as more important (median of participant-level mean differences: 1.25, $M_{diff} = 1.29$, $sd = 1.10$; comparison to 0 in separate multilevel regression model: $\beta = 0.31$, 95% CI: [0.06, 0.56], $p = 0.016$), and this was even more the case for capacities in the domain of *cognition and control* (median of participant-level mean differences: 2.38, $M_{diff} = 2.34$, $sd = 1.42$; comparison to 0 in separate multilevel regression model: $\beta = 0.56$, 95% CI:

[0.35, 0.76], $p < 0.001$). See Figure 3, panels A-B, for a visualization of these differences, and Supplemental Materials for the full results of these analyses.

Participants' intuitions that different aspects of mental life are driven by different mechanisms were also reflected in their responses to the forced-choice questions about the "most important" factor driving the development of each of these capacities; see Figure 3, Panel C. Participants overwhelmingly chose intrinsic mechanisms for capacities in the domain of *bodily sensations* (94% of all responses), and also tended to choose intrinsic mechanisms for capacities in the domain of *negative affect* (52% of responses, compared to 28% extrinsic choices; the remaining response fell outside of this categorization scheme). On the whole, participants demonstrated no strong preference for intrinsic or extrinsic mechanisms in the domain of *social connection* (32% of responses, compared to 45% extrinsic choices). Finally, participants tended to choose extrinsic mechanisms for capacities in the domain of *cognition and control* (53% of responses, compared to 12% intrinsic choices).

In sum, participants' responses were consistent with the following intuitive theory: In all aspects of mental life, development is driven by a combination of intrinsic and extrinsic mechanisms, but the relative importance of these mechanisms varies across domains. Capacities for *bodily sensations* are shaped primarily by intrinsic biological mechanisms, such as biological "preprogramming"; in other words, they are largely innate. Conversely, the development of capacities for *cognition and control* is driven primarily by extrinsic mechanisms, i.e., by observing and interacting with the world. Capacities in the more social-emotional aspects of mental life are intermediate between these extremes, with both intrinsic and extrinsic mechanisms exerting substantial influence; but capacities for *social connection* might be distinguished from capacities for *negative affect* by their heightened sensitivity to extrinsic mechanisms (in particular, observing and interacting with other people).

2 Discussion

In a series of three large-scale studies, we identified four distinct suites of mental capacities that are perceived by US adults to develop over human infancy and early childhood, *bodily sensations*, *negative affect*, *social connection*, and *cognition and control* (Study 1); charted how these different aspects of mental life are perceived to change over the first five years of a child's life (Studies 2-3); and explored the lay theories that underlie the observed differences in the perceived developmental trajectories of these four aspects of mental life (Study 3).

We found that participants considered *bodily sensations* (e.g., hunger, pain) to be present from very early in an infant's life—in many cases, "preprogrammed" and present at birth—leaving relatively little room for development over childhood. In contrast (and in line with previous work (Wang 2019; Berent, Platt, and Sandoboe 2019)), participants considered capacities for *cognition and control* (e.g., planning, self-control) to be largely absent at birth and to develop steadily and gradually over the first five years of life, driven primarily by what we called "extrinsic" mechanisms (e.g., observations and interactions with other people, explicit teaching, and active exploration on the part of the child).

Beliefs about the development of the more social-emotional aspects of mental life—*negative affect* (e.g., distress, frustration) and *social connection* (e.g., love, learning from others)—were intermediate between the extremes of *bodily sensations* and *cognition and control*. In the aggregate, participants considered capacities for *negative affect* and *social connection* to be present to some degree, but not fully, from birth; and to develop rapidly in the first two years of life before tapering off. Likewise, participants reported that development in these capacities was driven by a *combination* of the extrinsic mechanisms just described and more "intrinsic" mechanisms, such as physical maturation and "preprogramming." Both in their perceptions and in their explanations of development, participants' understanding of *negative affect* were somewhat more similar to their responses to capacities for *bodily sensations*, while their responses to capacities for *social connection* more closely resembled their understanding of *cognition and control*. We note that attributions of *negative affect* and *social connection* were particularly variable across individual participants, especially when it came to perceptions of the capacities of newborns; see Figure 2. This suggests that beliefs about development in

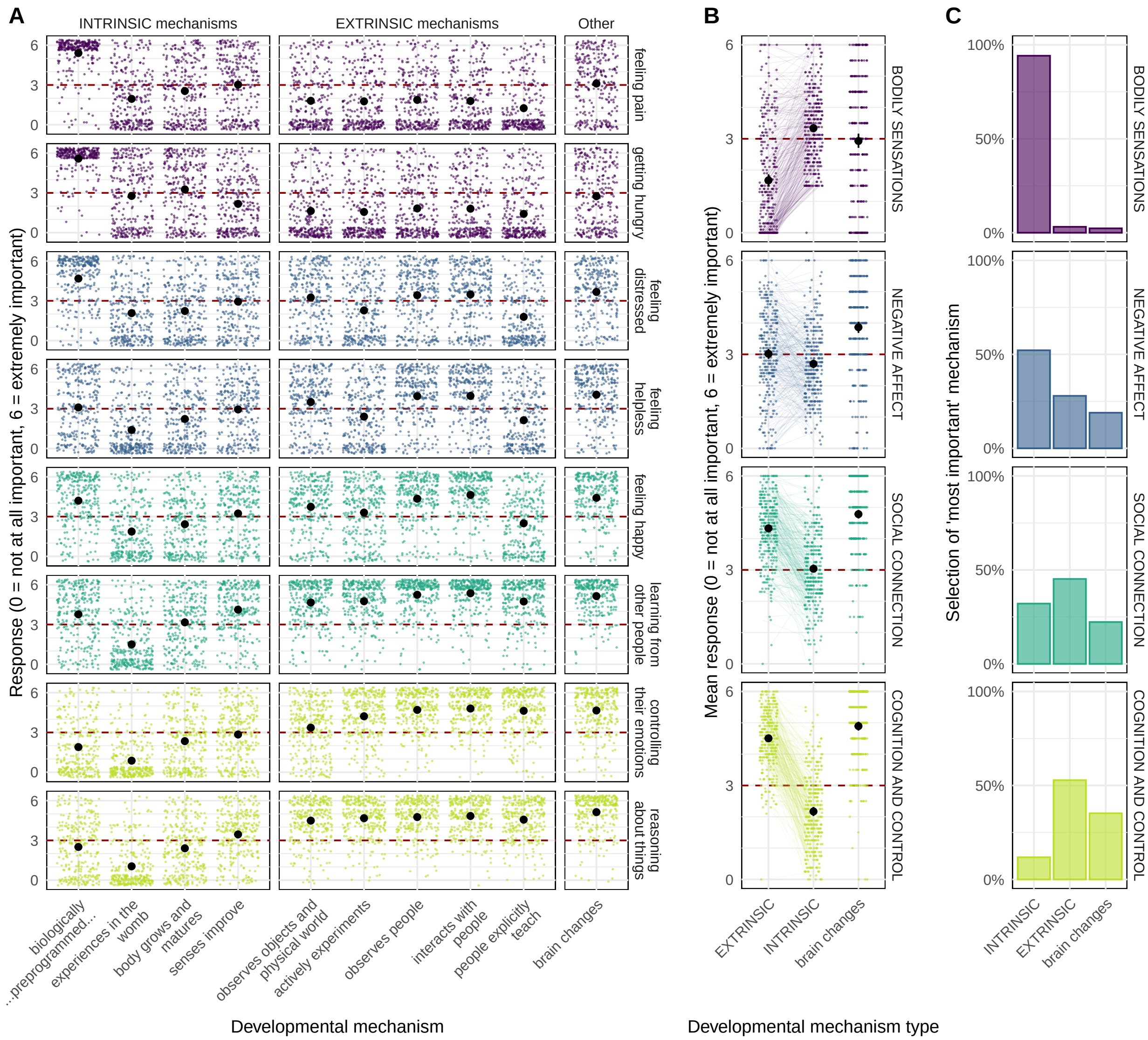

Figure 3: Perceived importance of various mechanisms in the development of four domains of mental life (Study 3); see main text for the full text of each mechanism. Panel A shows ratings for each developmental mechanism and both of the capacities within each domain; Panel B shows mean ratings for extrinsic vs. intrinsic mechanisms for each domain of capacities; and Panel C shows the percentage of trials on which participants selected extrinsic vs. intrinsic mechanisms as the 'most important' driver of development. Lighter points and lines represent individual participants' responses, black points correspond to mean scores across the sample, and error bars are bootstrapped 95% confidence intervals. The dotted red line at the midpoint of the response scale in Panels A and B is intended to aid visual comparison across domains.

these domains are especially sensitive to personal experience, social-cultural context, explicit education, or other forms of input.

In some respects, the results of these studies resonate well with previous work on mind perception among US adults. The factors that we refer to as *bodily sensations* and *cognition and control* highlight a sharp distinction between embodied, physiological experiences and the more cognitive and agentic aspects of mental life experiences—reminiscent of previous distinctions between “experience” and “agency” (Gray, Gray, and Wegner 2007), between “body” and “mind” (Weisman, Dweck, and Markman 2017b), and between “affect” and “regulation” (Malle 2019). These two factors were clearly evident in all of the factor solutions we examined, providing further evidence that this distinction is a particularly important aspect of how US adults reason about mental life. (See also (Weisman et al. 2021) for evidence that a distinction between bodily sensation and cognition is held in common across diverse cultural settings.)

However, these studies also highlight one way in which reasoning about the development of human mental life may diverge from reasoning about mental life in general: In their assessments of the mental lives of infants and children at different ages, participants differentiated between what we call *social connection* (e.g., capacities for excitement, humor, and love) and what we call *negative affect* (e.g., capacities for distress, helplessness, and frustration). These two factors have no obvious precedents in previous studies of mind perception. In the agency-experience framework (Gray, Gray, and Wegner 2007), *negative affect* would likely fall under the umbrella of “experience,” but *social connection* seems to combine aspects of both “experience” (e.g., happiness, sadness) and “agency” (e.g., learning, recognition); similarly, in Malle’s (2019) framework (Malle 2019), *negative affect* clearly resonates with “affect,” but *social connection* seems to combine aspects of both “regulation” and “reality interaction.” Meanwhile, in the body-heart-mind framework (Weisman, Dweck, and Markman 2017b), *social connection* and *negative affect* might both be considered part of the social-emotional domain of the “heart.” This difference from previous work could have many (or multiple) causes, including the wider range of capacities included in this study (in particular, the inclusion of capacities for feelings of helplessness, frustration, annoyance, neglect, loneliness, boredom, confusion, and being overwhelmed; see Supplemental Materials), or the narrower focus on humans (and, in particular, infants and children) as the targets of mind perception. Based on the findings of Studies 2 and 3, we propose that *social connection* and *negative affect* emerged as distinct factors because participants believed these two aspects of mental life develop differently: i.e., that they are present to different degrees at birth, develop at different rates over infancy and childhood, and are driven by different developmental mechanisms.

What do these studies reveal about US adults’ understanding of the contributions of nature vs. nurture to the development of human mental life? One consistent finding across these studies is that participants attributed many capacities to newborns, at least to a moderate degree. In addition to *bodily sensations* and *negative affect*—obvious aspects of a newborn’s experience of the world—participants also reported that newborns had fairly substantial social-cognitive abilities, including, critically, “learning from other people.” Indeed, in Study 4 participants considered biological “preprogramming” to play a rather important role in the ability to learn from other people, and to have some non-trivial impact even on the most purely cognitive ability included in that study, reasoning about things (see Figure 3). Rather than “intuitive empiricists” (Wang 2019; Berent, Platt, and Sandoboe in press), then, US adults might be better described as “intuitive constructivists” who viewed newborns as predisposed and innately equipped to learn from the people around them.

Adults’ intuitive theories are likely to have important consequences for the children in their care (Haimovitz and Dweck 2016; Hembacher and Frank 2020; Mukhopadhyay and Yeung 2010). We suspect that intuitive theories of the development of mental life could play a particularly important role in the quality of caregiver–child relationships in the first few years of a child’s life. During this period, caregivers cannot rely on children to clearly communicate through words; instead, caregivers often must *infer* what children think and feel. These inferences critically depend on the adult’s understanding of what the child is and is not capable of, and what scaffolding it would take for that child to become more capable. There is evidence of this across domains of development. For example, parent language use becomes more diverse and complex as children age and in concert with developing sophistication of the child’s own language competence (Rowe, Pan, and Ayoub 2005; Huttenlocher et al. 2010), and parents interact differently depending on whether a child is crawling versus walking (Karasik, Tamis-Lemonda, and Adolph 2014) or holding versus looking at an object (West and Iverson 2017). Likewise, representations of children's mental lives, including their sensations, perceptions, emotions, cognitive abilities, executive function, and social skills have been shown to play a critical role in guiding adults' expectations of a child, their reactions to that child's actions, and the nature and development of their relationship with the child (Vreeswijk, Maas, and Bakel 2012; Feldman and Reznick 1996). Caregivers' capacity to form an accurate representation of their child's internal states and to use this representation to guide their caregiving behavior (so called "mind-mindedness") is positively associated with children's wellbeing, including attachment security, theory of mind, and ultimately, school readiness (Meins et al. 2012, 2013; Bernier, McMahon, and Perrier 2017).

Critical next steps in this line of research, then, will involve assessing which aspects of adults' beliefs and theories about the development of mental life facilitate the kinds of caregiving behaviors that are most appropriate in a given cultural setting, most in line with caregivers' own values and goals, or most beneficial for children according to experts. For example, in a recent study drawing on similar foundations to the studies reported here, parents who attributed greater mental capacities to young children in general expressed more interest in and curiosity about their own young child's mental states, and, in turn, reported engaging in more positive parenting behaviors (Salo et al. 2021) (see also (Laranjo, Bernier, and Meins 2008)). An additional goal is to identify the gaps and misconceptions in these theories that might lead caregivers to over- or under-estimate a child's abilities and thus misinterpret the child's behaviors, miss opportunities to support the child's development, experience concern about their child's developmental progress, or even engage in neglectful or abusive behaviors toward the child. Identifying the antecedents of individual differences in these beliefs could be an especially important step for such clinically-focused applications. As is the case in many domains (Weisman and Markman 2017), interventions that leverage the power of intuitive theories to encourage positive and responsive caregiving behaviors hold great promise for creating meaningful and lasting behavioral changes in caregiver behavior, with important consequences for child wellbeing.

3 Methods

Methods, inclusion/exclusion criteria, and analyses marked as "preregistered" were preregistered on the Open Science Framework (OSF) website: (Study 1: https://osf.io/e6ajh/); Study 2: https://osf.io/j72dg; Study 3: https://osf.io/xh8ce/)). All studies were approved by the Stanford University Internal Review Board.

Note: This is a fully reproducible manuscript, written in RMarkdown using the "knitr" package for R (Xie 2021). The full, editable script for all analyses, figures, and tables (here and in the Supplemental Materials) is available in the .Rmd file that generated this document, which can be found in the following GitHub repository: https://github.com/kgweisman/baby_mental_life_ms.

3.1 Study 1

3.1.1 Participants

301 US adults participated via Amazon Mechanical Turk (MTurk) in July–August 2018. To be eligible for the study, participants were required to have gained approval for at least 95% of their previous work on MTurk, with at least 50 HITs completed; have MTurk accounts based in the US; indicate that they were between the ages of 18-45 years; and report that their English abilities were either "advanced" or "superior" (not "novice," "intermediate," or decline to provide information about English ability). Participants were paid $2.00 for approximately 10-15 minutes of their time.

According to self-report, participants ranged in age from 19-45 years (M = 31.37 years, sd = 5.75 years) and included more men (59%) than women (41%; <1% of participants identified as some other gender or declined to disclose). Participants predominantly identified as White (66%; <15% identified as any other race/ethnicity, identified as more than one race/ethnicity, or declined to disclose). 51% of participants had obtained at least a Bachelor's degree. 44% of participants indicated that they were parents.

An additional 77 participants completed the study but were excluded for failing one or more (out of three) embedded attention checks (e.g., failing to choose "34" in response to the question "Please select 34") or for indicating via a multiple choice question at the end of the survey that they had not paid attention, had not avoided distractions, or had not taken the study tasks seriously.

3.1.2 Materials and procedure

After completing a screening questionnaire (in which participants provided information about their gender/sex, age, and English abilities) and providing informed consent, participants were provided with an overview of the study, as follows: "In this study, we will ask you about the mental capacities of children of different ages, from newborns to 5-year-olds. We will show you example photos of children at three of the following ages to remind you of what children look like at that age, but please think about children of that age in general when answering these questions. There are 60 brief questions for each of the three ages (for example, 'To what extent is a newborn capable of feeling happy?'), followed by a few demographic questions about yourself. We are interested in your opinions about these questions. Please do not look up extra information about these questions—we just want to know what you think." Participants were shown an array of pictures of children at several target ages between 0-5 years; see "Target ages and accompanying photographs," below.

Participants then proceeded through three trials in which they assessed the mental lives of children at three target ages: birth, 9 months, and 5 years. On each trial, they were shown two representative photographs of children at the target age (with the photograph labeled "newborns," "9-month-olds," or "5-year-olds"), and asked to answer the following question for 60 capacities: "To what extent is a [newborn/9-month-old/5-year-old] capable of [this capacity]?" Participants responded on a sliding scale from 0 (labeled as "not at all capable") to 100 (labeled as "completely capable").

On the final page of the survey, participants were asked to provide additional demographic information.

3.1.2.1 Capacities The 60 capacities included in Study 1 were drawn from several areas of previous research. Our goals in selecting items were to: (1) balance the representation of the conceptual organization underlying mental capacity attributions in general, as identified in previous work (Gray, Gray, and Wegner 2007; Weisman, Dweck, and Markman 2017b; Malle 2019); (2) add items relevant to early development, as identified by existing measures of temperament and behavior in early life (Weisman, Dweck, and Markman 2017a, 2018); and (3) assess the broadest range of mental capacities within financial and participant burden constraints, as identified by extensive discussions among the authors drawing on our own research and clinical experience with infants and young children.

This process yielded a list of 60 capacities. Roughly half of this list (29 of 60 items) were drawn from (or closely based on) the items included in Weisman et al.'s recent studies (Weisman, Dweck, and Markman 2017b): "being aware of things," "feeling calm," "feeling embarrassed," "feeling guilty," "feeling happy," "feeling love," "feeling pain," "feeling pleasure," "feeling pride," "feeling sad," "feeling safe," "feeling scared," "feeling tired," "getting angry," "getting hungry," "getting hurt feelings," "having goals," "having self-control," "having thoughts," "having wants and desires," "hearing sounds," "making choices," "planning," "reasoning about things," "recognizing others' emotions," "recognizing somebody else," "remembering things," "seeing," and "telling right from wrong." By extension, the list included close variants on 14 of the 20 capacities evaluated in Gray et al.'s original study (Gray, Gray, and Wegner 2007).

The other half (31 of 60 items) were novel items, not used in previous studies of mind perception, but common in clinical assessments of infant temperament and behavior: "being afraid of somebody," "being angry at somebody," "being comforted by physical touch," "calming themselves down," "controlling their emotions," "detecting danger," "feeling annoyed," "feeling bored," "feeling confused," "feeling distressed," "feeling excited," "feeling frustrated," "feeling helpless," "feeling hopeless," "feeling lonely," "feeling neglected," "feeling overwhelmed," "feeling physically uncomfortable," "feeling textures (for example, 'smooth,' 'rough')," "feeling thirsty," "feeling too hot or too cold," "feeling worried," "finding something funny," "focusing on a goal," "getting pleasure from music," "imagining things," "learning from other people," "listening to somebody," "loving somebody," "thinking before they act," and "understanding what somebody else is thinking."

(See Supplemental Material for an item-by-item comparison of the capacities used here to those used in previous studies of mind perception (Gray, Gray, and Wegner 2007; Weisman, Dweck, and Markman 2017b, 2017a; Malle 2019).)

Capacities were presented in a random order each time they were displayed (i.e., order varied across both target ages and participants).

3.1.2.2 Target ages and accompanying photographs In planning this series of studies, we selected 13 target ages based on the developmental milestone ages identified by the CDC (Centers for Disease Control and Prevention 2021) with the addition of the American Academy of Pediatrics' recommendations for pediatrician visits before 2 months (American Academy of Pediatrics 2018): birth, 4 days, 1 month, 2 months, 4 months, 6 months, 9 months, 12 months, 18 months, 2 years, 3 years, 4 years, and 5 years. We limited Study 1 to just the youngest, median, and oldest target ages—presented to participants as "newborns," "9-month-olds" and "5-year-olds"—in order to maximize the number of capacities included in the study without over-burdening participants.

In selecting photos for each target age, we aimed to have photos of the same (or very similar-looking) children at all target ages so as to emphasize the question of the development of mental capacities over the course of an individual child's early life. We chose to illustrate each target age with two photos in order to emphasize that we were interested in children's mental capacities in general, rather than the experiences of a particular child in a particular moment. We also presented participants with instructions that underscored this point (see above). We included one boy and one girl at each target age in order to generalize across perceived sex/gender differences in children's early mental life. We used photographs of two (apparently) White, non-Hispanic children, for three reasons: (1) In order to avoid introducing spurious differences across target ages by confounding a target's age and race/ethnicity; (2) In order to match the anticipated race/ethnicity of the majority of participants on MTurk; and (3) Because of the limited set of high-resolution photographs of individual children of color at different points of development currently available to us. Conducting similar studies of adults' perceptions of the development of mental life with more ethnically and racially diverse participants, and examining the effects of sex, gender, race, and ethnicity on adults' perceptions of children's mental life, will be critical next steps in this line of research.

Target ages were presented in chronological order, with participants first assessing all 60 capacities for newborns, then 9-month-old infants, and finally 5-year-old children.

3.1.3 Analysis plan

To conduct the EFAs reported in Results, we proceeded as if each participant's ratings of the 60 mental capacities for each of the three target ages were a distinct source of data; in other words, as if we had 903 participants assessing one target age each, instead of 301 participants assessing three target ages each. (See (Weisman, Dweck, and Markman 2017b; Weisman et al. 2021), for similar treatments of within-subjects data in the context of EFA.) We used Pearson correlations to obtain minimal residual solutions and applied an oblique transformation (oblimin) to the resulting factor structures, using the "psych" package for R (Revelle 2021).

In order to determine how many factors to retain, we examined the results of three factor retention protocols: (1) Parallel analysis, which compares the observed correlation structure to the correlation structure arising from random datasets of the same size; (2) Minimizing the Bayesian Information Criterion (BIC), which is one method of optimizing both goodness of fit and parsimony; and (3) A set of factor retention criteria that have been used in Weisman et al.'s previous work (Weisman, Dweck, and Markman 2017b), in which they retained factors with eigenvalues greater than 1.0, which individually accounted for greater than 5% of the shared variance before transformation or rotation, and which were the "dominant" factor (the factor with the strongest absolute factor loading) for at least one mental capacity after transformation (a factor had to meet all three of these criteria in order to be retained). Our interpretation of how best to characterize our dataset (i.e., how many factors we observe) was guided by the degree of consensus among these three protocols and the interpretability of the retained factors under each protocol.

Parallel analysis suggested a 4-factor solution (accounting for 72% of the total variance); minimizing BIC suggested a 6-factor solution (accounting for 74% of the total variance); and Weisman et al.'s (2017) factor retention criteria suggested a 2-factor solution (accounting for 68% of the total variance). We present the 4-factor solution in Results because it was of intermediate size and because we judged the factors it revealed to be intelligible and of theoretical interest; see Supplemental Materials for the other solutions.

3.2 Study 2

3.2.1 Participants

304 US adults participated via MTurk in August 2018. Eligibility requirements were identical to Study 1. Participants were paid \$2.90 for approximately 15-20 minutes of their time. In response to the overrepresentation of men in Study 1, in Study 2 we recruited men and women through separate "Human Intelligence Tasks" (HITs).

According to self-report, participants ranged in age from 19-45 years ($M = 32.14$ years, $sd = 6.32$ years) and (per our recruitment strategy) included roughly equal numbers of men (51%) and women (49%). Participants predominantly identified as White (75%; <11% identified as any other race/ethnicity, identified as more than one race/ethnicity, or declined to disclose). 50% of participants had obtained at least a Bachelor's degree. 41% of participants indicated that they were parents.

An additional 90 participants completed the study but were excluded for failing one or more (out of four) attention checks or indicating that they had not paid attention (see Study 1).

3.2.2 Materials and procedure

After completing a screening questionnaire (in which participants provided information about their gender/sex, age, and English abilities) and providing informed consent, participants were provided with an overview of the study that was nearly identical to that used in Study 1.

Participants then proceeded through 13 trials in which they assessed the mental lives of children at 13 target ages: birth, 4 days, 1 month, 2 months, 4 months, 6 months, 9 months, 12 months, 18 months, 2 years, 3 years, 4 years, and 5 years. On each trial, they were shown two representative photographs of children at the target age, and asked to answer the following question for 20 capacities: "To what extent is a [newborn/4-day-old/etc.] capable of [this capacity]?" As in Study 1, participants responded on a sliding scale from 0 (labeled as "not at all capable") to 100 (labeled as "completely capable").

On the final page of the survey, participants were asked to provide additional demographic information.

3.2.2.1 Capacities In order to ask participants to assess a more fine-grained array of target ages without undue participant burden, we limited our list of capacities to 20 of the 60 capacities used in Study 1. To identify this list, we drew on the results of Study 1, selecting 5 items for each of the 4 factors identified there. For each factor, we aimed to select items that loaded strongly on that factor, did not cross-load strongly on other factors, were sufficiently distinguishable from each other in meaning (i.e., not overly redundant), and captured our qualitative understanding of the latent construct that each factor corresponded to.

To represent *bodily sensations*, we chose the following items: "getting hungry," "feeling pain," "feeling tired," "feeling physically uncomfortable," and "hearing sounds." In the oblimin-transformed 4-factor solution from Study 1 all of these items had loadings ≥ 0.75 on this factor, and absolute loadings ≤ 0.21 on the other three factors.

To represent *negative affect*, we chose the following items: "feeling distressed," "feeling lonely," "feeling frustrated," "feeling helpless," and "feeling overwhelmed." In Study 1 all of these items had loadings $\geq$ 0.35 on this factor, and absolute loadings $\leq$ 0.49 on the other three factors. As these numbers suggest, this was a difficult factor to represent, because there were no items that loaded very strongly on the factor (highest loading: 0.45) and because the highest-loading items tended to cross-load on other factors as well. Nonetheless, we decided to try to represent this latent construct because of its theoretical interest and potential clinical importance.

To represent *social connection*, we chose the following items: "feeling excited," "finding something funny," "loving somebody," "learning from other people," and "feeling happy." In the oblimin-transformed 4-factor solution from Study 1 all of these items had loadings $\geq$ 0.79 on this factor, and absolute loadings $\leq$ 0.16 on the other three factors.

Finally, to represent *cognition and control*, we chose the following items: "planning," "having self-control," "reasoning about things," "controlling their emotions," and "telling right from wrong." In the oblimin-transformed 4-factor solution from Study 1 all of these items had loadings $\geq$ 0.91 on this factor, and absolute loadings $\leq$ 0.11 on the other three factors.

Capacities were presented in a random order each time they were displayed (i.e., order varied across both target ages and participants).

3.2.2.2 Target ages and accompanying photographs The target ages for this study (birth, 4 days, 1 month, 2 months, 4 months, 6 months, 9 months, 12 months, 18 months, 2 years, 3 years, 4 years, and 5 years) were based on the developmental milestone ages described in Study 1. The pairs of photos used to illustrate each target age were identical to those used in Study 1; see Study 1, Methods, for more information.

As in Study 1, target ages were presented in chronological order, with participants first assessing all 20 capacities for newborns, then 4-day-old infants, then 1-month-old infants, and so forth.

3.2.3 Analysis plan

3.2.3.1 Preregistered confirmatory analysis of conceptual structure Based on the results of Study 1, we predicted that the correlational structure of participants' responses would reveal four underlying constructs corresponding to the four factors we identified in Study 1: *bodily sensations*, *negative affect*, *social connection*, and *cognition and control*. To test this hypothesis, we performed an EFA, following the methods established in Study 1. We predicted that, using the same guidelines we applied for conducting and interpreting EFA in Study 1, we would find support for a 4-factor solution, with factors that were similar to the factors revealed in that study (e.g., similar groups of capacities that loaded strongly on any given factor).

In line with our predictions, both parallel analysis and Weisman et al.'s (2017) factor retention criteria (Weisman, Dweck, and Markman 2017b) suggested a 4-factor solution, which accounted for 75% of the total variance in participants' capacity attributions. In this solution, all items loaded most strongly on the factors that they were selected to represent. Minimizing BIC suggested an 8-factor solution (accounting for 78% of the total variance); see Supplemental Materials.

3.2.3.2 Preregistered confirmatory analysis of perceived developmental trajectories We preregistered two hypotheses about the perceived developmental trajectories we anticipated to observe in Study 2. (1) We predicted that, on average, participants' perception of children's mental capacities would increase as a function of the target child's age, with participants generally attributing more and greater abilities to older children; and (2) We predicted that, in the domains of *cognition and control* and *social connection*, participants would perceive relatively more dramatic developmental changes extending later into childhood (i.e., lower intercepts and steeper slopes), whereas in the domains of *bodily sensations* and *negative affect* participants would perceive relatively smaller changes across development (i.e., higher intercepts and shallower slopes).

To test these hypotheses, we conducted a multilevel beta regression via a generalized additive model, regressing item-level responses onto the domain (i.e., which of the four "factors" this capacity was selected to represented) and a spline-based smooth of the target age of the child fitted separately for each domain, including the maximal random effects structure that would allow the model to converge. Using the "mgcv" package for R (Wood 2017), we specified this model as follows: *gamm(response ~ s(target age in years, by = domain) + domain, random = list(subject ID = ~1, capacity = ~1)*. Attempting to model random slopes for domain or for target age resulted in model convergence problems. Responses were rescaled to range from 0.005 to 0.995 in order to satisfy the constraints of the beta distribution. Domain was dummy-coded with *cognition and control* as the baseline.

These tests deviated slightly from the preregistered analysis. We originally planned to use "factor scores" (which take into account participants' responses to all 20 items and the relations of those items to all 4 factors) rather than the summary scores described above as our dependent variable for these tests. We planned to derive these factor scores by projecting Study 2 data into the conceptual space defined by the factor solution for Study 1; however, this projection was impossible to implement, because Study 2 included only a subset of the variables used in Study 1. Furthermore, upon reflection, we decided that using any kind of factor scores (even factor scores derived only from Study 2 data) would be inappropriate for testing our hypotheses, which hinge on assessing the *absolute* degree to which participants attributed different aspects of mental life to children of different ages; factor scores, which function much like z-scores, are instead designed to capture individual differences in responses (i.e., the degree to which a given participant attributed relatively greater or lesser capacities compared to the average of all participants).

In addition, we note that we originally planned to use a multilevel linear regression to analyze these scores. However, we now consider it misguided to model participants' responses using gaussian distribution, because—both in principle and in our empirical dataset—capacity ratings behaved asymptotically, plateauing near the ceiling of the scale (100, labeled "completely capable") at some point in development. The approach described here—using the beta distribution—is a far more accurate representation of these responses. Using generalized additive models via the "mgcv" package for R (Wood 2017) allowed us to fine-tune the shape of these perceived developmental trajectories via spline-based smoothing (analogous to fitting polynomial terms in the context of linear regression, but without specifying in advance the order of the polynomials included in the model).

3.3 Study 3

3.3.1 Participants

301 US adults participated via MTurk in April 2019. Eligibility requirements were identical to Studies 1-2. Participants were paid $2.90 for approximately 15-20 minutes of their time. As in Study 2, we recruited men and women separately.

According to self-report, participants ranged in age from 18-45 years ($M = 31.67$ years, $sd = 5.78$ years) and (per our recruitment strategy) included roughly equal numbers of men (53%) and women (47%). Participants predominantly identified as White (67%; <12% identified as any other race/ethnicity, identified as more than one race/ethnicity, or declined to disclose). 53% of participants had obtained at least a Bachelor's degree. 34% of participants indicated that they were parents.

An additional 79 participants completed the study but were excluded for failing two or more (out of eight) embedded attention checks or for failing to provide a reasonable response in well-formed English sentences to an open-ended comprehension check included at the end of the survey.

3.3.2 Materials and procedure

After completing a screening questionnaire (in which participants provided information about their gender/sex, age, and English abilities) and providing informed consent, participants were provided with an overview of the study, as follows: "In this study, we will ask you about the mental capacities of children of different ages. We will show you example photos of children at each of the following ages to remind you of what children look like at that age, but please think about children of that age in general when answering these questions. We will ask you about 8 different mental capacities: feeling happy, getting hungry, controlling emotions, feeling distressed, feeling pain, reasoning about things, learning from other people, and feeling helpless. For each mental capacity, we will ask you to assess the extent to which newborns (at birth) have this mental capacity, then 4-day-olds, 1-month-olds, 2-month-olds, 4-month-olds, and so on, ending with 5-year-olds. We'll also ask for your opinion about the different factors that might influence the development of these capacities, such as the child being 'preprogrammed' to have certain abilities, or the child learning from the people or objects around him or her. At the end of the survey, we will ask you a few demographic questions about yourself. We are interested in your opinions about these questions. Please do not look up extra information about these questions—we just want to know what you think."

Participants then proceeded through eight trials, in which they assessed each of the eight capacities in turn; the order of capacities was randomized across participants. On each trial, participant assessed children at all 13 target ages used in Study 2 in a fixed order from youngest to oldest. Each age was presented along with a representative pair of photographs (also used in Studies 1 and 2), and participants were asked to answer the following question: "To what extent is a [newborn/4-day-old/1-month-old/etc.] capable of [this capacity]?" Participants responded on a sliding scale from 0 (labeled as "not at all capable") to 100 (labeled as "completely capable").

On each trial, at the bottom of the page participants completed a set of questions about the possible mechanisms that drive development for the capacity in question. First, they were asked, "In your opinion, how important is each of the following factors in the development of children's capacity for [capacity]?" They provided independent ratings on a Likert-type scale from 0 (labeled as "not at all important") to 6 (labeled as "extremely important"), for the following 10 developmental mechanisms: "the child is biologically 'preprogrammed' to have this ability"; "the child has experiences in the womb that given them this ability"; "the child's body grows and matures (for example, muscles get stronger, child gets taller)"; "the child's brain changes (for example, brain grows bigger, more or fewer connections between neurons)"; "the child's senses improve (for example, vision gets sharper, hearing improves)"; "the child observes the objects and the physical world around him or her"; "the child observes the people around him or her"; "the child interacts with the people around him or her"; "people explicitly teach the child how to do this"; "the child actively experiments with how to do this." These items were presented in a fixed order (roughly, from what we perceived to be the most innate or biological mechanisms of development, to what we perceived to be the most learned or social). They were then provided an opportunity to write in "any factors that play a role in the development of children's capacity for [capacity]." Finally, they were asked to choose among these 10 possible mechanisms (or to write in another mechanism) to answer the question, "If you had to choose just one, which of the following factors is the most important in the development of capacities for [capacity]?" On the final page of the survey, participants were asked to provide additional demographic information.

3.3.2.1 Capacities Because Study 3 included additional questions probing participants' theories of developmental mechanisms, we reduced the set of mental capacities from 20 in Study 2 to eight in the current study to maintain an appropriate level of participant burden. To select these eight capacities, we drew on the results of Study 2, selecting two items for each of the four factors identified by EFA. For each domain, we selected items that loaded strongly on the relevant factor, did not cross-load strongly on other factors, were sufficiently distinguishable from each other in meaning (i.e., not overly redundant), and captured our qualitative understanding of the domain that each factor corresponded to. We chose "controlling their emotions" and "reasoning about things" to represent the domain of *cognition and control*; "getting hungry" and "feeling pain" to represent the domain of *bodily sensations*; "learning from other people" and "feeling happy" to represent the domain of *social connection*; and "feeling distressed" and "feeling helpless" to represent the domain of *negative affect.* Capacities were presented in a random order for each participant.

3.3.2.2 Target ages and accompanying photographs The 13 target ages for this study were identical to Study 2, with the exception that we added the parenthetical phrase "(at birth)" when referring to newborns.

Each target age was presented with the same pair of photographs used in Study 2. Target ages were presented in chronological order on each trial.

3.3.3 Analysis plan

3.3.3.1 Preregistered confirmatory analysis of perceived developmental trajectories We preregistered two hypotheses about the perceived developmental trajectories we anticipated to observe in Study 3; these were identical to our hypotheses for Study 2 (which were upheld in that study): (1) We predicted that, on average, participants' perception of children's mental capacities would increase as a function of the target child's age, with participants generally attributing more and greater abilities to older children; and (2) We predicted that, in the domains of *cognition and control* and *social connection*, participants would perceive relatively more dramatic developmental changes extending later into childhood (i.e., lower intercepts and steeper slopes), whereas in the domains of *bodily sensations* and *negative affect* participants would perceive relatively smaller changes across development (i.e., higher intercepts and shallower slopes).

Following Study 2, to test these hypotheses we conducted a multilevel beta regression via a generalized additive model, regressing item-level responses onto the domain and a spline-based smooth of the target age of the child fitted separately for each domain, including the maximal random effects structure that would allow the model to converge. Using the "mgcv" package for R (Wood 2017), we specified this model as follows: *gamm(responses ~ s(target age in years, by = domain) + domain, random = list(subject ID = ~1, capacity = ~1).* Again, attempting to model random slopes for domain or for target age resulted in model convergence problems. Again, responses were rescaled to range from 0.005 to 0.995, and domain was dummy-coded with *cognition and control* as the baseline.

(We note that, in contrast to Study 2, in Study 3 we did preregister this analysis, although we preregistered a linear regression rather than a beta regression via generalized additive model; see extended notes on our choice of this analysis approach under Study 2.)

3.3.3.2 Preregistered exploratory analysis of perceived developmental trajectories Beyond the two hypotheses described in the previous section, we also anticipated that perceptions of developmental trajectories in different domains would vary in their curvilinearity—e.g., development in one domain might be perceived to be gradual and linear, while development in another domain might be perceived to occur in stages, at an exponential rate, or to peak at a specific age. To explore these possibilities, we preregistered a regression analysis adding polynomial effects of target age; however, in our reconceptualization of the appropriate way to analyze our data given the distribution of the response variable (see Study 2), this exploratory analysis was superseded by the generalized additive model.

3.3.3.3 Preregistered exploratory analysis of developmental mechanisms Finally, we assessed which developmental mechanisms were considered to be the most or least important in the development of each of the individual mental capacities included in this study (*bodily sensations*, *negative affect*, *social connection*, and *cognition and control*). We specified in our preregistration that this assessment would be conducted primarily through visualization, but to complement this visualization we also conducted a multilevel linear regression regressing responses to this question onto type of developmental mechanism (extrinsic vs. intrinsic), domain, and an interaction between them, including the maximal random effects structure that allowed the model to converge. Using the "lme4" package for R (Bates et al. 2015), we specified this model as follows: *lmer(response ~ mechanism type * domain + (1 + mechanism type + domain | participant) + (1 | developmental mechanism) + (1 | capacity).* We also conducted separate, analogous regression analyses for each domain separately. In all of these analyses, mechanism type and domain were effect-coded for comparisons to the grand mean collapsing across mechanism types and domains. (Note that these analyses omitted the mechanism "the child's brain changes […]," because it was the only mechanism that was difficult to classify as either intrinsic or extrinsic via EFA and clustering analyses; see Results.)

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