THE DEVELOPMENT OF CONCEPTUAL REPRESENTATIONS OF MENTAL LIFE

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Abstract

Attributions of thoughts, beliefs, desires, intentions, emotions, perceptions, and sensations are at the core of human social life—but "mental life" is a complex concept, encompassing a wide range of experiences and abilities that vary along many dimensions. This makes ordinary people's representations of mental life a fascinating case study of abstract reasoning and its development: How do children come to represent this complex conceptual space? In this dissertation I describe a series of large-scale studies designed to explore this question among children (4-9y) and adults in the modern US context, using an empirical approach that unites recent work on the "dimensions of mind perception" with rich traditions of research on the development of the animate-inanimate distinction, lay biology and psychology, and theory of mind. These studies address three ontological questions about ordinary people's representations of mental life: (1) What are the conceptual units that anchor representations of mental life at different points in development? (2) How are these conceptual units organized in relation to each other, and how does this organization change over development? and (3) How do people of different ages deploy their conceptual representations of mental life to reason about specific entities in the world—namely, animate beings vs. inanimate objects? Results suggest that, over the course of early and middle childhood, US children's representations of mental life undergo substantial development in all three of these respects. These findings have important implications for children's social cognitive development.

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Dedication

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Note on Reproducibility

Anonymized data, analysis code, and code for producing this manuscript are available at https://github.com/kgweisman/dimkid/tree/master/dissertation.

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CHAPTER I: THEORETICAL FOUNDATIONS

The act of attributing mental life to other beings in the world is a fundamental part of human experience: From early in life, we look at others around us and see not just physical objects, but people—minds—with sensations, emotions, thoughts, and memories of their own.

Viewing others in this way lays the foundation for our social interactions. We might infer our friends' goals and try to help, or anticipate and attempt to thwart the plans of a foe. When someone appears to have forgotten or misunderstood something, we might step in to correct them, or we might decide that they are capable of figuring things out on their own. We might delight in each other's happiness, seek comfort from each other in times of sadness, and plan our actions to avoid (or to appear to avoid) causing others emotional or physical pain. These are just a few examples of how representations of *mental life*—goals, plans, thoughts, memories, reasoning abilities, emotions, perceptions, sensations, and the like—are at the core of human social life.

As these examples illustrate, mental life is complex, encompassing a wide range of experiences and abilities that vary along many dimensions. Some mental states are closely related to specific bodily organs (e.g., people see things with their eyes, feel hunger in their stomachs), and others less obviously so (where do people experience belief?). Some are positively or negatively valenced (e.g., pain feels bad, happiness feels good), others are more neutral, or vary in valence depending on the circumstance (thinking, smelling). Some mental states involve taking in information about the environment (e.g., seeing, hearing), while others involve storing or updating that information (remembering, learning), or using it to bring about changes in the external world (planning, making choices). In a given social context, certain mental states might be considered more appropriate or socially productive than others (e.g., love vs. anger, guilt vs. pride, excitement vs. contentment; Tsai, 2007). And people might believe that certain mental capacities are shared by a wide range of entities (e.g., even insects might experience hunger; even robots might have a capacity for memory), while others are limited to a smaller subset of beings (perhaps only humans experience embarrassment; Haslam, Kashima, Loughnan, Shi, & Suitner, 2008).

How do people come to represent this complex conceptual space? This is the question I aim to address in this dissertation. Representations of mental life are a particularly fascinating case study of abstract reasoning and its development, with roots in ancient philosophy and connections to rich traditions of work in many sub-fields of psychology. In this chapter, I discuss these theoretical foundations. I begin with hints from developmental psychology that representations of mental life may undergo dramatic changes over the course of early and middle childhood.

The possibility of conceptual change in representations of mental life

From the early work of Piaget through the present day, many seminal studies of cognitive development have touched on children's understanding of mental life. Long traditions of work on the animate-inanimate distinction, lay biology and psychology, and theory of mind all converge to suggest that the period of development between roughly 4-10 years of age is a time of rapid change in children's reasoning about many different experiences and abilities that might be considered part of mental life, as well as changes in children's tendency to attribute such capacities to fellow humans, animals, plants, natural objects, artifacts, and other entities in the world. These studies leave open, however, the question of whether these shifts in reasoning and attribution may be accompanied by changes to the underlying conceptual structure—the focus of this dissertation.

Related developments in early and middle childhood

Early explorations of children's understanding of mental life were rooted in a more basic question: How do children understand "life" at all? Capacities for desires, goals, intentions, and other mental states are one of the key features that distinguish animate beings like humans and animals from inanimate objects (Gelman & Spelke, 1981). Indeed, beginning with Piaget's (1929) classic work on what he termed "childhood animism," attributions of such mental states to inanimate beings have been considered a hallmark of an immature understanding of life and animacy. Since then, many foundational figures in the field of cognitive development—Carey, Flavell, R. Gelman, S. Gelman, Keil, Medin, Spelke, Waxman, and Wellman, among others—have taken up the questions of whether, when, and why young children might attribute mental states to inanimate objects; as well as the question of what might drive the apparent decline of these "over-attributions" over development (see Gelman & Spelke, 1981 for an early review; and Gelman & Opfer, 2002, for a more recent review).

One pivotal moment in this tradition of work was the publication of Carey's (1985) seminal exploration of conceptual change in the domains of lay psychology and biology. Using a combination of Piagetian-style interviews and quantitative experiments, Carey documented dramatic changes in children's understanding of what it means for something to be alive; why living things do the things they do (e.g., eat, sleep, etc.); and which set of entities in the world have these properties. These studies suggested that young children (at least in the 20th-century urban US context; cf. Herrmann, Waxman, & Medin, 2010; Medin, Waxman, Woodring, & Washinawatok, 2010) have an anthropocentric concept of life and life-related properties: Prior to roughly 7 years of age, children in Carey's studies appeared to base their assessment of whether entities are alive on judgments of their similarity to humans, and to ground their reasoning about activities like eating and sleeping in their understanding of human social-psychological behavior (e.g., we eat together at dinner time, we go to bed at night). Only older children appeared to draw on a more adult-like understanding of life as some kind of "vital force," grounded in and governing bodily processes and extending to a variety of entities that are quite different from humans. Over the course of early and middle childhood, Carey argued, children exchange an "animistic" theory of life for another, "vitalistic" one—in the process, demarcating the conceptual domain of living bodies ("lay biology") as separate from the conceptual domain of human social interactions ("lay psychology"). Together with other early work on the animate-inanimate distinction (e.g., Dolgin & Behrend, 1984; Gelman & Spelke, 1981; Gelman, Spelke, & Meck, 1983), Carey's findings have inspired a host of empirical studies of the development of lay biology and psychology, focusing in particular on the period between 4-10y of age (e.g., Coley, 1995; Erickson, Keil, & Lockhart, 2010; Gutheil, Vera, & Keil, 1998; Hatano & Inagaki, 1994; Jipson & Gelman, 2007; Medin et al., 2010; Ochiai, 1989; Opfer & Siegler, 2004). This case study has also piqued the interest of computational cognitive scientists, playing a role in the development and refinement of sophisticated computational approaches to modeling human-like conceptual change (e.g., Rogers & McClelland, 2003; Saxe, McClelland, & Ganguli, 2013).

Meanwhile, under the unifying label of "theory of mind," thousands of studies have documented major improvements over the course of early and middle childhood in children's abilities to take others' perspectives, predict and explain people's emotions, represent false beliefs, and integrate representations of beliefs and intentions in evaluating moral responsibility (for reviews, see Flavell, 1999; Gelman & Spelke, 1981; Gelman et al., 1983; Wellman, 2015). A search of the PsycInfo database for publications with the phrase "theory of mind" in the title yields well over 2000 results as of August 2019; a full review of these findings is far beyond the scope of this dissertation. Suffice it to say that these studies offer overwhelming evidence that becoming a sophisticated reasoner—and particularly a sophisticated social reasoner—requires substantial refinement of one's representations of others' experiences, abilities, beliefs, desires, and so forth.

Open questions

Studies of conceptual change in children's understanding of the mind have generally focused on changes in children's beliefs about the world (e.g., Does the child believe that the moon has intentions?); or on changes in children's intuitive theories (e.g., Does the child draw on social-psychological or biological causes when explaining an entity's behavior? Do they include beliefs, in addition to desires, in their representations of the mental states that drive people's actions?).

For the most part, however, these studies do not address the structural organization of children's representations of mental life—a key ontological structure underlying these beliefs and intuitive theories. Terms like "intention," "belief," and "desire" abound in the scientific theories reviewed in the previous section—but how well do these terms correspond to children's own understanding of types of mental states (or, for that matter, to that of adults)? How do children conceive of the similarities, distinctions, and logical relations among the wide variety of experiences and abilities that might be considered part of mental life? How might this organizational structure change over development?

In other words, although the field of developmental psychology has made great progress investigating changes in children's beliefs and intuitive theories about the mind, we have very little understanding of changes in *conceptual structure* in this domain. (See

Chi (2009); and Keil & Newman (2009); for extended discussions of different kinds of conceptual change.)

Questions about the parts and structure of the mind have their roots in antiquity; I return to parallels between the current work and these ancient lines of inquiry at the end of this chapter. First, however, I describe and reflect on a modern approach to investigating the structural organization of *adults'* representations of mental life, pioneered by a team of social psychologists in their work on the "dimensions of mind perception."

Gray, Gray, and Wegner's (2007) "dimensions of mind perception"

Twelve years ago, a team of social psychologists published a brief but highly impactful paper in the journal *Science*. The paper presented the results of a large-scale study in which adult participants were asked to compare the mental capacities of a variety of target characters, including two human adults, a child, an infant, a fetus, a person in a persistent vegetative state, a dead person, a chimpanzee, a dog, a frog, a robot, God, and themselves. From these assessments, the authors derived two axes of variability in participants' responses: a dimension they called "experience," which captured the extent to which participants considered a character to be capable of hunger, fear, pain, pleasure, rage, desire, personality, consciousness, pride, embarrassment, and joy; and a dimension they called "agency," which captured the extent to which participants considered a character to be capable of self-control, morality, memory, emotion recognition, planning, communication, and thought. They called these two dimensions the "dimensions of mind perception" (Gray et al., 2007).

The idea that attributions of different aspects of mental life might play distinct roles in human reasoning and behavior has captured the interest of psychologists and philosophers alike (see Epley & Waytz, 2010), and the particular dimensions of "experience" and "agency" that Gray et al. described have been invoked to inform such diverse topics as the objectification of women (Gray et al., 2011b); the dynamics of human–robot interaction (Brink, Gray, & Wellman, 2017; Gray & Wegner, 2012); the social–cognitive signatures of autism, psychopathy, and other disorders (Akechi, Kikuchi, Tojo, Hakarino, & Hasegawa, 2018; Gray et al., 2011a); beliefs about supernatural beings (Heiphetz, Lane, Waytz, & Young, 2018; Willard & McNamara, 2019); and general theories of moral reasoning (Gray et al., 2007, 2012; cf. Sytsma & Machery, 2012).

Beyond this, Gray et al.'s study was groundbreaking in several more general senses. It was among the first generation of psychological studies to be conducted entirely online, which yielded a dataset including well over 2000 participants—an order of magnitude larger than most samples in psychology at the time. It was ambitious in scope, including questions about such deep and difficult concepts as consciousness, morality, and self-control, applied to such socially charged entities as a human fetus, a person in a persistent vegetative state, a "social robot," and God. It made use of an entirely data-driven (rather than hypothesis-driven) statistical procedure—principal components analysis—which just a decade or so earlier was so prohibitively expensive in terms of time and computational power that hardly any mainstream psychologists knew how to conduct it. In other words, Gray et al. collected big data on a topic at the core of experimental philosophy and analyzed it using an unsupervised learning technique—all before "big data," "experimental philosophy," and "unsupervised learning" became the buzzwords that they are today.

Critiques

This study was not without its flaws. Critical reflection on Gray et al.'s (2007) methods was a major motivation for the studies of adults included in this dissertation (Studies 1a-1d, first published in Weisman, Dweck, & Markman, 2017). I describe these critiques in detail here in the spirit of seeking to deepen the field's understanding of their findings, and as a foundation for my own work, which was designed and executed with these critiques in mind.[1]

First, let us revisit Gray et al.'s study from the perspective of the participant, starting in the moments before data collection even began. Upon arrival to the website hosting the study, participants were told about the purpose of the study and introduced to the thirteen target characters whose minds they would be asked to consider. Photographs of target characters were presented alongside verbal descriptions that varied in their

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[1] Special thanks to Heather M. Gray for providing materials and further details about the implementation of the original study.

richness and detail (e.g., “Nicholas is a five-month-old baby” vs. “The Green Frog can be found throughout eastern North America. This classic ‘pond frog’ is medium-sized and green or bronze in color. Daily life includes seeking out permanent ponds or slow streams with plenty of vegetation”). Sometimes these descriptions included information about the correct way to assess certain mental capacities (e.g., “Gerald [the patient in a persistent vegetative state] *does not appear to communicate with others or make purposeful movements*”; “Many people believe that God is *the creator* of the universe and the *ultimate source of knowledge, power, and love*”; emphasis added), or featured anthropomorphic language—such as personal pronouns and names—that may have biased participants’ construals of more controversial entities (e.g., “*Toby* is a two-year-old wild chimpanzee”; *Kismet* [the “social robot”] perceives a variety of natural social signals from sound and sight, and delivers *his* own signals back to the human partner…"; emphasis added; Gray et al., 2007).

Participants were then asked to choose which condition they would like to participate in (e.g., choosing a survey that was described as asking them “to judge which character is more capable of experiencing physical or emotional pain” vs. one that was described as asking them “to judge which character is more capable of telling right from wrong and trying to do the right thing”; Gray et al., 2007). Participants could opt to participate in as many of these conditions as they liked, in whatever order they chose. This could well have introduced bias into participants’ responses (e.g., if participants who were more interested in moral philosophy were more likely to opt into the morality condition than the pain condition, or if participants disproportionately chose to complete the pain condition directly before the morality condition).

At this point, the study began in earnest. Each participant engaged in a series of comparisons between pairs of target characters, focusing on a single mental capacity for the duration of the survey. For example, a participant who chose the morality survey would proceed through all possible pairings of the 13 target characters, for a total of 78 trials per survey; on each trial the participant would answer the question “Which character do you think is more capable of telling right from wrong and trying to do the right thing?” on a five-point scale from “much more [character A]” to “much more [character B].” Reflecting on this experience from the perspective of the participant, I have come to believe that this procedure did not actually assess people's intuitions about the similarities and differences *among mental capacities*, but rather their intuitions about the similarities and differences *among social beings*. The explicit task for the participant, both within each trial and across trials, was to compare and contrast target characters. Only the minority of participants who opted to participate in more than one condition were asked to consider the similarities and differences across mental capacities—and even then, they likely assessed only a few capacities, and only in the context of in long experimental "blocks" of 78 trials per capacity. As I have argued elsewhere, this procedure likely encouraged participants to think about the similarities and differences among the target characters: What do characters have in common, and how do they differ? Conversely, assessing people's intuitions about the structure of mental life requires a sensitive measure that encourages participants to think about the connections and divisions among mental capacities themselves: Which capacities "go together," and which capacities are more distinct? (See Weisman et al., 2017.)

Aside from these critiques of the methods employed in Gray et al.'s (2007) study, their unusual analysis approach also bears critical reconsideration. 2399 completed surveys were included in the dataset, each of which consisted of questions about a single mental capacity for every possible pair of target characters (for a total of 78 datapoints per survey). Before conducting principal components analysis, however, this very large dataset was reduced to a much smaller set of summary scores on each mental capacity for each character. Translating the paired comparisons into summary scores necessitated the unconventional approach of averaging across all of the comparisons involving that character (i.e., treating a rating of "much more [character A]" as an absolute measure of character A's capacity, regardless of whether character A was compared to character B or character C) and reusing the same data to calculate summary scores for other characters. This process yielded a summary dataset consisting of "mean relative ratings" for 18 mental capacities for each of the 13 target characters—an extremely small dataset to enter into a dimensionality reduction technique like principal components analysis. Moreover, this summary dataset was of an inappropriate "shape" for this approach, featuring fewer "subjects" (13 target characters) than "items" (18 mental capacities); for comparison, best practices for this kind of dimensionality reduction commonly specify a subject-to-item ratio of 5:1 or even 10:1 (e.g., Costello & Osborne, 2005). In principle, one of the consequences of such a small subject-to-item ratio would be to constrain the possible outcomes of the analysis, rendering it very unlikely to detect more than one or two "dimensions." Indeed, the authors' interpretation of their results neglected to account for the fact that the first of these dimensions (what they termed "experience") accounted for fully 88% of the variance in characters' mean mental capacity scores, which calls into question whether this analysis detected any meaningful multi-dimensional structure in the first place.

Contributions

Despite what I perceive to be substantial flaws in this particular study, I continue to consider Gray et al.'s work to be a major inspiration for my own. I will conclude this section by highlighting three aspects of this work that I adopted (and attempted to expand and improve upon) in the studies included in this dissertation.

First, *a description of "mind" as a multidimensional construct*. Perhaps the most radical—and, I would argue, under-valued—contribution of Gray et al.'s work on mind perception was the very premise of their study: that people's understanding of mental life might be structured along multiple, meaningful "dimensions." Gray et al.'s study identified a level of conceptual organization intermediate between the broad concept of "mind" and the narrow definitions of individual mental states (e.g., "joy," "vision," "belief," "desire"). In so doing, it introduced the idea—absent from the majority of relevant work in developmental psychology, as I argued earlier—that such a conceptual organization might exist, that it can be identified empirically, and that it is worth studying. Most of the subsequent work stemming from Gray et al.'s findings has focused on the potential social and moral ramifications of the experience-agency framework (e.g., Akechi et al., 2018; Brink et al., 2017; Gray et al., 2011a, 2011b, 2012; Gray & Wegner, 2012; Heiphetz et al., 2018; Sytsma & Machery, 2012; Willard & McNamara, 2019). I would like to draw attention to the fact, however, that the original study actually attempted to describe the structure organization of representations of mental life *before* turning to these social behavioral implications. In my view, articulating this ontological question and attempting to answer it empirically stands as a key contribution to the field, regardless of my critiques of the design and analysis of this particular study.

Second, *an expansive view of mental life*. Gray et al. included an unprecedentedly wide variety of "mental capacities" in their study—not only the cognitive and emotional abilities that are commonly targeted in studies of reasoning about mental states, but also less common examples of mental states, such as physiological sensations and capacities for emotion recognition and moral reasoning. In my view, this expansive scope is critical for getting a holistic sense of this complicated domain.

Third—and perhaps most critically—*a bottom-up approach*. Gray et al. (2007) did not generate a theory of "dimensions of mind perception" a priori and set out to confirm or disconfirm this theory; neither did they ask participants to articulate their own conceptualization of this domain. Instead, they relied on an unsupervised learning algorithm to reconstruct participants' representations of a conceptual domain "from the bottom up." (See also Haslam et al., 2008, for a similar bottom-up approach to identifying which aspects of mental life might be considered central to "human nature," and which might be considered "uniquely human.") Such data-driven approaches have become more and more popular in social psychology, particularly as statistical computing software becomes faster and more accessible. Although this work is rarely portrayed as bearing on such "cognitive" topics as conceptual representations, I believe that such bottom-up approaches have tremendous potential to advance our understanding of conceptual representations of mental life and their development over childhood.

One of the primary advantages of such a bottom-up approach, in my view, is its potential to elucidate the kinds of deep conceptual structures that are difficult for participants to report on directly. Gray et al.'s particular implementation of this bottom-up approach is especially compelling to me as a developmental psychologist because of its simplicity. Their empirical paradigm rests on the premise that complex conceptual structures can be uncovered from participants' answers to relatively simple, concrete questions drawing on participants' knowledge or intuitions about familiar entities in the world. This style of questioning lends itself naturally to adaptation for young children.

Another major advantage of a bottom-up approach is that the conceptual structures it reveals can, in principle, differ dramatically from the assumptions of a research team. These are especially compelling advantages in the domain of conceptual *change*—in which, by definition, participants struggle to introspect and articulate their reasoning, and findings often conflict with adult intuitions (including the intuitions of adult researchers). In contrast to a top-down approach, in which the researcher must anticipate in advance one or more alternatives forms that this representation must take—and, if they are interested in its development, one or more dimensions along which this representation might vary over childhood—a bottom-up approach allows structures, and changes in these structures, to emerge organically, and to vary along both anticipated and unanticipated axes of comparison.

Promising precursors to using a bottom-up approach with children

To my knowledge, there have been only a few attempts to employ a bottom-up approach to study representations of mental life among children. First, in a series of studies with 8- to 11-year-old children, Fabricius, Schwanenflugel, and colleagues explored one corner of this conceptual space, focusing on how children come to distinguish among different "ways of knowing." In a representative study, 8- and 10-year-old children and adults rated the similarity of pairs of activities that involved various kinds of cognitive abilities (e.g., "Making a list at home of all the kids in your new class without missing any"; "Trying to find the North Star in the sky on a starry night"; Fabricius, Schwanenflugel, Kyllonen, Barclay, & Denton, 1989). Their results suggested that children gradually come to distinguish between more "perceptual" aspects of knowing (e.g., seeing, hearing) vs. more "conceptual" aspects of knowing (reasoning, understanding) at some point in middle childhood, only coming to represent ways of knowing along a second axis, how much they rely on "memory," later in adolescence [Fabricius et al. (1989); Schwanenflugel, Martin, & Takahashi (1999); Schwanenflugel et al. (1994b); Schwanenflugel et al. (1994a); Schwanenflugel, Fabricius, & Noyes (1996). (See also Rips & Conrad (1989) for a related pair of studies focused on adults' representations of what they termed "mental activities," including thinking, reasoning, and problem-solving; and Hoskens & De Boeck (1991) for work on adults' representations of "intelligence-related" mental capacities.)

More recently, Nook and colleagues have explored another important aspect of children's representations of mental life: their developing understanding of emotions. In their study, participants between the ages of 6 and 25 years rated the similarity of pairs of emotion words (e.g., "happy" vs. "angry"); these similarity ratings suggested that younger children first represent emotions along a one-dimensional space (positive vs. negative valence), before gradually coming to represent emotions along a second dimension (high vs. low arousal) over the course of later childhood and adolescence (Nook, Sasse, Lambert, McLaughlin, & Somerville, 2017).

Both of these fascinating results suggest that the conceptual organizations of "cognitive" and "emotional" states are revised and refined over development, in processes that extend well into middle childhood (and beyond)—but neither of these studies took the more expansive outlook of Gray et al. (2007) that I believe is critical for understanding this complex domain of human reasoning.

The current project

In this dissertation I unite the structural orientation, bottom-up approach, and sweeping scope provided by Gray et al.'s (2007) work on the "dimensions of mind perception" with the traditions of work from developmental psychology on the animate-inanimate distinction, lay biology and psychology, and theory of mind. My goal is to characterize the development of conceptual representations of mental life in the modern US context.

Three key questions, inspired by the ancients

In describing the theoretical roots of this project, I have focused on empirical studies from developmental and social psychology—but human inquiry into the nature of the mind is much older than the field of psychology. Interest in the nature and structure of the mind (often referred to as the "soul" or "psyche") extends back to the philosophers and spiritual leaders of antiquity, including extensive treatments of this topic by Socrates, by way of Plato; Aristotle; and the Buddha; among many others. A comprehensive analysis of these philosophical theories is beyond the scope of the current dissertation.

Importantly, what I pursue in my empirical work is not the *true* nature of mental life, but ordinary people's *perceptions* of its nature (what I refer to as their "conceptual representations"). I am indebted to these ancient philosophers, however, for a certain ontological bent toward this topic—which I think is worth spelling out here, because it differs in certain respects from mainstream approaches to conceptual representations in the modern empirical study of cognitive development. I have structured my exploration of conceptual representations of mental life around three deeply related questions:

1. What are the components, or "conceptual units," that anchor representations of mental life at different points in development?
2. How are these conceptual units organized in relation to each other, and how does this organization change over development?
3. How do people of different ages deploy their conceptual representations of mental life to reason about specific entities in the world—namely, animate beings vs. inanimate objects?

As it turns out, each of these questions parallels a key aspect of ancient philosophical inquiries into the nature of the mind (though I did not have such a lofty goal in mind at the outset of this work).

Plato, for example, describes a theory of the *psyche* (typically translated as "soul") that addresses (1) the parts of the soul (reason, spirit, and appetite); (2) the hierarchical relationships among these parts (reason as "the charioteer," whose role is to drive two "horses" which tend to pull in opposite directions: spirit and appetite); and (3) the way this structure can be useful in making sense of social life (e.g., in identifying classes of people who are ruled primarily by reason, spirit, or appetite). (See Brown, 2017 for a comprehensive summary and discussion.)

In a close parallel, Aristotle's *De Anima* also presents a theory of the soul (*psyche* in Greek; *anima* in Latin) that addresses (1) the distinct faculties of the soul (nutrition, perception, reason, and perhaps desire); (2) the hierarchical relationships among these faculties (the presence of reason in an entity implies the presence of perception and nutrition, but the reverse is not true; likewise, the presence of perception implies the presence of nutrition, but the reverse is not true); and (3) the way this structure makes sense of the variety of beings in the world (plants have only a nutritive soul; non-animals have both nutritive and perceptual souls; and only humans have nutritive, perceptual, and intellectual souls). (See Shields, 2016 for a comprehensive summary and discussion.)

The Buddha—a rough contemporary of Aristotle, located half a world a way and emerging from a very different cultural context and historical tradition—also appears to have touched on these three questions in his teachings on sentience, addressing (1) the aggregates (*skandha*) that compose sentient beings (material form, feelings, perceptions or thoughts, impulses or dispositions, and consciousness); (2) the ever-changing relationships among these components (particularly the fact that their aggregation in an individual sentient being is temporary and in some ways illusory); and (3) the way this structure impacts everyday life (namely, by distinguishing sentient beings from the non-sentient world, and binding sentient beings to a cycle of suffering). (See Emmanuel, 2015 for extended summary and discussion of relevant topics in Buddhist philosophy.)

Of course, both the content of these ancient theories and the modes of inquiry these thinkers employed differ dramatically from what we would recognize as theories of "the mind" in twenty-first century psychological science. But I have found their shared, three-pronged ontological approach—anchored by the basic questions *What are the units?*, *What are the relationships among them?* and *How are these structures deployed?*—to be extremely useful in my exploration of ordinary people's understanding of the mind in the modern US context. These three questions form the backbone of this dissertation.

Overview of the dissertation

The remainder of this dissertation is devoted to describing a series of empirical studies that shed new light on these three key questions about conceptual representations of mental life. I begin by identifying "conceptual units" at three points in development in the modern US context: early childhood (4-6y), middle childhood (7-9y), and adulthood (Chapter III). Next, I explore the relationships among these conceptual units, and how these relationships might evolve and change over this period of development (Chapter IV). I then consider the deployment of these conceptual representations in one aspect of social reasoning, using the apparent conceptual structure established in Chapters III-IV to shed light on children's developing mental capacity attributions to animate beings vs. inanimate objects (Chapter V). Finally, I synthesize my findings from these three lines of inquiry and step back to reflect on how these three aspects of conceptual development might be related to one another and the potential consequences of these representations of mental life in children's social development (Chapter VI). First, in Chapter II, I provide an overview of my general empirical approach and the specific methods I employed in the four large-scale studies included in this dissertation.

CHAPTER II: OVERVIEW OF METHODS

Chapter overview

In the following chapters, I address the three key questions about the development of representations of mental life introduced in Chapter I:

1. What are the components, or "conceptual units," that anchor representations of mental life at different points in development? (Chapter III)
2. How are these conceptual units organized in relation to each other, and how does this organization change over development? (Chapter IV)
3. How do people of different ages deploy their conceptual representations of mental life to reason about specific entities in the world—namely, animate beings vs. inanimate objects? (Chapter V)

The organization of Chapters III-V is somewhat unconventional. Rather than introducing a new study in each chapter, I analyze data from all four studies in Chapter III, and then return to re-analyze these same datasets in Chapter IV, and again in Chapter V; in other words, instead of proceeding study by study (including multiple analyses for each study), I proceed analysis by analysis, drawing on the full set of studies for each analysis. My goal in presenting these results in this unusual manner is to paint a holistic picture of developmental change in each of these distinct aspects of conceptual representation, without requiring the reader to look back and forth between chapters to make comparisons across parallel analyses (or switch back and forth between different complex analyses within a single chapter).

With this roadmap in mind, in the current chapter I describe the methods for all of the studies included in this dissertation ("Methods"). This chapter is intended to give the reader a general sense of the studies included in this dissertation and to provide the reader with an easily accessible resource for finding details about any particular study as it becomes relevant in Chapters III-VI.

General approach

In this dissertation, I examine conceptual representations of mental life by documenting participants' mental capacity attributions to a wide variety of familiar entities that might be perceived to vary in their mental lives, including humans, non-human animals, technologies, and inert objects. These studies were designed to capture participants' beliefs about the *co-occurrence* of a diverse range of mental capacities: When someone indicates that some entity has one capacity (e.g., for pain, or happiness, or memory), what other capacities does that person tend to attribute to that entity? The goal of these studies was to facilitate participants' engagement with deep questions about the nature of mental life—in particular, the similarities, differences, and relationships among different mental capacities—through simple questions grounded in concrete, real-world examples.

My general approach was inspired by Gray et al.'s (2007) study of the "dimensions of mind perception," discussed at length in Chapter I. In this study, each participant answered questions about many pairs of target characters (e.g., a robot vs. a fetus, a baby vs. an adult woman, an adult man vs. a chimpanzee, a dog vs. God), while focusing on a single mental capacity (e.g., joy). In other work on adults' understanding of the mind, participants have compared the mental capacities of different classes of target characters to humans as a point of reference (e.g., animals vs. humans, robots vs. humans, supernatural beings vs. humans; Haslam, Kashima, Loughnan, Shi, & Suitner, 2008).

In the current studies, I took a slightly different approach. Instead of asking participants to compare the relative mental capacities of many different characters or classes of characters, I asked participants to assess a wide variety of mental capacities for just one or two target characters (e.g., assessing a robot on many different sensory, perceptual, emotional, cognitive, and social abilities). As I argued in Chapter I, asking each participant to assess many mental capacities for just one or two target characters confers the major advantage of focusing participants' attention on the similarities, differences, and relationships among a wide range of mental capacities (rather than on the similarities, differences, and relationships among various target characters). Moreover, because this approach centers on asking participants straightforward questions in relatively simple language, it opens up the possibility of using the same experimental method to study conceptual representations across a wide age range—the primary goal of this dissertation.

These studies are based on the premise that *variability across participants* in their mental capacities can shed light on the three aspects of conceptual representation that are the focus of the current research:

1. Tracking the *covariance* of mental capacity attributions (Chapter III) provides a way of identifying "conceptual units." For example, if participants who endorsed Capacity X also tend to endorsed Capacities Y and Z, this provides some evidence that Capacities X, Y, and Z constitute a suite of mental capacities that are closely associated with the same underlying "conceptual unit."
2. Tracking *asymmetries* in mental capacity attributions (Chapter IV) provides a way of assessing the hierarchical organization of these units. For example, if many participants endorsed capacities associated with Conceptual Unit A without endorsing capacities associated with Conceptual Unit B, but very few participants did the reverse (endorsing capacities associated with Conceptual Unit B but not Conceptual Unit A), this provides some evidence that Conceptual Unit A might be considered more basic or fundamental than Conceptual Unit B, or a prerequisite for Conceptual Unit B.
3. Tracking *which mental capacities are attributed to which target characters* (Chapter V) provides a way of observing the application or deployment of these conceptual representations in reasoning about specific entities in the real world. For example, if participants who assessed the mental capacities of Characters 1, 2, and 3 shared one general pattern of mental capacity attributions, and participants who assessed the mental capacities of Characters 4, 5, and 6 shared another pattern, this provides some evidence that conceptual representations of mental life might play a role in structuring representations of (and interactions with) different classes of beings in the world.

(For more details on my operationalization of these general intuitions about how to analyze aspects of conceptual representation, see Chapters III-V.)

Each of these three lines of analysis requires variability across participants in which capacities (or which suites of capacities) they do or do not endorse, to what degree.

This dissertation features two variants of this general approach, i.e., two different strategies for eliciting conceptual representations of mental life through variability in their mental capacity attributions: (1) asking participants to assess the mental capacities of a select number of "edge cases" in social reasoning; and (2) asking participants to assess the mental capacities of a diverse range of target characters.

In the "edge case" variant of this experimental approach (employed in Studies 1a-1c, Study 2, and Study 4), this variability was introduced by asking participants to reason about entities that might be considered borderline cases in social reasoning: beetles and robots. This approach hinges on the fact that, in the US context at this point in history, the mental lives of beetles and robots (such as they may be) are unknown to most ordinary people, ambiguous even during direct observation of these entities, and generally considered up for debate, such that individual people are likely to differ in their sense of what capacities and experiences these entities might have. Thus, in the "edge case" variant of the experimental approach, the variability required for the analyses of conceptual structure just described emerges from a combination of (a) individual differences in participants' opinions or beliefs about a given target character and (b) differences between the two target characters themselves. Because beetles are animals and robots are artifacts, this particular pair also provides insight into the role of biological life in attributions of mental life—an issue of particular interest from a developmental perspective, given the long history of work on the development of the animate-inanimate distinction and its relation to folk psychology (Gelman & Spelke, 1981; Gelman, Spelke, & Meck, 1983; Gelman & Opfer, 2002).

In the "diverse characters" variant of this approach (employed in Study 1d and Study 3), a wider range of target characters were included in the design of the study, including humans (e.g., adults, children), non-human animals (e.g., mammals, birds, insects), technologies (e.g., robots, computers), and inert objects (e.g., toys, tools). In these studies, different subsets of participants were asked to reason about beings with dramatically different mental capacity profiles. Thus, in the "diverse characters" variant of the experimental approach, the required variability emerged primarily from differences among the wide variety of target characters (and, to a lesser degree, individual differences in participants' opinions or beliefs about a given target character). The inclusion of many diverse target characters offers a somewhat more representative picture of the wide variety of cases in which people might reason about mental life in the real world.

Interestingly, these two strategies for eliciting variability in mental capacity attributions have turned out to yield very similar pictures of the "conceptual units" included in adults' and children's representations of mental life (Chapter III). Meanwhile, these two approaches highlight somewhat different aspects of the organization of these conceptual units (Chapter IV) and the deployment of these representations in reasoning about animate beings vs. inanimate objects (Chapter V). I return to these points in the final chapter of this dissertation (Chapter VI).

In the following sections I include specifics about the experimental design, participants, materials, and procedure for each of these studies.

Methods

In all of the studies included in this dissertation, each participant was asked to assess 1-2 target characters (e.g., a beetle, a robot, a goat, etc.) on a wide range of sensory, perceptual, emotional, social, cognitive, and other mental capacities, ranging in number from 18-40 across studies and presented in either a random or a pseudo-random (counterbalanced) order. Participants were presented with a vivid, full-color photograph of their assigned target in a naturalistic context (e.g., a beetle on a leaf; a robot in an office; a goat in a grassy field), which they had access to throughout the study (see Figures 2.1 and 2.2). On each trial, participants were asked to assess whether the target entity was capable of a particular mental capacity.

Below I present details about the particular target characters and mental capacities included in each study, as well as the materials and physical setup.

Study 1: An adult endpoint

Note: The full detailed methods for Study 1 have been published in (Weisman, Dweck, & Markman, 2017). For the sake of comparison with Studies 2-4, I provide an abridged version here.

Study 1 was designed to investigate conceptual representations of mental life among US adults; as such, it provides an adult "endpoint" for the developmental processes under exploration in Studies 2-4.

Adults participated online via Amazon Mechanical Turk (MTurk). Participants were shown a vivid, full-color image and a label for their assigned target character(s) (e.g., “a robot”; “a beetle”), and were asked to rate the character(s) on 40 different mental capacities, presented in a random order. For each mental capacity, the participant was required to answer the question, “On a scale of 0 (Not at all capable) to 6 (Highly capable), how capable is a [target] of [capacity]?” Participants responded using this 7-point Likert-type scale. Note that in Weisman et al. (2017), this scale was recoded to run from -3 to +3 before analyses; in this dissertation, I maintain the 0 to +6 coding for comparability to Studies 2-4.

The list of 40 mental capacities employed in these studies included close variants of the 18 mental capacities featured in Gray et al.’s (2007) study of “mind perception,” as well as an additional 22 capacities generated from an a priori conceptual analysis of possible ontological categories of mental life (e.g., affective experiences, perceptual abilities, physiological sensations), with the constraint that each category should include at least five items of varying valence, complexity, and phrasing; see Table 2.1.

The set of target characters employed in these studies is presented in Figure 2.1.

Studies 1a-1c employed the “edge case” strategy for eliciting mental capacity attributions, which involved asking participants to assess the mental capacities of beetles and robots. In Studies 1a and 1b, participants (Study 1a: n=405 US adults; Study 1b: n=406 US adults) were randomly assigned to assess one of these two target characters on all 40 mental capacities. In Study 1c, n=200 US adults were asked to assess both target characters, presented side-by-side with left-right order determined randomly, on all 40 mental capacities.

Study 1d employed the “diverse characters” strategy for eliciting mental capacity attributions, which in this case involved asking participants to assess the mental capacities of 21 target characters, spanning a wide range of potential mental capacity profiles. The list of characters included an adult, a child, an infant, a person in a persistent vegetative state, a fetus, a chimpanzee, an elephant, a dolphin, a bear, a dog, a goat, a mouse, a frog, a blue jay, a fish, a beetle, a microbe, a robot, a computer, a car, or a stapler. In Study 1d, n=431 US adults were randomly assigned to assess one of these 21 target characters on all 40 mental capacities.

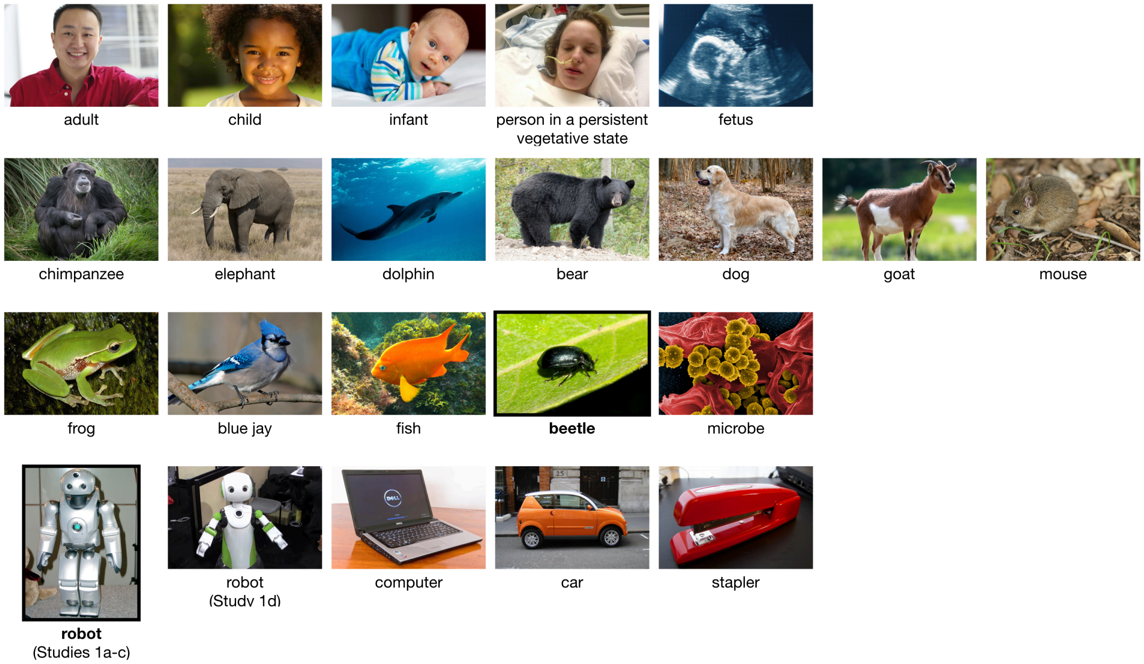

Figure 2.1: Target characters used in Studies 1a-1d, presented with the verbal label used to describe each character. Human characters are presented in the first row, non-human mammals in the second row, non-mammal living things in the third row, and inert objects in the fourth row. Studies 1a-1c employed the "edge case" variant of the general approach, in which participants assessed the mental capacities of beetles and robots; these characters are indicated with a black border. Study 1d employed the "diverse characters" variant of the general approach, in which participants assessed the wide variety of target characters presented here. Note that the picture used to illustrate the robot character varied between Studies 1a-1c vs. Study 1d.

Data processing

All analyses were conducted on raw data, in which participants' responses were recorded as integers between 0-6. All participants were required to answer all trials, and response times were not recorded, so there were no trials with missing data.

Table 2.1: Mental capacity items used in Studies 1-4. Capacities are grouped according to the a priori categories that guided the initial exploration of representations of mental life in Study 1 (as published in Weisman et al., 2017). In Studies 2-4, each item was associated with a preset definition (leftmost column). For items marked with an asterisk, this definition was provided to all participants; otherwise, it was provided to children (but not adults) only if they indicated that they did not understand the question. For a subset of participants in Study 3, two additional questions were asked at the very end of the study (listed under 'Additional questions (Study 3).' Study 4 included four additional items that did not align with items used in Studies 1-3 (listed under 'New items (Study 4)').

Study 1	Study 2	Study 3	Study 4	Definition (Studies 2-3)	Definition (Study 4)
Affective experiences (per Weisman et al., 2017)					
feeling happy	feel happy	feel happy	feel happy	like when you're feeling good	like when you feel good
feeling depressed	feel sad	feel sad	get sad	like when you're feeling unhappy	like when you feel unhappy
experiencing fear	feel scared	feel scared	get scared	like when you're feeling afraid	like when you feel afraid
getting angry	get angry	get angry	-	like when you're feeling mad	-
feeling calm	feel calm	-	-	like when you're feeling relaxed	-
experiencing joy	feel joy	-	-	like when you're feeling really, really, really happy	-
Perceptual abilities (per Weisman et al., 2017)					
detecting sounds	hear sounds	-	hear	like when you hear a noise	like when you hear sounds and noises
seeing things	see things	-	see	like when you see something	like when you see all the things that are around you
sensing temperatures	sense temperatures	sense temperatures	-	like when you feel warm or cold	-
detecting odors	smell things	smell things	smell things	like when you can smell something	like when you can tell if something smells sweet, or rotten

Study 1	Study 2	Study 3	Study 4	Definition (Studies 2-3)	Definition (Study 4)
perceiving depth	sense whether something is close by or far away	sense whether something is close by or far away	-	like when you can tell how far away something is	-
Physiological sensations (per Weisman et al., 2017)					
getting hungry	get hungry	get hungry	feel hungry	like when you feel like you need to eat something	like when you feel like you need to eat something
feeling tired	feel tired	feel tired	feel tired	like when you feel like you need to go to sleep	like when you feel sleepy
experiencing pain	feel pain	feel pain	-	like when something hurts	-
feeling nauseated	feel sick*	feel sick*	feel sick	like when you feel like you might throw up*	like when you feel like you might throw up
feeling safe	feel safe	-	-	like when you know that you're okay and you're not in danger	-
Cognitive abilities (per Weisman et al., 2017)					
doing computations	do math	-	-	like when you add or subtract numbers	-
having thoughts	have thoughts	-	think	like when you're thinking about something	like when you have a thought or an idea about something
reasoning about things	figure out how to do things	figure out how to do things	figure things out	like when you're trying to figure something out	like when you solve a puzzle or learn something new
remembering things	remember things	remember things	remember things	like when you remember something that happened before	like when you remember something that happened

Study 1	Study 2	Study 3	Study 4	Definition (Studies 2-3)	Definition (Study 4)
					yesterday
holding beliefs	have beliefs*	-	-	like when you think something is true*	-
Agentic capacities (per Weisman et al., 2017)					
having free will	decide what to do	-	-	like when you choose to do something or not to do it	-
making choices	make choices	make choices	-	like when you choose between different things	-
exercising self-restraint	have self-control*	-	-	like when you stop yourself from doing something you shouldn't do*	-
having intentions	make plans	-	-	like when you are planning to do something	-
working toward a goal	have goals*	-	-	like when you're working hard to do something or make something happen*	-
Social abilities (per Weisman et al., 2017)					
feeling love	feel love	feel love	love someone	like when you really like somebody and care about them a lot	like when you really like somebody and care about them a lot
recognizing someone	recognize somebody else	-	-	like when you know who somebody is	-
communicating with others	communicate with somebody else	-	-	like when you tell somebody something	-
experiencing guilt	feel guilty	feel guilty	feel sorry	like when you feel bad because you	like when you feel bad

Study 1	Study 2	Study 3	Study 4	Definition (Studies 2-3)	Definition (Study 4)
				did something mean	because you hurt somebody else
feeling disrespected	get hurt feelings	get hurt feelings	-	like when you feel bad because somebody insulted you or said something mean about you	-
understanding how others are feeling	understand how somebody else is feeling	-	-	like when you can tell whether somebody is happy or sad	-
feeling embarrassed	feel embarrassed	feel embarrassed	-	like when you feel embarrassed about something that happened to you	-
Other/miscellaneous (per Weisman et al., 2017)					
being conscious	be aware of things	be aware of things	-	like when you're conscious and you know what's going on	-
being self-aware	be aware of itself	-	-	like when you are thinking about yourself	-
experiencing pleasure	feel pleasure*	-	-	like when something feels really good*	-
having desires	have desires*	-	-	like when you really want something*	-
telling right from wrong	know what's nice and what's mean	-	-	like when you know what would be nice to do and what would be mean to do	-
having a personality	have a personality*	-	-	like when someone is shy and somebody	-

Study 1	Study 2	Study 3	Study 4	Definition (Studies 2-3)	Definition (Study 4)
				else is silly*	
experiencing pride	feel proud	feel proud	-	like when you feel really good about something you did	-
Additional questions (Study 3)					
-	-	[is] made out of metal	-	like it has metal inside of it	-
-	-	be turned on and off	-	like you can do something to turn it on and then turn it off	-
New items (Study 4)					
-	-	-	get thirsty	-	like when you feel like you need to drink something
-	-	-	hate someone	-	like when you really don't like somebody
-	-	-	get lonely	-	like when you feel sad because you miss somebody
-	-	-	know stuff	-	like when you know a fact or know how to do something

Study 2: Conceptual change between middle childhood (7-9y) and adulthood

The goal of Study 2 was to develop an experimental paradigm similar to that employed in Study 1 that could be used to explore the development of conceptual representations of mental life among children, and to conduct an initial exploration of these conceptual representations in middle childhood. Study 2 employed the "edge case" strategy used in Studies 1a-1c, with participants asked to reason about the mental lives of either a beetle or a robot.

Pilot testing suggested that children as young as 7 years of age found the paradigm easy and enjoyable, and work on the development of lay biology and psychology has suggested that these concepts may continue to develop well into middle childhood (e.g., Carey, 1985; Hatano & Inagaki, 1994; Piaget, 1929; cf. Gelman & Opfer, 2002). Thus, I targeted 7- to 9-year-old children for the first child sample. I also recruited a group of adults to validate this child-friendly paradigm, i.e., to evaluate whether it replicated the results of Study 1 (Weisman et al., 2017).

Recall that, in Study 1, adult participants evaluated target characters on 40 mental capacities using a seven-point Likert-type scale. Pilot testing suggested two necessary modifications for children: rewording some of the mental capacity items, and using a simpler response scale featuring only three (rather than seven) response options: *no*, *kinda*, or *yes*. This truncated scale allowed children to move fast enough through the study to answer all 40 mental capacity questions—the top priority in the design of these studies (as discussed in the opening section of this chapter).

Participants

In total, 400 people participated in this study.

Adults (n=200) participated via MTurk in July 2016. Adult participants had gained approval for at least 95% of their previous work on MTurk; had MTurk accounts based in the US; and indicated that they were at least 18 years of age. Adults were paid \$0.30 for approximately 2-3 minutes of their time (median duration: 2.48 min).

According to self report, the adult sample ranged in age from 18-65 years (median: 31y) and was roughly split between women (47%) and men (52%; 1% of participants identified as some other gender or opted not to disclose). Adults predominantly identified as White (81%; 8% identified as more than one race/ethnicity, 4% as any other race/ethnicity). The vast majority of adults reported English being their only native language (91%; an additional 7% indicated that English was one of multiple native languages for them.)

Children (*n*=200) participated at one of several San Francisco Bay Area museums or at their younger sibling's preschool between July-December 2016. The study took most children under 6 minutes to complete (median duration: 5.18 min). An additional 12 children participated but were excluded for being outside the target age range (*n*=7), being of unknown age (*n*=4), or being shown a target character other than a beetle or a robot (*n*=1). Children received a small thank-you gift (e.g., a sticker) for their participation.

Children ranged in age from 7.01-9.99 years (median: 8.31y). According to parental report, the child sample included slightly more girls (56%) than boys (42%; 2% of children's gender was non-binary or unknown). Parents predominantly identified their

8% of children were identified as any other race/ethnicity, and 22% of children's race/ethnicity was unknown). Roughly half of parents (46%) reported that their child was bilingual (though, anecdotally, parents' interpretations of "bilingual" ranged from taking classes at school to speaking a language at home).

Materials and procedure

Study 2 employed the "edge case" variant of the general approach: Participants were randomly assigned to assess the mental capacities of either a beetle (*n*=98 adults, *n*=104 children) or a robot (*n*=102 adults, *n*=96 children). The images used to depict these target characters are presented in Figure 2.2.

Instructions to participants focused on the idea that the research team wanted to know what participants thought "[beetles/robots] can do and can not do." Participants rated the target character on 40 mental capacities, presented in a random order for each participant. On each trial, participants responded *no*, *kinda*, or *yes* to the question "Do you think a [beetle/robot] can…?" The three response options were visible throughout the experiment.

The 40 mental capacities were designed to be as close as possible to those in Study 1, while being comprehensible to children in early elementary school. As in Study

1, each a priori category included at least five items of varying valence, complexity, and phrasing; see Table 2.1.

Figure 2.2: Target characters used in Studies 2-3, presented with the verbal label used to describe each character. Animal characters are presented in the first row, and inert objects in the second row. Studies 2 and 4 employed the "edge case" variant of the general approach, in which participants assessed the mental capacities of beetles and robots; these characters are indicated with a black border. Study 2 employed the "diverse characters" variant of the general approach, in which participants assessed the wider range of target characters presented here.

Each item was associated with a pre-set definition or explanation, to allow the data collection team to be consistent in our responses to participants (particularly children) if they asked for clarification; see Table 2.1. Children were encouraged at the beginning of the study to ask questions if they did not know what a word meant, in which case they given these definitions; adults were told that they could access these definitions by hovering over the text on the computer screen. Pilot testing suggested that seven items required clarification for most children, so these items were always accompanied by their definitions from the beginning of the trial (for both adults and children), as follows: *have a personality, like when someone is shy and somebody else is silly*; *have beliefs, like when you think something is true*; *feel pleasure, like when something feels really good*; *have desires, like when you really want something*; *have self- control, like when you stop yourself from doing something you shouldn't do*; *have goals, like when you're trying hard to do something or make something happen*; and *feel sick, like when you feel like you might throw up*.

Adults completed the study by clicking through a website at their own pace, with one trial presented on each page and no ability to go backwards. Children completed the study on an experimenter's laptop computer. The experimenter read the instructions and the first several trials out loud, requesting verbal responses from the child and selecting his or her response for her; after several trials, the experimenter gave the child the option to continue independently (reading the questions and selecting their answers themselves) if they desired. Roughly half of participants completed the remainder of the task independently.

Data processing

Trials with response times that were faster than a preset criterion of 250ms were dropped, and participants were retained regardless of skipped trials. Overall, only 1.24% of adults' trials (*n*=98) and 0.81% of children's trials (*n*=64) were missing data; in these cases, I imputed missing values using the median by target character, capacity, and age group.

Study 3: Conceptual change over early and middle childhood (4-9y)

Study 3 was designed with two goals in mind.

First, it aimed to extend the findings with 7- to 9-year-old children in Study 2 by expanding the list of the target characters to include not only the two "edge cases" from Study 2 (a beetle and a robot), but a also a wider range of animate beings (a bird, a goat, and an elephant) and inanimate objects (a computer, a teddy bear, and a doll)—i.e., by moving from the "edge case" strategy to the "diverse characters" strategy for eliciting mental capacity attributions.

Second, Study 3 assessed the earlier development of conceptual structure in a group of younger children: 4- to 6-year-old children. The time from 4-6 years has been identified as a period of especially dramatic development in several relevant domains, including lay psychology and theory of mind, lay biology and the animate-inanimate distinction, moral reasoning, and so on (for reviews, see Flavell, 1999; Gelman & Opfer, 2002; Wellman, 2015).

Participants

A total of 365 people participated in this study, including a group of adults, a group of "older" children (7-9y), and a group of "younger" children (4-6y).

Adults (*n*=116) participated via MTurk in September 2018. Adult participants had gained approval for at least 95% of their previous work on MTurk; had MTurk accounts based in the US; and indicated that they were at least 18 years old. Adults were paid $0.45 for approximately 2-4 minutes of their time (median duration: 3.02 min). An additional 22 adults participated but were excluded for failing to respond sensibly to an open-ended question about what they had been asked to do in the study (e.g., copying and pasting text from the question, writing "good study," or describing a different study, e.g., "I wrote an essay about nature"; *n*=11) or for failing to pass one or more attention checks (e.g., "Please select no"; *n*=11). According to self report, the final adult sample ranged in age from 20-69 years (median: 38y) and included slightly more men (53%) than women (47%). Adults predominantly identified as White (84%; 2% identified as more than one 4% as any other race/ethnicity).

Two groups of children were recruited for this study: "older" children (7-9y) and "younger" children (4-6y). The planned sample size was 120 per age group, but the research team also retained a handful of extra participants who completed the study on the final day of data collection for each group.

The group that I refer to as "older children" (*n*=125) ranged in age from 7.08-9.98 years (median: 8.56y), and participated at one of several San Francisco Bay Area museums or at their younger sibling's preschool between July-December 2016. The study took most older children under 4 minutes to complete (median duration: 2.70 min). According to parental report, the sample of older children included slightly more boys (54%) than girls (45%); 1% of children's gender was non-binary or unknown). Parents predominantly identified their children as White (30%), South Asian (14%), multiracial 7% of children were identified as any other race/ethnicity, and 22% of children's parents declined to provide information on their race/ethnicity.

"Younger children" (*n*=124) ranged in age from 4.00-6.98 years (median: 5.03y), and participated either at a university-affiliated preschool or at a Bay Area museum between January-June 2017. The study took most younger children under 6 minutes to complete (median duration: 3.58 min). According to parental report and school records, the sample of younger children included roughly the same number of girls (48%) and 6% of children were identified as any other race/ethnicity, and 5% of children's parents declined to provide information on their race/ethnicity).

An additional 7 children participated but were excluded for being outside the target age ranges. At museums (but not at the preschool), children received a small thank-you gift (e.g., a sticker) for their participation.

Materials and procedure

Pilot testing suggested that working with younger children would require making a briefer experimental paradigm with fewer than the 40 questions included in Study 2; limiting the list to 20 questions seemed to allow children as young as 4 years of age to complete the study easily and without getting bored or frustrated, while still including enough items to facilitate the exploratory "dimensionality reduction" approach to uncovering conceptual structure (Chapter III).

Table 2.2: Sample sizes by target character and age group for Study 2.

Character	Adults	Older children (7-9y)	Younger children (4-6y)
elephant	15	17	14
goat	18	14	14
mouse	9	15	15
bird	14	15	12
beetle	11	17	14
robot	18	14	12
computer	10	11	14
teddy bear	6	10	16
doll	15	12	13
TOTAL N	116	125	124

Study 3 employed the "diverse characters" variant of the general approach. Participants were assigned to evaluate one of the following target characters: an elephant, a goat, a mouse, a bird, a beetle, a teddy bear, a doll, a robot, or a computer (*n* per character: 6-18 adults, 10-17 older children, and 12-16 younger children; see Table 2.2 for exact counts). The images used to depict these target characters are presented in Figure 2.2.

Participants were assigned to target characters randomly, with two exceptions: (1) The doll and teddy bear conditions were run last for older children (but included in the initial randomization scheme for adults and younger children); and (2) Toward the end of data collection with children, children were assigned to conditions that had the fewest participants. (This was not possible with adults, which is why the number of adults per condition was more variable than the number of children per condition.) As in Study 1, a vivid, high-resolution photo of the target character in a naturalistic context was visible for the duration of the study.

Instructions and procedure were identical to Study 2, with two exceptions: (1) Participants rated the target character on 20 (rather than 40) mental capacities; and (2) For younger children, the experimenter read all questions out loud and children responded verbally.

The 20 mental capacities were a subset of the 40 items used in Study 2, chosen to cover a similar range of capacities as included in Studies 1-2 (see Table 2.1). These items were also selected to include some of the strongest-loading items for each of the factors uncovered among adults in Study 2 (see Chapter III for further discussion). As in Study 2, each mental capacity was associated with a short, preset definition. With the exception of the item *feel sick*, which was always presented along with its definition (*like when you feel like you might throw up*) for both adults and children, these definitions were only given to children if they indicated that they did not know what a word meant; both older and younger children were encouraged at the beginning of the study to ask clarification questions. In Study 3 adult participants did not have access to these definitions.

After completing the 20 questions about mental capacities, a subset of participants also answered two additional questions: "Is a [target] made out of metal?" and "Can a [target] be turned on and off?" These questions were always asked last, were not intended to be included in any of the primary analyses, and will not be analyzed here.

Data processing

As in Study 2, I planned to drop trials with response times that were faster than a preset criterion of 250ms, but there were none among children, and I failed to record response times among adults. As in Study 2, participants were retained regardless of skipped trials. Overall, none of adults' trials, none of older children's trials, and only 1.22% of younger children's trials (*n*=30) were missing data. In these cases, I imputed missing values using the median by target character, capacity, and age group.

Study 4: A focus on early childhood (4-5y)

The primary goal of Study 4 was to provide a conceptual replication and extension of Study 3, with a special focus on the youngest children included in the previous studies (4-year-old children). In light of concerns about vocabulary, attention, and use of the response scale among preschool-age children in Study 3, I designed an even more child-friendly version specifically tailored to be appropriate for young preschoolers, by streamlining the experimental protocol, providing more scaffolding for the response scale, and including only vocabulary items that were pre-tested to be familiar to young preschool children.

To extend the results of Study 3, and for the sake of completeness of the comparison between children in early childhood, middle childhood, and adulthood, in Study 4 I returned to the "edge case" strategy for eliciting mental capacity attributions, limiting the target characters to a beetle and a robot (as in Studies 1a-1c and Study 2).

Note: At the time of the submission of this dissertation, the sample of 4- to 5-year-old children for Study 4 was only partially complete. All results using this sample should thus be considered preliminary and not conclusive.

Participants

148 people participated in this study, including a group of adults and a group of 4- to 5-year-old children.

Adults (*n*=104) participated via MTurk in September 2018. Adult participants had gained approval for at least 95% of their previous work on MTurk; had MTurk accounts based in the US; and indicated that they were at least 18 years old. Adults were paid $0.45 for approximately 2-4 minutes of their time (median duration: 3.76 min). An additional 21 adults participated but were excluded for failing to respond sensibly to an open-ended question about what they had been asked to do in the study (see Study 3 for examples; *n*=16) or for failing to pass one or more attention checks (e.g., "Please select no"; *n*=5). According to self report, the final adult sample ranged in age from 23-71 years (median: 35y) and included slightly more men (56%) than women (43%). Adults predominantly identified as White (71%; 12% identified as Black; 7% identified as more 12% as any other race/ethnicity).

The planned sample size was 100 4- to 5-year-old children; at the time of the submission of this dissertation, this partial sample consisted of 44 children ranging in age from 4.02-5.59 years (median: 4.73y). Children participated at a university-affiliated preschool in the Bay Area between January-July 2018. The research team did not record study duration. According to school records, the sample of younger children included slightly more girls (34%) than boys (23%). Children were predominantly identified as 5% of children were identified as any other race/ethnicity, and 43% of children's parents declined to provide information on their race/ethnicity).

Materials and procedure

Materials and procedure were adapted from Studies 2-3 to be more appropriate for young preschoolers, with two primary goals in mind: Streamlining the experimental protocol to improve children's comprehension and attention to the task, and limiting mental capacities to words that are highly familiar to young preschool children.

In order to streamline the experimental protocol, the task was moved off of the computer (for children but not adults); the experimenter instead used printed photographs to illustrate the target characters (measuring approximately 5 x 8 inches, printed in color and laminated) and recorded children's responses by hand. At the time of testing, the experimenter and child sat side by side at a table, with the photograph placed on the table directly in front of the child for the duration of the task.

The introduction to the task was also streamlined. The experimenter began by placing the photograph of the first target character in front of the child and asking, "Can you tell me what this is?" If a child provided an answer other than "beetle" or "robot," the experimenter said something to the effect of, “I’m going to call it a [beetle/robot]”; otherwise, the experimenter affirmed the child’s correct response. The experimenter then said, “We’re going to play a game about [beetles/robots]”; reminded children, “If you ever want to stop playing, you can just let me know and we’ll go back to the classroom” (per this university preschool’s protocol); and then launched directly into the first question (e.g., “Can beetles get sad?”).

To scaffold children’s use of the three-point response scale, the experimenter provided the child with a physical representation of the scale consisting of three large boxes, separated by blank space, containing the words “NO,” “KINDA,” and “YES” written in large font with all capital letters (to aid children with at least some reading skills in recognizing these words); color-coded according to the intensity of response (NO = very light blue, KINDA = medium blue, YES = dark blue); and ordered from left (NO) to right (YES). Each box measured approximately 2 x 4 inches; the boxes were laminated with slightly less than 1 inch of empty space between them (through which the table was visible); see Figure 2.3. In addition to providing these visual and spatial cues to the fact that there were three response options—no, yes, and something conceptually and literally “in between” these extremes—the experimenter described (and then reiterated) these response options on the first three trials (“You can say no [pointing to NO], kinda [pointing to KINDA], or yes [pointing to YES]”). The experimenter repeated these options on the first three trials for all children, and on any other trials when a child took more than a few seconds to answer or provided a response other than saying “yes,” “kinda” or “sorta,” “no,” or clearly pointing to one of the three options on the response scale.

Figure 2.3: Example participant in Study 4.

For each of the two target characters (beetle, robot; see Figure 2.2), children answered 18 questions about its mental capacities; see Table 2.1. These items were chosen to be as short as possible and to be highly familiar to young preschool children. They were selected from a larger pilot study in which 3- to 5-year-old children were asked to complete stories that began with each of these mental capacities as a premise (e.g., “Let’s imagine a person who *loves someone*. What happens next?”; “Now let’s pretend that someone *remembers something*. What happens next?”) and were judged on the appropriateness of their story completion. Items were also selected to provide a conservative test of developmental differences between younger and older children in the “conceptual units” observed in Study 3; see Chapter III for discussion. As in Studies 2-3, each mental capacity was associated with a short, preset definition (see Table 2.1). Unlike Studies 2-3, none of these definitions were considered mandatory; instead, for all 18 items, definitions were provided to children only if they expressed uncertainty about what a word meant or did not respond after prompting use of the response scale. As in Study 3, in Study 4 adult participants did not have access to these definitions.

Children first assessed all 18 mental capacities for one of the two target characters (e.g., the beetle), then completed an easy jigsaw puzzle featuring clothing and accessories appropriate for a rainy day (which took about 30-60 s to complete), and finally assessed all 18 mental capacities for the other target character (e.g., the robot).

This modified procedure—particularly moving the experiment off of the computer for children—required several changes to the experimental design. Rather than randomly assigning children to assess the beetle first or the robot first, the order of target characters was counterbalanced in advance. Likewise, rather than asking about the 18 mental capacities in a random order, questions about the first target character were asked in one of 8 pre-made random orders, and questions about the second target character were asked in the reverse order. The order of the target characters (beetle-robot or robot-beetle) and the order of the mental capacity questions (sequences 1-8) were fully crossed across participants.

Adults participated in an online version of this same task, without a break between target characters. As in Studies 1-2, adults clicked through a website at their own pace, with one trial presented on each page and no ability to go backwards.

Data processing

The research team did not record response times or use this as a criterion for inclusion. As in Studies 1-3, participants were retained regardless of skipped trials. Overall none of adults' trials and only 1.64% of children's trials (*n*=25) were missing data; in these cases, I imputed missing values using the median by target character, capacity, and age group.

Chapter conclusion

The goal of this chapter was to provide a roadmap for the remainder of the dissertation and to describe the general approach and specific methods employed in these four studies. In the following chapters I present three analyses of this collection of datasets, beginning with an attempt to identify the "conceptual units" available to participants of different ages as they assessed the mental capacities of the target characters included in these studies.

CHAPTER III: CHANGES IN CONCEPTUAL UNITS

Chapter overview

In this chapter, I focus on the first of my three key questions about the development of representations of mental life: *What are the components, or "conceptual units," that anchor representations of mental life at different points in development?* As described in Chapter II, to address this question I draw on data from all of the current studies (Studies 1-4); for details about the methods of these studies, see Chapter II. The goal of this chapter is to provide "snapshots" of the sets of conceptual units available to participants in early childhood, middle childhood, and adulthood. (Note that this was the primary planned analysis for all of the studies included in this dissertation; see, e.g., Weisman, Dweck, & Markman (2017).)

General analysis plan

High-level overview

In analyzing these datasets with an eye toward identifying "conceptual units," the basic insight is that tracking the covariance of mental capacity attributions provides a way of discovering suites of mental capacities that "hang together" in reasoning about mental life, and that these suites of mental capacities might correspond to the units of some larger conceptual representation of this general domain. To borrow an example from Chapter II: If participants who endorse Capacity X also tend to endorse Capacities Y and Z, this provides some evidence that Capacities X, Y, and Z constitute a suite of mental capacities that are closely associated with the same underlying "conceptual unit."

In other words, my goal in the current chapter is to uncover a set of latent constructs—"conceptual units"—that could have given rise to the correlations among mental capacity attributions as observed in a given group of participants. A canonical way to identify latent constructs via observed correlations is exploratory factor analysis (EFA), a form of dimensionality reduction that posits that the observed variables in a given dataset are related, to varying degrees, to a smaller set of unobserved "factors"; and that individual observations of each of these variables reflect a combination of (a) the state of these latent factors, (b) a particular variable's relationship to each of these latent factors, and (c) noise. Following this logic, I posit that, for any of the current datasets, the many mental capacities included in that dataset are related, to varying degrees, to a smaller set of latent "conceptual units"; and that a participant's attributions of each of these mental capacities to a particular target character reflect a combination of (a) the participant's beliefs about the extent to which these conceptual units apply to that target character, (b) each mental capacity's relationships to each of the conceptual units, and (c) noise. In other words, one way to identify conceptual units for a particular sample of interest (e.g., US adults; children of different age groups) is to conduct an EFA over participants' mental capacity attributions and treat the resulting "factors" as candidate conceptual units.

Details of analyses

In the remainder of this chapter, I report EFAs for each age group included in each of the current studies (Studies 1-4). Conducting an EFA requires making a variety of analysis choices, including how to handle missing data, what kind of correlations to use, the choice of factoring algorithm, how to determine the number of factors to retain, the choice of rotation method (if any), and the method for calculating factor scores. In the analysis code for this chapter I have included easy short cuts for the interested reader to explore different options for each of these parameters. Here, I have set all of these parameters to be constant across EFAs of different samples so as to maximize comparability across studies. To conduct these EFAs, I use the "psych" package for R (Revelle, 2018).

Missing data

For all EFAs, I impute missing trial-level data (e.g., skipped trials among child participants) using the median response for that mental capacity among other participants who evaluated the same target character. For example, if an 8-year-old participant in the "beetle" condition failed to provide a response to a question about a beetle's capacity for happiness, I fill in this datapoint with the median response to the happiness question among all other children from the 7- to 9-year-old age group for that study who evaluated the beetle (ignoring responses from other age groups, and ignoring children who evaluated some other target character). Across all studies, fewer than 1.65% of trials in any age group were missing data. In my judgment, the advantages of retaining the most participants per sample (particularly for EFA, which is highly sensitive to sample size) justify imputing values for this small number of missing datapoints.

Correlation type

I conduct analyses over Pearson correlations among mental capacity attributions, using pairwise complete observations. In principle, polychoric correlations are better suited to handle responses on the three-point scales employed in Studies 2-4; however, in my experience with these data, conducting EFAs with polychoric correlations instead of Pearson correlations tends to generate errors further down the analysis pipeline (e.g., generating correlation matrices that are not positive definite) and appears to be somewhat vulnerable to over-fitting (e.g., suggesting retaining six or more factors that each account for only a very small amount of the shared variance).

Factoring algorithm

I use ordinary least squares to find the minimum residual solution, which is robust to a variety of ways that matrices can be "badly behaved" (see Revelle, 2018). While this dissertation does not include a systematic exploration of all of the factoring algorithms available when conducting EFA, in my casual explorations of the various algorithms available I have yet to observe any substantial differences to the number of factors retained or to the resulting solutions that would change the interpretations offered here.

Factor retention protocol

I examine 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) The factor retention protocol reported in the original publication of Study 1 (Weisman et al., 2017), which specifies extracting the maximal number of factors according to an analysis of degrees of freedom and retaining factors that meet all three of the following criteria: (a) have eigenvalues >1.00, (b) individually account for >5% of the shared variance before rotation, and (c) are the "dominant" factor (the factor with the strongest absolute factor loading) for at least 1 mental capacity after rotation.

For each study, my interpretation of how best to characterize the dataset (i.e., how many factors I observed) is determined by the degree of consensus among these three protocols and by the interpretability of the retained factors under each protocol (e.g., the percent of shared variance explained by each factor, the strength of factor loadings for each factor, and my subjective assessment of the ease with which I can identify the "latent construct" captured by each factor). See Table 3.1 for the results of all factor retention protocols for all studies and samples. In the main text of this chapter, I focus on just one or two solutions (see Table 3.1, rightmost column); any suggested solutions that are not discussed in this chapter can be found in Appendix A.

Rotation

To maximize interpretability, I present varimax-rotated solutions, in which factors are constrained to be orthogonal (i.e., inter-factor correlations are constrained to be 0) and rotated to maximize the sum of the variances of the squared factor loadings with the goal of achieving simple structure (see Revelle, 2018, for discussion). For unrotated solutions and solutions applying oblique ("oblimin") transformations, in which factors are allowed to correlate, see Appendix A.

Study 1: An adult endpoint

In the context of this dissertation, Study 1 serves the role of describing a developmental endpoint for conceptual representations of mental life. In this chapter, I focus on what these studies can reveal about the fundamental components of this representation: What are the conceptual units available to US adults in reasoning about the mental lives of various beings in the world?

An in-depth analysis and discussion of these results is provided in the original publication of these studies (Weisman et al., 2017). Here I present these analyses anew, with slight tweaks to the analysis pipeline to maximize comparability to Studies 2-4—namely, examining multiple factor retention protocols (rather than only one), and recoding the response scale used in these studies to begin at 0 (rather than being centered at 0).

Special notes on data processing and analysis

In Study 1c, participants assessed two target characters side by side (in contrast to Studies 1a, 1b, and 1d, in which each participant assessed just one target character). In the current analyses (as in the original publication of these results; Weisman et al., 2017), I treat each participant's assessments of each target character as a separate set of observations (as if they came from different participants), in effect doubling the sample size for these studies (but ignoring the within-subject design).

Results

Study 1a

In Study 1a, 405 US adults each assessed a single target character on 40 mental capacities. This study employed the "edge case" variant of the general approach, with participants randomly assigned to assess either a beetle or a robot. (See Chapter II and Weisman et al. (2017), for detailed methods.)

How many conceptual units?

Two of the three protocols for determining how many factors to retain (parallel analysis and the factor retention criteria reported in the original publication of Study 1; Weisman et al., 2017) suggested retaining three factors, while the third (minimizing BIC) suggested retaining five factors; see Table 3.1.

Three of the five factors suggested by minimizing BIC were qualitatively very similar to the three factors suggested by the other protocols, and even in the 5-factor solution these three factors together accounted for fully 94% of the shared variance. The fourth and fifth factors each accounted for <4% of the shared variance, and neither was the dominant factor for any of the 40 mental capacities included in this study. Indeed, factor loadings for these two factors were all quite weak (absolute loadings all <0.33). Given all this, I will limit my interpretations to the three-factor solution; see Appendix A for the 5-factor solution.

Table 3.1: Number of factors suggested by three factor retention protocols: parallel analysis, minimizing BIC, and the factor retention criteria specified in Weisman et al. (2017). Results are grouped by study and age group. The final column gives the focus of my interpretation in Chapter III; see Appendix A for additional solutions not reported in this chapter.

	Parallel analysis	**Minimizing BIC**	**Weisman et al. (2017)**	**Focus of interpretation**
Study 1: An adult endpoint				
1a	3	5	3	3-factor solution
1b	3	4	3	3-factor solution
1c	3	4	3	3-factor solution
1d	4	5	3	3-factor solution
Study 2: Conceptual change between middle childhood (7-9y) and adulthood				
Adults	4	3	3	3- and 4-factor solutions
Children (7-9y)	3	3	3	3-factor solution
Study 3: Conceptual change over early and middle childhood (4-9y)				
Adults	3	4	3	3-factor solution
Older children (7-9y)	3	3	3	3-factor solution
Younger children (4-6y)	2	1	3	2- and 3-factor solutions
Study 4: A focus on early childhood (4-5y)				
Adults	3	3	3	3-factor solution
Children (4-5y)	2	1	4	2-, 3-, and 4-factor solutions

What are these conceptual units?

After rotation, the first factor corresponded primarily to physiological sensations related to biological needs—a suite of capacities that I will refer to as BODY (a label employed in the original reporting of this study; Weisman et al. (2017)). It was the dominant factor for such items as *getting hungry*, *experiencing pain*, *feeling tired*, and *experiencing fear*, and accounted for 41% of the shared variance in the rotated three-factor solution, and 25% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to capacities for self- and other-relevant emotions—a suite of capacities that I will refer to as HEART (as in Weisman et al. (2017)). It was the dominant factor for such items as *feeling embarrassed*, *experiencing pride*, *feeling love*, and *experiencing guilt*, and accounted for 39% of the shared variance in the rotated three-factor solution, and 24% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to perceptual-cognitive abilities to detect and use information about the environment—a suite of capacities that I will refer to as MIND (as in Weisman et al. (2017)). It was the dominant factor for such items as *remembering things*, *recognizing someone*, *sensing temperatures*, and *communicating with others*, and accounted for 21% of the shared variance in the rotated three-factor solution, and 13% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 62% of the total variance in participants' mental capacity attributions. See Figure 3.1 for all factor loadings.

Study 1b

Study 1b was a direct replication of Study 1a: 406 US adults each assessed a single target character (either a beetle or a robot) on 40 mental capacities. (See Chapter II and Weisman et al. (2017), for detailed methods.)

How many conceptual units?

Two of the three protocols for determining how many factors to retain (parallel analysis and the factor retention criteria reported in the original publication of Study 1; Weisman et al., 2017) suggested retaining three factors, while the third (minimizing BIC) suggested retaining four factors; see Table 3.1.

Three of the four factors suggested by minimizing BIC were qualitatively very similar to the three factors suggested by the other protocols, and together accounted for fully 96% of the shared variance. The fourth factor accounted for only 4% of the shared variance, and was not the dominant factor for any of the 40 mental capacities included in this study, with weak loadings for all capacities (absolute loadings all <0.35).

Given all this, I will again focus the remainder of my analyses on the three-factor solution; see Appendix A for the four-factor solution.

What are these conceptual units?

After rotation, the first factor corresponded primarily to the physiological sensations that I labeled BODY in Study 1a (see also Weisman et al. (2017)). It was the dominant factor for such items as *getting hungry*, *experiencing pain*, *feeling tired*, and *experiencing fear*, and accounted for 42% of the shared variance in the rotated three-factor solution, and 25% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to the social-emotional abilities that I labeled HEART in Study 1a (see also Weisman et al. (2017)). It was the dominant factor for such items as *experiencing guilt*, *experiencing pride*, *feeling embarrassed*, and *feeling disrespected*, and accounted for 35% of the shared variance in the rotated three-factor solution, and 21% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to the perceptual-cognitive abilities that I referred to as MIND in Study 1a (see also Weisman et al. (2017)). It was the dominant factor for such items as *communicating with others*, *detecting sounds*, *remembering things*, and *working toward a goal*, and accounted for 23% of the shared variance in the rotated three-factor solution, and 14% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 59% of the total variance in participants' mental capacity attributions. See Figure 3.1 for all factor loadings.

Study 1c

In Study 1c, 200 US adults each assessed two target characters on 40 mental capacities. Like Studies 1a and 1b, this study employed the "edge case" variant of the general approach; but in this study, all participants assessed both of these target characters side by side (with left-right position counterbalanced across participants). (See Chapter II and Weisman et al. (2017), for detailed methods.)

How many conceptual units?

Two of the three protocols for determining how many factors to retain (parallel analysis and the factor retention criteria reported in the original publication of Study 1; Weisman et al., 2017) suggested retaining three factors, while the third (minimizing BIC) suggested retaining four factors; see Table 3.1.

Much as in Studies 1a and 1b, three of the four factors suggested by BIC were qualitatively very similar to the three factors suggested by the original factor retention criteria, and together accounted for fully 96% of the shared variance. The fourth factor accounted for only 4% of the shared variance and was not the dominant factor for any of the 40 mental capacities included in this study, with weak factor loadings for all capacities (absolute loadings all <0.34). Given all this, I will again focus the remainder of my analyses on the three-factor solution; see Appendix A for the four-factor solution.

What are these conceptual units?

After rotation, the first factor corresponded primarily to the physiological sensations that I labeled BODY in Studies 1a and 1b (see also Weisman et al. (2017)). It was the dominant factor for such items as *getting hungry*, *experiencing pain*, *feeling tired*, and *experiencing fear*, and accounted for 42% of the shared variance in the rotated three-factor solution, and 25% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to the social-emotional abilities that I labeled HEART in Studies 1a and 1b (see also Weisman et al. (2017)). It was the dominant factor for such items as *experiencing pride*, *experiencing guilt*, *feeling disrespected*, and *feeling embarrassed*, and accounted for 38% of the shared variance in the rotated three-factor solution, and 23% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to the perceptual-cognitive abilities that I referred to as MIND in Studies 1a and 1b (see also Weisman et al. (2017)). It was the dominant factor for such items as *detecting sounds*, *remembering things*, *recognizing someone*, and *communicating with others*, and accounted for 20% of the shared variance in the rotated three-factor solution, and 12% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 60% of the total variance in participants' mental capacity attributions. See Figure 3.1 for all factor loadings.

Study 1d

In Study 1d, 431 US adults each assessed a single target character on 40 mental capacities. Unlike Studies 1a-1c, this study employed the "many characters" variant of the general approach, in which participants were randomly assigned to assess one of the following 21 target characters: an adult, a child, an infant, a person in a persistent vegetative state, a fetus, a chimpanzee, an elephant, a dolphin, a bear, a dog, a goat, a mouse, a frog, a blue jay, a fish, a beetle, a microbe, a robot, a computer, a car, or a stapler. (See Chapter II and Weisman et al. (2017), for detailed methods.)

How many conceptual units?

Each of the three factor retention protocols suggested a different number of factors to retain; see Table 3.1.

The retention criteria used in the original reporting of this study (Weisman et al. (2017)) suggested retaining three factors.

Parallel analysis suggested retaining four factors. However, three of these four factors were qualitatively very similar to the three factors suggested by Weisman et al.'s (2017) original retention criteria, and together accounted for fully 98% of the shared variance. The fourth factor accounted for only 2% of the shared variance and was not the dominant factor for any of the 40 mental capacities included in this study, with weak loadings for all capacities (absolute loadings all <0.31).

Likewise, minimizing BIC suggested retaining five factors, but three of these five factors were qualitatively very similar to the three factors suggested by the original retention criteria, and together accounted for fully 94% of the shared variance. The fourth and fifth factors each accounted for <4% of the shared variance, and neither was the dominant factor for any of the 40 mental capacities included in this study. Indeed, factor loadings for these two factors were all quite weak (absolute loadings all <0.38).

Given all this, I will once more focus the remainder of my analyses on the three-factor solution; see Appendix A for the 4- and 5-factor solutions.

What are these conceptual units?

After rotation, the first factor corresponded primarily to the physiological sensations that I labeled BODY in Studies 1a-1c (see also Weisman et al. (2017)). It was the dominant factor for such items as *experiencing pain*, *feeling tired*, *getting hungry*, and *experiencing fear*, and accounted for 41% of the shared variance in the rotated three-factor solution, and 31% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to the social-emotional abilities that I labeled HEART in Studies 1a-1c (see also Weisman et al. (2017)). It was the dominant factor for such items as *holding beliefs*, *experiencing guilt*, *feeling embarrassed*, and *telling right from wrong*, and accounted for 34% of the shared variance in the rotated three-factor solution, and 25% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to the perceptual-cognitive abilities that I referred to as MIND in Studies 1a-1c (see also Weisman et al. (2017)). It was the dominant factor for such items as *detecting sounds*, *sensing temperatures*, *communicating with others*, and *remembering things*, and accounted for 25% of the shared variance in the rotated three-factor solution, and 19% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 74% of the total variance in participants' mental capacity attributions. See Figure 3.1 for all factor loadings.

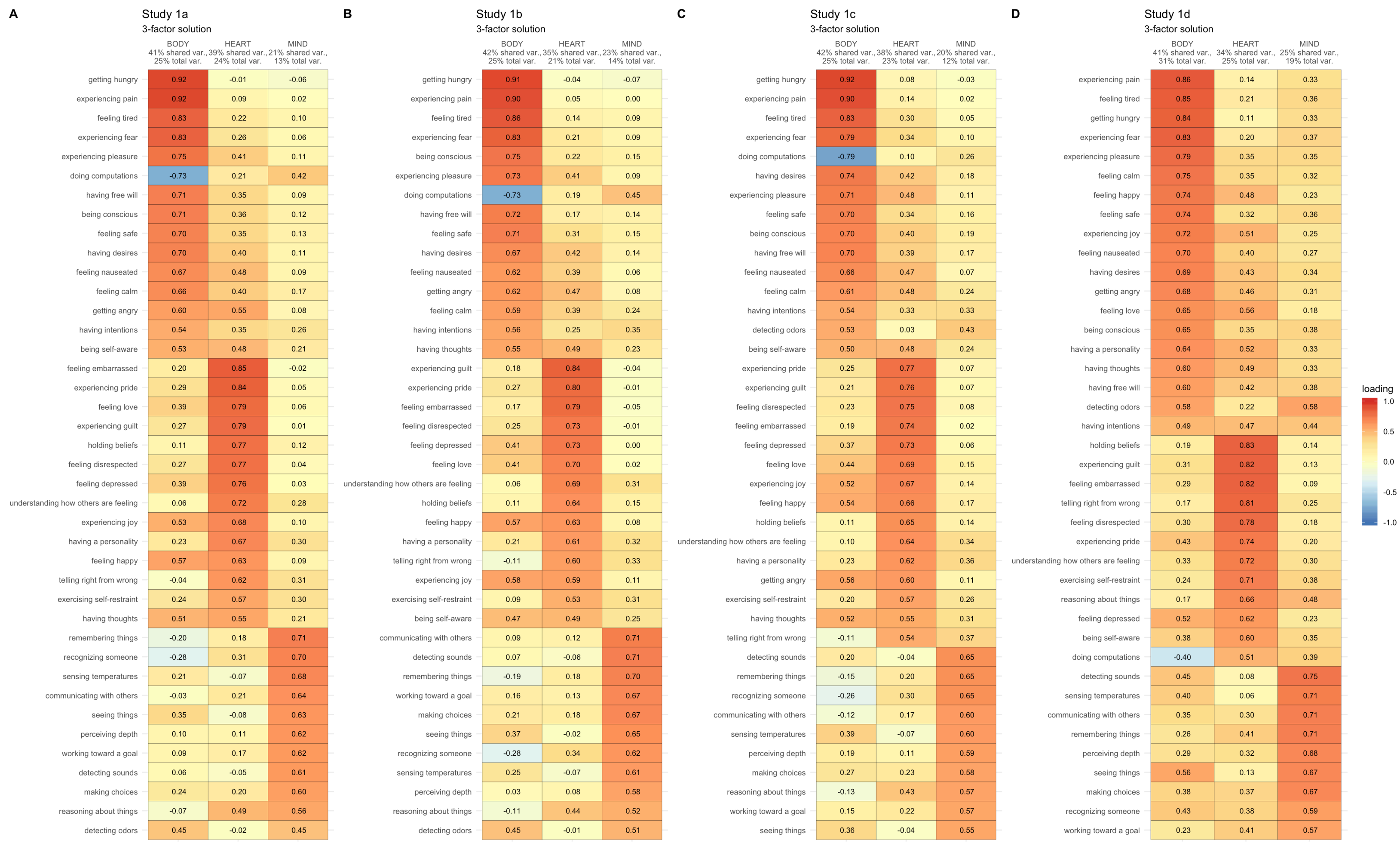

Figure 3.1: Factor loadings from exploratory factor analyses of Studies 1a-1d (see also Weisman et al., 2017). (A-B) In Studies 1a and 1b, US adults assessed one of two 'edge case' characters (a beetle or a robot). (C) In Study 1c, US adults assess both of these 'edge cases' side by side (with left-right position counterbalanced across participants). (D) In Study 1d, US adults assessed one of 21 diverse target characters. In this and all figures portraying factor loadings, factors have been plotted in the same order (BODY, HEART, MIND), when applicable, to facilitate comparison across studies. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Discussion

The general pattern that emerged from Studies 1a-1d is clear and appears to be highly reliable: In four large-scale studies, US adults' mental capacity attributions were anchored by a three-way distinction between the physiological sensations of the BODY, the social-emotional abilities of the HEART, and the perceptual-cognitive abilities of the MIND. Given the range of mental capacities included in each study, a number of additional or alternative factors could have emerged—including "experience" or "agency," as in Gray et al.'s (2007) work on mind perception). Nonetheless, a common set of factors—i.e., a stable set of "conceptual units"—emerged across independent analyses of four studies, whether participants judged a single "edge case" target character in isolation (Studies 1a and 1b), compared two "edge cases" that highlighted a contrast in biological animacy (Study 1c), or evaluated a diverse range of target characters, from inert objects to canonical social partners (Study 1d). For an extended discussion of these results, see Weisman et al. (2017).

Studies 1a-1d provide a clear developmental endpoint for this aspect of conceptual representations of mental life: As a group, US adults appear to have access to three fundamental conceptual units—BODY, HEART, and MIND—when reasoning about the mental lives of various beings in the world. Studies 2-4 were designed to explore the developmental trajectory that leads up to this endpoint: How do US children come to represent mental life in this way?

Study 2: Conceptual change between middle childhood (7-9y) and adulthood

Study 2 provides a first glimpse of the emergence of conceptual representations of mental life prior to adulthood. In this chapter, I focus on the fundamental components of this representation: What are the conceptual units available to US children in reasoning about the mental lives of various beings in the world, and how do they compare to those available to US adults (as revealed in Study 1)?

Pursuing this question with children required developing an age-appropriate experimental paradigm. In particular, the wording of some of the 40 mental capacities employed in Study 1 was modified to use more age-appropriate vocabulary, and participants responded on a three-point scale ("no," coded as 0; "kinda," coded as 0.5, "yes," coded as 1), , rather than a seven-point scale. Study 2 employed the "edge case" variant of the general approach, with participants randomly assigned to assess either a beetle or a robot. As in Studies 1a, 1b, and 1d, in Study 2 each participant assessed a single target character on all 40 mental capacities. To validate the modified paradigm (i.e., to assess whether this paradigm produced similar results to Study 1), and to provide a direct comparison for child participants, participants included a sample of 200 US adults. As an initial foray into exploring development in this domain, the child sample consisted of 200 US children between the ages of 7.01-9.99y (median: 8.31y). (See Chapter II for detailed methods.)

Results

Adults

How many conceptual units?

Two of the three protocols for determining how many factors to retain (minimizing BIC and the factor retention criteria employed in the original publication of Study 1; Weisman et al., 2017) suggested retaining three factors, while the third (parallel analysis) suggested retaining four factors; see Table 3.1. Unlike in Studies 1a-1d, in which factors beyond the first three uniformly accounted for very small amounts of the shared variance, were not the dominant factor for any mental capacities, and tended to have weak factor loadings for all mental capacities, none of these considerations clearly rules out the fourth factor suggested by parallel analysis. Given this, I will present and interpret both three- and four-factor solutions.

What are these conceptual units?

Three-factor solution

First, I will examine the three-factor solution suggested by minimizing BIC and by the factor retention criteria employed in the original publication of Study 1 (Weisman et al., 2017). Importantly, this is the number of factors retained among US adults in all of my previous studies with US adults (Studies 1a-1d).

After rotation, the first factor corresponded primarily to the social-emotional abilities that I labeled HEART in Study 1 (see also Weisman et al. (2017)). It was the dominant factor for such items as *feel proud*, *feel joy*, *feel sad*, and *feel happy*, and accounted for 37% of the shared variance in the rotated three-factor solution, and 18% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to the physiological sensations that I labeled BODY in Study 1 (see also Weisman et al. (2017)). It was the dominant factor for such items as *get hungry*, *feel pain*, *feel scared*, and *feel tired*, and accounted for 37% of the shared variance in the rotated three-factor solution, and 18% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to the perceptual-cognitive abilities that I referred to as MIND in Study 1 (see also Weisman et al. (2017)). It was the dominant factor for such items as *figure out how to do things*, *make choices*, *recognize somebody else*, and *sense whether something is close by or far away*, and accounted for 25% of the shared variance in the rotated three-factor solution, and 12% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 48% of the total variance in participants' mental capacity attributions. See Figure 3.2 for all factor loadings.

Four-factor solution

In the four-factor solution suggested by parallel analysis, after rotation, the first factor corresponded primarily to physiological sensations (BODY). It was the dominant factor for such items as *get hungry*, *feel pain*, *feel scared*, and *feel tired*, and accounted for 34% of the shared variance in the rotated four-factor solution, and 17% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to the social-emotional abilities (HEART). It was the dominant factor for such items as *feel joy*, *feel proud*, *feel sad*, and *feel love*, and accounted for 33% of the shared variance in the rotated four-factor solution, and 17% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to the more "cognitive" and "agentic" of the perceptual-cognitive abilities that I have been referring to as MIND. It was the dominant factor for such items as *decide what to do*, *have thoughts*, *make choices*, and *figure out how to do things*, and accounted for 19% of the shared variance in the rotated four-factor solution, and 10% of the total variance in participants' mental capacity attributions.

The fourth factor corresponded primarily to the more "perceptual" of the perceptual-cognitive abilities that I have been referring to as MIND. It was the dominant factor for such items as *hear sounds*, *sense temperatures*, *see things*, and *sense whether something is close by or far away*, and accounted for 13% of the shared variance in the rotated four-factor solution, and 7% of the total variance in participants' mental capacity attributions.

Together, these four factors accounted for 51% of the total variance in participants' mental capacity attributions. See Figure 3.2 for all factor loadings.

Interim discussion

Two of the three factor retention protocols suggested a three-factor solution, which was characterized by a distinction between BODY, HEART, and MIND. This three-factor structure is highly similar to the three-factor structures revealed by Studies 1a-1d, suggesting that the child-friendly paradigm developed for Study 2 was valid: Providing adult participants with more "child-friendly" items to assess using a three-point (rather than seven-point) response scale elicited the same conceptual units that have been revealed by more complex, "adult-friendly" experimental paradigms.

Meanwhile, I would summarize the four-factor solution suggested by parallel analysis as a slight variant on this three-factor solution—again characterized by distinct constructs of BODY and HEART but including a further differentiation of the suite of mental capacities I have referred to as MIND into cognitive/agentic abilities (e.g., thinking, choosing, reasoning, planning) vs. perceptual abilities (e.g., hearing, seeing, sensing). Reanalyzing Studies 1a-1d using different EFA parameters (in particular, retaining more factors and examining an oblique transformation of EFA solutions rather than an orthogonal rotation) provides some converging evidence for this cognitive/agentic vs. perception distinction in the correlation structure of US adults' mental capacity attributions; see Appendix A. However, this distinction does not appear to be robust enough to emerge reliably across studies and analysis decisions in the kinds of experimental paradigms employed in this dissertation.

Children (7-9y)

How many conceptual units?

All three protocols for determining how many factors to retain suggested retaining three factors; see Table 3.1.

What are these conceptual units?

After rotation, the first factor corresponded primarily to social-emotional abilities. An analysis of factor congruence with the three-factor solution among adults confirmed that this factor was most similar to adults' HEART factor (cosine similarity with HEART: 0.97; with MIND: 0.42; with BODY: 0.41). It was the dominant factor for such items as *feel proud*, *feel happy*, *feel joy*, and *get hurt feelings*, and accounted for 50% of the shared variance in the rotated three-factor solution, and 18% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to physiological sensations. An analysis of factor congruence confirmed that this factor was most similar to adults' BODY factor (cosine similarity with BODY: 0.91; with HEART: 0.26; with MIND: 0.03). It was the dominant factor for such items as *get hungry*, *feel pain*, *smell things*, and *feel scared*, and accounted for 30% of the shared variance in the rotated three-factor solution, and 11% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to perceptual-cognitive abilities. An analysis of factor congruence confirmed that this factor was most similar to adults' MIND factor (cosine similarity with MIND: 0.94; with HEART: 0.35; with BODY: 0.01). It was the dominant factor for such items as *be aware of itself*, *be aware of things*, *figure out how to do things*, and *sense whether something is close by or far away*, and accounted for 20% of the shared variance in the rotated three-factor solution, and 7% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 35% of the total variance in participants' mental capacity attributions. See Figure 3.2 for all factor loadings, and Table 3.2 for cosine similarities between child and adult factors.

In sum, like adults in Study 1, and like the three-factor solution for adults in the current study, 7- to 9-year-old children's mental capacity attributions were dominated by a three-way distinction between physiological, social-emotional, and perceptual-cognitive abilities—i.e., BODY, HEART, and MIND.

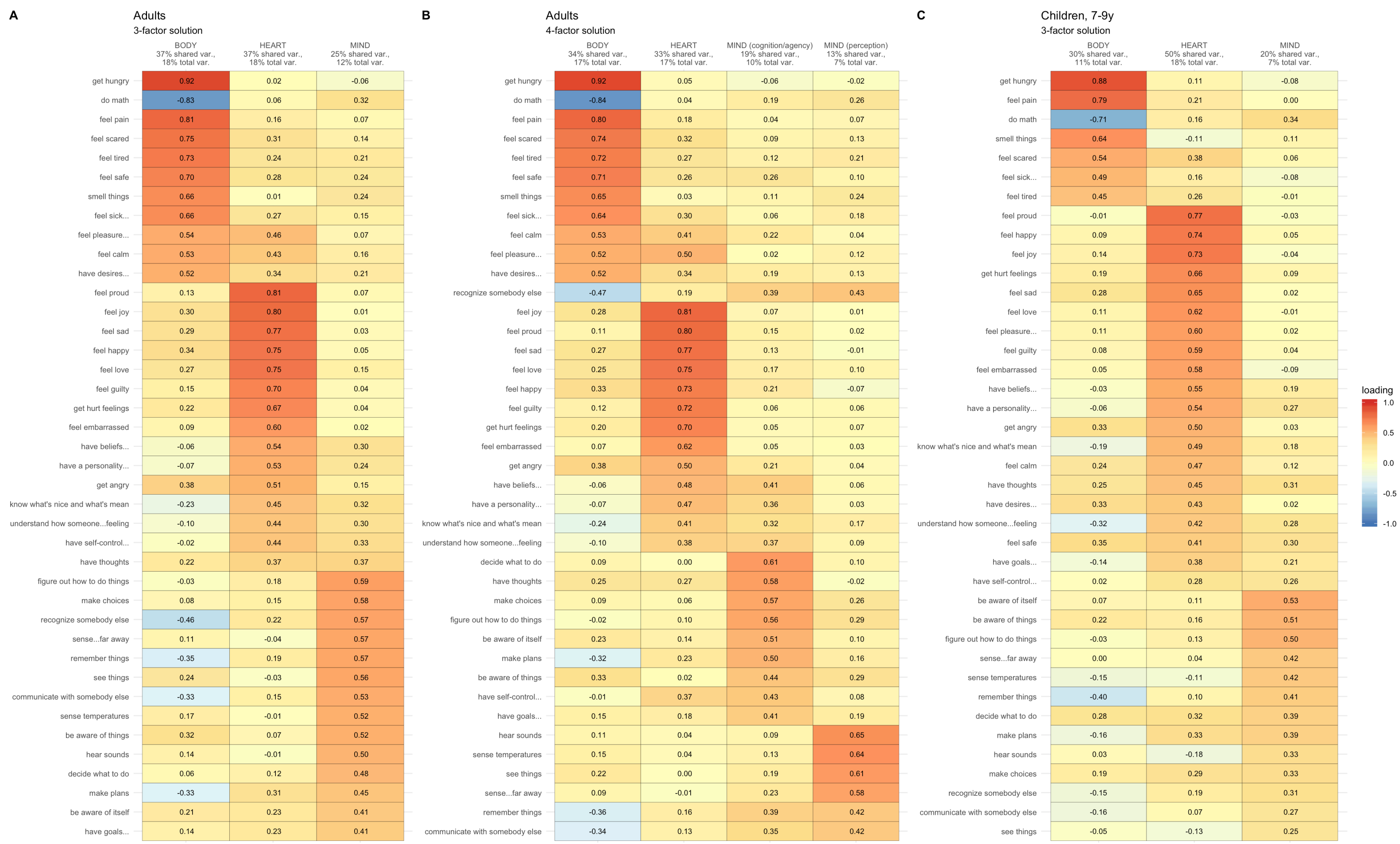

Figure 3.2: Factor loadings from exploratory factor analyses of Study 2, in which participants assessed one of two 'edge case' characters (a beetle or a robot). (A) Results for US adults, retaining 3 factors (as suggested by minimizing BIC and by the original factor retention criteria reported in Weisman et al., 2017). (B) Results for US adults, retaining 4 factors (as suggested by parallel analysis). (C) Results for US children ages 7-9y. In this and all figures portraying factor loadings, factors have been plotted in the same order (BODY, HEART, MIND), when applicable, to facilitate comparison across studies. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Discussion

Exploratory factor analyses suggested that by middle childhood (7-9y), the conceptual structure underlying US children's attributions of mental life is very similar to that of US adults, anchored by suites of mental capacities related to BODY (physiological sensations), HEART (social-emotional abilities), and MIND (perceptual-cognitive abilities). In principle, a number of additional or alternative latent factors could have emerged from the factor analysis of children's responses. For example, children might have distinguished primarily between internal "experience" and external action or "agency" (Gray et al., 2007), or they might have demonstrated finer-grained groupings of mental capacities based on phrasing, rote knowledge, etc. Instead, the latent conceptual structure underlying children's responses appears to be very similar to that of adults, both in this study and Weisman et al.'s (2017) previous work. In other words, any dramatic developmental changes to this conceptual structure likely occur prior to the age of 7y.

Study 3: Conceptual change over early and middle childhood (4-9y)

Study 3 continues my exploration of the emergence of conceptual representations of mental life in childhood. Again, in this chapter, I focus in particular on the fundamental components of this representation: What are the conceptual units available to US children at different points in development?

In Study 3, I aimed to extend my findings with 7- to 9-year-old children in Study 2 by expanding the list of the target characters to include not only the two "edge cases" from Study 2 (a beetle and a robot), but a also a wider range of animate beings (a bird, a goat, and an elephant) and inanimate objects (a computer, a teddy bear, and a doll)—in other words, employing the "diverse characters" (rather than "edge cases") variant of the overall approach. In Study 1, these two approaches yielded very similar pictures of the conceptual units available to adults (see also Weisman et al. (2017)). I reasoned that if this three-part conceptual structure is stable and robust by the age of 7-9y, it should manifest among 7- to 9-year-old children under the same range of conditions that it does among adults.

This study also provides a first glimpse of the earlier development of this conceptual structure in a group of younger children (ages 4-6y).

Participants in Study 3 each assessed a single target character on 20 mental capacities. Participants were randomly or pseudo-randomly assigned to assess one of the following nine characters: an elephant, a goat, a mouse, a bird, a beetle, a teddy bear, a doll, a robot, or a computer. To make the study appropriate for children as young as 4 years of age, participants assessed a subset of the 40 mental capacities employed in Study 2, chosen to represent the three "conceptual units" revealed by Studies 1 and 2 (BODY, HEART, and MIND) and to cover a similar range of mental capacities as Studies 1 and 2. As in Study 2, participants responded on a three-point scale ("no," coded as 0; "kinda," coded as 0.5, "yes," coded as 1).

To validate the modified paradigm (i.e., to assess whether this paradigm produced similar results to Studies 1 and 2), and to provide a direct comparison for child participants, participants included a sample of 116 US adults, as well as a sample of 125 "older" children (7.08-9.98y; median: 8.56y), and a sample of 124 "younger" children (4-6.98y; median: 5.03y). (See Chapter II for detailed methods.)

Results

Adults

How many conceptual units?

Two of the three protocols for determining how many factors to retain (parallel analysis and the factor retention criteria employed in the original publication of Study 1; Weisman et al., 2017) suggested retaining three factors, while the third (minimizing BIC) suggested retaining four factors; see Table 3.1.

Three of the four factors suggested by minimizing BIC were qualitatively very similar to the three factors suggested by the other protocols, and together accounted for fully 94% of the shared variance. The fourth factor accounted for only 6% of the shared variance, was the dominant factor for only one of the 40 mental capacities included in this study (*feel happy*), and had moderately weak factor loadings for all other capacities (absolute loadings <0.43). Given all this, I will again focus the remainder of my analyses on the three-factor solution; see Appendix A for the four-factor solution.

What are these conceptual units?

After rotation, the first factor corresponded primarily to the physiological sensations that I labeled BODY in Studies 1 and 2 (see also Weisman et al. (2017)). It was the dominant factor for such items as *feel pain*, *get hungry*, *feel tired*, and *smell things*, and accounted for 38% of the shared variance in the rotated three-factor solution, and 29% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to the social-emotional abilities that I labeled HEART in Studies 1 and 2 (see also Weisman et al. (2017)). It was the dominant factor for such items as *feel guilty*, *get hurt feelings*, *feel embarrassed*, and *feel proud*, and accounted for 33% of the shared variance in the rotated three-factor solution, and 26% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to the perceptual-cognitive abilities that I referred to as MIND in Studies 1 and 2 (see also Weisman et al. (2017)). It was the dominant factor for such items as *sense whether something is close by or far away*, *sense temperatures*, *figure out how to do things*, and *be aware of things*, and accounted for 29% of the shared variance in the rotated three-factor solution, and 23% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 78% of the total variance in participants' mental capacity attributions. See Figure 3.3 for all factor loadings.

In sum, as in Study 1 and the three-factor solution for Study 2, the conceptual structure revealed by this analysis among adults was characterized by a three-way distinction between BODY, HEART, and MIND. This suggests that the modified child-friendly paradigm developed for Study 3 was valid: Using a shorter list of items and a wider range of target characters elicited the same three conceptual units that were revealed in Studies 1 and 2.

Older children (7-9y)

How many conceptual units?

As was the case among this age group in Study 2, all three factor retention protocols suggested retaining three factors; see Table 3.1.

What are these conceptual units?

After rotation, the first factor corresponded primarily to physiological sensations. An analysis of factor congruence confirmed that this factor was most similar to adults' BODY factor (cosine similarity with BODY: 0.97; with HEART: 0.65; with MIND: 0.63). It was the dominant factor for such items as *get hungry*, *feel scared*, *feel pain*, and *smell things*, and accounted for 39% of the shared variance in the rotated three-factor solution, and 21% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to social-emotional abilities. An analysis of factor congruence confirmed that this factor was most similar to adults' HEART factor (cosine similarity with HEART: 0.98; with BODY: 0.66; with MIND: 0.48). It was the dominant factor for such items as *feel guilty*, *feel proud*, *feel embarrassed*, and *feel sad*, and accounted for 35% of the shared variance in the rotated three-factor solution, and 19% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to perceptual-cognitive abilities. An analysis of factor congruence confirmed that this factor was most similar to adults' MIND factor (cosine similarity with MIND: 0.96; with BODY: 0.62; with HEART: 0.47). It was the dominant factor for such items as *figure out how to do things*, *make choices*, *remember things*, and *sense temperatures*, and accounted for 26% of the shared variance in the rotated three-factor solution, and 14% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 54% of the total variance in participants' mental capacity attributions. See Figure 3.3 for all factor loadings, and Table 3.2 for cosine similarities between child and adult factors.

I consider this to be a close conceptual replication of Study 1, suggesting that by the age of 7-9y, this three-part conceptual structure is stable and robust to a range of experimental conditions.

Younger children (4-6y)

How many conceptual units?

Each of the three factor retention protocols suggested a different number of factors to retain; see Table 3.1.

Minimizing BIC suggested a null solution consisting of a single factor; in other words, this protocol indicated that the correlation structure of younger children's responses provided no evidence for distinct latent constructs.

Meanwhile, parallel analysis suggested retaining two factors, and the retention criteria employed in the original publication of Study 1 [Weisman et al. (2017))

suggested retaining three factors. In both the two- and three-factor solutions, each factor accounted for a substantial amount of the shared variance, was the dominant factor for several mental capacities, and had strong factor loadings for some subset of mental capacities.

Given all this, I will present and interpret both two- and three-factor solutions; see Appendix A for the null, one-factor solution suggested by minimizing BIC.

What are these conceptual units?

Two-factor solution

First, I will examine the two-factor solution suggested by parallel analysis.

After rotation, the first factor encompassed both physiological sensations and emotions. An analysis of factor congruence indicated that this factor was most similar to adults' BODY factor, but was also quite similar to adults' HEART factor (cosine similarity with BODY: 0.93; with HEART: 0.88; with MIND: 0.70). It was the dominant factor for such items as *get hungry*, *feel sick*, *feel happy*, and *get angry*, and accounted for 65% of the shared variance in the rotated two-factor solution, and 25% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to perceptual-cognitive abilities, as well as one complex negative emotion (*feel guilty*). An analysis of factor congruence confirmed that this factor was most similar to adults' MIND factor (cosine similarity with MIND: 0.94; with BODY: 0.73; with HEART: 0.70). It was the dominant factor for such items as *sense temperatures*, *remember things*, *feel guilty*, and *sense whether something is close by or far away*, and accounted for 35% of the shared variance in the rotated two-factor solution, and 14% of the total variance in participants' mental capacity attributions.

Together, these two factors accounted for 39% of the total variance in participants' mental capacity attributions. See Figure 3.3 for all factor loadings, and Table 3.2 for cosine similarities between child and adult factors.

In relation to the BODY-HEART-MIND structure found among older children and adults, I would describe this two-factor structure as being anchored by a contrast between the more abstract, cognitive capacities of the MIND vs. a set of warmer, more visceral experiences that constitute a more integrated representation of BODY-HEART.

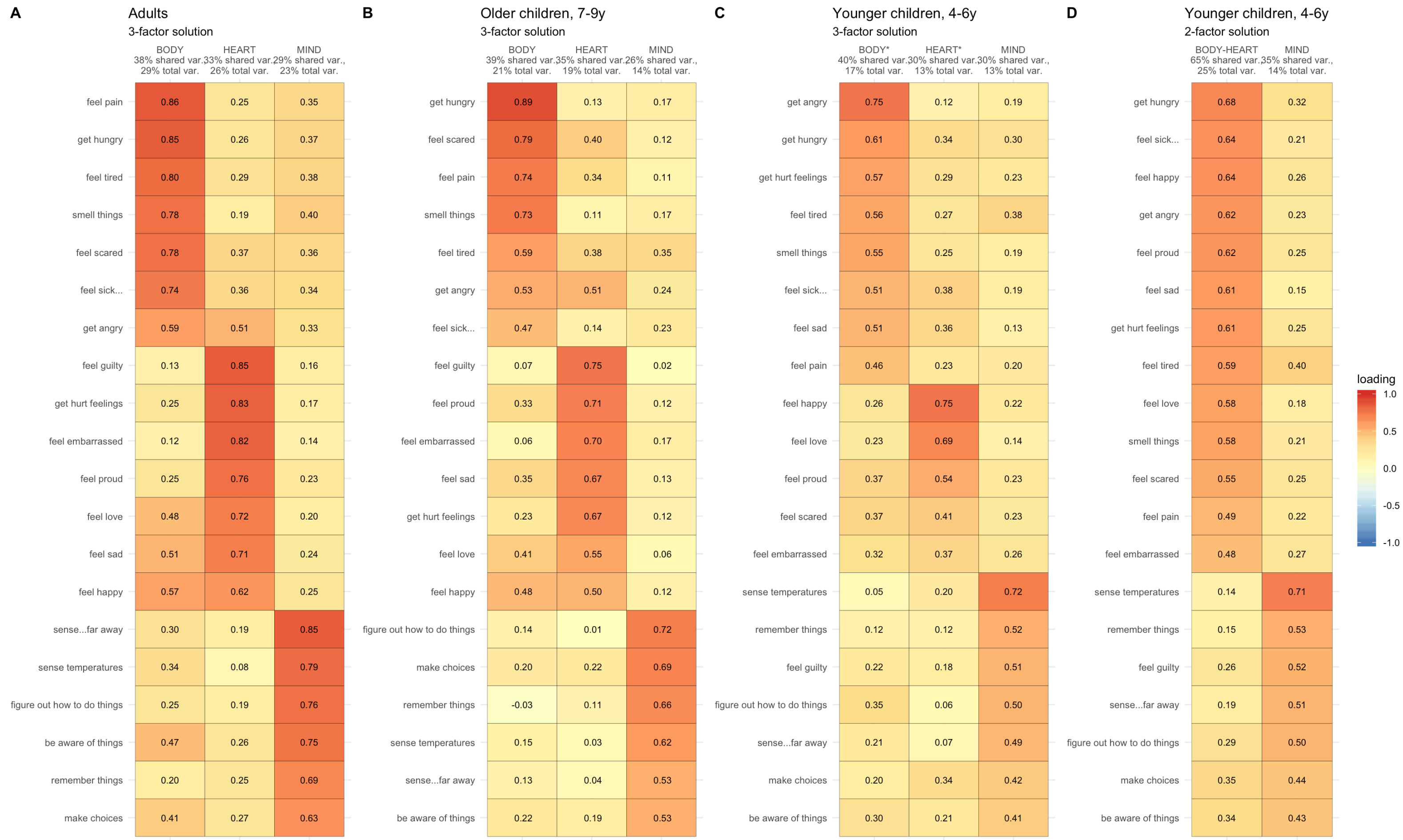

Figure 3.3: Factor loadings from exploratory factor analyses of Study 3, in which participants assessed one of nine diverse target characters. (A) Results for US adults. (B) Results for US children ages 7-9y. (C) Results for US children ages 4-6y, retaining three factors (as suggested by the original factor retention criteria reported in Weisman et al., 2017). (D) Results for US children ages 4-6y, retaining two factors (as suggested parallel analysis). In this and all figures portraying factor loadings, factors have been plotted in the same order (BODY, HEART, MIND), when applicable, to facilitate comparison across studies. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Three-factor solution

I will now turn to the three-factor solution suggested by the factor retention criteria employed in the original publication of Study 1 (Weisman et al., 2017). Importantly, this is also the number of factors retained among US adults and older children in this study.

After rotation, the first factor corresponded primarily to physiological sensations, as well as some positive emotions. An analysis of factor congruence indicated that this factor was most similar to adults' BODY factor, but was also quite similar to adults' HEART factor (cosine similarity with BODY: 0.92; with HEART: 0.81; with MIND: 0.70). It was the dominant factor for such items as *get angry*, *get hungry*, *get hurt feelings*, and *feel tired*, and accounted for 40% of the shared variance in the rotated three-factor solution, and 17% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to perceptual-cognitive abilities, as well as one complex negative emotion (*feel guilty*). An analysis of factor congruence confirmed that this factor was most similar to adults' MIND factor (cosine similarity with MIND: 0.94; with BODY: 0.71; with HEART: 0.67). It was the dominant factor for such items as *sense temperatures*, *remember things*, *feel guilty*, and *figure out how to do things*, and accounted for 30% of the shared variance in the rotated three-factor solution, and 13% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to social-emotional abilities, with particularly strong loadings for positive emotions. An analysis of factor congruence indicated that this factor was most similar to adults' HEART factor, but also quite similar to adults' BODY factor (cosine similarity with HEART: 0.87; with BODY: 0.81; with MIND: 0.62). It was the dominant factor for such items as *feel happy*, *feel love*, *feel proud*, and *feel scared*, and accounted for 30% of the shared variance in the rotated three-factor solution, and 13% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 43% of the total variance in participants' mental capacity attributions. See Figure 3.3 for all factor loadings, and Table 3.2 for cosine similarities between child and adult factors.

I would describe this conceptual structure as reminiscent of the BODY-HEART-MIND structure found among older children and adults, but not as fully "adult-like." In particular, in this solution, the physiological sensations associated with the BODY among older children and adults are not as clearly differentiated from the emotional experiences associated with the HEART.

Discussion

The results of Study 3 suggest that a three-part conceptual structure—anchored by BODY, HEART, and MIND—is reliable and robust among 7- to 9-year-old US children. As with adults in Studies 1a-1c vs. Study 1d, the capacities that "hang together" in older children's reasoning when target characters are perceived to vary in mental capacity profiles (Study 3) appear to be highly similar to those that "hang together" when participants disagree about the mental lives of controversial "edge cases" in social reasoning (Study 2).

Meanwhile, this study suggests that this conceptual structure undergoes substantial changes between early and middle childhood. Like older children and adults, 4- to 6-year-old children's responses were characterized by strong correlations among a suite of perceptual and cognitive capacities that I have labeled MIND. This highlights one aspect of conceptual structure that seems to be relatively stable from early childhood onward. However, in contrast to the clear distinction between physiological abilities and social-emotional abilities that characterized mental capacity attributions among older children and adults, younger children's responses suggest that they perceived physiological and social-emotional abilities to be more closely integrated and the line between them to be more blurred.

One indication of this blurring comes from the two-factor solution suggested by parallel analysis, in which a single BODY-HEART factor emerged and was highly congruent with both the BODY and HEART factors of adults (cosine similarity with BODY: 0.93; with HEART: 0.88) factors of adults. Among the mental capacities that 0.60) on this factor were both physiological sensations (e.g., *get hungry*, *feel sick*…) and social-emotional experiences (*feel happy*, *feel proud*, *feel sad*, *get hurt feelings*), suggesting that younger children perceived physiological and social-emotional abilities to "go together" to a considerable degree.

Even in the three-factor solution suggested by the original factor retention criteria reported in Weisman et al. (2017), the distinction between physiological and social-emotional abilities was somewhat blurred. While the first factor, which I have labeled BODY*, was highly congruent with adults' BODY factor (cosine similarity: 0.92), it was also the dominant factor for two canonical social-emotional items (*get hurt feelings*, *feel sad*). And while the third factor, which I have labeled HEART*, was highly congruent with adults' HEART factor (cosine similarity: 0.87), there were several canonical social- 0.40: *feel embarrassed*, *feel sad*, *get hurt feelings*, *feel guilty*). Stepping back, it is not clear that "physiological vs. social-emotional" is the best way to characterize the differences between these two factors. In fact, given that the strongest-loading items for BODY* were negatively valenced (*get angry*, *get hungry*, *get hurt feelings*) while the strongest-loading items for HEART* were positively valenced (*feel happy*, *feel love*, *feel proud*), it seems plausible that the more salient distinction among this age group may have been positive vs. negative valence, rather than BODY vs. HEART. The salience of negative vs. positive experiences among younger children is consistent with recent work on the development of emotion concepts, which suggests that emotion representations are dominated by a single dimension of valence in early to middle childhood, before unfolding into a two-dimensional space characterized by valence and arousal over the course of later childhood and adolescence (Nook, Sasse, Lambert, McLaughlin, & Somerville, 2017).

Finally, the very fact that different approaches to factor retention yielded different results is further evidence that, although a distinction between BODY and HEART may be nascent among 4- to 6-year-old children, this distinction may not be as robust as it appears to be among older children or adults.

Study 4: A focus on early childhood (4-5y)

Note: At the time of the submission of this dissertation, the sample of 4- to 5-year-old children for Study 4 was only partially complete. All results using this sample should thus be considered preliminary and not conclusive.

One major limitation of Studies 2 and 3 was that the study protocol involved a rather advanced set of mental state vocabulary terms, including a variety of complex mental capacities (e.g., guilt, pride, awareness, depth perception) and using somewhat complicated syntax for some items (e.g., *sense whether something is close by or far away*, *figure out how to do things*). For 4- to 6-year-old children, in particular, some of the mental capacity items might have been outside of the range of words they normally hear in discussions of mental states—let alone the words they normally use themselves. In addition, younger children may have found some aspects of the experimental paradigm distracting (e.g., being seated in front of the experimenter's laptop computer without being allowed to use it themselves) or difficult (e.g., using a three-point scale with minimal visual scaffolding).

With these considerations in mind, in Study 4 I focused on 4- to 5-year-old children, using a simpler set of mental capacities and a streamlined version of the experimental paradigm, with the aim of getting a clearer picture of conceptual structure and mental capacity attributions at this earlier point in development.

In Study 4, 104 US adults and 43 US children between the ages of 4.02-5.59y (median: 4.73y) each assessed two target characters on 18 mental capacities. To make the study appropriate for children in this age range, this study employed a new set of 18 mental capacities (some but not all of which were used in Studies 1-3). In addition, participants were presented with a more child-friendly visual representation of the response scale. This study employed the "edge case" variant of the general approach, with participants assessing both a beetle or a robot in sequence (with order counterbalanced across participants). (See Chapter II for detailed methods.)

As briefly described in Chapter II, the 18 mental capacities employed in Study 4 were selected from a larger pilot study in which 3- to 5-year-old children were asked to complete stories that began with each of these mental capacities as a premise (e.g., "Let's imagine a person who *loves someone*. What happens next?"; "Now let's pretend that someone *remembers something*. What happens next?") and were judged on the appropriateness of their story completion.

Among the items that emerged from this pilot study as reasonable candidates for inclusion in Study 4, I selected items to represent the three "conceptual units" revealed by Studies 1-3 (BODY, HEART, and MIND). The goal here was to create a conservative test of developmental differences between younger and older children in the "conceptual units" observed in Study 3, by constructing materials that should maximize the chances of observing similar conceptual units among this youngest age group children. If 4- to 5-year-old children in fact have access to conceptual units similar to BODY, HEART, and

MIND, the mental capacities employed in Study 4 (and the generally more child-friendly protocol) should provide the best chances of surfacing this conceptual structure. Conversely, if Study 4 were to reveal differences in conceptual structure despite these modifications, and despite stacking the odds *against* developmental differences in the selection of mental capacities, this would provide stronger evidence for conceptual change in the number and/or kind of conceptual units available to children at different points in development.

The final set of BODY items included feel hungry, get thirsty, feel sick, feel tired, get scared, and smell things. HEART items included love someone, hate someone, feel happy, get sad, feel sorry, and get lonely. MIND items included see, hear, think, remember things, know stuff, and figure things out (see also Table 2.1 in Chapter II). I ensured that each category included a variety of phrasings (e.g., "feel hungry" vs. "get thirsty"; "remember things" vs. "know stuff") and valences when appropriate (e.g., happiness vs. sadness). When possible, I varied these aspects of phrasing orthogonally with categories: The framings "get X" vs. "feel X" appeared roughly equally often among the BODY and HEART items; and the word "things" appeared equally often among the BODY and MIND items.

Special notes on data processing and analysis

In Study 4, participants assessed two target characters one after another. As with Study 1d (the only other study in which participants assessed more than one target character), in the current analyses I treat each participant's assessments of each target character as a separate set of observations (as if they came from different participants), in effect doubling the sample size (but ignoring the within-subject design).

Results

Adults

How many conceptual units?

All three protocols for determining how many factors to retain suggested retaining three factors; see Table 3.1.

What are these conceptual units?

After rotation, the first factor corresponded primarily to physiological sensations (BODY). It was the dominant factor for such items as *get thirsty*, *feel hungry*, *smell things*, and *feel tired*, and accounted for 41% of the shared variance in the rotated three-factor solution, and 17% of the total variance in participants' mental capacity attributions, and 29% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to social-emotional abilities (HEART). It was the dominant factor for such items as *love someone*, *get sad*, *hate someone*, and *feel sorry*, and accounted for 35% of the shared variance in the rotated three-factor solution, and 25% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to perceptual-cognitive abilities (MIND). It was the dominant factor for such items as *figure things out*, *remember things*, *know stuff*, and *think*, and accounted for 23% of the shared variance in the rotated three-factor solution, and 16% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 70% of the total variance in participants' mental capacity attributions. See Figure 3.4 for all factor loadings.

In sum, as in Studies 1-3, EFA of adults' responses revealed a conceptual structure characterized by a three-way distinction between BODY, HEART, and MIND. This suggests that the modified preschooler-friendly paradigm was valid: Using simpler vocabulary and a within-subjects approach to target characters elicited the same intuitive ontology of mental life, among US adults, that was revealed in Studies 1-3.

Children (4-5y)

How many conceptual units?

Each of the three factor retention protocols suggested a different number of factors to retain; see Table 3.1.

As among younger children in Study 3, minimizing BIC suggested a null solution consisting of a single factor; in other words, this protocol indicated that the correlation structure of children's responses provided no evidence for distinct latent constructs.

Meanwhile, parallel analysis suggested retaining two factors, and the retention criteria used in Weisman et al. (2017) suggested retaining four factors. In both the two- and four-factor solutions, as well as a three-factor solution (included for completeness), each factor accounted for a substantial amount of the shared variance, was the dominant factor for several mental capacities, and had at least moderately strong factor loadings for some subset of mental capacities.

Given all this, I will present and interpret two, three-, and four-factor solutions; see Appendix A for the null, one-factor solution suggested by minimizing BIC.

What are these conceptual units?

Two-factor solution

First, I will examine the two-factor solution suggested by parallel analysis. Importantly, this is also the number of factors retained among 4- to 6-year-old children in Study 2.

After rotation, the first factor corresponded primarily to physiological sensations. An analysis of factor congruence indicated that this factor was most similar to adults' BODY factor (cosine similarity with BODY: 0.94; with HEART: 0.60; with MIND: 0.47). It was the dominant factor for such items as *feel hungry*, *smell things*, *get thirsty*, and *feel tired*, and accounted for 54% of the shared variance in the rotated three-factor solution, and 15% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to perceptual-cognitive abilities. An analysis of factor congruence confirmed that this factor was most similar to adults' MIND factor (cosine similarity with MIND: 0.85; with HEART: 0.77; with BODY: 0.38). It was the dominant factor for such items as *remember things*, *know stuff*, *love someone*, and *feel sorry*, and accounted for 46% of the shared variance in the rotated three-factor solution, and 13% of the total variance in participants' mental capacity attributions.

Together, these two factors accounted for 28% of the total variance in participants' mental capacity attributions. See Figure 3.4 for all factor loadings, and Table 3.2 for cosine similarities between child and adult factors.

I would describe this conceptual structure as reminiscent of the BODY-HEART vs. MIND structure found among 4- to 6-year-old children in Study 2.

Three-factor solution

Although none of the factor retention protocols suggested retaining three factors, I will examine a three-factor solution here for completeness (since it is intermediate between the two- and four-factor solutions suggested by parallel analysis and Weisman et al.'s factor retention criteria). This three-factor solution is also meant to facilitate comparison to adults' BODY-HEART-MIND framework.

After rotation, the first factor corresponded primarily to physiological sensations. An analysis of factor congruence indicated that this factor was most similar to adults' BODY factor (cosine similarity with BODY: 0.95; with HEART: 0.57; with MIND: 0.43). It was the dominant factor for such items as *feel hungry*, *smell things*, *get thirsty*, and *feel tired*, and accounted for 43% of the shared variance in the rotated three-factor solution, and 14% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to perceptual-cognitive abilities. An analysis of factor congruence confirmed that this factor was most similar to adults' MIND factor (cosine similarity with MIND: 0.88; with HEART: 0.64; with BODY: 0.38). It was the dominant factor for such items as *know stuff*, *remember things*, *think*, and *hear*, and accounted for 35% of the shared variance in the rotated three-factor solution, and 12% of the total variance in participants' mental capacity attributions.

The third factor corresponded primarily to social-emotional abilities. An analysis of factor congruence confirmed that this factor was most similar to adults' HEART factor (cosine similarity with HEART: 0.80; with MIND: 0.45; with BODY: 0.38). It was the dominant factor for such items as *get lonely*, *love someone*, and *feel sorry*, and accounted for 22% of the shared variance in the rotated three-factor solution, and 7% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 33% of the total variance in participants' mental capacity attributions. See Figure 3.4 for all factor loadings, and Table 3.2 for cosine similarities between child and adult factors.

I would describe this conceptual structure as strongly reminiscent of the BODY-HEART-MIND structure found among older children and adults in this and previous studies.

Four-factor solution

Finally, I now turn to the four-factor solution suggested by Weisman et al.'s (2017) factor retention criteria.

After rotation, the first factor corresponded primarily to perceptual-cognitive abilities, as well as some positive social-emotional abilities (e.g., *love someone*, *feel happy*). An analysis of factor congruence indicated that this factor was most similar to adults' MIND factor (cosine similarity with MIND: 0.87; with HEART: 0.67; with BODY: 0.32). It was the dominant factor for such items as *know stuff*, *remember things*, *love someone*, and *think*, and accounted for 30% of the shared variance in the rotated four-factor solution, and 12% of the total variance in participants' mental capacity attributions.

The second factor corresponded primarily to physiological sensations, with an exceptionally strong factor loading for *feel sick*. An analysis of factor congruence confirmed that this factor was most similar to adults' BODY factor (cosine similarity with BODY: 0.87; with HEART: 0.56; with MIND: 0.35). It was the dominant factor for such items as *feel sick*, *feel tired*, *smell things*, and *get scared*, and accounted for 29% of the shared variance in the rotated four-factor solution, and 11% of the total variance in participants' mental capacity attributions.

The third factor also corresponded primarily to physiological sensations, as well as some perceptual abilities (e.g., *hear*, *see*). An analysis of factor congruence indicated that this factor was most similar to adults' BODY factor (cosine similarity with BODY: 0.78; with MIND: 0.50; with HEART: 0.41). It was the dominant factor for such items as *get thirsty*, *hear*, *feel hungry*, and *see*, and accounted for 22% of the shared variance in the rotated four-factor solution, and 8% of the total variance in participants' mental capacity attributions.

The fourth factor corresponded primarily to social-emotional abilities, particularly negative emotions. An analysis of factor congruence indicated that this factor was most similar to adults' HEART factor (cosine similarity with HEART: 0.77; with BODY: 0.45; with MIND: 0.40). It was the dominant factor for such items as *get lonely*, *get sad*, and *feel sorry*, and accounted for 19% of the shared variance in the rotated four-factor solution, and 7% of the total variance in participants' mental capacity attributions.

Together, these three factors accounted for 38% of the total variance in participants' mental capacity attributions. See Figure 3.4 for all factor loadings, and Table 3.2 for cosine similarities between child and adult factors.

I would summarize the four-factor solution as a variant on the three-factor solutions common among adults and older children in Studies 1-3. This solution is characterized by distinct constructs of HEART and MIND, suggests a further differentiation of what I've referred to as BODY into sub-categories that are not easy to label or describe.

Table 3.2: Factor congruence (as indexed by cosine similarity) between children's and adults' factors from the three-factor solution for the corresponding study (BODY, HEART, and MIND columns). Results are grouped by study and age group. In principle, cosine similarities could range from -1 (which would indicate that two factors are perfect opposites of each other) to +1 (which would indicate that two factors are perfectly identical to each other). Cosine similarities with absolute values greater than or equal to 0.75 are marked in bold.

Children's factor	BODY	HEART	MIND
Study 2, 7- to 9-year-old children			
BODY	0.91	0.26	0.03
HEART	0.41	0.97	0.43
MIND	0.01	0.35	0.94
Study 3, 7- to 9-year-old children			
BODY	0.97	0.65	0.63
HEART	0.66	0.98	0.48
MIND	0.62	0.47	0.96
Study 3, 4- to 6-year-old children (3-factor solution)			
BODY*	0.92	0.81	0.70
HEART*	0.81	0.87	0.62

Children's factor	BODY	HEART	MIND
MIND	0.71	0.67	0.94
Study 3, 4- to 6-year-old children (2-factor solution)			
BODY-HEART	0.93	0.88	0.70
MIND	0.73	0.70	0.94
Study 4, 4- to 5-year-old children (2-factor solution)			
BODY-HEART	0.94	0.60	0.47
MIND-HEART	0.38	0.77	0.85
Study 4, 4- to 5-year-old children (3-factor solution)			
BODY	0.95	0.57	0.43
HEART*	0.38	0.80	0.45
MIND	0.38	0.64	0.88
Study 4, 4- to 5-year-old children (4-factor solution)			
BODY (nausea)	0.87	0.56	0.35
BODY (other)	0.78	0.41	0.50
HEART*	0.45	0.77	0.40
MIND*	0.32	0.67	0.87

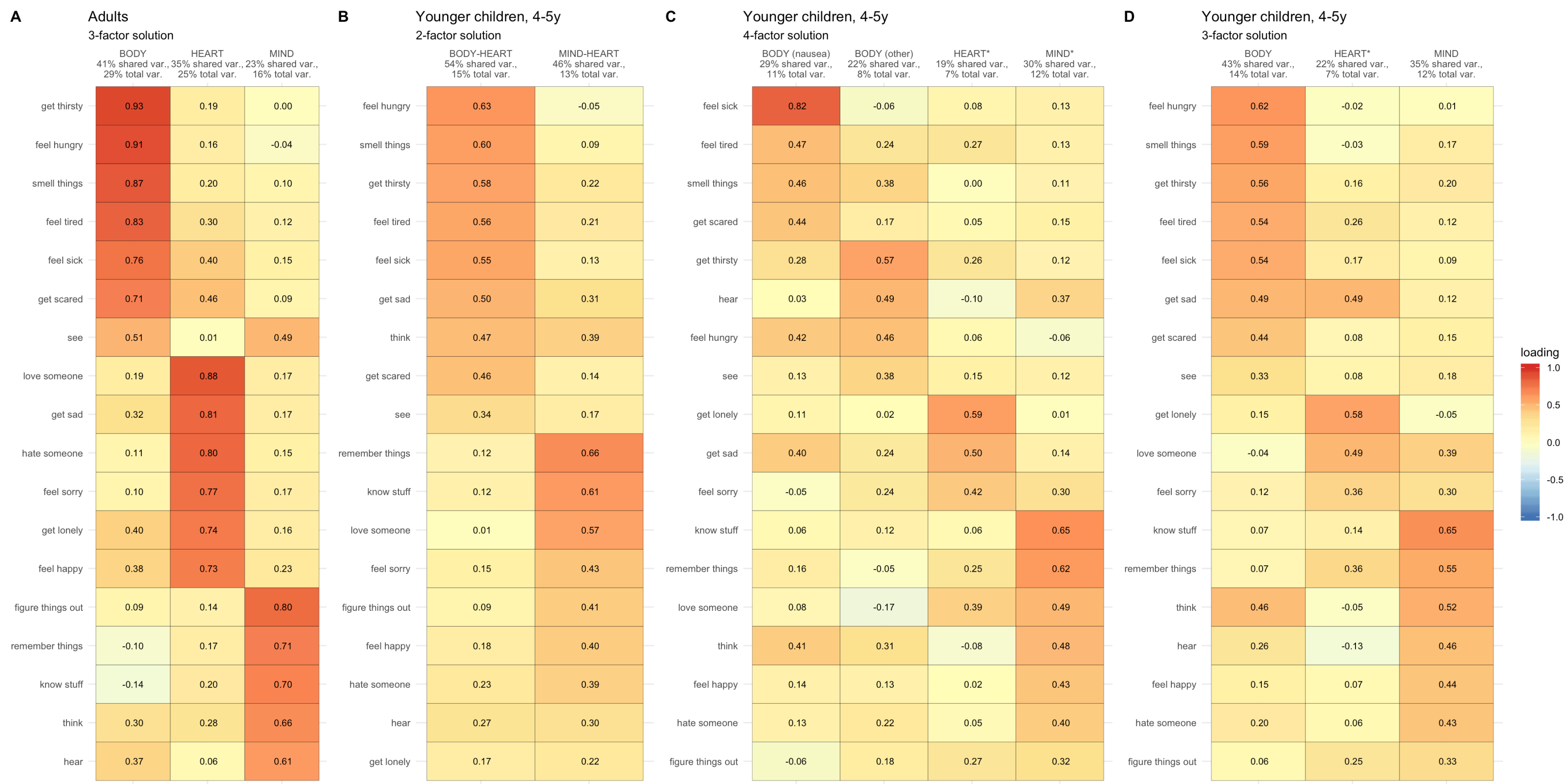

Figure 3.4: Factor loadings from exploratory factor analyses of Study 4, in which participants assessed two 'edge case' target characters (a beetle and a robot), one after another (with order counterbalanced across participants). (A) Results for US adults. (B) Results for US children ages 4-5y, retaining three factors (as suggested by parallel analysis). (C) Results for US children ages 4-5y, retaining four factors (as suggested by the original factor retention criteria reported in Weisman et al., 2017). In this and all figures portraying factor loadings, factors have been plotted in the same order (BODY, HEART, MIND), when applicable, to facilitate comparison across studies. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Discussion

Using a paradigm that was tailored for preschool-age children and that featured vocabulary items expressly designed to pick out (adult) notions of BODY, HEART, and MIND in a balanced way (6 items per factor), Study 4 provided some indications that the conceptual units available to young children may be more "adult-like" than Study 3 would suggest. However, even in this modified paradigm, there are several indications that this three-part conceptual structure is not fully mature by the age of 4-5y.

First, the similarities. As with the younger (4- to 6-year-old) children in Study 3, 4- to 5-year-old children's responses in Study 4 were characterized by strong correlations among a suite of perceptual and cognitive capacities that I have been referring to as MIND. This suite of MIND abilities was relatively robust to analysis choices and emerged clearly in both Studies 3 and 4, bolstering my earlier claim that this is one aspect of conceptual structure that may be relatively stable from early in childhood.

Study 4 suggests that these similarities may extend even further. Requesting a three-factor solution (although not recommended by any of the three factor retention protocols employed here) results in recognizable BODY and MIND factors as well as a nascent HEART* factor, on which half of the mental capacities that were designated as 0.40: __). The four-factor solution suggested by Weisman et al.'s factor retention protocol also includes a very similar HEART-like factor; see Figure 3.4. This is a substantially more adult-like conceptual structure than was observed among 4- to 6-year-old children in Study 3.

However, as in Study 3, the fact that different approaches to factor retention yielded different results is further evidence that this BODY-HEART-MIND framework is not exactly "robust" among preschool-age children.

Consider first young children's understanding of the social-emotional abilities that I designated as representative of HEART. In Study 3, the social-emotional domain appeared to be the site of the most striking differences between 4- to 6-year-old children, on the one hand, and older children and adults on the other. EFAs of 4- to 5-year-old children's responses in Study 4 offer convergent evidence that young children may not consider the social-emotional abilities that constitute what I have called HEART among adults to hang together as one clearly distinct component of mental life. In the two-factor solution suggested by parallel analysis, the six designated HEART items tended to be among the lower-loading items on both factors, and the two strongest loadings among HEART items were on opposite factors (*get sad* loaded moderately strongly on the BODY-HEART factor, and *love someone* loaded moderately strongly on the *MIND-HEART* factor; see Figure 3.4). Even in the more adult-like three-factor solution, two of the six designated HEART items did *not* load strongly on the ostensive HEART* factor 0.30: __); indeed, the dominant factor for these two items was MIND*, not HEART*. These observations also hold in the four-factor solution suggested by Weisman et al.'s (2017) original factor retention protocol; in fact, in this solution, MIND* was the dominant factor for three of the six designated HEART items. As a point of comparison, among adults in Study 4 all six of the designated HEART items loaded most strongly on the HEART factor, suggesting these divergent patterns are not due merely to the use of a new set of mental capacity terms.

In addition, Study 4 provides new evidence that young children's understanding of the domain of physiological sensations (BODY) may also diverge from that of adults. In the more adult-like three-factor solution, the factor that I have labeled BODY* elicited 0.40) from one designated HEART item (*get sad*) and one designated MIND item (*think*), in addition to the six canonical physiological sensations that were designated as BODY items a priori. Moreover, in the four-factor solution physiological sensations actually differentiated into two distinct factors (though not on any easily interpretable line, in my view). Again, among adults in Study 4 all six of the designated BODY items loaded most strongly on the BODY factor, suggesting these divergent patterns are not due merely to the use of a new set of mental capacity terms. Instead, these results suggest that the conceptual unit that I have called BODY may not be as robust, distinct, and unified among young children as it appears to be among adults.

Comparing the "size" of conceptual units across Studies 1-4

In the previous sections in this chapter, I described EFA results for Studies 1-4 and offered both qualitative comparisons of the "meaning" of the conceptual units revealed by these analyses and quantitative assessments of the similarity of conceptual units across different age groups within each study (see Table 3.2). In this final section, I explore one additional aspect of these analyses: the "size" of the conceptual units identified in each sample.

For each of the EFA solutions reported earlier in this chapter, I included but did not discuss three additional pieces of information about the solution: (a) the *total variance* in mental capacity attributions explained by the factors in combination; (b) the *proportion of total variance* explained by each factor, and (c) the proportion of the *shared variance explained* by each factor. Here I reflect on what these metrics might reveal about the sets of conceptual units revealed by EFA and compare the "size" of these conceptual units across studies and age groups.

Analyses: Total variance, proportion of total variance, and proportion of shared variance explained

For each EFA solution, the *total variance* in the measured variables explained by all of the retained factors in combination can be estimated by taking the mean communality across all variables (where "communality" is a measure of the degree to which a given variable is correlated with all other variables, indexed by the sum of the squared loadings of that variable on each of the retained factors). This could range, in theory, from 0-100%, and provides an indication of how well the "conceptual units" identified by EFA account for the observed correlations among mental capacity attributions in a particular sample—which in turn might be taken as a gauge of the size of the set of conceptual units identified by this analysis. The total variance explained by each of the EFA solutions discussed in this chapter is illustrated in Figure 3.5, panel A.

A researcher might also be interested in assessing the size of a single conceptual unit, either in the absolute or in relation to the other conceptual units identified by that EFA solution. To this end, the *proportion of total variance* in all the measured variables explained by a particular factor can be calculated by dividing the sum of squared loadings for that factor across all variables by the total number of measured variables. (The *total variance* for a given EFA solution, discussed in the previous paragraph, is the sum of these proportions across all factors in that solution.) This could range, in theory, from 0% up to the total variance for that solution (given in Figure 3.5, panel A), and provides an indication of the absolute size of the particular conceptual unit in question. The proportion of total variance explained by each factor, for each EFA solution discussed in this chapter, is illustrated in Figure 3.5, panel B.

Another approach to estimating the size of each factor is to examine the *proportion of shared variance* explained by each factor (relative to the other factors in that EFA solution). For a given solution, the "shared variance" explained by the combination of all of the factors in that solution is, by definition, 100%. The proportion of this "shared variance" explained by a single factor can be calculated by dividing the sum of squared loadings for that factor by the sum of the sum of squared loadings for all factors in a given solution. For example, in a three-factor solution, if all factors were of equal size, each would account for 33% of the shared variance; if one factor instead accounted for 50% of the shared variance and the others each accounted for 25%, this would provide some evidence that the first factor is in some sense larger or more important than the other two factors. The proportion of shared variance explained by each factor, for each EFA solution discussed in this chapter, is illustrated in Figure 3.5, panel C.

In my view, this last index of size is the most useful way to compare the size of conceptual units across the various studies and age groups presented in this chapter, because it allows me to compare the sizes of similar conceptual units (e.g., factors that I have labeled BODY) identified in different age groups or in studies using different experimental paradigms, even though these age groups or studies might vary in the *total variance* explained by their respective EFA solutions (which would, in turn, impose different constraints on how much of this total variance each factor could explain, in theory). For example, in Study 4, the three-factor solution for adults explained 70% of the total variance, which places a relatively high "ceiling" on the proportion of total variance that could be explained by a single factor; in comparison, the three-factor solution for children explained 33% of the total variance, placing a much lower "ceiling" on the proportion of total variance that could be explained by a single factor. While it is interesting to note that the BODY-like factors in these solutions explained 29% of the total variance in adults' responses and only 14% of the total variance in children's responses (Figure 3.5, panel B), it is in my view more illuminating that in both solutions the BODY-like factor explained a very similar proportion of the *shared* variance in each of these samples (among adults: 41%; among children: 43%; Figure 3.5, panel C).

Results (all studies)

The total variance explained by the EFAs reported in this chapter (Figure 3.5, panel A) tended to be largest for adult samples (range: 48-78%; left column), smaller for samples of 7- to 9-year-old children (range: 35-54%; middle column), and lowest in the youngest samples of children (range: 28-43%; right column). This could be taken to indicate that the conceptual structures identified by EFA were more robust and perhaps played a bigger role in adults' mental capacity attributions, relative to children (at least in this general experimental paradigm). However, this pattern is also in line with a domain-general decrease in the "noise" inherent to participants' behavioral responses with development.

Among adults (Figure 3.5, left columns), a clear pattern emerged in the relative size of these factors as indexed by variance explained (see panel B for the proportion of total variance explained, and panel C for the proportion of shared variance explained). In all eight of the EFA solutions included in this chapter, adults' BODY and HEART factors explained a disproportionately large amount of the variance (more than would be expected if all factors were equal in size; see panel C), and their MIND factor explained a disproportionately small amount (less than would be expected if all factors were equal in size). In most of these solutions, the BODY factor explained slightly more variance than the HEART factor, but these differences were generally quite small. This suggests that the conceptual units I have referred to as BODY and HEART may play especially large roles in US adults' representations of mental life, at least when they are assessing the mental capacities of various beings in the world.

Among 7- to 9-year-old children (Figure 3.5, middle columns), a similar pattern to that of adults was observed in Study 3 (orange), with children's BODY and HEART factors explaining more variance than their MIND factor (see panel B for the proportion of total variance explained, and panel C for the proportion of shared variance explained). However, in Study 2 (purple), children's HEART factor explained far more variance than either of the other factors. This raises the possibility that the conceptual unit I have called HEART looms especially large in the representations of children in this age range—

perhaps because it has emerged relatively recently as a distinct unit in its own right. Further studies would be required to determine whether this phenomenon is reliable and the circumstances under which is more or less likely to manifest.

Among 4- to 6-year-old children (Study 3) and 4- to 5-year-old children (Study 4; Figure 3.5, right columns), the BODY-like factors explained disproportionately large amounts of variance (see panel B for the proportion of total variance explained, and panel C for the proportion of shared variance explained). This holds true across all solutions for both studies (when combining the two BODY-like factors in the four-factor solution) and was particularly pronounced in the two-factor solution for Study 3 (orange, top row), in which younger children's BODY-HEART factor was nearly twice the 'size' of their MIND factor—perhaps a harbinger of an impending split between BODY and HEART as young children's conceptual representations become more like the older children and adults around them. The variance explained by younger children's HEART-like factors in the three-factor solutions for Studies 3 and 4 (middle row) appears to have been somewhat smaller than it was among older children and adults, particularly in Study 4 (turquoise), while the relative proportion of shared variance explained by the more MIND-like factors appears to have been roughly comparable to that of adults in all studies.

Taken together, these observations are generally consistent with the possibility that the conceptual unit that I have called MIND may be relatively mature by the preschool years, not only in its content (the perceptual-cognitive abilities that are closely associated with this conceptual unit) but also in its relative size. By contrast, I would interpret these patterns as providing further indication of an ongoing negotiation of the physiological (BODY) and social-emotional (HEART) domains during early childhood, and perhaps extending into middle childhood.

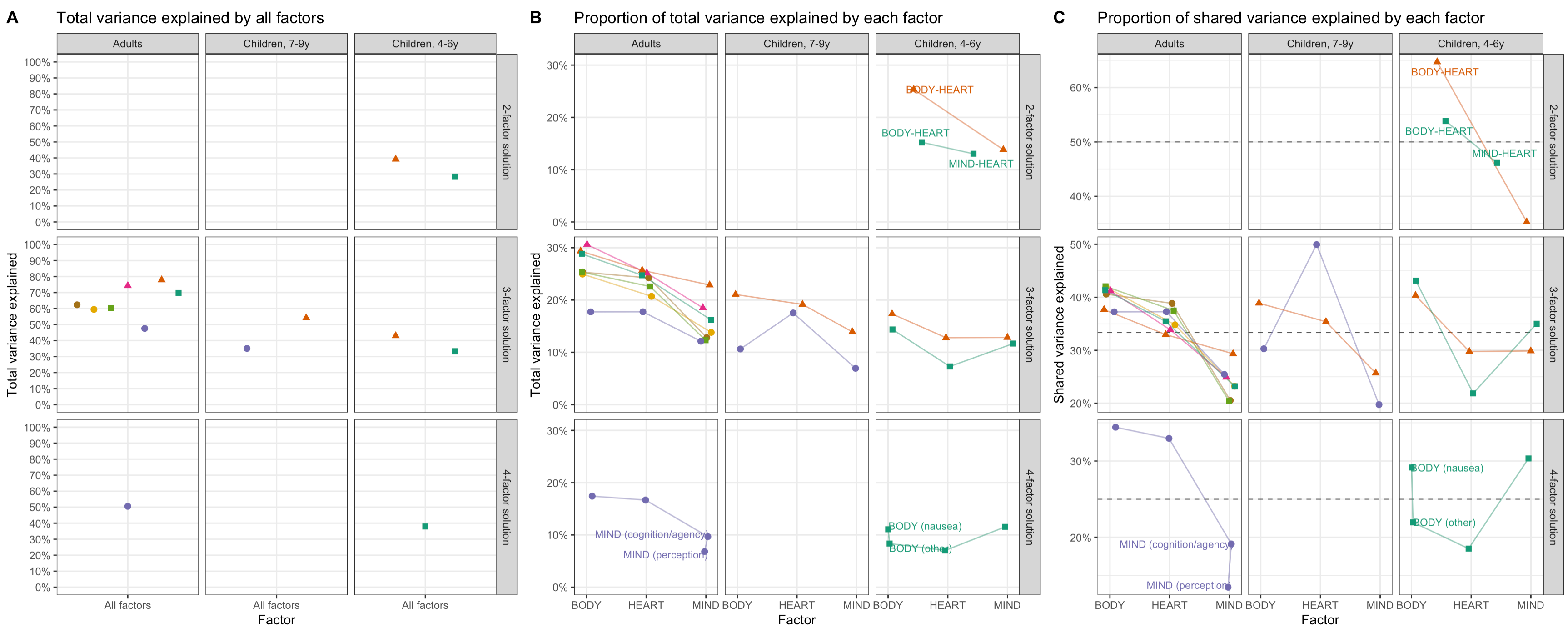

Figure 3.5: Estimates of the 'size' of factors in each of the EFA solutions reported in this chapter, organized by study, age group, and solution. Note that children in the '4-6y' age range were significantly younger in Study 4 (mean age: 4.73y) than in Study 3 (mean age: 5.10y; Welch's t(123.90) = 4.14, p < 0.001); children in the '7-9y' age range did not differ significantly in age across Studies 2 (mean age: 8.35y) and 3 (mean age: 8.50y; Welch's t(239.39) = -1.57, p = 0.118).

General discussion

In four large-scale studies (total *N*=492 children and 2062 adults), I set out to explore the development of US children's conceptual representations of mental life between 4-9y of age and compare them to the representations of adults in their general cultural context. In this chapter, I have focused on one aspect of these representations: the "conceptual units" available to participants of different ages in reasoning about the mental lives of other beings.

Studies with adults using different experimental approaches (asking participants to assess the mental lives of edge cases or a diverse range of target characters), their between- vs. within-subjects design, the number and range of mental capacities included, and the response options available to participants all converged to suggest that adults' conceptual representations of mental life are anchored by a three-way distinction between the physiological sensations of the BODY, the social-emotional abilities of the HEART, and the perceptual-cognitive abilities of the MIND. EFA solutions consistently revealed these three conceptual units, never revealed fewer than these three units, and only rarely suggested additional finer-grained distinctions. The combination of these three conceptual units generally accounted for a substantial amount of the total variance in adults' mental capacity responses (48-78%; see previous section)—which is particularly impressive given the many other potential influences on participants' mental capacity attributions (e.g., their recollection of specific interactions with entities similar to the target character(s) they were assessing; individual differences in their interpretation of such complicated concepts as "having free will," "being conscious," or "holding beliefs"). In sum, I consider these studies to provide strong evidence that BODY, HEART, and MIND are robust, reliable, and important components of a typical US adult's conceptual representation of mental life. (For further discussion of Study 1 EFA results, with a particular focus on the social implications of this conceptual structure, see Weisman et al. (2017).)

Meanwhile, analyses of the conceptual units underlying children's mental capacity attributions (Studies 2-4) suggested both meaningful continuity and some substantial changes in the conceptual units that seem to be available to children at different points in development.

Both younger children (4-6y of age) and older children (7-9y of age) treated perceptual-cognitive abilities (MIND) as a distinct component of mental life: Abilities to detect, store, and use information about the environment traveled together in their attributions, and were endorsed somewhat independently from physiological or social-emotional abilities. This held true across studies that featured different experimental approaches ("edge case" vs. "diverse characters"), designs (between- vs. within-subjects), and varying sets of mental capacities. Such robust continuity across this wide age range is particularly striking given the open-ended, exploratory nature of these studies. A priori, for any of these samples it seemed quite plausible that EFA would reveal a suite of highly correlated "experiential" perceptual abilities (e.g., seeing, hearing, perhaps along with emotional experience) that was distinct from the more "cognitive" or "agentic" abilities (e.g., thinking, remembering, as in Gray et al., 2007). Likewise, it could have easily been the case that younger children did not share any consensus view of which mental capacities "go together" in this experimental paradigm, in which case EFA would have revealed no stable factor structure (i.e., retention protocols would have suggested null, 1-factor solutions more frequently, and the "factors" revealed would have been more difficult to interpret). In light of these alternative possibilities, the fact that a MIND-like factor emerged in every age group in every study—and in each case was highly similar to the MIND factor of adults in that experimental paradigm—should be interpreted as strong evidence for a substantial degree of continuity in this conceptual unit from early childhood, with no evidence of substantial change through middle childhood. (Of course, a full test of developmental continuity would require further sampling between 10-18y of age.)

Like adults, in addition to the perceptual-cognitive abilities of the MIND, older children (7-9y of age) made a further differentiation between the physiological sensations of the BODY vs. the social-emotional abilities of the HEART. In other words, the set of conceptual units available to 7- to 9-year-old children in these studies appears to have been very similar to those available to their adult counterparts. In one of the two studies with this age group (Study 2, but not Study 3), an analysis of the variance explained by each of these conceptual units hinted at the possibility that HEART may loom especially large (larger than BODY or MIND) in older children's representations of mental life; this is in contrast to studies with adults, in which the HEART factor never explained more of the variance than the BODY factor (see previous section). This could be interpreted as something of a relic from a developmentally earlier conceptual representation in which capacities related to BODY and HEART were more integrated (see next paragraph). However, since this was only apparent in one of the two studies with this age group, I would urge the reader to interpret this finding with caution and focus primarily on the overwhelming similarity between the sets of conceptual units that seem to characterize the representations of older children and adults.

Among younger children, similarities to adults' representations of BODY and HEART were evident, but more tenuous. In both of the studies with this age group (4- to 6-year-old children in Study 3; 4- to 5-year-old children in Study 4), retaining three factors revealed conceptual units that were at least moderately similar to adults' BODY and HEART, suggesting that this distinction is nascent, if not fully mature, among young children. Similarities between young children and adults were especially striking in Study 4, which was specifically designed to offer the best chance of discovering this adult-like representation among preschool-age children. However, even in this "best-shot" scenario, substantial differences emerged: For example, the canonical social-emotional abilities *feel happy* and *hate someone* were much more strongly associated with MIND factor than with HEART. (See Study 4 results for more examples of differences between children and adults in their EFA solutions.)

Moreover, in both samples of younger children, different factor retention protocols suggested retaining different numbers of factors; this was not the case in either of the samples of older children, and this fact alone provides some indication that younger children's representations were less identifiable and less robust. Beyond this, in several of the EFA solutions of younger children's responses, their representations appeared to be notably *un*-adult-like. For example, in the two-factor solution for younger children in Study 3, physiological sensations and social-emotional abilities appeared to be integrated into a single conceptual unit that I labeled BODY-HEART. In contrast, social-emotional abilities were, if anything, more closely associated with the MIND among younger children in Study 4—but a distinction between positively-valenced vs. negatively-valenced abilities seemed to better characterize children's representations than a distinction between "physiological" (BODY) vs. "social-emotional" abilities (HEART). Taken together, these two studies do not paint a clear picture of a single, robust conceptual representation among 4- to 6-year-old children; instead, the variability across studies and analysis decisions suggests a lack of robustness, and the various divergences from adults' response patterns hint at many different ways that younger children's understanding of mental life might change and evolve over early childhood.

Chapter conclusion

In this chapter, I explored one aspect of conceptual representations of mental life among US children and adults: The fundamental conceptual units available to people as they assess and reason about the mental lives of various beings in the world. Studies 2-4 are consistent with the following theory: Over the course of early childhood, the set of conceptual units available to children expands in number and the individual conceptual units (particularly BODY and HEART) are refined in their content and their size, reaching an adult-like state (BODY, HEART, and MIND) some time in the early elementary school years.

Of course, this is not the only possible interpretation of the pattern of results presented here; follow-up studies that provide snapshots of a larger number of narrower age ranges, further analyses that aim to capture this aspect of conceptual development more continuously, and further studies employing different designs (e.g., to capture conceptual change at the level of the individual) or employ different experimental paradigms (e.g., to test the hypothesis that younger children consider physiological sensations and social-emotional abilities to be more similar or related to each other than do older children or adults) could provide converging evidence or could challenge this theoretical interpretation. The primary role of the studies and analyses discussed here has been to inspire the hypothesis stated in the previous paragraph and to lay the foundation for future tests of this hypothesis, in turn refining a general theory of conceptual development in this domain.

In the next chapter, I apply the same exploratory spirit to another aspect of these conceptual representations: the *relationships among* these conceptual units.

CHAPTER IV: CHANGES IN ORGANIZATION OF CONCEPTUAL UNITS

Chapter overview

In this chapter, I focus on the second of my three key questions about the development of representations of mental life: How are the conceptual units that anchor representations of mental life organized in relation to each other, and how does this organization change over development? As in Chapter III, to address this question I draw on data from all of the current studies (Studies 1-4); for details about the methods of these studies, see Chapter II. The goal of this chapter is to provide "snapshots" of the organization of conceptual units in early childhood, middle childhood, and adulthood.

General analysis plan

High-level overview

In this chapter, I examine the relationships among the "conceptual units" identified in Chapter III. How does a participant's assessment of one conceptual unit for a particular target character (e.g., the degree to which he or she indicates that a beetle is capable of the physiological sensations of the BODY) affect that participant's assessments of other conceptual units for that target character (e.g., his or her assessment of the beetle's capacities in the domains of HEART or MIND)?

I focus in particular on the possibility that the mental capacity attributions documented by the studies included in this dissertation—re-analyzed as indicators of the broader "conceptual units" identified in Chapter III—might shed light on the *hierarchical organization* of these conceptual units, i.e., which conceptual units might be more basic or fundamental vs. more complex, and whether any of these conceptual units might or might not be considered to depend on the presence of others. In Chapter II, I illustrated this with the following example: If many participants endorse capacities associated with Conceptual Unit A without endorsing capacities associated with Conceptual Unit B, but very few participants do the reverse (endorsing capacities associated with Conceptual Unit B but not Conceptual Unit A), this provides some evidence that Conceptual Unit A is more basic or fundamental than Conceptual Unit B, or that Conceptual Unit B somehow depends on (perhaps requires) Conceptual Unit A.

Here I will translate this general interest in the relationships among conceptual units, as well as the specific intuition about how to detect the kinds of asymmetries that would be the signature of hierarchical relationships, into a specific analysis plan to be applied to each of these datasets in turn.

Details of analyses

Unlike the previous chapter, in which I employed a canonical approach to identifying latent constructs through analyses of correlation structures—exploratory factor analysis (EFA)—in this chapter there is no tried-and-true method for meeting my analysis goals. Instead, I chart my own course through these datasets, using the EFA solutions reported in Chapter II to score participants' endorsements of each conceptual unit for the particular target character(s) that they assessed, examining holistic visualizations of the relationships among these endorsements, and then conducting more targeted regression analyses of difference scores between conceptual units as one index of asymmetrical (and possibly hierarchical) relationships between conceptual units.

Scoring endorsements of conceptual units

The first step in these analyses is to transform participants' ratings of individual mental capacities into "scores" that indicate the extent to which they endorsed a particular conceptual unit for the target character(s) that they were assigned to assess. To do this, I make use of the EFAs presented in Chapter III—which originally served to identify a set of conceptual units in a particular sample—to a new end: the construction of "scales" for each of these conceptual units. Scale construction is a common use of EFA and similar dimensionality reduction analyses (if anything, more common than using EFA to make the kinds of theoretical arguments featured in Chapter II).

For each EFA solution, I construct a scale for each of the factors (conceptual units) identified by that solution. First, I sort each of the mental capacities included in that study into categories based on their loadings on each of the factors in that solution. For each mental capacity, I identify the "dominant" factor as the factor with the largest positive factor loading. For example, if the mental capacity *feel happy* had loadings of 0.60 on the BODY factor, 0.70 on the HEART factor, and 0.30 on the MIND factor, I would sort it into the HEART category. For each factor, I take the six highest-loading items as a candidate scale, then "drop" the capacities with the smallest factor loadings on their respective dominant factors until I have the same number of mental capacities in each category. For example, if the BODY factor were the dominant factor for nine mental capacities, the HEART factor for six capacities, and the MIND factor for five capacities, for each factor I would keep only the capacities with the five highest positive loadings on that factor, in order to construct three scales of equal length (and a maximum length of six items).

To calculate scores on these scales, I take the average of all items, rescaling scores to range from 0 to 1 to facilitate comparison across studies. This yields a dataset in which each participant is associated with one score (between 0 and 1) for each of the conceptual units identified in the relative EFA solution, for each of the target characters that that participant assessed.

In this chapter, I apply this method to all of the three-factor solutions for adult samples as presented in Chapter III (Studies 1-4), yielding *BODY*, *HEART*, and *MIND* scores for each target character as assessed by each participant. (I ignore the aberrant four-factor solution for adults in Study 2 suggested by one of the three factor retention protocols considered in that chapter, since this was the only study out of the seven considered in which a four-factor solution appeared to add any value beyond the robust BODY-HEART-MIND framework common to all studies.)

I use these three-factor adult solutions to assess datasets from both adults and children, allowing me to explore the relationships among a “mature” set of conceptual units (on the assumption that, over development, children will ultimately come to a consensus with the adults in their cultural context).

For the first sample of “older” children (7-9y of age, Study 2), I also briefly consider a second set of conceptual units: BODY, HEART, and MIND as defined by EFAs of the children’s own responses (rather than adults’ responses). Because the EFAs for older children and adults are so similar (see Chapter II and Table 4.10), the outcomes of these two approaches to constructing *BODY*, *HEART*, and *MIND* scales should yield very similar results. (Indeed, for the second sample of “older” children, Study 3, the scales that would emerge from EFA of their responses are identical to the scales that emerge from EFA of adult responses, with the exception of a single item on the *BODY* scale; see Table 4.10.)

For “younger” children (4-6y of age, Study 3; 4-5y of age, Study 4), I have chosen *not* to examine the various sets of two to four conceptual units that would be defined by EFAs of children’s own responses. As discussed at length in Chapter II, EFAs of younger children’s responses were less robust and reliable than those of older children or adults, with different factor retention protocols generating different EFA solutions. For the purposes of the current chapter, this would mean assessing multiple additional sets of conceptual units for each of these samples. I have chosen to prioritize comparability across samples and studies over completeness in the main text of this chapter; the interested reader can find these alternative analyses (for Study 3 only) in Appendix B.

This is not the only way to approach “scoring” participants on these conceptual units. For example, instead of constructing scales to capture each conceptual unit, I could have examined factor scores—summaries of each factor (conceptual unit) based on a participant’s responses to all mental capacities and the relationships between all mental capacities and all factors included in that EFA solution. However, much like *z*-scores, factor scores indicate where a participant falls in relation to other participants in the sample, and do not provide the kind of absolute score that is key to my goal in this chapter, which is to analyze relationships among factors in terms of the extent to which individual participants indicated that target characters “possessed” the conceptual units BODY, HEART, and MIND, and to compare these scores across samples and studies (rather than only across participants within a sample). (Indeed, factor scores are designed to be symmetrical around zero, which precludes the kind of analyses of *asymmetries* between “scores” for BODY, HEART, and MIND that are the backbone of this chapter.)

Even within the “scale” approach described in this section, there are many parameters of this analysis that I could have set differently. For example, I could have considered absolute factor loadings rather than raw factor loadings, which would allow for mental capacities that loaded especially strongly *negatively* on a particular factor to contribute (negatively) to scores on that conceptual unit; I could have omitted the step of making the scales for all factors within a single EFA solution equal length; I could have chosen to use only the top four or five (rather than six) mental capacities across all EFA solutions, or to set no limit on the number of items in a scale; or I could have implemented absolute thresholds for how strongly a mental capacity must load on a factor in order to count toward the score for that conceptual unit, or absolute limits on the degree to which a mental capacity can "cross-load" on non-dominant factors and still count toward the score for any one conceptual unit. However, these kinds of details differ quite dramatically across studies and age groups. For example, in some samples there are no strong negative factor loadings, and in others there are; if I considered absolute loadings rather than raw loadings, I could end up comparing scores from a "bipolar" scale in one sample to scores from a "unipolar" scale in another sample, making the comparison more difficult to interpret. Likewise, some EFA solutions tended to feature generally weaker factor loadings than others; if I were to impose absolute thresholds for the strength of factor loadings, I could end up comparing scores from scales of wildly different lengths across samples. In my view, the analysis decisions outlined above maximize comparability across studies and age groups—the primary goal of this chapter. (Note, however, that in the analysis code for this chapter I have included easy short cuts for the interested reader to explore different options for each of these parameters.)

Visualizing relationships

After constructing scales to capture participants' endorsement of each conceptual unit, my next step is to characterize the relationships among scores on these three scales (*BODY*, *HEART*, and *MIND*). This is a truly exploratory endeavor: At the outset of this work, I had no strong hypotheses about these relationships, and only high-level intuitions about which aspects of these relationships would be of greatest interest in understanding these conceptual representations. Accordingly, I begin each section with a holistic visualization of the relationships between the three pairs of conceptual units, presenting scatterplots of participants' scores on each pair of scales (*BODY* vs. *HEART*, *BODY* vs. *MIND*, and *HEART* vs. *MIND*) and offering informal descriptions of what I consider to be the most striking features of these scatterplots. In addition to motivating my subsequent formal analyses, these informal descriptions are intended to guide future research targeting additional aspects of the relationships among conceptual units that are outside of the scope of the current dissertation.

Formal analyses of asymmetries

As I described in the opening of this chapter, one aspect of the relationships among conceptual units that is of particular interest to me is the possibility of asymmetries in these relationships. Were participants more likely to attribute BODY without HEART, or HEART without BODY? What about BODY vs. MIND, or HEART vs. MIND? Such asymmetries might reveal which conceptual units are more basic or fundamental, whether any of these conceptual units might be considered to depend on the presence of others—in other words, whether conceptual representations (in any particular sample) might be characterized by a hierarchical structure among conceptual units. Likewise, age-related differences in the direction or strength of these asymmetries might hint at developmental changes in these hierarchical structures over early and middle childhood.

Guided by this theoretical interest, the last step in my analyses in this chapter is to examine differences between scores on the *BODY*, *HEART*, and *MIND* scales. For each pair of conceptual units (e.g., BODY vs. HEART), I calculate a simple difference between scores on these two scales (in this case, subtracting participants' *HEART* scores from their *BODY* scores). In the visualizations described in the previous section, this corresponds to the perpendicular distance between a particular datapoint and the line of). (The directions of these difference scores were chosen arbitrarily; e.g., I could have chosen to subtract participants' *BODY* scores from their *HEART* scores.)

Here I describe my principles for interpreting these difference scores. A summary of these difference scores across all samples and studies can be found at the end of this chapter (Figure 4.10, panel A).

In my view, difference scores close to zero provide no evidence for or against a hierarchical relationship between conceptual units. This is illustrated most dramatically by the many scenarios in which we would observe difference scores of zero. A difference score of zero could occur if a participant attributes very little in the way of mental life to a particular target character (e.g., an inert object), or if a participant attributes maximal mental life to a particular target character (e.g., an adult human), or if a participant endorses two conceptual units to a middling degree (e.g., indicating that a beetle has middling capacities in both the *BODY* and *MIND* domains). None of these patterns of attribution should be considered evidence against a possible hierarchical relationship between the conceptual units in question.

Meanwhile, if participants within a sample have radically divergent difference scores—e.g., if roughly half of participants have much higher *HEART* than *MIND* scores and roughly half have much lower *HEART* than *MIND* scores—I interpret this as some evidence *against* systematic hierarchical relationships between the conceptual units in question.

It is only an abundance of non-zero difference scores running in the same direction for many participants within a sample that, in my view, provides evidence *for* systematic hierarchies among the conceptual units. Consensus across participants in the direction of asymmetry between endorsements of two conceptual units would be particularly meaningful in the current studies, because these studies were designed with the express purpose of eliciting *variability* in mental capacity attributions across participants—either by asking participants about "edge cases" (a beetle, a robot), whose particular mental capacity profiles are likely to be the subject of disagreement across individuals; or by asking different participants to consider a variety of "diverse characters" (including inert objects, technologies, and a wide range of animals and humans), whose mental capacity profiles are likely considered to vary dramatically. (See Chapter II for further discussion of these two variants of the experimental approach.) Differences in individual participants' knowledge, experience, and opinions, and differences in the target characters assessed by different participants, were key features of the design of these studies; it was critical to the success of the EFAs presented in Chapter III that participants varied in the degree to which they endorsed particular mental capacities. If, despite this variability, participants nonetheless converge on a common pattern of *relative* endorsements across two conceptual units—e.g., if most participants endorse capacities included in the *MIND* scale more strongly than they endorse capacities included in the *HEART* scale, regardless of the absolute strength of these endorsements—this provides some evidence of a common conceptual framework that places these conceptual units in asymmetrical, perhaps hierarchical, relation to one another.

To operationalize these principles and test for consensus in the direction of difference scores between any two conceptual units, I compare difference scores to zero via Bayesian regressions, using the "brms" package for R (Burkner, 2017). I conduct a separate regression analysis for each pair of conceptual units, accounting for differences between target characters (effect-coded so as to center the intercept at the grand mean) and accounting for within-subjects designs when appropriate (i.e., for Study 1c and Study 4) by including maximal random effects structures (random intercepts for participants). In these analyses, I am primarily interested in whether the intercept is estimated to be differentiable from zero, which I gauge by assessing whether the 95% credible interval for the intercept contains zero.

I conduct many such regressions in this chapter: One for each of the three pairs of conceptual units (*BODY - HEART*, *BODY - MIND*, and *HEART - MIND*), for each age group, for each sample. A summary of these intercepts across all samples and studies can be found at the end of this chapter (Figure 4.10, panel B). In addition, for studies that include a developmental comparison (Studies 2-4), I conduct an additional analysis for each of the three pairs of conceptual units, including main effects and interactions to compare the age groups included (dummy-coded with adults as the baseline); these analyses provide formal assessments of the degree to which children differ from adults in the asymmetry of their responses to these conceptual units. I do not implement any "corrections" for multiple comparisons, in part because my evaluations of these analyses are based on credible intervals rather than *p*-values or other frequentist indices of statistical significance. Parameter estimates (*b*) can be used as indices of effect size.

Study 1: An adult endpoint

In the context of this dissertation, Study 1 serves to describe a developmental endpoint for conceptual representations of mental life. In this chapter, I focus on what this study can reveal about the relationships among the conceptual units discussed in Chapter III. These analyses were not included in the original publication of this work (Weisman et al., 2017).

Studies 1a-1c employed the "edge case" variant of the general approach, with participants assessing the mental capacities of a beetle, a robot, or both. Studies 1a and 1b were identical: US adults (Study 1a: *n*=405; Study 1b: *n*=406) each assessed a single target character on 40 mental capacities. Study 1c employed very similar methods, with the exception that participants (*n*=200) each assessed *both* target characters side by side (with left-right position counterbalanced across participants). Because these studies were so similar, in this chapter, I will discuss them in tandem.

Table 4.1: Scales for each of the conceptual units identified by EFA for US Adults in Studies 1a-1d (see Chapter III). A checkmark indicates that a mental capacity was included in a scale for a particular study.

Capacity	Study 1a	Study 1b	Study 1c	Study 1d
BODY scale				
getting hungry	✓	✓	✓	✓
experiencing pain	✓	✓	✓	✓
feeling tired	✓	✓	✓	✓
experiencing fear	✓	✓	✓	✓
experiencing pleasure	✓	✓	✓	✓
having free will	✓			
being conscious		✓		
having desires			✓	
feeling calm				✓
HEART scale				
feeling embarrassed	✓	✓	✓	✓
experiencing pride	✓	✓	✓	✓
feeling love	✓	✓	✓	
experiencing guilt	✓	✓	✓	✓
holding beliefs	✓			✓
feeling disrespected	✓	✓	✓	✓
feeling depressed		✓	✓	
telling right from wrong				✓
MIND scale				
remembering things	✓	✓	✓	✓
recognizing someone	✓		✓	
sensing temperatures	✓		✓	✓
communicating with others	✓	✓	✓	✓

Capacity	Study 1a	Study 1b	Study 1c	Study 1d
seeing things	✓	✓		✓
perceiving depth	✓		✓	✓
detecting sounds		✓	✓	✓
working toward a goal		✓		
making choices		✓		

Study 1d employed the "diverse characters" variant of the general approach, in which 431 US adults were randomly assigned to assess the same set of 40 mental capacities used in Studies 1a-1d for one of the following 21 target characters: an adult, a child, an infant, a person in a persistent vegetative state, a fetus, a chimpanzee, an elephant, a dolphin, a bear, a dog, a goat, a mouse, a frog, a blue jay, a fish, a beetle, a microbe, a robot, a computer, a car, or a stapler. (See Chapter II and Weisman et al., 2017, for detailed methods.)

Results

Studies 1a-1c

Scale construction

For each of these three studies, following the steps described in the "General analysis plan," above, yielded *BODY*, *HEART*, and *MIND* scales of 6 items each, with a large degree of overlap in items across studies; see Table 4.1.

Visualization

The visualizations of relationships among scores on these *BODY*, *HEART*, and *MIND* scales are remarkably similar across Studies 1a-1c (see Figure 4.1, rows A-C).

BODY vs. HEART

First I consider the relationship between BODY and HEART (Figure 4.1, leftmost column: panels A1, B1, and C1). To my eyes, the most striking features of these visualizations are that (1) there is a positive relationship between scores on the *BODY* and *HEART* scales (an observation confirmed by significantly positive Pearson correlations; Study 1a: $r = 0.50$; $p < 0.001$; 95% CI: [0.42, 0.57]; Study 1b: $r = 0.48$; $p < 0.001$; 95%

CI: [0.40, 0.55]; Study 1c: Study 1c: $r = 0.60$; $p < 0.001$; 95% CI: [0.53, 0.66]); and (2) , dotted diagonal line), and certainly no datapoints in the upper left corner of the plot of these plots. Individual participants tended to endorse the mental capacity items included in the *BODY* scale at least as strongly, and often more strongly, than they endorsed items included in the *HEART* scale—in other words, many participants attributed more BODY than HEART to the target character in question, but virtually no participants attribute more HEART than BODY. This asymmetry appears to have been driven primarily by participants' assessments of the beetle (in red); for the robot (in blue), *BODY* and *HEART* scores appear to have been more similar (close to the dotted line), and were generally quite low.

BODY vs. MIND

Next I consider the relationship between BODY and MIND (Figure 4.1, center column: panels A2, B2, and C2). Similar to the BODY vs. HEART comparison, two notable features of these visualizations are that (1) there is a positive relationship between scores on the *BODY* and *MIND* scales (an observation confirmed by significantly positive Pearson correlations; Study 1a: $r = 0.10$; $p = 0.036$; 95% CI: [0.01, 0.20]; Study 1b: $r = 0.21$; $p < 0.001$; 95% CI: [0.12, 0.31]; Study 1c: Study 1c: $r = 0.16$; $p = 0.001$; 95% CI: , dotted diagonal line) than above it, and no datapoints in the lower right corner of the plot of these plots. Most participants tended to endorse the mental capacity items included in the *MIND* scale roughly as strongly, and sometimes more strongly, than they endorsed items included in the *BODY* scale, while relatively few participants endorsed *MIND* items less strongly than *BODY* items. However, visual inspection suggested that this asymmetry was less extreme than the asymmetry between *BODY* and *HEART* scores just described. In this case, the asymmetry between *BODY* and *MIND* appears to have been driven primarily by participants' assessments of the robot (in blue); for the beetle (in red), *BODY* and *MIND* scores appear to have been more similar (close to the dotted line).

HEART vs. MIND

Finally I consider the relationship between HEART and MIND (Figure 4.1, rightmost column: panels A3, B3, and C3). Again, two features of these visualizations are particularly striking: (1) There is a positive relationship between scores on the *MIND* and *HEART* scales (an observation confirmed by significantly positive Pearson correlations;

Study 1a: $r = 0.21$; $p < 0.001$; 95% CI: [0.12, 0.30]; Study 1b: $r = 0.15$; $p = 0.002$; 95% CI: [0.06, 0.25]; Study 1c: Study 1c: $r = 0.27$; $p < 0.001$; 95% CI: [0.18, 0.36]); and (2) , dotted diagonal line). The asymmetry between *MIND* and *HEART* scores appears to have been particularly extreme: Almost *all* participants endorsed the mental capacity items included in the *MIND* scale more strongly than the items included in the *HEART* scale. In this case, this asymmetry appears to be born out for both target characters, but perhaps more exaggerated for the beetle (in red) than the robot (in blue).

Analysis of asymmetries

Here I provide a formal analysis of the asymmetries revealed by the visualizations in the previous section. For each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND), I conducted a Bayesian regression to compare difference scores between these two conceptual units to zero, controlling for differences in assessments of the two "edge cases" that were featured as target characters in these studies (a beetle vs. a robot), and including maximal random effects structures (in this case, no random effects for Studies 1a and 1b, and random intercepts for participants in Study 1c). See Figure 4.2, panels A-C for visual depictions of these difference scores.

BODY vs. HEART

Across Studies 1a-1c, *BODY* vs. *HEART* difference scores were substantially non-zero, in the direction of participants endorsing *BODY* items more strongly than *HEART* items (see the "Intercept" row for the "BODY-HEART" comparison in Table 4.2). As I speculated in the previous section, in all studies this difference was driven by participants' assessments of the beetle; in the aggregate, difference scores were reduced to 0 for the robot (see the "Robot vs. GM" row for the "BODY-HEART" comparison in Table 4.2).

BODY vs. MIND

Across Studies 1a-1c, *BODY* vs. *MIND* difference scores were substantially non-zero, in the direction of participants endorsing *MIND* items more strongly than *BODY* items (see the "Intercept" row for the "BODY-MIND" comparison in Table 4.2). In all studies this difference was driven by participants' assessments of the robot; in the aggregate, difference scores were reduced to 0 for the beetle (see the "Robot vs. GM" row for the "BODY-MIND" comparison in Table 4.2).

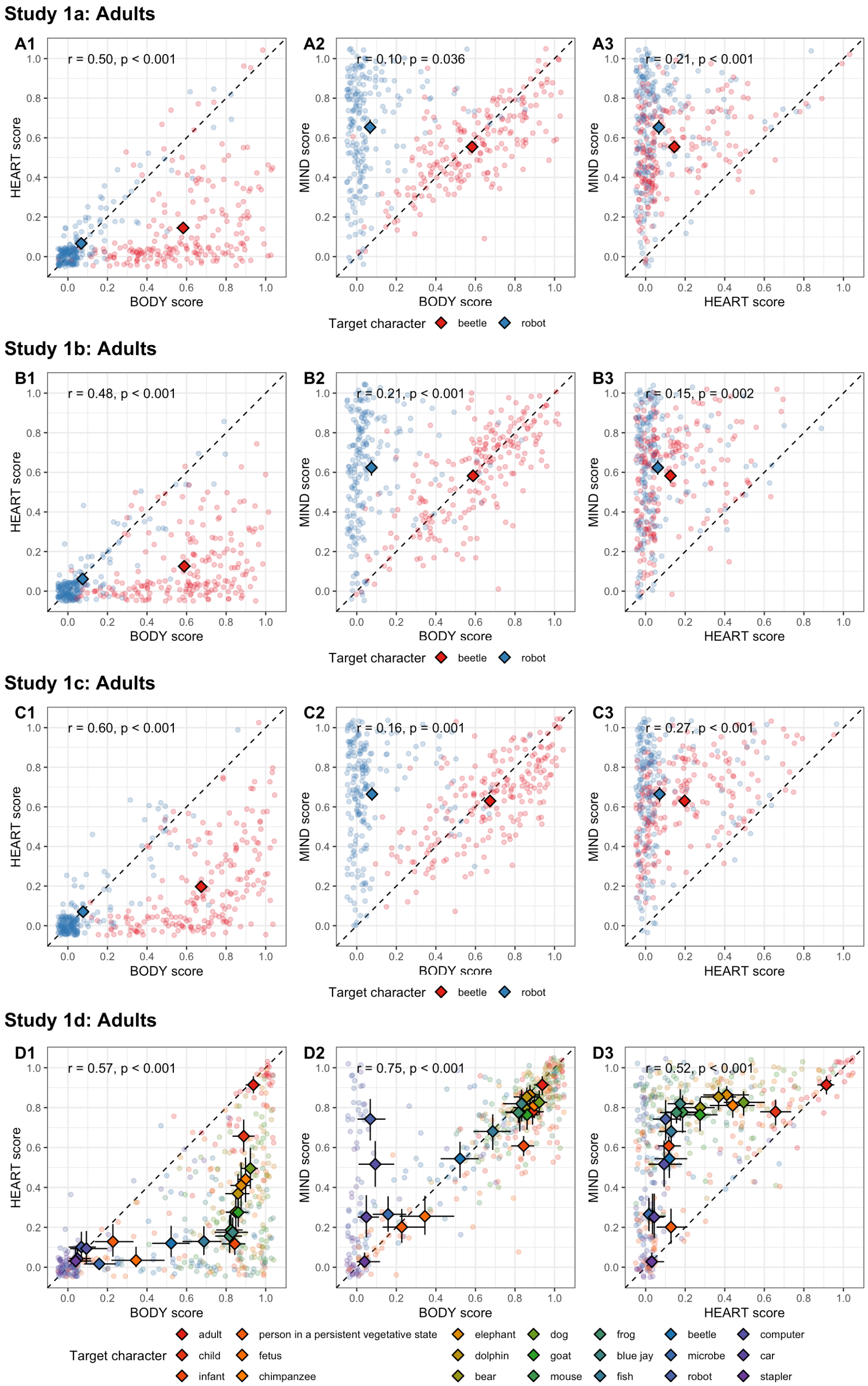

Figure 4.1: Relationships among US adults' attributions of conceptual units in Studies 1a-1d, organized by study (rows) and pair of conceptual units (columns). For each conceptual unit, scores could range from 0-1. Individual participants are plotted as small, translucent circles, and mean scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. The dotted line corresponds to equal endorsements of the two conceptual units plotted. Pearson correlations are reported for each pair of conceptual units.

HEART vs. MIND

Across Studies 1a-1c, *HEART* vs. *MIND* difference scores were substantially non-zero, in the direction of participants endorsing *MIND* items more strongly than *HEART* items (see the "Intercept" row for the "HEART-MIND" comparison in Table 4.2). In all studies this difference was somewhat exaggerated in assessments of the robot, relative to the beetle (see the "Robot vs. GM" row for the "HEART-MIND" comparison in Table 4.2).

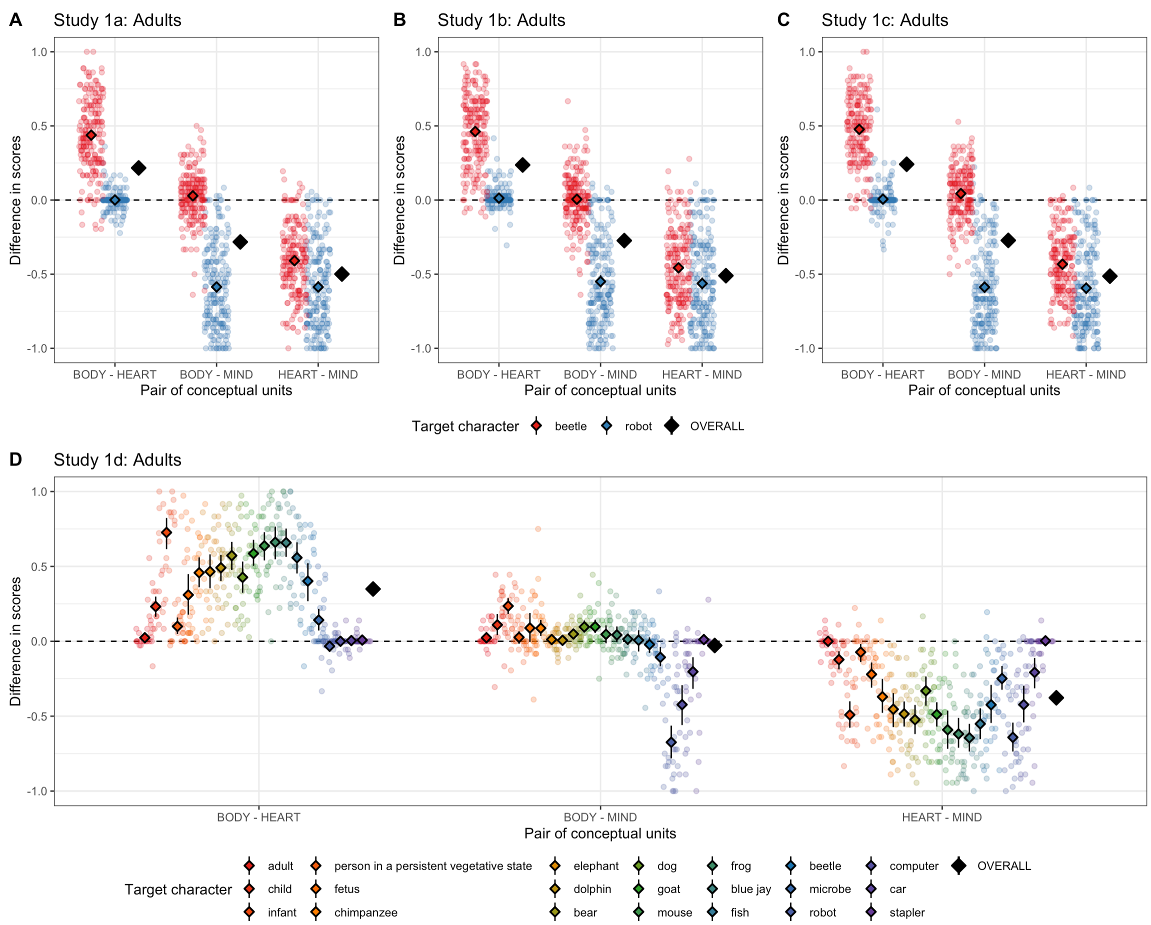

Figure 4.2: Difference scores between conceptual units among US adults in Studies 1a-1d. For each conceptual unit, scores could range from 0-1, such that difference scores could range from -1 to +1. Individual participants are plotted as small, translucent circles, and mean difference scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. The dotted line corresponds to equal endorsements of the two conceptual units plotted (i.e., a difference score of 0).

Table 4.2: Regression analyses of difference scores for US adults in Studies 1a-1c. The table presents results from separate Bayesian regressions of each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND). Each regression included two fixed effect parameters: (1) the intercept, which I treat as an index of the asymmetry in attributions of the two conceptual units in question; and (2) a difference between target characters, reported here as a difference between the robot and the grand mean (GM). Intercepts are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	Study 1a			**Study 1b**			**Study 1c**		
Parameter	**b**	**95% CI**		**b**	**95% CI**		**b**	**95% CI**	
BODY - HEART									
Intercept	**0.22**	**[0.20, 0.24]**	*	**0.24**	**[0.22, 0.25]**	*	**0.24**	**[0.22, 0.26]**	*
Robot vs. GM	-0.22	[-0.24, -0.20]	*	-0.22	[-0.24, -0.21]	*	-0.23	[-0.25, -0.22]	*
BODY - MIND									
Intercept	**-0.28**	**[-0.30, -0.25]**	*	**-0.27**	**[-0.29, -0.25]**	*	**-0.27**	**[-0.29, -0.25]**	*
Robot vs. GM	-0.31	[-0.33, -0.28]	*	-0.28	[-0.30, -0.25]	*	-0.32	[-0.34, -0.29]	*
HEART - MIND									
Intercept	**-0.50**	**[-0.52, -0.47]**	*	**-0.51**	**[-0.54, -0.48]**	*	**-0.51**	**[-0.54, -0.49]**	*
Robot vs. GM	-0.09	[-0.11, -0.06]	*	-0.05	[-0.08, -0.03]	*	-0.08	[-0.10, -0.06]	*

Interim discussion

Across Studies 1a-1c, visual inspection of the relationships among the conceptual units identified in Chapter III (BODY, HEART, and MIND) suggested that all of these relationships are characterized by two features: (1) Positive contingencies, such that the more strongly a participant endorsed one conceptual unit, the more strongly they tended to endorse the others; and (2) Robust asymmetries, such that participants tended to endorse MIND more strongly than BODY or HEART, and HEART more strongly than MIND. These asymmetries were most pronounced for comparisons involving HEART, with the vast majority of participants in all three of these studies endorsing both BODY and MIND more strongly than HEART for both of the "edge case" characters included in these studies (a beetle and a robot). Formal analyses of difference scores across the *BODY*, *HEART*, and *MIND* scales in Studies 1a-1c confirmed these observations.

Study 1d

Scale construction

Following the steps described in the "General analysis plan," above, yielded *BODY*, *HEART*, and *MIND* scales of 6 items each, with a large degree of overlap in items between these scales and the scales derived from Studies 1a-1c; see Table 4.1.

Visualization

Visualizations of relationships among scores on these *BODY*, *HEART*, and *MIND* scales are provided in Figure 4.1, row D.

BODY vs. HEART

First I consider the relationship between BODY and HEART (Figure 4.1, panel D1). Much as in Studies 1a-1c (rows A-C), the most striking features of this visualization are that (1) there is a positive relationship between scores on the *BODY* and *HEART* scales ($r = 0.57$; $p < 0.001$; 95% CI: [0.50, 0.63]); and (2) there are virtually no datapoints , dotted diagonal line), and certainly no datapoints in the upper left corner of the plot. Individual participants tended to endorse the mental capacity items included in the *BODY* scale at least as strongly, and often more strongly, than they endorsed items included in the *HEART* scale—in other words, many participants attributed more BODY than HEART to the target character in question, but virtually no participants attributed more HEART than BODY.

Visual inspection of mean scores by target character further revealed that, in the aggregate, characters that received relatively low *BODY* scores (e.g., inert objects, technologies, the fetus, the person in a persistent vegetative state, and such "lower" life forms as a microbe) received universally low mean *HEART* scores, while characters that received relatively high *BODY* scores (e.g., "higher" life forms like animals and typical humans) varied in their mean *HEART* scores. This raises the intriguing possibility that attributions of BODY and HEART may have been governed by some sort of "threshold" model, in which attributions of any substantial amount of HEART depend on the target character having a certain degree of BODY.

BODY vs. MIND

Next I consider the relationship between BODY and MIND (Figure 4.1, panel D2). As in Studies 1a-1c, two notable features of this visualization are that (1) there is a positive relationship between scores on the *BODY* and *MIND* scales ($r = 0.75$; $p < 0.001$; 95% CI: [0.71, 0.79]); and (2) there are datapoints in the upper left but not the lower right corner of the plots. However, while participants who assessed certain target characters (namely, the technologies) tended to endorse the mental capacity items included in the *MIND* scale roughly as strongly, and sometimes more strongly, than they endorsed items included in the *BODY* scale, participants who assessed other target characters, if anything, appear to have shown the reverse pattern, endorsing *MIND* items slightly less strongly than *BODY* items. In other words, there appears to be less consistency in the "asymmetry" between BODY and MIND in Study 1d than there was in Studies 1a-1c.

HEART vs. MIND

Finally I consider the relationship between HEART and MIND (Figure 4.1, panel D1). Much as in Studies 1a-1c (rows A-C), the most striking features of this visualization are that (1) there is a positive relationship between scores on the *HEART* and *MIND* scales ($r = 0.52$; $p < 0.001$; 95% CI: [0.45, 0.59]); and (2) there are virtually no datapoints , dotted diagonal line), and certainly no datapoints in the lower right corner of the plot. Individual participants tended to endorse the mental capacity items included in the *MIND* scale at least as strongly, and often more strongly, than they endorsed items included in the *HEART* scale—in other words, many participants attributed more MIND than

HEART to the target character in question, but virtually no participants attributed more HEART than MIND.

Visual inspection of mean scores by target character further revealed that, in the aggregate, characters that received relatively low *MIND* scores (e.g., inert objects, the fetus, and such "lower" life forms as a microbe) received universally low mean *HEART* scores, while characters that received relatively high *MIND* scores (e.g., more sophisticated technologies as well as "higher" life forms like animals and typical humans) varied in their mean *HEART* scores. As in the BODY vs. HEART comparison discussed earlier, this raises the intriguing possibility that attributions of HEART and MIND may have been governed by some sort of "threshold" model, in which attributions of any substantial amount of HEART depend on the target character having a certain degree of MIND.

Analysis of asymmetries

Here I provide a formal analysis of the asymmetries revealed by the visualizations in the previous section. As in Studies 1a-1c, for each pair of conceptual units, I conducted a Bayesian regression to compare difference scores to zero, controlling for differences in assessments of the 21 "diverse characters" that were featured as target characters in these studies. See Figure 4.2, panel D, for visual depictions of these difference scores.

BODY vs. HEART

These regression analyses confirmed that in Study 1d, as in Studies 1a-1c, *BODY* vs. *HEART* difference scores were substantially non-zero, in the direction of participants endorsing *BODY* items more strongly than *HEART* items (see the "Intercept" row for the "BODY-HEART" comparison in Table 4.3).

This asymmetry was more pronounced for some characters, and less pronounced for others—namely, humans (who generally received high scores on both the *BODY* and *HEART* scales) and technologies (who generally received low scores on both the *BODY* and *HEART* scales). A full discussion of the differences between target characters is beyond the scope of this chapter, but it is worth noting that there were no characters for whom this asymmetry was systematically reversed (i.e., who were generally considered to have more HEART than BODY capacities). See Figure 4.2, panel D, and the various comparisons of target characters to the grand mean for the "BODY-HEART" comparison in Table 4.3.

BODY vs. MIND

These regression analyses indicated that in Study 1d, in contrast to Studies 1a-1c, *BODY* vs. *MIND* difference scores were only very slightly non-zero, in the direction of participants endorsing *MIND* items more strongly than *BODY* items (see the "Intercept" row for the "BODY-MIND" comparison in Table 4.3).

Again, this asymmetry was more pronounced for some characters—namely, technologies (who generally received high scores on the *MIND* scale and low scores on the *BDOY* scale)—and less pronounced for others. Indeed, there were some characters (e.g., the child, the infant, the fetus, and a handful of non-human animals) for whom this asymmetry tended to run in the opposite direction, with participants attributing more BODY than MIND capacities. See Figure 4.2, panel D, and the various comparisons of target characters to the grand mean for the "BODY-MIND" comparison in Table 4.3.

HEART vs. MIND

These regression analyses confirmed that in Study 1d, as in Studies 1a-1c, *HEART* vs. *MIND* difference scores were substantially non-zero, in the direction of participants endorsing *MIND* items more strongly than *HEART* items (see the "Intercept" row for the "HEART-MIND" comparison in Table 4.3).

Similar to the BODY vs. HEART comparison, this asymmetry was less pronounced for humans (who generally received high scores on both the *HEART* and *MIND* scales), and more pronounced for other characters. A full discussion of the differences between target characters is beyond the scope of this chapter, but it is worth noting that there were no characters for whom this asymmetry was systematically reversed (i.e., who were generally considered to have more HEART than MIND capacities). See Figure 4.2, panel D, and the various comparisons of target characters to the grand mean for the "HEART-MIND" comparison in Table 4.3.

Interim discussion

In Study 1d, many of the results obtained in Studies 1a-1c were upheld. In particular, (1) The relationships between BODY vs. HEART and between MIND vs. HEART were positive, such that the more strongly a participant endorsed one conceptual unit, the more strongly they tended to endorse the other; and (2) There were robust asymmetries in these positive relationships, such that participants tended to endorse either BODY or MIND more strongly than HEART.

Visual inspection of the BODY vs. MIND scatterplot for Study 1d suggested that this relationship was quite variable across participants and across target characters—even more variable and less robust than what was observed in Studies 1a-1c. Formal analyses confirmed that, in the aggregate, there was a slight tendency for participants to endorse MIND more strongly than BODY, but this asymmetry was weak and highly contingent on the particular target character that participants were assigned to assess.

Discussion

Studies 1a-1d converged to suggest that, among US adults, the relationships among BODY, HEART, and MIND, are characterized by being (1) positive, such that the more strongly a participant endorsed one conceptual unit, the more strongly they tended to endorse the other; and (2) asymmetrical, such that certain conceptual units are systematically endorsed more strongly than others.

In particular, the vast majority of participants across all four of these studies endorsed both BODY and MIND at least as strongly, and often more strongly, than they endorsed HEART, regardless of which target character they were assessing or how strong their endorsements were in absolute terms. Taken together, I consider this to be fairly strong evidence that the conceptual units that I have called BODY and MIND are more basic or fundamental than the unit that I refer to as HEART.

The relationship between these two more "basic" conceptual units appears to be more complicated. Across Studies 1a-1d, in the aggregate participants tended to endorse MIND (slightly) more strongly than BODY. However, in each study this asymmetry was driven by assessments of a particular kind of target character: technologies (the robot in Studies 1a-1c; the robot, computer, and car in Study 1d). For other target characters (including the beetle in Studies 1a-1c, as well as many of the target characters in Study 1d), average difference scores hovered around zero, with some participants endorsing BODY more strongly than MIND, others endorsing MIND more strongly than BODY, and still others endorsing BODY and MIND to roughly equal degrees. In Study 1d there were even a few target characters—namely, immature humans and a handful of non-human animals—for whom difference scores systematically ran in the opposite direction to what was observed among technologies, with participants endorsing BODY more strongly than MIND. Taken together, these observations suggest that asymmetries in attributions of BODY vs. MIND are more variable across individual participants and more sensitive to differences in target characters—and, by extension, that there is no general or robust hierarchical relationship between these two conceptual units in US adults' conceptual representations of mental life.

Table 4.3: Regression analyses of difference scores for US adults in Study 1d. The table presents results from separate Bayesian regressions of each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND). Each regression included two fixed effect parameters: (1) the intercept, which I treat as an index of the asymmetry in attributions of the two conceptual units in question; and (2) a difference between target characters, reported here as a difference between each character and the grand mean (GM). Intercepts are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

Study 1d			
Parameter	**b**	**95% CI**	
BODY - HEART			
Intercept	**0.35**	**[0.33, 0.37]**	*
Adult vs. GM	-0.33	[-0.42, -0.24]	*
Child vs. GM	-0.12	[-0.21, -0.03]	*
Infant vs. GM	0.37	[0.28, 0.46]	*
PVS vs. GM	-0.25	[-0.34, -0.17]	*
Fetus vs. GM	-0.04	[-0.14, 0.05]	
Chimpanzee vs. GM	0.10	[0.02, 0.19]	*
Elephant vs. GM	0.11	[0.03, 0.20]	*
Dolphin vs. GM	0.14	[0.05, 0.22]	*
Bear vs. GM	0.22	[0.13, 0.31]	*
Dog vs. GM	0.07	[-0.01, 0.15]	
Goat vs. GM	0.23	[0.15, 0.32]	*
Mouse vs. GM	0.28	[0.19, 0.38]	*

Frog vs. GM	0.31	[0.22, 0.40]	*
Blue jay vs. GM	0.30	[0.21, 0.39]	*
Fish vs. GM	0.20	[0.11, 0.30]	*
Beetle vs. GM	0.05	[-0.04, 0.14]	
Microbe vs. GM	-0.21	[-0.30, -0.12]	*
Robot vs. GM	-0.39	[-0.47, -0.30]	*
Computer vs. GM	-0.35	[-0.44, -0.27]	*
Car vs. GM	-0.35	[-0.43, -0.27]	*
BODY - MIND			
Intercept	**-0.02**	**[-0.04, -0.01]**	*
Adult vs. GM	0.05	[-0.02, 0.12]	
Child vs. GM	0.13	[0.06, 0.20]	*
Infant vs. GM	0.26	[0.19, 0.33]	*
PVS vs. GM	0.05	[-0.02, 0.12]	
Fetus vs. GM	0.11	[0.04, 0.18]	*
Chimpanzee vs. GM	0.11	[0.04, 0.18]	*
Elephant vs. GM	0.04	[-0.03, 0.10]	
Dolphin vs. GM	0.03	[-0.04, 0.09]	
Bear vs. GM	0.07	[0.00, 0.14]	*
Dog vs. GM	0.12	[0.06, 0.18]	*
Goat vs. GM	0.12	[0.05, 0.19]	*
Mouse vs. GM	0.07	[0.00, 0.14]	
Frog vs. GM	0.07	[0.00, 0.13]	
Blue jay vs. GM	0.04	[-0.03, 0.11]	
Fish vs. GM	0.03	[-0.04, 0.10]	
Beetle vs. GM	0.00	[-0.07, 0.07]	

Microbe vs. GM	-0.08	[-0.15, -0.02]	*
Robot vs. GM	-0.65	[-0.72, -0.58]	*
Computer vs. GM	-0.40	[-0.47, -0.33]	*
Car vs. GM	-0.18	[-0.24, -0.12]	*
HEART - MIND			
Intercept	**-0.38**	**[-0.40, -0.35]**	*
Adult vs. GM	0.38	[0.28, 0.47]	*
Child vs. GM	0.25	[0.16, 0.35]	*
Infant vs. GM	-0.11	[-0.21, -0.02]	*
PVS vs. GM	0.30	[0.21, 0.40]	*
Fetus vs. GM	0.15	[0.05, 0.25]	*
Chimpanzee vs. GM	0.01	[-0.09, 0.10]	
Elephant vs. GM	-0.08	[-0.17, 0.02]	
Dolphin vs. GM	-0.11	[-0.20, -0.02]	*
Bear vs. GM	-0.15	[-0.24, -0.05]	*
Dog vs. GM	0.05	[-0.04, 0.14]	
Goat vs. GM	-0.11	[-0.21, -0.02]	*
Mouse vs. GM	-0.21	[-0.32, -0.12]	*
Frog vs. GM	-0.24	[-0.34, -0.15]	*
Blue jay vs. GM	-0.27	[-0.36, -0.17]	*
Fish vs. GM	-0.18	[-0.27, -0.08]	*
Beetle vs. GM	-0.05	[-0.15, 0.05]	
Microbe vs. GM	0.13	[0.03, 0.22]	*
Robot vs. GM	-0.27	[-0.36, -0.17]	*
Computer vs. GM	-0.05	[-0.14, 0.05]	
Car vs. GM	0.17	[0.08, 0.26]	*

Study 2: Conceptual change between middle childhood (7-9y) and adulthood

In the context of this dissertation, Study 2 serves to provide an initial investigation of representations of mental life earlier in development, in what I have called middle childhood (7-9y). In this chapter, I focus on what this study can reveal about changes in the relationships among the conceptual units BODY, HEART, and MIND between middle childhood and adulthood.

In Study 2, 200 US adults and 200 US children between the ages of 7.01-9.99 years (median: 8.31y) each assessed a single target character on 40 mental capacities. This study employed the "edge case" variant of the general approach, with participants randomly assigned to assess either a beetle or a robot. (See Chapter II for detailed methods.)

Results

Adults

Scale construction

Following the steps described in the "General analysis plan," above, yielded *BODY*, *HEART*, and *MIND* scales of 6 items each; see Table 4.10.

Visualization and analysis of asymmetries

Visualizations of relationships among scores on these *BODY*, *HEART*, and *MIND* scales are provided in Figure 4.3, row A. Here I combine my informal descriptions of these visualizations with formal analyses of difference scores between conceptual units, controlling for differences in assessments of the two "edge cases" that were featured as target characters in these studies. See Figure 4.5, panel A, for visual depictions of these difference scores, and Table 4.4 for the full results of these Bayesian regression analyses.

BODY vs. HEART

As in Study 1, among adults in Study 2 there was a was a positive relationship between scores on the *BODY* and *HEART* scales ($r = 0.46$; $p < 0.001$; 95% CI: [0.34, 0.56]). The visualization of this relationship (Figure 4.3, panel A1) featured very few , dotted diagonal line)—an asymmetry which appeared to have been driven primarily by assessments of the beetle (in red). A regression analysis confirmed that adults' *BODY* vs. *HEART* difference scores were substantially non-zero, in the direction of participants endorsing *BODY* items more strongly than *HEART* items (see the “Intercept” row for the “BODY-HEART” comparison in Table 4.4), and this asymmetry was driven primarily by participants’ assessments of the beetle (see the “Robot vs. GM” row for the “BODY-HEART” comparison in Table 4.4).

BODY vs. MIND

Unlike Study 1, among adults in Study 2 the relationship between scores on the *BODY* and *MIND* scales was not significantly positive ($r = 0.04$; $p = 0.615$; 95% CI: [-0.10, 0.17]). As in Study 1, the visualization of this relationship (Figure 4.3, panel A2) , dotted diagonal line) than above it, and no datapoints in the lower right corner of the plot—an asymmetry which appeared to have been driven primarily by assessments of the robot (in blue) and which generally appeared to be less extreme than the other two comparisons. A regression analysis confirmed that adults’ *BODY* vs. *MIND* difference scores were substantially non-zero, in the direction of participants endorsing *MIND* items more strongly than *BODY* items (see the “Intercept” row for the “BODY-MIND” comparison in Table 4.4), and this asymmetry was driven primarily by participants’ assessments of the robot (see the “Robot vs. GM” row for the “BODY-MIND” comparison in Table 4.4).

HEART vs. MIND

As in Study 1, among adults in Study 2 there was a positive relationship between scores on the *HEART* and *MIND* scales ($r = 0.20$; $p = 0.005$; 95% CI: [0.06, 0.33]). As in Study 1, the visualization of this relationship (Figure 4.3, panel A3) featured virtually no , dotted diagonal line)—an asymmetry which appeared to have been especially extreme. A regression analysis confirmed that adults’ *HEART* vs. *MIND* difference scores were substantially non-zero, in the direction of participants endorsing *MIND* items more strongly than *HEART* items (see the “Intercept” row for the “HEART-MIND” comparison in Table 4.4); this asymmetry was somewhat exaggerated in assessments of the robot (see the “Robot vs. GM” row for the “HEART-MIND” comparison in Table 4.4).

Interim discussion

The relationships among adults’ endorsements of the conceptual units in Study 2 were very similar to those revealed by Study 1: (1) With the exception of BODY vs. MIND, these inter-unit relationships were positive, such that the more strongly a participant endorsed one conceptual unit, the more strongly they tended to endorse the others; and (2) There were robust asymmetries in these positive relationships, such that participants tended to endorse MIND more strongly than BODY or HEART, and HEART more strongly than MIND. These asymmetries were particularly pronounced for comparisons involving HEART, with virtually every participant endorsing both BODY and MIND more strongly than HEART for both of the "edge case" characters included in this study (a beetle and a robot). Formal analyses of difference scores across the *BODY*, *HEART*, and *MIND* scales among adults in Study 2 confirm these informal observations.

The similarity in results among adults in Studies 1 and 2 offers further evidence that this conceptual organization is robust to differences in experimental methods, including differences in the set of mental capacities and in the response scales employed in these studies.

Children (7-9y)

The primary goal of Study 2 was to begin investigating the development of these conceptual representations: What are the relationships among BODY, HEART, and MIND among children ages 7-9y, and how do these relationships compare to those among adults, as described in the previous section?

I begin my exploration of this aspect of conceptual change by applying the same *BODY*, *HEART*, and *MIND* scales (derived from EFA of adults' responses) to children's responses, examining the same visualizations, and conducting the same regression analyses. I then conduct a formal comparison of children's and adults' results ("Developmental comparison"), before briefly considering what the relationships between BODY, HEART, and MIND might look like if they were indexed by scales derived from EFA of children's, rather than adults' responses ("Children (7-9y), using children's own scales").

Visualization and analysis of asymmetries

Visualizations of relationships among scores on these *BODY*, *HEART*, and *MIND* scales are provided in Figure 4.3, row B. Here I combine my informal descriptions of these visualizations with formal analyses of difference scores between conceptual units, controlling for differences in assessments of the two "edge cases" that were featured as target characters in these studies. See Figure 4.5, panel B, for visual depictions of these difference scores, and Table 4.4 for the full results of these Bayesian regression analyses.

BODY vs. HEART

As among adults in this study (Figure 4.3, panel A1), the relationship between children's scores on the *BODY* and *HEART* scales (panel B1) was positive (r = 0.39; p < 0.001; 95% CI: [0.27, 0.50]), and there appear to be somewhat fewer datapoints above , dotted diagonal line) than below it. However, this asymmetry is less striking among children than it was among adults: While many children attributed more BODY than HEART to the target character in question (like the vast majority of adults), quite a few children attributed more HEART than BODY. Indeed, a regression analysis revealed that children's BODY vs. HEART difference scores were not quite differentiable from zero (the lower bound of the 95% credible interval was effectively zero; see the "Intercept" row for the "BODY-HEART" comparison in Table 4.4). Moreover, the direction of difference varied substantially across target characters (see the "Robot vs. GM" row for the "BODY-HEART" comparison in Table 4.4), with children tending to attribute more BODY than HEART to the beetle but, if anything, more HEART than BODY to the robot.

BODY vs. MIND

As among adults in this study (Figure 4.3, panel A2), there was no significant relationship between children's scores on the *BODY* and *MIND* scales (panel B3; r = 0.00; p = 0.950; 95% CI: [-0.13, 0.14]). In the visualization of children's scores there , dotted diagonal line) than above it, but this asymmetry is less striking among children than it was among adults: While many children attributed more MIND than BODY to the target character in question (like the vast majority of adults), quite a few children attributed more BODY than MIND. A regression analysis confirmed that, on the whole, children's BODY vs. MIND difference scores were substantially non-zero, in the direction of children endorsing *MIND* items more strongly than *BODY* items (see the "Intercept" row for the "BODY-MIND" comparison in Table 4.4), but this difference varied substantially across target characters (see the "Robot vs. GM" row for the "BODY-MIND" comparison in Table 4.4), with children tending to attribute more MIND than BODY to the robot but, if anything, more BODY than MIND to the beetle.

HEART vs. MIND

As among adults in this study (Figure 4.3, panel A3), the relationship between children's scores on the *HEART* and *MIND* scales (panel B3) was positive (r = 0.18; p = 0.013; 95% CI: [0.04, 0.31]), and there appear to be somewhat fewer datapoints below , dotted diagonal line) than above it. However, as in the BODY vs. HEART and BODY vs. MIND comparisons just discussed, this asymmetry is less striking among children than it was among adults: While many children attributed more MIND than HEART to the target character in question (like the vast majority of adults), quite a few children attributed more HEART than MIND. A regression analysis confirmed that, on the whole, children's HEART vs. MIND difference scores were substantially non-zero, in the direction of children endorsing *MIND* items more strongly than *HEART* items (see the "Intercept" row for the "HEART-MIND" comparison in Table 4.4); this difference was present for both target characters, but exaggerated in assessments of the robot (see the "Robot vs. GM" row for the "BODY-MIND" comparison in Table 4.4).

Developmental comparison

The preceding visualizations and analyses all suggest that children's responses were generally less asymmetrical than those of adults. This is perhaps easiest to observe in Figure 4.3, row C, which presents (hypothetical) "movement" between the mean placement for a target character among children (beginning of arrow) and the mean placement for a target character among adults (arrowhead), for each pair of conceptual units. In each case, this "movement" either maintains a similar distance from the line of) (as with mean assessments of the robot in the BODY vs. HEART space, panel C1; and the beetle in the BODY vs. MIND space, panel C2) or moves away from the line of equivalence toward the upper left and lower right corners of the plot (as with mean assessments of the beetle in the BODY vs. HEART space, panel C1; the robot in the BODY vs. MIND space, panel C2; and both characters in the HEART vs. MIND space, panel C3). Analysis of changes in *absolute* attributions of BODY, HEART, and MIND, is pursued in Chapter V; for the purposes of the current chapter, the primary observation of interest is that these "shifts" between child and adult assessments of these characters generally point in the direction of stable or increasing (not decreasing) asymmetries over developmental time.

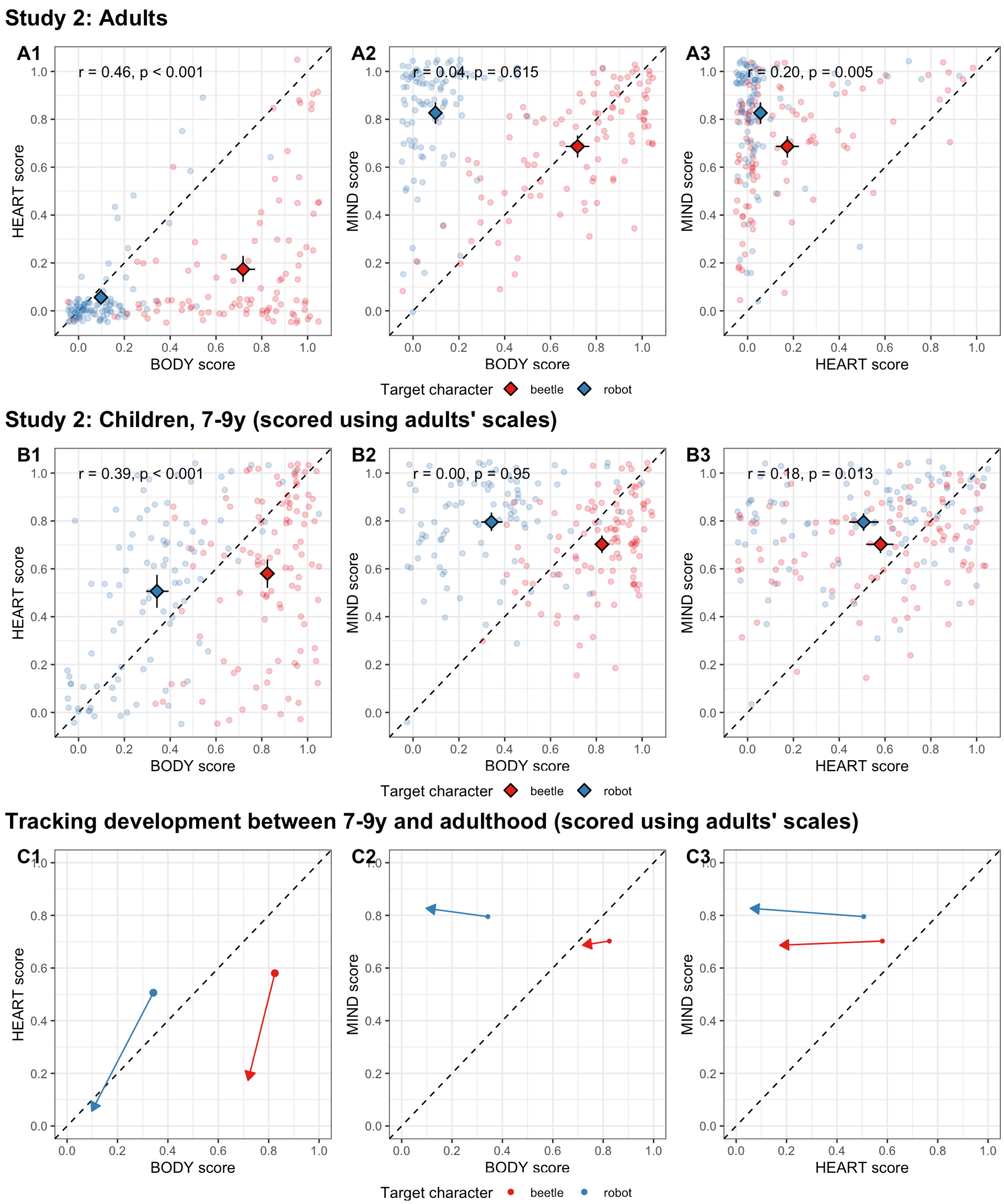

Figure 4.3: Relationships among US adults' and children's attributions of conceptual units in Study 2, scored using adults' BODY, HEART, and MIND scales (see Table 4.10). Plots are organized by sample (rows) and by pair of conceptual units (columns). (A) Adults. (B) Children (7-9y of age), scored using adults' scales. (C) A visualization of development between 7-9y and adulthood, using mean scores by character and age group. For each conceptual unit, scores could range from 0-1. In panels A-B, individual participants are plotted as small, translucent circles, and mean scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. The dotted line corresponds to equal endorsements of the two conceptual units plotted. Pearson correlations are reported for each pair of conceptual units.

To assess the size and robustness of these apparent developmental differences, I conducted formal comparisons of difference scores between conceptual units between these two age groups. For each pair of conceptual units, I pooled data from both age groups and modified my regression analyses to include a main effect of age group (comparing children's difference scores to the baseline set by adults) and an interaction between age group and target character (assessing whether the observed differences between characters varied by age group).

These analyses confirmed that difference scores for all three pairs of conceptual units were substantially closer to zero among children, as compared to adults (see the "Children vs. adults" rows for each comparison in Table 4.5). The difference between target characters was attenuated among children in the BODY vs. MIND comparison, but not in other comparisons (see the "Robot vs. GM" rows in Table 4.5).

Interim discussion

Both visual inspection and formal analyses of the relationships among BODY, HEART, and MIND suggest that the asymmetries in relationships among 7- to 9-year-old children's endorsements of these conceptual units were similar in direction—but substantially attenuated in size—relative to the baseline set by adults. This suggests that the proposed hierarchical relationships between these conceptual units are nascent in this age group, but may not be fully robust or "mature."

Children (7-9y), using children's own scales

The previous analyses made use of *BODY*, *HEART*, and *MIND* scores derived from EFAs of adults' mental capacity representations to examine the relationships among these conceptual units among both adults and children. But Chapter III suggested that, while 7- to 9-year-old children's conceptual units were very similar to those of adults, they were not exactly identical. What would the relationships among BODY, HEART, and MIND look like if they were assessed using scales derived from children's own responses, rather than adults'? Here I briefly consider this possibility for children in Study 2; for parallel analyses for children in Study 3, see Appendix B.

Scale construction

Following the steps described in the "General analysis plan," above, yielded *BODY*, *HEART*, and *MIND* scales of 6 items each. Notably, children's *BODY* and

HEART scales were very similar to the *BODY* and *HEART* scales derived from adults in this study, differing by only one item each. The *MIND* scales for children vs. adults had three items in common, and differed by three items; see Table 4.10.

Visualization and analysis of asymmetries

Visualizations of relationships among scores on these child-based *BODY*, *HEART*, and *MIND* scales are provided in Figure 4.4, and difference scores between pairs of conceptual units are depicted in Figure 4.5, panel C. As these plots illustrate, the pattern of results using these child-based scales was virtually identical to the pattern of results using the adult-based scales as discussed in the previous section; see Table 4.5 for a juxtaposition of the regression analyses. This suggests that this attenuation of asymmetries across pairs of conceptual units was not merely due to the operationalization of BODY, HEART, and MIND using adults' rather than children's EFA solutions; these developmental differences were observed regardless of whether these conceptual units were indexed by scales designed to capture adults' or children's construals of BODY, HEART, and MIND.

Discussion

Study 2 provided further confirmation of the robustness of the asymmetric relationships among conceptual units in adults' representations of mental life as revealed by Study 1. Using a modified experimental paradigm, a slightly different set of mental capacities, and a three-point (rather than seven-point) response scale revealed the same pattern of asymmetries in adults' endorsements of BODY, HEART, and MIND: Regardless of which of the two "edge cases" they assessed, adults systematically endorsed both BODY and MIND at least as strongly, and often more strongly, than HEART, while the relationship between BODY and MIND was more contingent on the target character under evaluation.

Study 2 also affords the first glimpse into the development of this aspect of conceptual representations of mental life among 7- to 9-year-old children. A variety of visualizations and analyses converged to suggest that, on the whole, the *directions* of these relationships among conceptual units are in place by this point in development, but these asymmetries are not nearly as pronounced or robust among children as they are among adults.

There are some hints from Study 2 that the asymmetry between BODY vs. HEART may be a point of particular immaturity for 7- to 9-year-old children: While very few adults in this study (or in any previous study) endorsed *HEART* capacities more strongly than *BODY* capacities for any target character, quite a lot of children did—particularly if they happened to assess the robot. Indeed, on the whole, children in this study showed no systematic asymmetry between these two conceptual units.

Study 3: Conceptual change over early and middle childhood (4-9y)

Study 3 builds on the investigation of middle childhood (7-9y) initiated in Study 2 and extends this exploration of conceptual change into earlier childhood (4-6y). In this chapter, I again focus on what this study can reveal about changes in the relationships among the conceptual units BODY, HEART, and MIND over the course of early and middle childhood (7-9y).

As a reminder, in the main text of this chapter I analyze children's responses with respect to the "mature" conceptual units BODY, HEART, and MIND, as defined by EFA of *adults'* responses. (See Appendix B for further analyses with respect to the conceptual units identified through EFA of children's own mental capacity attributions, as presented in Chapter III.)

In Study 3, 116 US adults, 125 "older" children (7.08-9.98 years; median: 8.56y), and 124 "younger" children (4.00-6.98 years; median: 5.03y) each assessed a single target character on 20 mental capacities. This study employed the "diverse characters" variant of the general approach, with participants randomly or pseudo-randomly assigned to assess one of the following 9 characters: an elephant, a goat, a mouse, a bird, a beetle, a teddy bear, a doll, a robot, or a computer. (See Chapter II for detailed methods.)

Results

Adults

Scale construction

Following the steps described in the "General analysis plan," above, yielded *BODY*, *HEART*, and *MIND* scales of 6 items each; see Table 4.10.

Figure 4.4: Relationships among children's attributions of conceptual units in Study 2, scored using their own scales (see Table 4.10). Plots are organized by pair of conceptual units (columns). For each conceptual unit, scores could range from 0-1. Individual participants are plotted as small, translucent circles, and mean scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. The dotted line corresponds to equal endorsements of the two conceptual units plotted. Pearson correlations are reported for each pair of conceptual units.

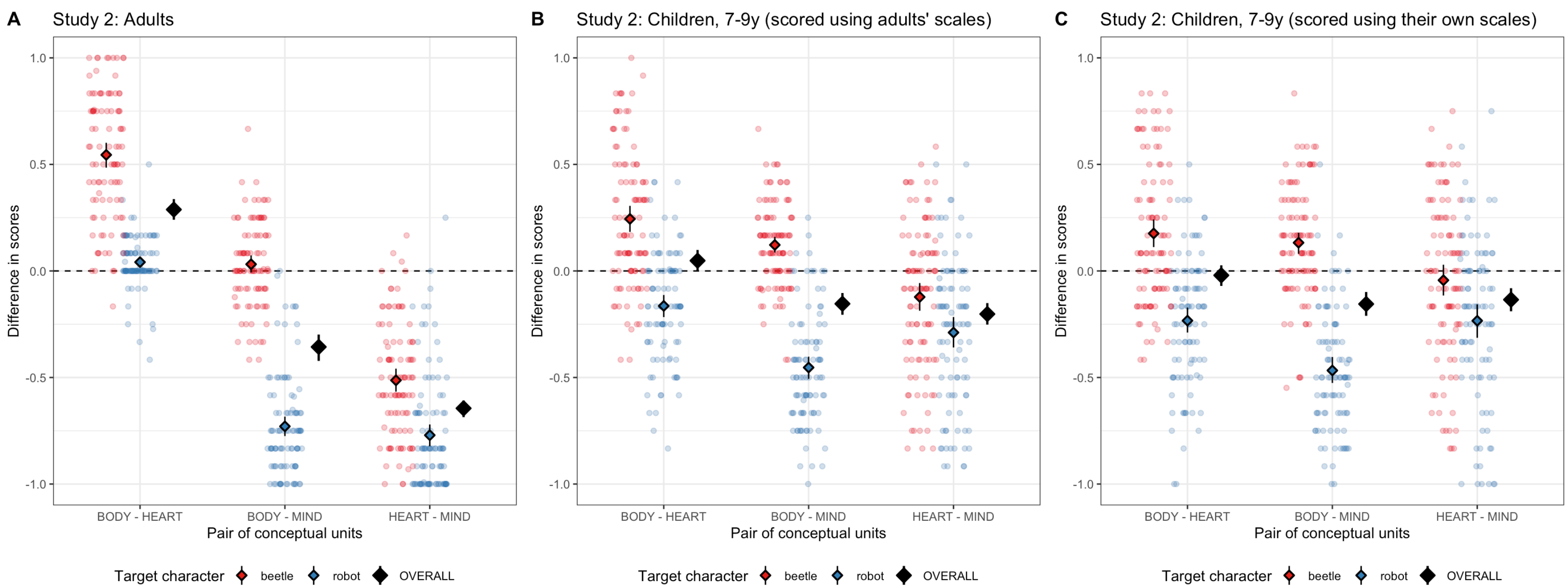

Figure 4.5: Difference scores between conceptual units among US adults and children in Study 2. This includes difference scores using adults' BODY, HEART, and MIND scales (panel B) and difference scores using children's own scales (panel C; see Table 4.10). For each conceptual unit, scores could range from 0-1, such that difference scores could range from -1 to +1. Individual participants are plotted as small, translucent circles, and mean difference scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. The dotted line corresponds to equal endorsements of the two conceptual units plotted (i.e., a difference score of 0).

Table 4.4: Regression analyses of difference scores among US adults and children (7-9y of age) in Study 2. For children, this includes an analysis using adults' BODY, HEART, and MIND scales (middle columns), as well as an analysis using scales derived from EFA of children's own mental capacity attributions (rightmost columns). The table presents results from separate Bayesian regressions of each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND). Each regression included two fixed effect parameters: (1) the intercept, which I treat as an index of the asymmetry in attributions of the two conceptual units in question; and (2) a difference between target characters, reported here as a difference between the robot and the grand mean (GM). The intercepts are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	Adults			**Children, 7-9y (using adults' scales)**			**Children, 7-9y (using their own scales)**		
Parameter	**b**	**95% CI**		**b**	**95% CI**		**b**	**95% CI**	
BODY - HEART									
Intercept	**0.29**	**[0.26, 0.32]**	*	**0.04**	**[0.00, 0.08]**		**-0.03**	**[-0.07, 0.01]**	
Robot vs. GM	-0.25	[-0.28, -0.22]	*	-0.20	[-0.24, -0.16]	*	-0.20	[-0.25, -0.16]	*
BODY - MIND									
Intercept	**-0.35**	**[-0.38, -0.32]**	*	**-0.17**	**[-0.20, -0.13]**	*	**-0.17**	**[-0.21, -0.13]**	*
Robot vs. GM	-0.38	[-0.41, -0.35]	*	-0.29	[-0.32, -0.26]	*	-0.30	[-0.34, -0.26]	*
HEART - MIND									
Intercept	**-0.64**	**[-0.68, -0.60]**	*	**-0.21**	**[-0.25, -0.16]**	*	**-0.14**	**[-0.19, -0.08]**	*
Robot vs. GM	-0.13	[-0.17, -0.09]	*	-0.08	[-0.13, -0.04]	*	-0.09	[-0.15, -0.04]	*

Table 4.5: Regression analyses of age group differences in difference scores in Study 2. The table presents results from separate Bayesian regressions of each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND). Each regression included four fixed effect parameters: (1) the intercept among adults, which I treat as an index of the asymmetry in attributions of the two conceptual units in question among adults; (2) the overall difference between children and adults (collapsing across target characters); (3) a difference between target characters among adults, reported here as a difference between the robot and the grand mean (GM); and (4) the interaction between this difference between target characters and the difference between age groups. The developmental comparisons are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	Developmental comparison		
Parameter	**b**	**95% CI**	
BODY - HEART			
Intercept	0.29	[0.26, 0.33]	*
Children vs. adults	**-0.25**	**[-0.31, -0.20]**	*
Robot vs. GM	-0.25	[-0.29, -0.21]	*
Interaction	**0.05**	**[-0.01, 0.10]**	
BODY - MIND			
Intercept	-0.35	[-0.38, -0.32]	*
Children vs. adults	**0.18**	**[0.14, 0.23]**	*
Robot vs. GM	-0.38	[-0.41, -0.35]	*
Interaction	**0.09**	**[0.05, 0.14]**	*
HEART - MIND			
Intercept	-0.64	[-0.69, -0.60]	*
Children vs. adults	**0.44**	**[0.38, 0.50]**	*
Robot vs. GM	-0.13	[-0.17, -0.09]	*
Interaction	**0.04**	**[-0.02, 0.10]**	

Visualization and analysis of asymmetries

Visualizations of relationships among scores on these *BODY*, *HEART*, and *MIND* scales are provided in Figure 4.6, row A. Here I combine my informal descriptions of these visualizations with formal analyses of difference scores between conceptual units, controlling for differences in assessments of the nine “diverse characters” that were featured as target characters in these studies. See Figure 4.7, panel A, for visual depictions of these difference scores, and Table 4.6 for the full results of these Bayesian regression analyses.

BODY vs. HEART

As among adults in Studies 1 and 2, two striking features of the relationship between BODY and HEART among adults in Study 3 (Figure 4.6, panel A1) are that scores on these scales were positively correlated ($r = 0.65$; $p < 0.001$; 95% CI: [0.53, 0.75]), and virtually no adults attributed more HEART than BODY to the target character they were assigned to assess. A regression analysis confirmed that *BODY* vs. *HEART* difference scores were substantially non-zero, in the direction of participants endorsing *BODY* items more strongly than *HEART* items (see Figure 4.7, panel A, and the “Intercept” row for the “BODY-HEART” comparison in Table 4.6).

The asymmetry between BODY and HEART appears to have been primarily driven by responses to the animate beings: Visual inspection of mean scores by target character (Figure 4.6, panel A1) revealed a suite of characters—namely, inanimate objects—that, in the aggregate, received very low *BODY* scores and very low *HEART* scores. This suite of characters appears to be distinct from the other characters—all animate beings—all of which, in the aggregate, received relatively high *BODY* scores, but varied in their mean *HEART* scores. Echoing Study 1d, this raises the intriguing possibility that adults’ attributions of BODY and HEART may have been governed by some sort of “threshold” model, in which attributions of any substantial amount of HEART depend on the target character having a certain degree of BODY. It is also worth noting that, even among this wider range of target characters, there were no characters for whom the BODY-HEART asymmetry was systematically reversed (i.e., who were generally considered to have more HEART than BODY capacities).

BODY vs. MIND

As among adults in Studies 1 and 2, two striking features of the relationship between BODY and MIND among adults in Study 3 (Figure 4.6, panel A2) are that scores on these scales were positively correlated ($r = 0.73$; $p < 0.001$; 95% CI: [0.63, 0.80]), and very few adults endorsed BODY much more strongly than MIND for the target character they were assigned to assess (i.e., there were no datapoints in the lower right corner of the plot). A regression analysis confirmed that *BODY* vs. *MIND* difference scores were substantially non-zero, in the direction of participants endorsing *MIND* items more strongly than *BODY* items (see Figure 4.7, panel A, and the "Intercept" row for the "BODY-MIND" comparison in Table 4.6).

Echoing Study 1d, however, the asymmetry between BODY vs. MIND was overwhelmingly driven by responses to the two technologies (particularly the robot). Adults who assessed one of the technologies (a robot or a computer) tended to endorse the mental capacity items included in the *MIND* scale roughly as strongly, and often more strongly, than they endorsed items included in the *BODY* scale—but adults who assessed other target characters, if anything, appear to have shown the reverse pattern, endorsing *MIND* items slightly less strongly than *BODY* items. (See Figure 4.7, panel B, and the various comparisons of target characters to the grand mean for the "BODY-MIND" comparison in Table 4.6.)

HEART vs. MIND

As among adults in Studies 1 and 2, two striking features of the relationship between HEART and MIND among adults in Study 3 (Figure 4.6, panel A3) are that scores on these scales were positively correlated ($r = 0.53$; $p < 0.001$; 95% CI: [0.38, 0.65]), and virtually no adults attributed more HEART than MIND to the target character they were assigned to assess. A regression analysis confirmed that *HEART* vs. *MIND* difference scores were substantially non-zero, in the direction of participants endorsing *MIND* items more strongly than *HEART* items (see Figure 4.7, panel A, and the "Intercept" row for the "HEART-MIND" comparison in Table 4.6).

Much like the BODY-HEART comparison, these regression results also suggest that the asymmetry between HEART and MIND was more pronounced for some characters than others, and particularly weak for the two inert objects (the teddy bear and the doll; see Figure 7, panel C, and the various comparisons of target characters to the grand mean for the “HEART-MIND” comparison in Table 4.6.). Indeed, visual inspection of mean scores by target character (Figure 4.6, panel A3) suggested that, in the aggregate, characters that received low *MIND* scores also received low mean *HEART* scores, while characters that received relatively high *MIND* scores (e.g., the robot and all of the animate beings) varied in their mean *HEART* scores. Again, this echoes the intriguing possibility, raised by Study 1d, that attributions of HEART and MIND may have been governed by some sort of “threshold” model, in which attributions of any substantial amount of HEART depend on the target character having a certain degree of MIND.

Interim discussion

Among adults in Study 3, both informal observations and formal analyses revealed very similar results to Studies 1 and 2—namely, positive relationships between conceptual units that were further characterized by systematic asymmetries, with participants endorsing BODY and MIND at least as strongly, and often more strongly, than HEART. As in Study 1d—the only other study that employed the “diverse characters” approach employed in Study 3—the asymmetry between BODY vs. MIND appeared to be somewhat weaker and more variable across participants and target characters.

Older children (7-9y)

Among children in Study 2, the asymmetrical relationships among BODY, HEART, and MIND appeared to be similar in direction but weaker in strength to those of adults—with the possible exception of the BODY vs. HEART comparison, for which children’s responses revealed no systematic asymmetry. Study 3 provided an opportunity to reassess these relationships in a new sample of 7- to 9-year-old children (using a slightly different experimental paradigm).

Visualization and analysis of asymmetries

Visualizations of relationships among 7- to 9-year-old children’s scores on the *BODY*, *HEART*, and *MIND* scales are provided in Figure 4.6, row B. Here I combine my informal descriptions of these visualizations with formal analyses of difference scores between conceptual units, controlling for differences in assessments of the nine “diverse characters" that were featured as target characters in these studies. See Figure 4.7, panel B, for visual depictions of these difference scores, and Table 4.6 for the full results of these Bayesian regression analyses.

BODY vs. HEART

As among adults in this study, the relationship between 7- to 9-year-old children's scores on the *BODY* and *HEART* scales (Figure 4.6, panel B1) was positive ($r = 0.58$; $p < 0.001$; 95% CI: [0.45, 0.68]), and there were somewhat fewer datapoints below the line of , dotted diagonal line) than above it. In contrast to Study 2, this asymmetry was strong enough in this sample of 7- to 9-year-old children to be distinguishable from zero (see the "Intercept" row for the "BODY-HEART" comparison in Table 4.6), although the asymmetry still appears to have been weaker that the corresponding asymmetry in adults.

This analysis further revealed that, as among adults, this asymmetry between *BODY* vs. *HEART* scores was driven by children's assessments of the animate beings (see the various comparisons of target characters to the grand mean for the "BODY-HEART" comparison in Table 4.6.). Indeed, for one target character of particular interest—the robot—the asymmetry ran in the opposite direction: In the aggregate, children attributed more HEART than BODY to this unusual social partner. This aligns with this age group's responses to the robot in Study 2—and stands in contrast to adults, among whom there were no characters who elicited an asymmetry in this direction.

Echoing the visualizations of adults' responses in this study, there do appear to be two suites of characters in this visualization of 7- to 9-year-old children's responses (Figure 4.6, panel B1): inanimate objects (characterized by generally low *BODY* scores) and animate beings (characterized by generally high *BODY* scores). However, while among adults only animate beings varied in their mean *HEART* scores, among children there appears to be substantial variability in *HEART* scores in both of these groups of characters. In other words, this visualization did not provide evidence of the kind of "threshold" model that might govern adults' responses.

BODY vs. MIND

Among 7- to 9-year-old children, as among adults in this study, the relationship between scores on the *BODY* and *MIND* scales was positive ($r = 0.41$; $p < 0.001$; 95% CI: [0.26, 0.55]). In contrast to adults, however, children showed no evidence of asymmetry in their *BODY* vs. *MIND* scores: Their difference scores were not substantially different from zero (see the "Intercept" row for the "BODY-MIND" comparison in Table 4.6), and it is clear from the visualization that some children attributed more MIND than BODY to the target character in question (particularly if they were evaluating one of the two technologies), but others attributed more BODY than MIND (particularly if they were evaluating one of the animate beings). Such between-character differences appear to have been even more pronounced among children than they were among adults (see Figure 4.7, panel B, and the various comparisons of target characters to the grand mean for the "BODY-MIND" comparison in Table 4.6.)

HEART vs. MIND

As among adults in this study, the relationship between 7- to 9-year-old children's scores on the *HEART* and *MIND* scales was positive ($r = 0.30$; $p = 0.001$; 95% CI: [0.13, 0.45]), and children's difference scores were substantially non-zero, in the direction of stronger endorsements for *MIND* items compared to *HEART* items (see the "Intercept" row for the "HEART-MIND" comparison in Table 4.6). Again, however, this asymmetry was much less striking among children than it was among adults: While many children attributed more MIND than HEART to the target character in question (like the vast majority of adults), quite a few children attributed more HEART than MIND (see Figure 4.6, panel B3).

This asymmetry appeared to be present across the range of target characters included in this study, though it was more pronounced for some characters (e.g., the technologies; see Figure 4.7, panel B, and the various comparisons of target characters to the grand mean for the "BODY-MIND" comparison in Table 4.6.)

Visual inspection of mean scores by target character revealed no evidence of the kind of "threshold" model discussed for adults.

Interim discussion

As in Study 2, the relationships among BODY, HEART, and MIND among 7- to 9-year-old children were broadly similar to those of adults, but attenuated in strength. These children tended to endorse both BODY and MIND at least somewhat more strongly than HEART, but there was no systematic asymmetry between MIND and

BODY. Instead, children's relative endorsements of BODY and MIND were highly contingent on the type of target character under consideration.

In Study 3, the asymmetry in 7- to 9-year-old children's *BODY* vs. *HEART* scores was strong enough to be differentiable from zero (in contrast to this age group in Study 2). Interestingly, however, children in this study diverged from this general response pattern in their assessments of the robot, endorsing *HEART* items more strongly than *BODY* items for this unusual "social" partner. Together with the results of Study 2, this suggests that 7- to 9-year-old children have an adult-like intuition that beings might have physiological sensations (BODY) without social-emotional abilities (HEART) but not social-emotional abilities without physiological sensations—but may make an exception to this general rule for certain exceptional entities.

Younger children (4-6y)

In addition to building on the results of Studies 1 and 2 in re-assessing conceptual representations among adults and 7- to 9-year-old children, Study 3 also provided an initial foray into this aspect of conceptual representations among younger children (4-6y of age). In Chapter III, EFA suggested that 4- to 6-year-old children have only a nascent understanding of the suites of physiological sensations, social-emotional abilities, and perceptual-cognitive capacities that I have argued form the "conceptual units" of adults' representations. Nonetheless, children in this age range may share other aspects of adults' representations of this conceptual space. How do younger children's representations of the relationships among BODY, HEART, and MIND compare to those of older children and adults?

Visualization and analysis of asymmetries

Visualizations of relationships among 4- to 6-year-old children's scores on the *BODY*, *HEART*, and *MIND* scales are provided in Figure 4.6, row C. Here I combine my informal descriptions of these visualizations with formal analyses of difference scores between conceptual units, controlling for differences in assessments of the nine "diverse characters" that were featured as target characters in these studies. See Figure 4.7, panel C, for visual depictions of these difference scores, and Table 4.6 for the full results of these Bayesian regression analyses.

Prior to commenting on each of these comparisons individually, one striking feature of the visualizations of younger children's responses is that they all look quite similar. Each pair of conceptual units is characterized by two suites of characters: (1) group of inanimate objects which, in the aggregate, received moderately low scores on all scales; and (2) a group of animate beings which, in the aggregate, received moderately high scores on all scales. This was more pronounced among younger children than in either of the other age groups.

BODY vs. HEART

As among adults and older children, the relationship between 4- to 6-year-old children's *BODY* and *HEART* scores was positive ($r = 0.73$; $p < 0.001$; 95% CI: [0.64, 0.81]), and their difference scores were substantially non-zero, in the direction of participants endorsing *BODY* items more strongly than *HEART* items (see the "Intercept" row for the "BODY-HEART" comparison in Table 4.6). Again, this asymmetry appears to have been driven by responses to the animate beings (see Figure 4.7, panel C, and the various comparisons of target characters to the grand mean for the "BODY-HEART" comparison in Table 4.6). However, the visualization of 4- to 6-year-old children's responses makes it clear that the asymmetry between BODY vs. HEART was quite weak, , Figure 4.7, panel C).

BODY vs. MIND

As among adults and older children, the relationship between 4- to 6-year-old children's *BODY* and *MIND* scores was positive ($r = 0.57$; $p < 0.001$; 95% CI: [0.44, 0.68]). Younger children's *BODY* vs. *MIND* difference scores were substantially non-zero—but this asymmetry ran in the opposite direction of older children and adults, with children endorsing *MIND* items *less* strongly than *BODY* items (see the "Intercept" row for the "BODY-MIND" comparison in Table 4.6). This asymmetry appears to have been driven by responses to animate beings. (See Figure 4.7, panel C, and the various comparisons of target characters to the grand mean for the "BODY-MIND" comparison in Table 4.6.) Again, however, the visualization of 4- to 6-year-old children's responses makes it clear that the asymmetry between BODY vs. MIND was quite weak, with only , Figure 4.7, panel C).

HEART vs. MIND

As among adults and older children, the relationship between 4- to 6-year-old children's *HEART* and *MIND* scores was positive ($r = 0.60$; $p < 0.001$; 95% CI: [0.47, 0.70]). However, in contrast to adults and older children, younger children's *HEART* vs. *MIND* difference scores did not differ substantially from zero, and varied only subtly across target characters. (See Figure 4.7, panel C, and the various comparisons of target characters to the grand mean for the "BODY-HEART" comparison in Table 4.6.)

Interim discussion and general observations about development

Both informal observations and formal analyses of difference scores suggested that, like adults in all studies and like older children in this study, 4- to 6-year-old children tended to endorse BODY more strongly than HEART. However, these younger children diverged from their older counterparts by systematically endorsing BODY more strongly than MIND, and by failing to show any systematic asymmetry between HEART and MIND.

Developmental comparison

General developmental trends across these three age groups are perhaps easiest to observe in Figure 4.6, row D, which presents (hypothetical) "movement" between the mean placement for a target character among younger children (beginning of arrow), older children (middle "joint" of arrow), and adults (arrowhead), for each pair of conceptual units. In each case, this "movement" either maintains a similar distance from) (as with mean assessments of the inert objects and technologies in the BODY vs. HEART space, panel D1; and the inert objects and animate beings in the BODY vs. MIND space, panel D2; and the inert objects in the HEART vs. MIND space, panel D3) or moves away from the line of equivalence toward the upper left and lower right corners of the plot (as with mean assessments of the animate beings in the BODY vs. HEART space, panel D1; the technologies in the BODY vs. MIND space, panel D2; and the technologies and animate beings in the HEART vs. MIND space, panel D3). Analysis of changes in *absolute* attributions of BODY, HEART, and MIND, is pursued in Chapter V; for the purposes of the current chapter, the primary observation of interest is that these "shifts" across age groups generally point in the direction of stable or increasing (not decreasing) asymmetries over developmental time. This aligns quite well with my observations of "movement" between 7-9y and adulthood in Study 2.

To assess the size and robustness of these apparent developmental differences, I conducted formal comparisons of difference scores between conceptual units among these three age groups. For each pair of conceptual units, I pooled data across age groups and modified my regression analyses to include a main effect of age group (comparing both older and younger children's difference scores to the baseline set by adults) and an interaction between age group and target character (assessing whether the observed differences between characters varied by age group).

These analyses confirmed that *BODY* vs. *HEART* difference scores and *HEART* vs. *MIND* difference scores were substantially closer to zero among both older and younger children, as compared to adults (see the "Older vs. adults" and "Younger children vs. adults" rows for the "BODY-HEART" and "HEART-MIND" comparisons in Table 4.7).

Meanwhile, *BODY* vs. *MIND* difference scores were not differentiable from adults among older children in this analysis—likely because this was the weakest of the asymmetries among adults. In contrast, the asymmetry between *BODY* and *MIND* scores was so substantially different among younger children, compared to adults, that it reversed in sign (see the "Older vs. adults" and "Younger children vs. adults" rows for the "BODY-MIND" comparison in Table 4.7).

For each pair of conceptual units, a handful of the differences between target characters differed substantially across age groups (see Table 4.7); this is outside of the scope of the current chapter.

Discussion

Study 3 provided yet more confirmation of the robustness of the asymmetric relationships among conceptual units in adults' representations of mental life as revealed by Studies 1 and 2 (using yet another experimental paradigm, a smaller set of mental capacities, and a different set of diverse target characters): Yet again, adults systematically endorsed both BODY and MIND at least as strongly, and often more strongly, than HEART regardless of which target character they assessed, while the relationship between BODY and MIND was more contingent on the target character under evaluation.

This study also supports and extends the developmental story that began in Study 2. Study 3 provided even stronger evidence than Study 2 that, by middle childhood (7-9y of age), children hold weak but otherwise adult-like intuitions about the asymmetrical relationships among BODY, HEART, and MIND: Among this sample of 7- to 9-year-old children, these relationships all appeared similar in direction to those documented among adults, although they were generally attenuated in strength.

In particular, the use of a diverse range of target characters in Study 3 shed light on the failure of 7- to 9-year-old children in Study 2 to demonstrate an adult-like pattern of endorsing BODY more strongly than HEART to the "edge cases" featured in that study (the beetle and the robot): In Study 3 older children's responses suggested that children in this age range *do* in fact appear to share this tendency with adults when confronted with most target characters, but may treat robots as a particular exception to this general rule.

In fact, this particular aspect of the adult pattern of asymmetrical relationships among BODY, HEART, and MIND—a tendency to endorse BODY more strongly than HEART—appeared to be emergent even among the sample of younger children (4-6y of age) in this study. However, these younger children showed no sign of systematically endorsing MIND more strongly than HEART—and actually showed the opposite of the adult tendency in the case of BODY vs. MIND, endorsing BODY more strongly than MIND for most target characters.

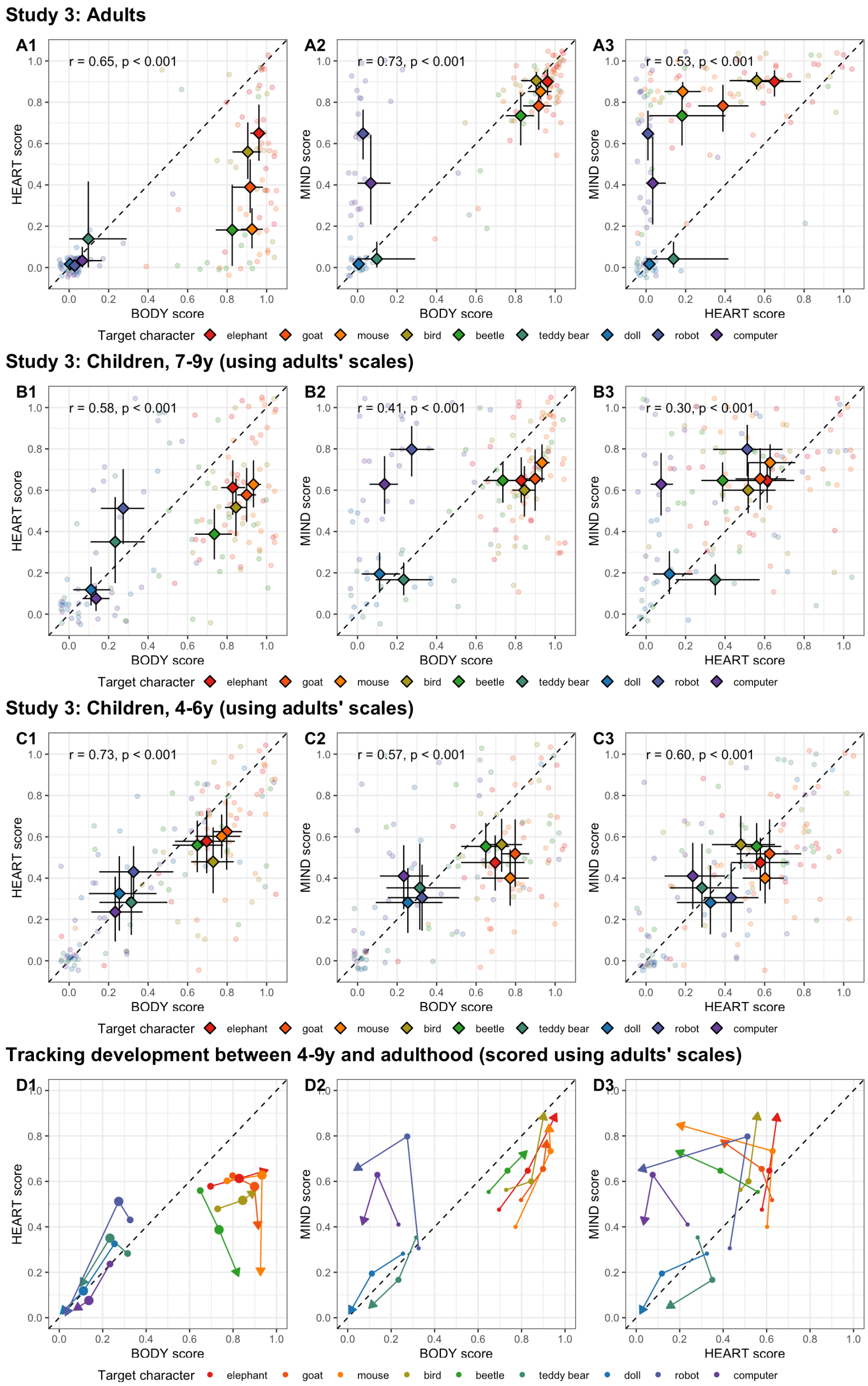

Figure 4.6: Relationships among US adults', older children's, and younger children's attributions of conceptual units in Study 3, scored using adults' BODY, HEART, and MIND scales (see Table 4.10). (A) Adults. (B) Older children (7-9y of age). (C) Younger children (4-6y of age). (D) A visualization of development between 4-9y and adulthood, using mean scores by character and age group. Plots are organized by sample (rows) and by pair of conceptual units (columns). For each conceptual unit, scores could range from 0-1. In panels A-C, individual participants are plotted as small, translucent circles, and mean scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. The dotted line corresponds to equal endorsements of the two conceptual units plotted. Pearson correlations are reported for each pair of conceptual units.

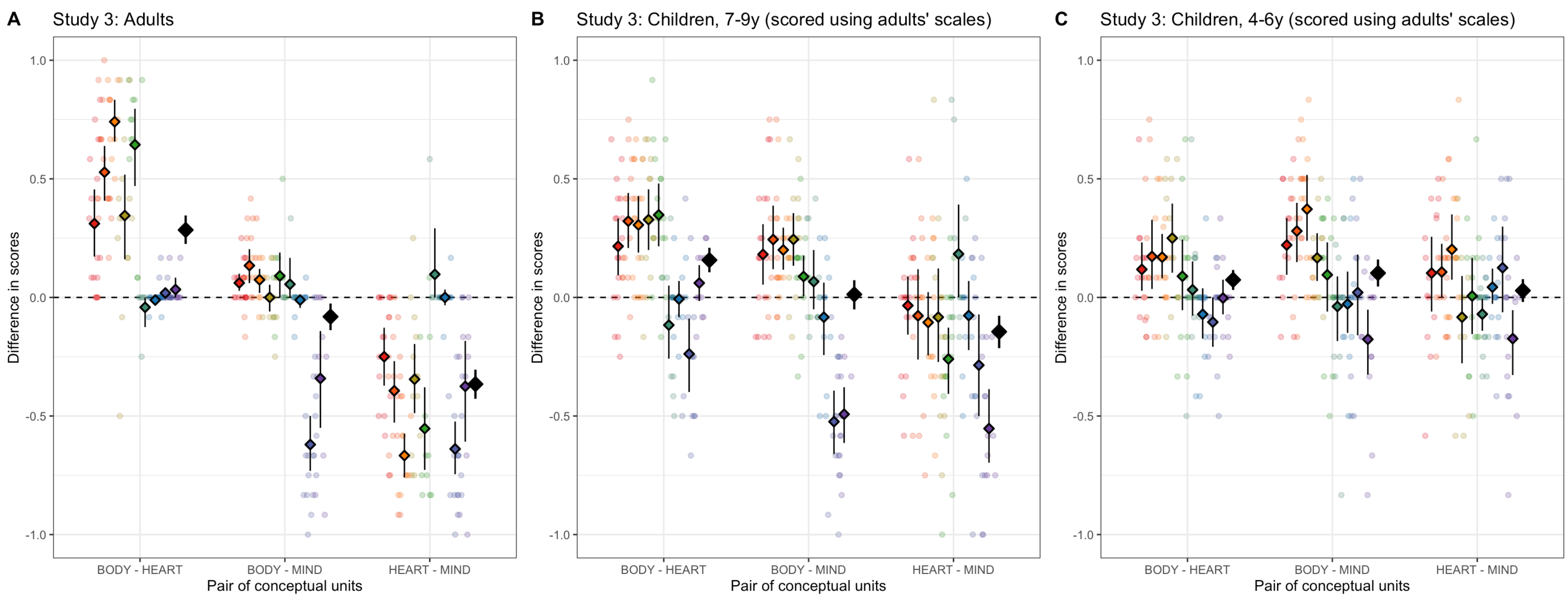

Figure 4.7: Difference scores between conceptual units among US adults and children in Study 3. This includes difference scores using adults' BODY, HEART, and MIND scales (panel B) and difference scores using children's own scales (panel C; see Table 4.10). For each conceptual unit, scores could range from 0-1, such that difference scores could range from -1 to +1. Individual participants are plotted as small, translucent circles, and mean difference scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. The dotted line corresponds to equal endorsements of the two conceptual units plotted (i.e., a difference score of 0).

Table 4.6: Regression analyses of difference scores among US adults, older children (7-9y of age), and younger children (4-6y of age) in Study 3. The table presents results from separate Bayesian regressions of each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND). Each regression included nine fixed effect parameters: (1) the intercept, which I treat as an index of the asymmetry in attributions of the two conceptual units in question; and (2-9) a set of parameters estimating the difference between target characters and the grand mean (GM). The intercepts are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	Adults			Children, 7-9y (using adults' scales)			Children, 4-6y (using adults' scales)		
Parameter	**b**	**95% CI**		**b**	**95% CI**		**b**	**95% CI**	
BODY - HEART									
Intercept	**0.29**	**[0.24, 0.33]**	*	**0.14**	**[0.09, 0.18]**	*	**0.07**	**[0.03, 0.12]**	*
Elephant vs. GM	0.02	[-0.09, 0.13]		0.08	[-0.03, 0.19]		0.02	[-0.09, 0.13]	
Goat vs. GM	0.24	[0.14, 0.35]	*	0.19	[0.06, 0.31]	*	0.18	[0.06, 0.31]	*
Mouse vs. GM	0.45	[0.32, 0.59]	*	0.17	[0.05, 0.30]	*	-0.07	[-0.19, 0.04]	
Bird vs. GM	0.06	[-0.05, 0.17]		0.19	[0.07, 0.31]	*	-0.14	[-0.27, -0.02]	*
Beetle vs. GM	0.36	[0.24, 0.48]	*	0.21	[0.09, 0.33]	*	0.05	[-0.07, 0.16]	
Teddy bear vs. GM	-0.33	[-0.49, -0.16]	*	-0.25	[-0.40, -0.11]	*	0.10	[-0.01, 0.21]	
Doll vs. GM	-0.30	[-0.41, -0.19]	*	-0.14	[-0.27, -0.01]	*	0.10	[-0.01, 0.20]	
Robot vs. GM	-0.27	[-0.37, -0.16]	*	-0.37	[-0.51, -0.25]	*	-0.18	[-0.29, -0.06]	*
BODY - MIND									
Intercept	**-0.06**	**[-0.10, -0.03]**	*	**-0.01**	**[-0.05, 0.04]**		**0.10**	**[0.05, 0.15]**	*
Elephant vs. GM	0.12	[0.04, 0.21]	*	0.19	[0.08, 0.30]	*	-0.01	[-0.14, 0.13]	

Goat vs. GM	0.20	[0.12, 0.28]	*	0.25	[0.13, 0.37]	*	0.07	[-0.08, 0.21]	
Mouse vs. GM	0.13	[0.03, 0.24]	*	0.21	[0.09, 0.32]	*	-0.28	[-0.41, -0.15]	*
Bird vs. GM	0.06	[-0.03, 0.15]		0.25	[0.14, 0.37]	*	-0.13	[-0.27, 0.01]	
Beetle vs. GM	0.15	[0.06, 0.25]	*	0.10	[-0.02, 0.21]		0.12	[-0.01, 0.25]	
Teddy bear vs. GM	0.12	[-0.02, 0.25]		0.07	[-0.07, 0.22]		0.18	[0.04, 0.31]	*
Doll vs. GM	0.05	[-0.04, 0.14]		-0.07	[-0.20, 0.06]		0.27	[0.14, 0.41]	*
Robot vs. GM	-0.56	[-0.64, -0.48]	*	-0.52	[-0.63, -0.40]	*	-0.08	[-0.22, 0.06]	
HEART - MIND									
Intercept	**-0.35**	**[-0.40, -0.30]**	*	**-0.14**	**[-0.20, -0.08]**	*	**0.03**	**[-0.02, 0.08]**	
Elephant vs. GM	0.10	[-0.03, 0.22]		0.11	[-0.05, 0.27]		-0.02	[-0.16, 0.11]	
Goat vs. GM	-0.05	[-0.17, 0.08]		0.07	[-0.10, 0.23]		-0.11	[-0.26, 0.03]	
Mouse vs. GM	-0.32	[-0.48, -0.15]	*	0.04	[-0.13, 0.20]		-0.20	[-0.34, -0.06]	*
Bird vs. GM	0.00	[-0.13, 0.14]		0.06	[-0.10, 0.22]		0.02	[-0.13, 0.16]	
Beetle vs. GM	-0.21	[-0.36, -0.06]	*	-0.12	[-0.28, 0.04]		0.07	[-0.06, 0.21]	
Teddy bear vs. GM	0.45	[0.26, 0.64]	*	0.33	[0.12, 0.53]	*	0.08	[-0.05, 0.21]	
Doll vs. GM	0.35	[0.22, 0.47]	*	0.07	[-0.12, 0.25]		0.17	[0.04, 0.31]	*
Robot vs. GM	-0.29	[-0.41, -0.17]	*	-0.14	[-0.31, 0.03]		0.10	[-0.05, 0.24]	

Table 4.7: Regression analyses of age group differences in difference scores in Study 3. The table presents results from separate Bayesian regressions of each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND). Each regression included 27 fixed effect parameters: (1) the intercept (for adults), which I treat as an index of the asymmetry in attributions of the two conceptual units in question among adults; (2-3) the overall differences between older children vs. adults and younger children vs. adults (collapsing across target characters); (4-11) a set of parameters estimating the difference between target characters and the grand mean (GM), among adults; and (12-27) the interactions between these difference between target characters and the differences between age groups. The developmental comparisons of the intercepts are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

Developmental comparison			
Parameter	**b**	**95% CI**	
BODY - HEART			
Intercept	0.28	[0.24, 0.33]	*
Older children vs. adults	**-0.15**	**[-0.21, -0.09]**	*
Younger children vs. adults	**-0.21**	**[-0.28, -0.15]**	*
Elephant vs. GM	0.36	[0.22, 0.49]	*
Goat vs. GM	0.06	[-0.06, 0.18]	
Mouse vs. GM	-0.25	[-0.39, -0.11]	*
Bird vs. GM	-0.30	[-0.41, -0.18]	*
Beetle vs. GM	0.03	[-0.09, 0.14]	
Teddy bear vs. GM	0.24	[0.14, 0.35]	*
Doll vs. GM	0.46	[0.32, 0.59]	*
Robot vs. GM	-0.27	[-0.37, -0.16]	*
Older children vs. adults * Elephant vs. GM	-0.15	[-0.33, 0.03]	
Older children vs. adults * Goat vs. GM	0.13	[-0.03, 0.30]	
Older children vs. adults * Mouse vs. GM	0.17	[-0.01, 0.37]	
Older children vs. adults * Bird vs. GM	0.16	[-0.01, 0.32]	
Older children vs. adults * Beetle vs. GM	0.05	[-0.11, 0.21]	
Older children vs. adults * Teddy bear vs. GM	-0.06	[-0.21, 0.10]	
Older children vs. adults * Doll vs. GM	-0.29	[-0.47, -0.10]	*

Developmental comparison			
Parameter	**b**	**95% CI**	
Older children vs. adults * Robot vs. GM	-0.11	[-0.26, 0.05]	
Younger children vs. adults * Elephant vs. GM	-0.34	[-0.53, -0.17]	*
Younger children vs. adults * Goat vs. GM	0.12	[-0.06, 0.28]	
Younger children vs. adults * Mouse vs. GM	0.18	[-0.01, 0.36]	
Younger children vs. adults * Bird vs. GM	0.15	[-0.02, 0.32]	
Younger children vs. adults * Beetle vs. GM	0.02	[-0.15, 0.18]	
Younger children vs. adults * Teddy bear vs. GM	-0.14	[-0.30, 0.02]	
Younger children vs. adults * Doll vs. GM	-0.36	[-0.54, -0.18]	*
Younger children vs. adults * Robot vs. GM	0.09	[-0.07, 0.25]	
BODY - MIND			
Intercept	-0.06	[-0.11, -0.02]	*
Older children vs. adults	**0.05**	**[-0.01, 0.11]**	
Younger children vs. adults	**0.16**	**[0.10, 0.22]**	*
Elephant vs. GM	0.15	[0.02, 0.29]	*
Goat vs. GM	0.06	[-0.05, 0.18]	
Mouse vs. GM	-0.28	[-0.42, -0.15]	*
Bird vs. GM	0.05	[-0.06, 0.17]	
Beetle vs. GM	0.12	[0.01, 0.24]	*
Teddy bear vs. GM	0.20	[0.09, 0.30]	*
Doll vs. GM	0.14	[0.00, 0.27]	
Robot vs. GM	-0.56	[-0.66, -0.46]	*
Older children vs. adults * Elephant vs. GM	-0.05	[-0.23, 0.12]	
Older children vs. adults * Goat vs. GM	0.19	[0.03, 0.35]	*
Older children vs. adults * Mouse vs. GM	-0.20	[-0.39, -0.01]	*
Older children vs. adults * Bird vs. GM	-0.13	[-0.30, 0.04]	

Developmental comparison

Parameter	**b**	**95% CI**	
Older children vs. adults * Beetle vs. GM	0.07	[-0.09, 0.22]	
Older children vs. adults * Teddy bear vs. GM	0.06	[-0.10, 0.21]	
Older children vs. adults * Doll vs. GM	0.07	[-0.11, 0.25]	
Older children vs. adults * Robot vs. GM	0.04	[-0.12, 0.20]	
Younger children vs. adults * Elephant vs. GM	-0.16	[-0.34, 0.02]	
Younger children vs. adults * Goat vs. GM	0.00	[-0.16, 0.17]	
Younger children vs. adults * Mouse vs. GM	0.00	[-0.17, 0.18]	
Younger children vs. adults * Bird vs. GM	-0.18	[-0.34, -0.01]	*
Younger children vs. adults * Beetle vs. GM	0.00	[-0.16, 0.16]	
Younger children vs. adults * Teddy bear vs. GM	-0.02	[-0.17, 0.14]	
Younger children vs. adults * Doll vs. GM	0.14	[-0.03, 0.32]	
Younger children vs. adults * Robot vs. GM	0.48	[0.31, 0.64]	*
HEART - MIND			
Intercept	-0.35	[-0.40, -0.29]	*
Older children vs. adults	**0.20**	**[0.13, 0.28]**	*
Younger children vs. adults	**0.38**	**[0.30, 0.46]**	*
Elephant vs. GM	-0.21	[-0.37, -0.05]	*
Goat vs. GM	0.00	[-0.14, 0.15]	
Mouse vs. GM	-0.03	[-0.20, 0.15]	
Bird vs. GM	0.35	[0.20, 0.49]	*
Beetle vs. GM	0.10	[-0.05, 0.24]	
Teddy bear vs. GM	-0.04	[-0.17, 0.09]	
Doll vs. GM	-0.32	[-0.49, -0.14]	*
Robot vs. GM	-0.29	[-0.43, -0.16]	*
Older children vs. adults * Elephant vs. GM	0.09	[-0.12, 0.29]	

Developmental comparison			
Parameter	**b**	**95% CI**	
Older children vs. adults * Goat vs. GM	0.06	[-0.15, 0.26]	
Older children vs. adults * Mouse vs. GM	-0.38	[-0.61, -0.15]	*
Older children vs. adults * Bird vs. GM	-0.28	[-0.50, -0.07]	*
Older children vs. adults * Beetle vs. GM	0.01	[-0.18, 0.21]	
Older children vs. adults * Teddy bear vs. GM	0.11	[-0.09, 0.31]	
Older children vs. adults * Doll vs. GM	0.36	[0.13, 0.58]	*
Older children vs. adults * Robot vs. GM	0.15	[-0.05, 0.35]	
Younger children vs. adults * Elephant vs. GM	0.19	[-0.03, 0.41]	
Younger children vs. adults * Goat vs. GM	-0.12	[-0.32, 0.10]	
Younger children vs. adults * Mouse vs. GM	-0.17	[-0.39, 0.05]	
Younger children vs. adults * Bird vs. GM	-0.33	[-0.54, -0.13]	*
Younger children vs. adults * Beetle vs. GM	-0.02	[-0.23, 0.17]	
Younger children vs. adults * Teddy bear vs. GM	0.12	[-0.07, 0.33]	
Younger children vs. adults * Doll vs. GM	0.49	[0.27, 0.72]	*
Younger children vs. adults * Robot vs. GM	0.39	[0.18, 0.59]	*

Study 4: A focus on early childhood (4-5y)

Note: At the time of the submission of this dissertation, the sample of 4- to 5-year-old children for Study 4 was only partially complete. All results using this sample should thus be considered preliminary and not conclusive.

Study 4 builds on Study 3 by providing a targeted investigation of representations of mental life in the preschool years (4-5y). In this chapter, I again focus on what this study can reveal about the relationships among the conceptual units BODY, HEART, and MIND at the earliest point in development that I have examined so far, and compare this conceptual organization to that documented among adults. As a reminder, in this chapter

I analyze young children's responses with respect to the "mature" conceptual units BODY, HEART, and MIND, as defined by EFA of *adults'* responses.

In Study 4, 104 US adults and 43 US children between the ages of 4.02-5.59 years (median: 4.73y) each assessed two target characters on 18 mental capacities, with all aspects of the experimental design tailored to be appropriate for this youngest age group. This study employed the "edge case" variant of the general approach, with participants assessing both a beetle and a robot in sequence (with order counterbalanced across participants). (See Chapter II for detailed methods.)

Results

Adults

Scale construction

Following the steps described in the "General analysis plan," above, yielded *BODY*, *HEART*, and *MIND* scales of 5 items each; see Table 4.10.

Visualization and analysis of asymmetries

Visualizations of relationships among scores on these *BODY*, *HEART*, and *MIND* scales are provided in Figure 4.8, row A. These visualizations are all extremely similar to those discussed at length in previous studies featuring these "edge case" target characters (Studies 1a-1c, Study 2).

As in previous studies, for each pair of conceptual units, I conducted a Bayesian regression to compare difference scores between these two conceptual units to zero, controlling for differences in assessments of the two "edge cases" that were featured as target characters in these studies. As in Study 1d, I accounted for the within-subjects design of Study 4 by including random intercepts for participants. See Figure 4.9, panel D, for visual depictions of these difference scores.

BODY vs. HEART

As in previous adult samples, adults' *BODY* vs. *HEART* difference scores were positively related ($r = 0.50$; $p < 0.001$; 95% CI: [0.39, 0.60]) and were substantially non-zero, in the direction of participants endorsing *BODY* items more strongly than *HEART* items (see the "Intercept" row for the "BODY-HEART" comparison in Table 4.8), and this asymmetry was driven primarily by participants' assessments of the beetle 9see

Figure 4.9, panel A, and the "Robot vs. GM" row for the "BODY-HEART" comparison in Table 4.8).

BODY vs. MIND

As in previous adult samples, adults' *BODY* vs. *MIND* difference scores were positively related ($r = 0.25$; $p < 0.001$; 95% CI: [0.11, 0.37]) and substantially non-zero, in the direction of participants endorsing *MIND* items more strongly than *BODY* items (see the "Intercept" row for the "BODY-MIND" comparison in Table 4.8), and this asymmetry was driven primarily by participants' assessments of the robot. Indeed, in this study, this asymmetry actually tended to go in the *opposite* direction for participants' assessments of the beetle (BODY endorsements stronger than MIND endorsements), echoing children's response patterns in previous studies. (See Figure 4.9, panel A, and the "Robot vs. GM" row for the "BODY-MIND" comparison in Table 4.8.)

HEART vs. MIND

As in previous adult samples, adults' *HEART* vs. *MIND* difference scores were positively related ($r = 0.40$; $p < 0.001$; 95% CI: [0.28, 0.51]) and were substantially non-zero, in the direction of participants endorsing *MIND* items more strongly than *HEART* items (see the "Intercept" row for the "HEART-MIND" comparison in Table 4.8), and this asymmetry was somewhat exaggerated in assessments of the robot (see Figure 4.9, panel A, and the "Robot vs. GM" row for the "HEART-MIND" comparison in Table 4.8).

Interim discussion

Like adults in Studies 1-3, adults in Study 4 tended to endorse BODY and MIND more strongly than HEART. As in previous studies that used the "edge case" variant of the experimental approach, this study also revealed an asymmetry between BODY and MIND, with adults tending to attribute MIND more strongly than BODY—however, this asymmetry was limited to assessments of the robot, and if anything ran in the opposite direction for assessments of the beetle.

Children (4-5y)

Study 4 was expressly designed to provide the best chance of observing adult-like conceptual representations among 4- to 5-year-old children. What did the relationships among BODY, HEART, and MIND look like in this age group under these circumstances?

Visualization and analysis of asymmetries

Visualizations of relationships among 4- to 5-year-old children's scores on the *BODY*, *HEART*, and *MIND* scales are provided in Figure 4.8, row B. Here I combine my informal descriptions of these visualizations with formal analyses of difference scores between conceptual units, controlling for differences in assessments of the nine "diverse characters" that were featured as target characters in these studies and accounting for the within-subjects design of Study 4 by including random intercepts for participants. See Figure 4.9, panel B, for visual depictions of these difference scores, and Table 4.8 for the full results of these Bayesian regression analyses.

BODY vs. HEART

As among adults in this study, the relationship between children's scores on the *BODY* and *HEART* scales was positive ($r = 0.41$; $p < 0.001$; 95% CI: [0.22, 0.57]), and children's *BODY* vs. *HEART* difference scores were significantly non-zero, in the direction of participants endorsing *BODY* items more strongly than *HEART* items (see the "Intercept" row for the "BODY-HEART" comparison in Table 4.8). However, yet again, this asymmetry was much less striking among children than it was among adults (Figure 4.8, panel B1): While, like the vast majority of adults, many children attributed more BODY than HEART to the target character in question (particularly to the beetle, in red), quite a few children attributed more HEART than BODY (particularly to the robot, in blue). The results of the regression analysis confirmed that the BODY vs. HEART asymmetry varied substantially across target characters in this age group (see Figure 4.9, panel B, and the "Robot vs. GM" row for the "BODY-HEART" comparison in Table 4.8).

BODY vs. MIND

As among adults in this study, the relationship between children's scores on the *BODY* and *MIND* scales was positive ($r = 0.41$; $p < 0.001$; 95% CI: [0.21, 0.57]). However, there was no obvious evidence of any asymmetry in children's attributions of these two conceptual units: children's *BODY* vs. *MIND* difference scores were not differentiable from zero (see the "Intercept" row for the "BODY-MIND" comparison in

Table 4.8). This appears to be due to the fact that the asymmetry ran in different directions for the two target characters (see Figure 4.9, panel B): for the robot (in blue) many children endorse *MIND* items more strongly than *BODY* items, but for the beetle (in red) many children endorsed BODY more strongly than MIND. The results of the regression analysis confirmed that the BODY vs. MIND asymmetry varied substantially across target characters in this age group (see Figure 4.9, panel B, and the "Robot vs. GM" row for the "BODY-MIND" comparison in Table 4.8).

HEART vs. MIND

As among adults in this study, the relationship between children's scores on the *HEART* and *MIND* scales was positive ($r = 0.53$; $p < 0.001$; 95% CI: [0.36, 0.67]), and children's *HEART* vs. *MIND* difference scores were significantly non-zero, in the direction of participants endorsing *MIND* items more strongly than *HEART* items (see the "Intercept" row for the "HEART-MIND" comparison in Table 4.8). However, yet again, this asymmetry was much less striking among children than it was among adults (Figure 4.8, panel B3): While, like the vast majority of adults, many children attributed more MIND than HEART to the target character in question, quite a few children attributed more HEART than MIND. The direction and strength of the asymmetry did not vary systematically across target characters (see the "Robot vs. GM" row for the "HEART-MIND" comparison in Table 4.8)

Interim discussion

Using a particularly child-friendly paradigm, 4- to 5-year-old children were relatively "adult-like" than their 4- to 6-year-old peers in Study 2 in their tendencies to endorse BODY and MIND more strongly than HEART. However, children failed to show the adult-like tendency to endorse MIND more strongly than BODY for these two edge cases; instead, like older children in Studies 2 and 3, the asymmetry between BODY and MIND appeared to be highly contingent on which target was being assessed.

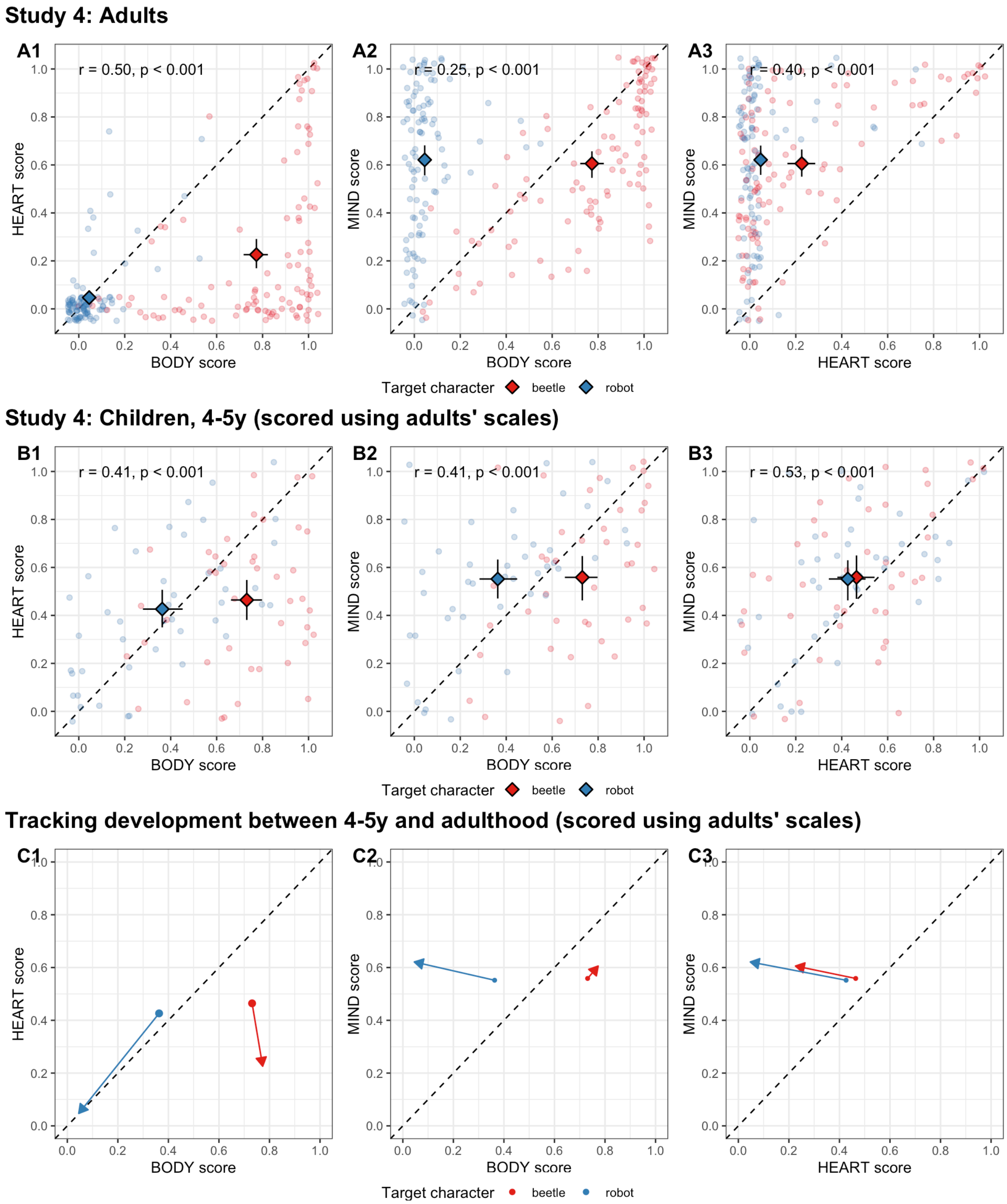

Figure 4.8: Relationships among US adults', older children's, and younger children's attributions of conceptual units in Study 4, scored using adults' BODY, HEART, and MIND scales (see Table 4.10). Plots are organized by sample (rows) and by pair of conceptual units (columns). (A) Adults. (B) Children (4-6y of age), scored using adults' scales. (C) A visualization of development between 4-6y and adulthood, using mean scores by character and age group. For each conceptual unit, scores could range from 0-1. In panels A-B, individual participants are plotted as small, translucent circles, and mean scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. The dotted line corresponds to equal endorsements of the two conceptual units plotted. Pearson correlations are reported for each pair of conceptual units.

Developmental comparison

The visualizations and analyses described in the previous section suggested that children's responses were generally less asymmetrical than those of adults. This is perhaps easiest to observe in Figure 4.8, row D, which presents (hypothetical) "movement" between the mean placement for a target character among children (beginning of arrow) and the mean placement for a target character among adults (arrowhead), for each pair of conceptual units. In each case, this "movement" either) (as with mean assessments of the robot in the BODY vs. HEART space, panel D1; and the beetle in the BODY vs. MIND space, panel D2) or moves away from the line of equivalence toward the upper left and lower right corners of the plot (as with mean assessments of the beetle in the BODY vs. HEART space, panel D1; the robot in the BODY vs. MIND space, panel D2; and both characters in the HEART vs. MIND space, panel D3). Analysis of changes in *absolute* attributions of BODY, HEART, and MIND, is pursued in Chapter V; for the purposes of the current chapter, the primary observation of interest is that these "shifts" between child and adult assessments of these characters generally point in the direction of stable or increasing (not decreasing) asymmetries over developmental time.

To assess the size and robustness of these apparent developmental differences, I conducted formal comparisons of difference scores between conceptual units between these two age groups. I pooled data from both age groups and modified my regression analyses to include a main effect of age group (comparing children's difference scores to the baseline set by adults) and an interaction between age group and target character (assessing whether the observed differences between characters varied by age group).

For each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, HEART vs. MIND), children's difference scores were substantially attenuated (closer to zero), as compared to adults (see the "Children vs. adults" rows for each comparison in Table 4.9), and the difference between target characters was also attenuated among children (see the "Robot vs. GM" rows for each comparison in Table 4.9).

Discussion

Study 4 provided yet more confirmation of the robustness of the asymmetric relationships among conceptual units in adults' representations of mental life as revealed by Studies 1-3 (using yet another set of mental capacities and a within-subjects design): Again, adults systematically endorsed both BODY and MIND at least as strongly, and often more strongly, than HEART regardless of which target character they assessed, while the relationship between BODY and MIND was contingent on the target character under evaluation.

This study also supports and extends the developmental story that unfolded through Studies 2 and 3. As in Study 3, the young children in this study (4-5y of age) showed an adult-like tendency to endorse BODY more strongly than HEART. Moreover, in this particularly child-friendly experimental paradigm, these children also showed an emergent adult-like tendency to endorse MIND more strongly than HEART, though this asymmetry was much weaker among children than among adults. The relationship between BODY and MIND among the young children in this sample varied by target character, to a greater degree than it did among adults. But in most respects the 4- to 5-year-old children in this study demonstrated a more adult-like (albeit attenuated) sense of the relationships among BODY, HEART, and MIND than their similar-aged peers in Study 3.

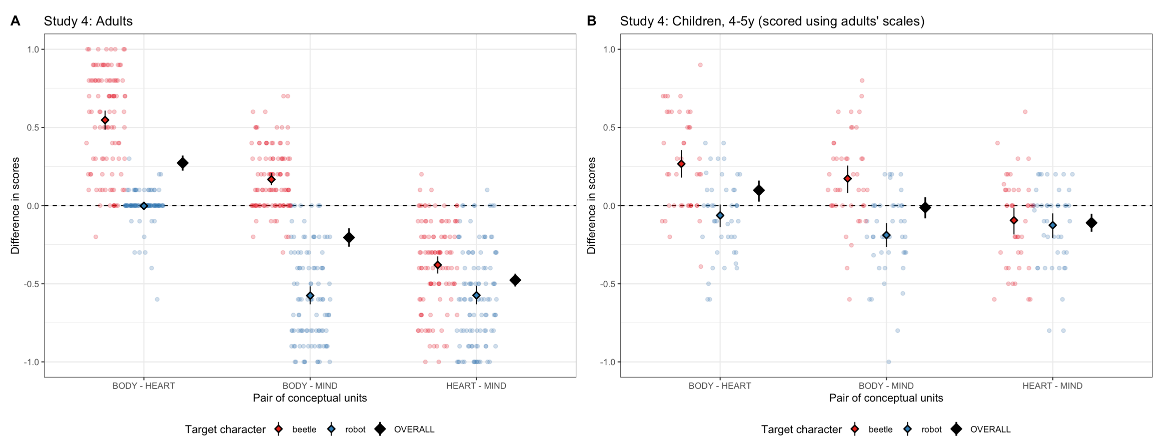

Figure 4.9: Difference scores between conceptual units among US adults and children in Study 4. For each conceptual unit, scores could range from 0-1, such that difference scores could range from -1 to +1. Individual participants are plotted as small, translucent circles, and mean difference scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. The dotted line corresponds to equal endorsements of the two conceptual units plotted (i.e., a difference score of 0).

Table 4.8: Regression analyses of difference scores among US adults and children (4-5y of age) in Study 4. The table presents results from separate Bayesian regressions of each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND). Each regression included two fixed effect parameters: (1) the intercept, which I treat as an index of the asymmetry in attributions of the two conceptual units in question; and (2) a difference between target characters, reported here as a difference between the robot and the grand mean (GM). The intercepts are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	Adults			**Children, 4-6y (using adults' scales)**		
Parameter	**b**	**95% CI**		**b**	**95% CI**	
BODY - HEART						
Intercept	**0.27**	**[0.24, 0.31]**	*	**0.10**	**[0.04, 0.16]**	*
Robot vs. GM	-0.27	[-0.31, -0.24]	*	-0.17	[-0.23, -0.10]	*
BODY - MIND						
Intercept	**-0.20**	**[-0.24, -0.17]**	*	**-0.01**	**[-0.07, 0.05]**	
Robot vs. GM	-0.37	[-0.41, -0.34]	*	-0.18	[-0.24, -0.12]	*
HEART - MIND						
Intercept	**-0.48**	**[-0.52, -0.43]**	*	**-0.11**	**[-0.17, -0.05]**	*
Robot vs. GM	-0.10	[-0.14, -0.06]	*	-0.02	[-0.07, 0.04]	

Table 4.9: Regression analyses of age group differences in difference scores in Study 4. The table presents results from separate Bayesian regressions of each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND). Each regression included four fixed effect parameters: (1) the intercept (for adults), which I treat as an index of the asymmetry in attributions of the two conceptual units in question among adults; (2) the overall difference between children and adults (collapsing across target characters); (3) a difference between target characters (among adults), reported here as a difference between the robot and the grand mean (GM); and (4) the interaction between this difference between target characters and the difference between age groups. The developmental comparisons are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	Developmental comparison		
Parameter	**b**	**95% CI**	
BODY - HEART			
Intercept	0.27	[0.24, 0.31]	*
Children vs. adults	**-0.17**	**[-0.23, -0.11]**	*****
Robot vs. GM	-0.27	[-0.31, -0.24]	*
Interaction	**0.11**	**[0.05, 0.17]**	*****
BODY - MIND			
Intercept	-0.20	[-0.24, -0.17]	*
Children vs. adults	**0.20**	**[0.13, 0.26]**	*****
Robot vs. GM	-0.37	[-0.41, -0.34]	*
Interaction	**0.19**	**[0.13, 0.25]**	*****
HEART - MIND			
Intercept	-0.48	[-0.52, -0.44]	*
Children vs. adults	**0.37**	**[0.29, 0.45]**	*****
Robot vs. GM	-0.10	[-0.13, -0.06]	*
Interaction	**0.08**	**[0.01, 0.15]**	*****

Table 4.10: Scales for each of the conceptual units identified by EFA for US Adults in Studies 2-4 and for 7- to 9-year-old children in Studies 2 and 3. (See Appendix B for alternative scales based on younger children's EFA results, for Study 3.) A checkmark indicates that a mental capacity was included in a scale for a particular sample.

	Study 2		**Study 3**		**Study 4**
Capacity	**Adults**	**Children, 7-9y**	**Adults**	**Children, 7-9y**	**Adults**
BODY scale					
get/feel hungry	✓	✓	✓	✓	✓
feel pain	✓	✓	✓	✓	
feel/get scared	✓	✓	✓	✓	
feel tired	✓	✓	✓	✓	✓
feel safe	✓				
smell things	✓	✓	✓	✓	✓
get/feel sick[...]		✓	✓		✓
get thirsty					✓
get angry				✓	
HEART scale					
feel proud	✓	✓	✓	✓	
feel joy	✓	✓			
feel/get sad	✓	✓	✓	✓	✓
feel happy	✓	✓			
feel love/love someone	✓	✓	✓	✓	✓
feel guilty/sorry	✓		✓	✓	✓
get hurt feelings		✓	✓	✓	
feel embarrassed			✓	✓	
hate someone					✓
get lonely					✓

	Study 2		Study 3		Study 4
Capacity	**Adults**	**Children, 7-9y**	**Adults**	**Children, 7-9y**	**Adults**
MIND scale					
figure out how to do things/figure things out	✓	✓	✓	✓	✓
make choices	✓		✓	✓	
recognize somebody else	✓				
sense...far away	✓	✓	✓	✓	
remember things	✓	✓	✓	✓	✓
see [things]	✓				
be aware of itself		✓			
be aware of things		✓	✓	✓	
sense temperatures		✓	✓	✓	
know stuff					✓
have thoughts/think					✓
hear [sounds]					✓

General discussion

In this chapter, I focused on a second aspect of the development of conceptual representations of mental life: the relationships among the "conceptual units" identified among US adults in the previous chapter: BODY, HEART, and MIND. I focused in particular on analyses that might bring to light possible *hierarchical relations* among BODY, HEART, and MIND: Do these studies provide any evidence about which of these conceptual units might be more "basic" vs. more complex, or whether any of these conceptual units might be considered to depend on the presence of others? How might this conceptual organization change over development?

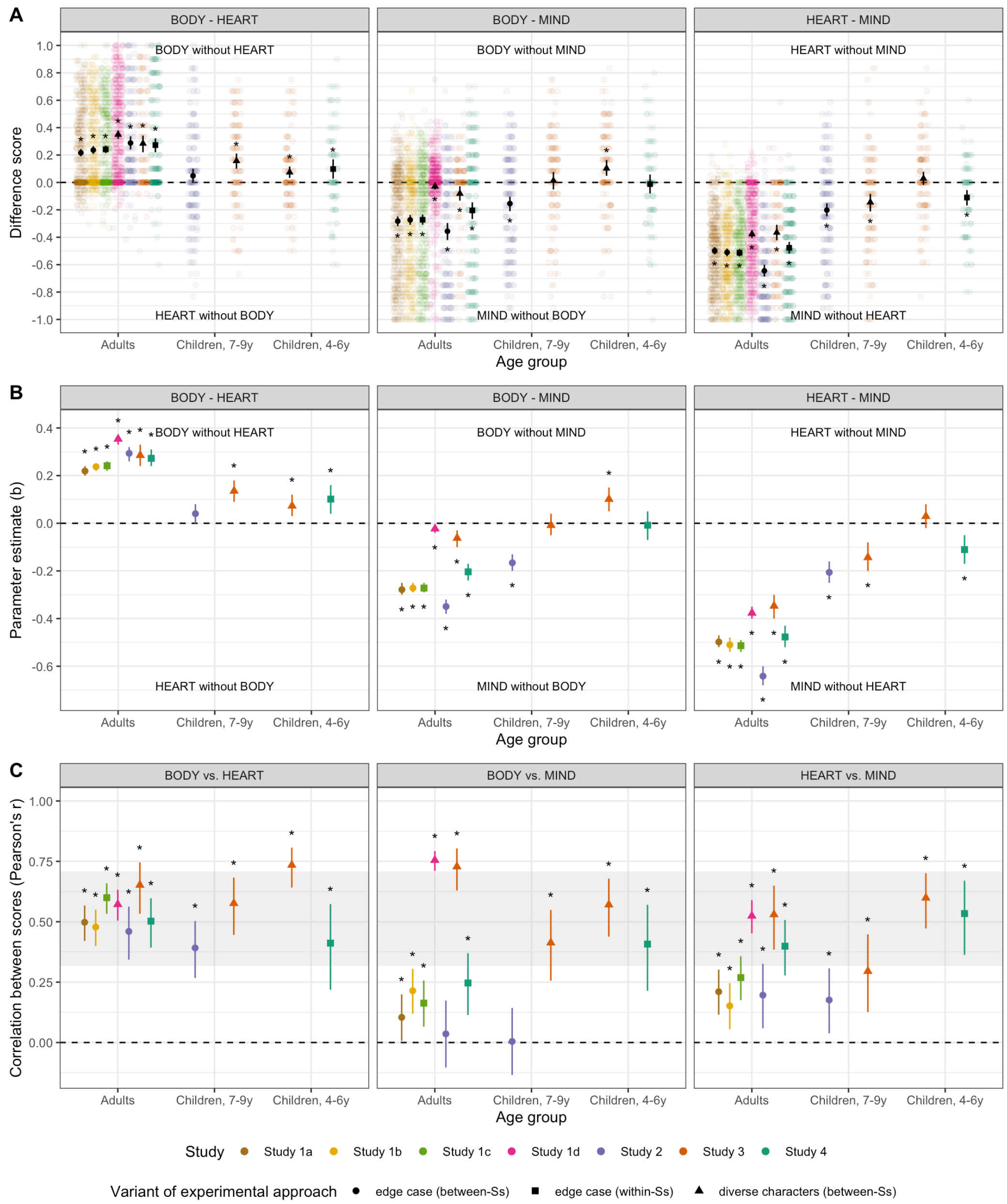

Figure 4.10: Summaries of the relationships between attributions of BODY, HEART, and MIND for all studies. (A) Difference scores for each pair of conceptual units (ignoring target characters). Positive difference scores correspond to participants who attributed the first conceptual unit more strongly than the second; negative difference scores correspond to participants who attributed the second conceptual unit more strongly than the first. (B) Intercepts from independent Bayesian regression analyses for each pair of conceptual units and each sample of participants, accounting for differences between target characters and including random intercepts for participants when appropriate (Studies 1d and 2). Positive intercepts indicate samples in which participants tended to attribute the first conceptual unit more strongly than the second; negative intercepts indicate samples in which participants tended to attribute the second conceptual unit more strongly than the first. (C) Pearson correlations between scores on each of the scales (theoretical range: -1 to +1). Positive correlations indicate that higher scores in one scale were associated with higher scores in the other scale. To assist the reader in assessing effect size, the shaded area highlights values of r that correspond to scores in one scale accounting for between 10-50% of the variance of scores in the other scale. For all panels, error bars are 95% CIs and asterisks indicate CIs that do not include zero.

Table 4.11: Percentage of difference scores that were negative, zero, or positive for each pair of conceptual units across all studies and samples. For each sample, the final column gives the percentage of target character assessments that were either zero or went in the modal direction of asymmetry among adults for that pair of conceptual units (positive or BODY - HEART; negative for BODY - MIND and HEART - MIND).

		Direction of asymmetry			
Age group	**Study**	**negative**	**zero**	**positive**	**Modal adult tendency**
BODY - HEART					
Adults	Study 1a	11%	35%	54%	89%
	Study 1b	8%	31%	61%	92%
	Study 1c	7%	36%	57%	93%
	Study 1d	5%	19%	76%	95%
	Study 2	6%	25%	70%	94%
	Study 3	4%	39%	57%	96%
	Study 4	5%	40%	55%	95%
Children, 7-9y	Study 2	41%	12%	47%	59%
	Study 3	23%	16%	61%	77%
Children, 4-6y	Study 3	27%	27%	46%	73%
	Study 4	30%	23%	47%	70%
					BODY - MIND
Adults	Study 1a	66%	6%	28%	72%
	Study 1b	68%	7%	25%	75%
	Study 1c	66%	5%	29%	71%
	Study 1d	33%	21%	46%	54%
	Study 2	67%	10%	23%	77%
	Study 3	31%	34%	35%	65%
	Study 4	50%	17%	32%	68%
Children, 7-9y	Study 2	54%	10%	36%	64%
	Study 3	38%	8%	54%	46%

		Direction of asymmetry			
Age group	Study	negative	zero	positive	Modal adult tendency
Children, 4-6y	Study 3	23%	24%	53%	47%
	Study 4	42%	20%	38%	62%
					HEART - MIND
Adults	Study 1a	94%	3%	2%	98%
	Study 1b	94%	3%	2%	98%
	Study 1c	96%	3%	1%	99%
	Study 1d	85%	11%	4%	96%
	Study 2	96%	2%	2%	98%
	Study 3	72%	25%	3%	97%
	Study 4	90%	8%	2%	98%
Children, 7-9y	Study 2	66%	11%	24%	76%
	Study 3	56%	17%	27%	73%
Children, 4-6y	Study 3	35%	20%	45%	55%
	Study 4	48%	24%	28%	72%

An adult endpoint

Studies with adults using different sets of target characters ("edge cases" vs. "diverse characters") and mental capacities, using different response scales, and featuring different experimental designs (between- vs. within-subjects) all converged to suggest a robust hierarchical structure among BODY, HEART, and MIND among US adults: BODY and MIND appear to be more fundamental or "basic" conceptual units than HEART in adults' representations of mental life.

My evidence for this claim is that, across all seven studies with adults, individual participants endorsed the physiological sensations of the BODY and the perceptual-cognitive abilities of the MIND at least as strongly, often more strongly, and almost never less strongly, than the social-emotional abilities of the HEART. See Figure 4.10 for a summary of difference scores in all studies (panel A) and intercepts from regression models comparing these difference scores to zero (panel B).

These tendencies were strong and strikingly reliable: Across studies, 89-96% of individual adults' assessments of target characters yielded *BODY* scores that were at least as high or higher than *HEART* scores, and fully 96-99% yielded *MIND* scores that were at least as high or higher than *HEART* scores (see Table 4.11, "BODY - HEART" and "HEART - MIND" sections; see also Figure 4.10, panel A, leftmost and rightmost columns). This is a remarkable level of consistency across participants and studies. After all, participants were responding to questions about individual mental capacities presented in a random order, with no explicit indication of which capacities would be grouped together to form "scales" in these analyses; and different participants were assessing different target characters, bringing their own personal experiences with and beliefs about these characters to bear on their assessments. Despite these important sources of variability, virtually *no* adult participants answered these questions in such a way as to indicate that any of the target characters included in these studies had more in the way of social-emotional abilities (HEART) than physiological sensations (BODY) or perceptual-cognitive abilities (MIND). I take these robust asymmetries to be strong evidence of a hierarchical organization of conceptual units: Among US adults, BODY and MIND appear to function as more "basic" or "fundamental" components of mental life than HEART.

This pattern of findings—never attributing HEART more strongly than BODY or MIND—is consistent with the possibility that adults' mental capacity attributions are governed by an intuitive theory of mental life specifying that, in order for a being to have the social-emotional abilities of the HEART, it must also have the physiological sensations of the BODY and the perceptual-cognitive abilities of the mind.

A re-plotting and re-analysis of participants' *BODY*, *HEART*, and *MIND* scores in Studies 1-4 provides some preliminary evidence for this kind of joint dependency—i.e., for the "and" embedded in the previous sentence. My logic here is that if, as a group, a sample of participants holds the theory that HEART requires a combination of BODY *and* MIND, then strong endorsements of *HEART* abilities should only occur among participants who also gave strong endorsements of *both BODY* and *MIND* abilities. This is, indeed, exactly what I observe among adults across Studies 1-4 (see Figure 4.11, top row): High *HEART* scores (plotted in more reddish colors) were only observed when both *BODY* scores (on the horizontal axis) and *MIND* scores (on the vertical axis) were also high (i.e., in the upper right corner of each plot). (This visualization is further supported by regression analyses including interactive effects of *BODY* and *MIND* scores on *HEART* scores; see Appendix B.)

Relatedly, as I speculated in the discussion of adults' results for individual studies, visualizations of adults' mental capacity attributions suggested that they might be governed by some sort of "threshold" model, in which attributions of any substantial amount of HEART depend on the target character having *a certain degree* of BODY and MIND. In the "edge case" studies (Studies 1a-1c, 2, and 4), only adults who granted a target character at least a moderate degree of BODY and MIND abilities granted it any HEART abilities; likewise, in the "diverse characters" studies (Studies 1d and 3), only characters that were (in the aggregate) granted at least moderate degrees of BODY and MIND abilities were granted any HEART abilities. (In the visualizations of adults' responses, this manifested as a large number of datapoints toward the outer "edges" of the plots; see, e.g., Figure 4.11.) This kind of pattern appears to have been specific to relationships between BODY vs. HEART and MIND vs. HEART (not BODY vs. MIND). This would be an interesting line of inquiry for future research. In contrast to the robust asymmetries in adults' attributions of BODY vs. HEART and MIND vs. HEART, their attributions of the two more "basic" conceptual units—BODY and MIND—were less robustly asymmetrical. On the whole, most assessments of target characters yielded *MIND* scores that were at least as high or higher than *BODY* scores—but across studies this was true in only 54-77% of individual participants' assessments of target characters (see Table 4.11, "BODY - MIND" section; see also Figure 4.10, panel A, center column). In studies that featured "edge cases" as target characters (Studies 1a-1c, 2, and 4), this asymmetry (MIND more than BODY) tended to be limited to assessments of the robot; there was a fair degree of variability in whether individual participants attributed more BODY or more MIND to the beetle, and in one case (Study 4) the mean *BODY* score was actually higher than the mean *MIND* score for the beetle (see Figure 4.2, panels A-C; Figure 4.5, panel A; and Figure 4.9, panel A). Likewise, in studies that featured a wider range of "diverse characters" (Study 1d and Study 3), only technological "beings" reliably received higher *MIND* than *BODY* scores from adult participants, and certain other beings (e.g., immature humans, some non-human animals) tended to receive higher *BODY* than *MIND* scores (see Figure 4.2, panel D; and Figure 4.7, panel A). Taken together, I consider these findings to indicate that there is no general hierarchical relationship between BODY and MIND in US adults' conceptual representations of mental life: Instead, adults appear to assess a being's capacity for physiological sensation somewhat independently of its capacities for perception and cognition, and consider it quite plausible for different beings in the world to have relatively more or less of either of these aspects of mental life.

Of course, none of these conceptual units appears to be assessed *completely* independently of the others: Attributions of mental capacities in each of these domains were at least moderately correlated with each other (see Figure 4.10, panel C). For every pair of conceptual units, correlations between scores on the two relevant scales were almost always positive in adult samples (with the single exception of the adult sample in Study 2). The correlations between adults' scores on the *BODY* and *HEART* scales appear to have been particularly strong and reliable across studies; this privileged relationship between BODY and HEART might have its roots in early childhood—a point in development when children in this cultural context fail to draw a sharp distinction between physiological sensations and social-emotional abilities (as revealed by the analyses presented in Chapter III; see also Appendix A for an alternative set of exploratory factor analyses using an oblique rotation, which allows for an assessment of the correlations *between factors themselves* rather than an assessment of correlations between participants' scores on these factors). More generally, the ubiquitous positive relationships between attributions of BODY, HEART, and MIND are, in my view, evidence that BODY, HEART, and MIND are indeed part of the same "concept" of mental life.

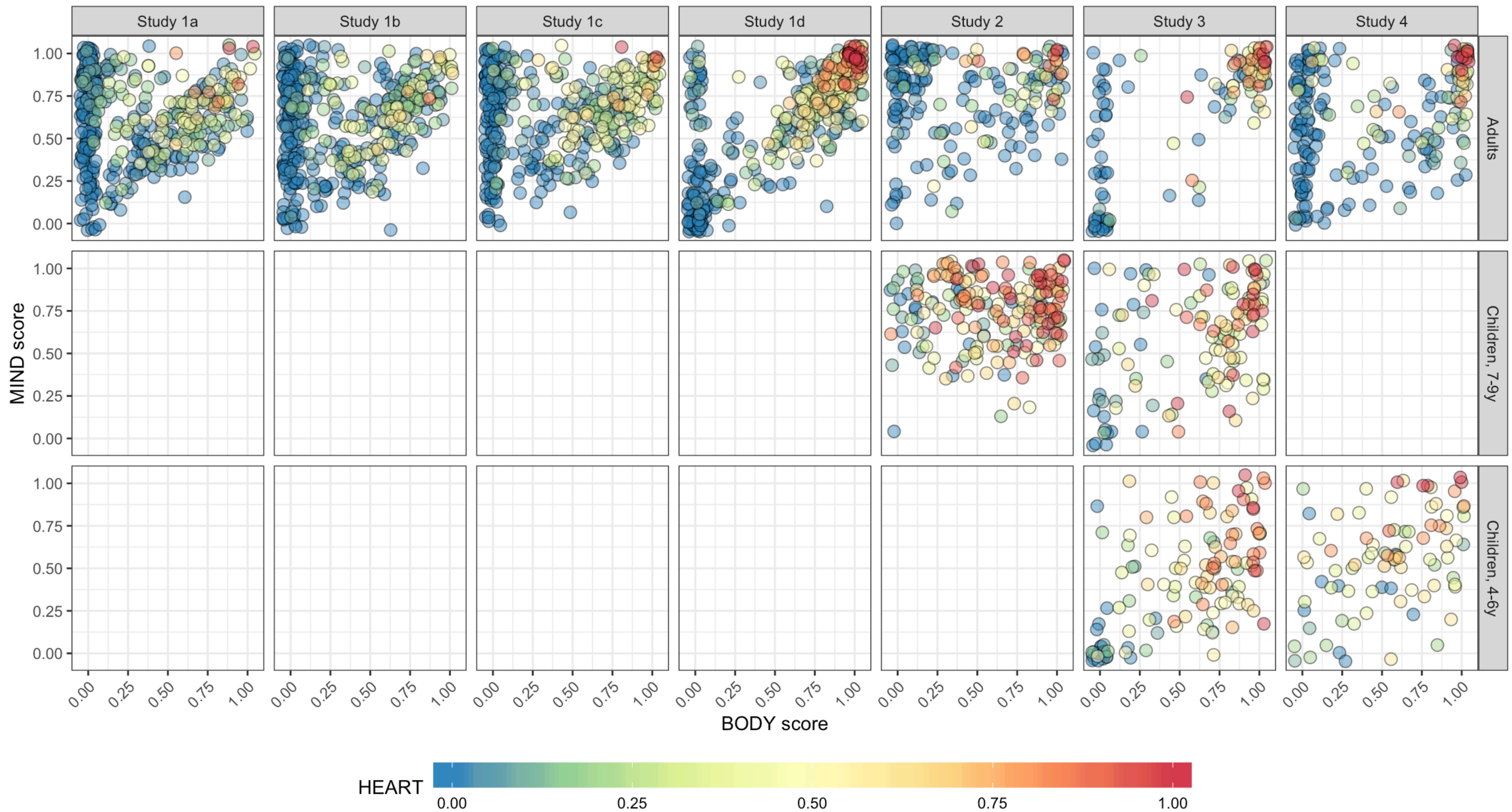

Figure 4.11: Participants' endorsements of HEART as a function of their joint BODY and MIND endorsements. Results from all samples, in all studies, are plotted here, using adults' BODY, HEART, and MIND scales for all samples. For each conceptual unit, scores could range from 0-1, such that difference scores could range from -1 to +1. If endorsements of HEART depend jointly on endorsements of both BODY and MIND, then red dots (strong HEART endorsements) should occur only in the upper right corner of each plot.

It would be fascinating to explore the nature and implications of the hierarchical relationships between BODY, HEART, and MIND in future work. In particular, do adults' assessments reflect their observations of the co-occurrence of mental capacities in the world, or might they reflect something deeper about their understanding of the causal systems that give rise to different aspects of mental life? In other words, do adults think it is impossible, or simply unlikely, for a being to have social-emotional abilities without being instantiated in a physiological body (BODY), or without having abilities to perceive and represent the environment (MIND)? How might such intuitive theories inform, or be informed by, people's understanding of exceptional beings such as "social" technologies or spiritual/supernatural beings (who lack biological bodies)? One intriguing possibility is that adults consider the abilities subsumed under BODY and MIND to be *prerequisites* for the social-emotional abilities associated with HEART, and might have intuitive theories that specify how and why physiological and perceptual-cognitive abilities contribute to emotional experiences and social interactions. These intuitive theories might also inform adults' beliefs about the existence, abilities, and limitations of such exceptional entities as "social" technologies and spiritual or supernatural beings. I consider this to be an especially interesting direction for future work.

A developmental trajectory

Beyond establishing an adult endpoint for this aspect of conceptual representations of mental life, the studies discussed in this chapter also provided a glimpse of the development of relationships among BODY, HEART, and MIND over the course of early and middle childhood (4-9y).

First, it is worth noting that, across studies, I observed generally positive relationships between conceptual units (the only exception being the BODY vs. MIND comparison for older children in Study 2; see Figure 4.10, panel C). As with adults, this provides some evidence that the mental capacities included in these studies are all part of the same conceptual space even for young children (namely, an understanding of "mental life").

Beyond this, these studies suggested that, by the preschool years, children have an emerging understanding of the physiological sensations of the BODY and the perceptual-cognitive abilities of the MIND as being somehow more "basic" than the social-emotional abilities of the HEART—but that these asymmetries continue to become stronger and more robust over the course of childhood.

My evidence for this claim comes from the fact that, as among adults, among most of the child samples included in these studies participants' mental capacity attributions yielded stronger *BODY* and *MIND* scores than *HEART* scores (see Figure 4.10, panels A and B). However, these two asymmetries—which I have taken to be signatures of hierarchical relationships between BODY vs. HEART and between HEART vs. MIND—all appeared to be much weaker in size and less reliable across studies than they were among adults. This was true even among 7- to 9-year-old children, whose "conceptual units" (BODY, HEART, and MIND) otherwise appeared to be quite similar to that of adults (see Chapter III). Likewise, the hypothesis that attributions of HEART are *jointly* dependent on attributions of *BODY* and *MIND*, which seemed highly plausible among adults (as discussed in the previous section), was not supported among either 7- to 9-year-old or 4- to 6-year-old children (see Figure 4.11, middle and bottom rows, and regression analyses in Appendix B).

Meanwhile, in the BODY vs. MIND comparison, there was some indication that, early in development, children hold intuitions that differ from adults not only in degree (size of asymmetry) but perhaps in kind (direction of asymmetry). In all studies, adults tended to endorse MIND somewhat more strongly than BODY, in the aggregate (though as noted earlier, individual participants' difference scores appeared to be contingent on the target character they were assigned to assess). In contrast, in half of the child samples in these studies (7- to 9-year-old children in Study 3; 4- to 5-year-old children in Study 4) there was *no* systematic asymmetry in children's *BODY* vs. *MIND* scores—and in one sample, (4- to 6-year-old children in Study 3), children actually demonstrated the *opposite* tendency, endorsing BODY more strongly, on average, than MIND.

Analyses that take into account children's exact age offer even stronger evidence that asymmetries between conceptual units generally become more adult-like—both in size and in direction—with increasing age, both among 7- to 9-year-old children in Study 2 and among 4- to 9-year-old children in Study 3; see Appendix B. (Analyses of Study 4 provided no evidence of shifts toward adult-like patterns among 4- to 5-year-old children, but this is not surprising given the smaller sample size and more restricted age range.)

In addition to the age-related changes in size (and perhaps direction) of the asymmetries among BODY, HEART, and MIND just described, there are some indications that these developmental differences may also reflect changes in the degree of consensus across individual participants with age. This is most striking for the BODY vs. HEART and HEART vs. MIND comparisons: In contrast to the strong consensus among adults in the direction of asymmetry for these two pairs of conceptual units (with 89-99% of individual assessments of target characters demonstrating the modal adult pattern of asymmetry; see discussion in previous paragraphs), across studies only 59-77% of assessments among older children and 55-73% among younger children conformed to the adult pattern of asymmetry. (See also Figure 4.10, panel A, for distributions of difference scores within each of the child samples.)

Taken together, this set of observations of differences across age groups suggest that development in the organization of the conceptual units I have called BODY, HEART, and MIND may involve at least three kinds of changes: (1) Increases in the *size* of these asymmetries (i.e., the extremeness or strictness of these hierarchical relationships); (2) Changes in the *direction* of some of these asymmetries (namely, the relative "basic-ness" of BODY vs. MIND; and (3) Increases in the degree of *consensus* across individuals in whether BODY and/or MIND are treated as more basic than HEART.

Chapter conclusion

In this chapter, I explored a second aspect of conceptual representations of mental life among US children and adults: The *relational organization* of the three conceptual units—BODY, HEART, and MIND—that seem to anchor adults' and older children's understanding of mental life, as identified in Chapter III.

Studies 1-4 are consistent with the following theory: By the preschool years, US children treat physiological sensations (BODY) as particularly basic or fundamental aspects of mental life, and they quickly come to see perceptual-cognitive abilities (MIND) as roughly equally "basic." In contrast, the social-emotional abilities of the HEART are perceived to be less basic, i.e., to occupy a different position in the hierarchical structure that characterizes this conceptual domain. Over the course of childhood—and extending beyond the oldest non-adult sample included in the current studies (7-9y)—these hierarchical relationships become increasingly stark, applying more universally to any kind of "being" in the world, and the degree of consensus across individuals increases. In its "mature" state, this hierarchical structure admits of virtually no exceptions: It governs mental capacity attributions to all kinds of target entities among all participants. Regardless of the degree to which a person attributes any particular mental capacity to any particular being in the world, US adults virtually never violate the rule that in order to have any social-emotional abilities (HEART), a being must also have some degree of physiological sensations (BODY) and perceptual-cognitive abilities (MIND). The analyses discussed in this chapter formed the basis of this theory and lay the foundation for future confirmatory tests and extensions of this theory.

In the next chapter, I apply the same exploratory spirit to a third and final aspect of conceptual representations of mental life: the application or deployment of these conceptual units in reasoning about various kinds of beings.

CHAPTER V: CHANGES IN DEPLOYMENT OF THE CONCEPT

Chapter overview

In this chapter, I focus on the third of my three key questions about the development of representations of mental life: How do people of different ages deploy their conceptual representations of mental life to reason about specific entities in the world? Even more than other chapters, this question comes to life most vividly in the context of developmental comparisons; therefore I draw primarily on data from Studies 2-4, which included both adult and child samples. For details about the methods of all studies, see Chapter II. The goal of this chapter is to provide "snapshots" of mental capacity attributions to various target characters in early childhood, middle childhood, and adulthood, and to explore in finer-grained detail more continuous changes in children's beliefs about the mental lives of these characters between 4-9y of age.

To structure this exploration, I focus in particular on age-related differences in children's and adults' assessments of animate beings vs. inanimate beings. As discussed in Chapter I, the animate-inanimate distinction has been the topic of extensive empirical and theoretical in both cognitive and developmental psychology, extending back at least as far as Piaget, with roots in some of the earliest discussions of mental life in the Western tradition. In the past few decades, empirical work on the animate-inanimate distinction has focused in particular on differences between animates vs. inanimates in their behaviors (e.g., their ability to engage in self-propelled movements or to effect causal changes in the world), their observable properties (e.g., having eyes and faces, containing blood, having organs on the inside), and the biological processes that they engage in or are subjected to (e.g., growth, reproduction, death; see Gelman & Spelke, 1981; Gelman & Opfer, 2002 for reviews). Some studies have also explored children's developing understanding of the minds of animate beings—but not with the structure provided by the current analysis of naturally occurring "conceptual units." In this chapter, I aim to push this aspect of the field's understanding of the animate-inanimate distinction forward by providing a structured analysis of attributions of physiological sensations (BODY), social-emotional abilities (HEART), and perceptual-cognitive capacities (MIND) to animate vs. inanimate beings in large samples of 4- to 9-year-old US children and adults.

General analysis plan

High-level overview

In analyzing these datasets with an eye toward documenting the application or deployment of the conceptual representations described in Chapters III-IV, the basic insight is that the attribution of specific mental capacities to specific target characters provides evidence of how conceptual representations of mental life are deployed in everyday social cognition. In Chapter II, I illustrated this with the following example: If participants who assess the mental capacities of Characters 1, 2, and 3 share one general pattern of mental capacity attributions, and participants who assess the mental capacities of Characters 4, 5, and 6 share another pattern, this provides some evidence that conceptual representations of mental life might play a role in structuring representations of (and interactions with) different classes of beings in the world. Here I will translate this general intuition into a specific analysis plan to be applied to each of these datasets in turn.

Details of analyses

All analyses in this chapter make use of the *BODY*, *HEART*, and *MIND* scales developed in Chapter IV to summarize participants' responses in terms of the conceptual units identified among adults in each study (as presented in Chapter III).

For each study, I conduct two analyses of scores each of these three domains (BODY, HEART, and MIND), via Bayesian regressions. First, I compare age groups (e.g., adults vs. children), with an eye toward assessing both overall differences between age groups and differential sensitivity to the distinction between animate beings vs. inanimate objects in that domain. Second, I examine age-related differences within the child samples, again with an eye toward assessing overall increases or decreases in attributions with increasing age as well as increases or decreases in children's sensitivity to the animate-inanimate distinction in that domain. For all analyses, I conduct Bayesian regressions on raw scores (which ranged from 0-1 for each domain), including maximal random effects structures (contingent on the range of characters included in the study and the within- vs. between-subjects design of the study).

For two of these studies—Study 2 and Study 4, which both employed the "edge case" variant of the general empirical approach—the comparison between "animate beings" and "inanimate objects" is redundant with a full comparison of all target characters included in the study. To maximize comparability (and minimize unnecessary complexity), I have chosen to analyze Study 3 in a similar way, looking at differences between two groups of target characters (five animate beings vs. four inanimate objects) rather than attempting to analyze all possible differences among the nine "diverse characters" included in that study.

In addition to these study-specific analyses, I include both visual and numerical summaries of findings across studies and samples in the General Discussion, as well as an additional regression analysis aimed at comparing the degree of the animate-distinction across domains (BODY, HEART, and MIND) and age groups (adults, 7- to 9-year-old children, and 4- to 6-year-old children), pooling data from Studies 2-4. This analysis again includes a maximal random effects structure (random intercepts for participants nested within studies and for specific target characters); rather than being conducted over raw scores (which ranged from 0-1), it is conducted over centered scores (centered to range from -0.5 to +0.5). See Table 5.7, caption, for more details about the coding of the parameters included in this analysis.

Study 2: Conceptual change between middle childhood (7-9y) and adulthood

In the context of this dissertation, Study 2 serves to provide an initial investigation of representations of mental life earlier in development, in what I have called middle childhood (7-9y). In this chapter, I focus on what this study can reveal about changes in the deployment of this concept between middle childhood and adulthood: How do US 7- to 9-year-old children's attributions of BODY, HEART, and MIND compare to those of adults in their cultural context?

To review, in Study 2, 200 US adults and 200 US children between the ages of 7.01-9.99 years (median: 8.31y) each assessed a single target character on 40 mental capacities. This study employed the "edge case" variant of the general approach, with participants randomly assigned to assess either a beetle or a robot. (See Chapter II for detailed methods.)

Special notes on data processing and analysis

To facilitate comparison between children and adults in Study 2, I use adults' *BODY*, *HEART*, and *MIND* scales (as described in Chapter IV) to analyze both age groups.

Results

Children vs. adults

See Figure 5.1, panel A, for *BODY*, *HEART*, and *MIND* scores for both target characters among the 7- to 9-year-old children and adults in Study 2.

In the aggregate, both children and adults seem to have considered the beetle—the animate "edge case" featured in this study—to be a being with a moderately high degree of physiological sensations (mean *BODY* score among adults: 0.72, 95% CI: [0.67-0.77]; among children: 0.82, 95% CI: [0.79-0.86]) and perceptual-cognitive capacities (mean *MIND* score among adults: 0.69, 95% CI: [0.64-0.73]; among children: 0.70, 95% CI: [0.67-0.74]). However, adults and children appear to have diverged in their assessments of its abilities in the HEART domain: While adults tended to grant very little in the way of social-emotional abilities (mean *HEART* score among adults: 0.17, 95% CI: [0.12-0.23]), children's *HEART* scores tended to hover around the midpoint of the scale (mean: 0.58, 95% CI: [0.52-0.64]).

For the robot—the inanimate "edge case" featured in this study—both adults and children, in the aggregate, indicated a high degree of perceptual-cognitive abilities (mean *MIND* score among adults: 0.83, 95% CI: [0.78-0.87]; among children: 0.80, 95% CI: [0.76-0.83]), and appeared to agree that the robot had less in the way of physiological sensations and social-emotional abilities than the beetle. However, the two age groups appear to have diverged in their assessments of the absolute degree of BODY and HEART that they were willing to grant the robot: Adults granted very little in either domain (mean *BODY* score: 0.10, 95% CI: [0.07-0.12]; mean *HEART* score: 0.06, 95% CI: [0.03-0.09]), while children granted middling abilities in both domains (mean *BODY* score: 0.34, 95% CI: [0.30-0.39]; mean *HEART* score: 0.51, 95% CI: [0.44-0.57]).

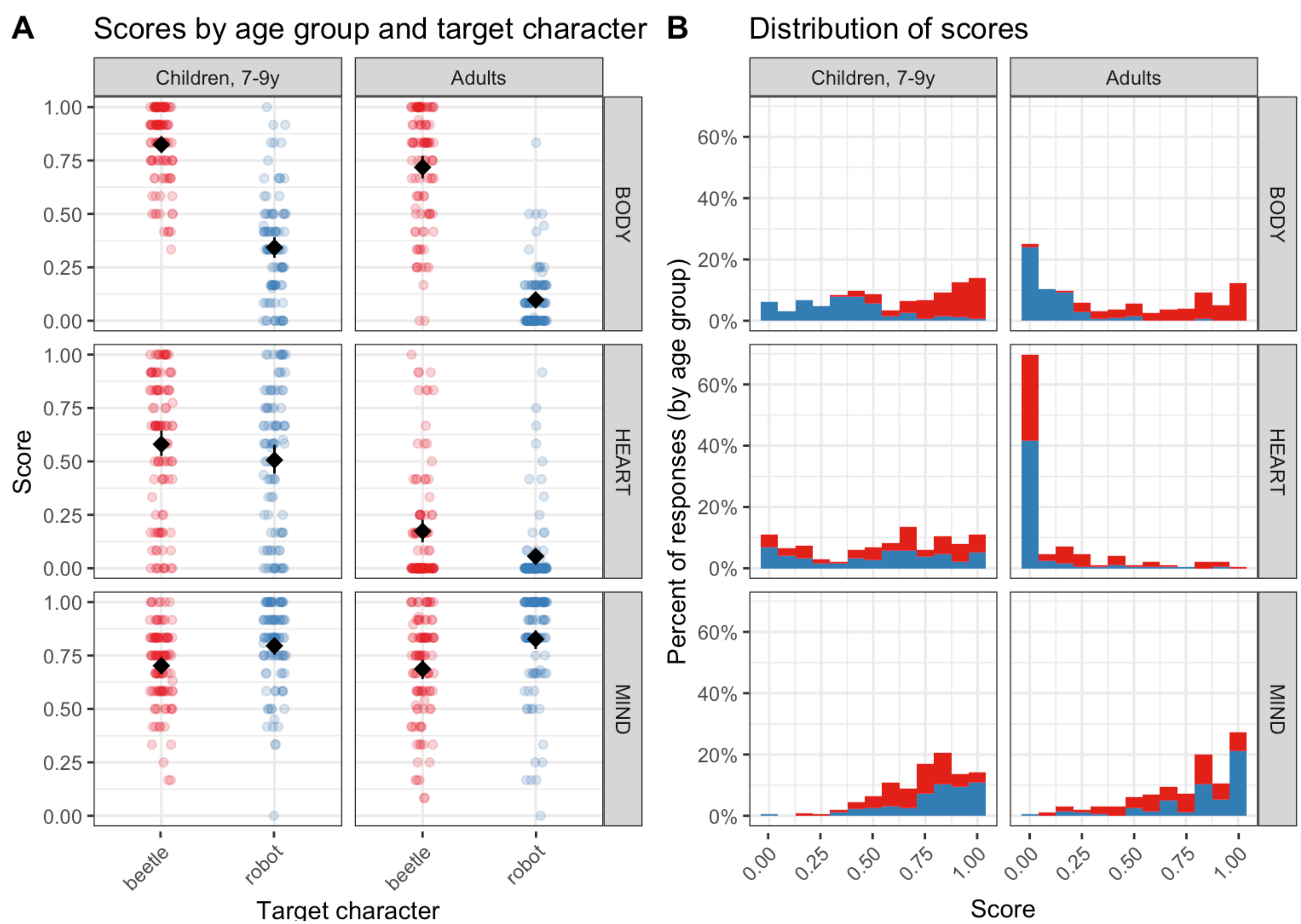

Figure 5.1: Attributions of BODY, HEART, and MIND among children (7-9y) and adults in Study 2. For each conceptual unit, scores could range from 0-1. Plots include (A) scores by target character, and (B) distributions of scores. Individual participants are plotted as small, translucent circles, and mean scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals.

Table 5.1: Regression analyses of age group differences in BODY, HEART, and MIND scores among the 7- to 9-year-old children and adults in Study 2 (scored using adults' scales, as presented in Chapter IV). For each conceptual unit, the table presents a Bayesian regression with 4 fixed effect parameters: (1) the intercept, which is an index of attributions of that conceptual unit among adults; (2) the overall difference in scores for the beetle compared to the grand mean ('GM') among adults; (3) the difference between children's and adults' scores, collapsing across target characters; and (4) the interactive effect of age group and target character. Age effects are highlighted in bold, because they are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	BODY			**HEART**			**MIND**		
Parameter	**b**	**95% CI**		**b**	**95% CI**		**b**	**95% CI**	
Intercept (adults)	0.41	[0.38, 0.44]	*	0.11	[0.08, 0.15]	*	0.76	[0.73, 0.79]	*
Beetle vs. GM (adults)	0.31	[0.28, 0.34]	*	0.06	[0.02, 0.10]	*	-0.07	[-0.10, -0.04]	*
Children vs. adults	**0.18**	**[0.14, 0.22]**	*	**0.43**	**[0.37, 0.48]**	*	**-0.01**	**[-0.05, 0.03]**	
Interaction	**-0.07**	**[-0.11, -0.03]**	*	**-0.02**	**[-0.08, 0.03]**		**0.02**	**[-0.02, 0.07]**	

Table 5.2: Regression analyses of age-related differences in BODY, HEART, and MIND scores among the 7- to 9-year-old children in Study 2 (scored using adults' scales, as presented in Chapter IV). For each conceptual unit, the table presents a Bayesian regression with 4 fixed effect parameters: (1) the intercept, which is an index of attributions of that conceptual unit, collapsing across target characters, at the mean age for this sample (8.36y); (2) the overall difference in scores for the beetle compared to the grand mean ('GM'), at the mean age for this sample (8.36y); (3) the overall effect of age on scores, collapsing across target characters; and (4) the interactive effect of age and target character. The last two effects are highlighted in bold, because they are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	BODY			**HEART**			**MIND**		
Parameter	**b**	**95% CI**		**b**	**95% CI**		**b**	**95% CI**	
Intercept	0.58	[0.55, 0.61]	*	0.54	[0.50, 0.59]	*	0.75	[0.72, 0.77]	*
Beetle vs. GM	0.24	[0.21, 0.27]	*	0.04	[0.00, 0.08]		-0.05	[-0.07, -0.02]	*

	BODY			HEART			MIND		
Parameter	b	95% CI		b	95% CI		b	95% CI	
Exact age (centered)	-0.03	[-0.07, 0.00]	*	-0.08	[-0.13, -0.02]	*	0.04	[0.01, 0.07]	*
Interaction	0.05	[0.02, 0.09]	*	0.04	[-0.01, 0.09]		0.01	[-0.02, 0.04]	

Figure 5.2: Changes in attributions of BODY, HEART, and MIND among 7- to 9-year-old children in Study 2. For each conceptual unit, scores could range from 0-1. Individual children are plotted as small, translucent circles; mean scores among adults are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. Lines correspond to simple linear regressions (formula: score ~ age).

A series of Bayesian regression analyses confirmed these general impressions (see Table 5.1 and Figure 5.1). Children's *BODY* scores were generally higher than adults', particularly for the robot; as a result, the difference between the beetle and the robot was attenuated among children, relative to adults (i.e., the interaction term was non-zero). Children's *HEART* scores were also higher than adults', but this difference did not vary substantially across target characters . There were no substantial differences between children and adults in their *MIND* scores.

Taken together, these observations highlight one especially striking difference between children and adults: For both edge cases, regardless of animacy status, children attributed substantially more HEART than did adults. Indeed, fully 70% of adults in Study 2 had *HEART* scores < 0.08 (i.e., answered at most *one* of the 6 *HEART* items with a response of "KINDA," and otherwise answered "NO" to all *HEART* items). The more uniform distribution of children's *HEART* scores across the 0-1 range stands in stark contrast to this adult standard; see Figure 5.1, panel B.

Age-related differences between 7-9y

In the previous section, I compared the attributions of 7- to 9-year-old children as a group to those of adults. Here, I explore age-related differences within the child sample: How might children's attributions change over the age range included in this study?

If the snapshots of children vs. adults are reflective of *developmental* changes, I would expect that, with increasing age, children's responses would become increasingly adult-like. Based on the age group comparisons in the previous section, this would mean that age would be associated with lower *BODY* scores, particularly for the robot; and with lower *HEART* scores for both target characters.

In fact, this is exactly what I observe among the 7- to 9-year-old children in this study (see Table 5.2, and Figure 5.2).

In line with an adult-like understanding of the animate-inanimate distinction, *BODY* scores were generally higher among children who assessed the beetle (the animate target character) than among children who assessed the robot. With age, however, children's *BODY* scores generally decreased, driven by changes in children's attributions of BODY to the robot. As a result, the difference between the beetle and the robot increased over the age range (i.e., the interaction term was non-zero).

Meanwhile, children's *HEART* scores did not differ reliably across the two target characters in this study—but with age, children's *HEART* scores for both characters generally decreased.

Finally, *MIND* scores were generally higher among children who assessed the robot than among children who assessed the beetle. In addition to the predicted age-related differences in the BODY and HEART domains, children's *MIND* scores for both characters generally increased with age.

Discussion

Adults in Study 2 distinguished strongly between the animate character (the beetle) vs. the inanimate character (the robot) in terms of their capacities in the BODY domain. They granted both of these "edge cases" relatively limited abilities in the HEART domain, and relatively strong abilities in the MIND domain (with the robot actually exceeding the beetle in its perceived MIND abilities).

Like adults, 7- to 9-year-old children clearly respected the animate-inanimate distinction in their attributions of BODY abilities. Even among these relatively "old" children, however, there was room for increasing "adult-like-ness" across the age range: This distinction between the physiological sensations of a beetle vs. robot grew larger with increasing age, driven by decreases in *BODY* scores for the robot.

The biggest difference between children and adults in Study 2 was in the HEART domain. Children attributed far more HEART abilities—to both the beetle and the robot—than did adults, and although this tendency decreased across the age range, it did not appear to reach adult-like levels even among the oldest children in this sample (see Figure 5.2, center panel).

Children's attributions of MIND to these edge cases were generally adult-like, and changed only slightly over the age range, increasing to fully adult-like levels. Like adults, children generally attributed many MIND scores to both characters, and particularly to the robot.

Study 3: Conceptual change over early and middle childhood (4-9y)

Study 3 builds on the investigation of middle childhood (7-9y) initiated in Study 2 and extends this exploration of conceptual change into earlier childhood (4-6y). In this chapter, I again focus on what this study can reveal about changes in the deployment of this concept—i.e., the attribution of BODY, HEART, and MIND to various beings in the world—over the course of early and middle childhood (7-9y).

To review, in Study 3, 116 US adults, 125 “older” children (7.08-9.98 years; median: 8.56y), and 124 “younger” children (4.00-6.98 years; median: 5.03y) each assessed a single target character on 20 mental capacities. This study employed the “diverse characters” variant of the general approach, with participants randomly or pseudo-randomly assigned to assess one of the following 9 characters: an elephant, a goat, a mouse, a bird, a beetle, a teddy bear, a doll, a robot, or a computer. (See Chapter II for detailed methods.)

Special notes on data processing and analysis

As in Study 2, to facilitate comparison between the three age groups included in Study 3, I use adults’ *BODY*, *HEART*, and *MIND* scales (as described in Chapter IV) to analyze both age groups.

Results

Children vs. adults

See Figure 5.3, panel A, for *BODY*, *HEART*, and *MIND* scores for each of the nine target characters among the younger children (4-6y), older children (7-9y), and adults in Study 3, and Figure 5.3, panel B, for a visualization of scores with target characters grouped into animate beings (elephant, goat, mouse, bird beetle) vs. inanimate objects (teddy bear, doll, robot, computer). To facilitate comparison with Studies 2 and 4, I will focus here on animacy status, rather than analyzing all target characters individually.

In the aggregate, all three age groups seem to have considered the animate beings included in this study to have a relatively high degree of physiological sensations (mean *BODY* score among adults: 0.91, 95% CI: [0.88-0.94]; among older children: 0.84, 95% CI: [0.81-0.87]; among younger children: 0.73, 95% CI: [0.67-0.78]), and a middling degree of social-emotional abilities (mean *HEART* score among adults: 0.42, 95% CI: [0.34-0.50]; among older children: 0.54, 95% CI: [0.48-0.61]; among younger children: 0.57, 95% CI: [0.51-0.64]). Assessments of animate beings’ abilities in the MIND domain appear to have varied more by age group: While adults tended to grant animate beings a high degree of perceptual-cognitive abilities (mean *MIND* score among adults: 0.84, 95% CI: [0.79-0.88]), younger children's *MIND* scores tended to hover around the midpoint of the scale (mean: 0.50, 95% CI: [0.44-0.56]), with older children falling in between (mean: 0.66, 95% CI: [0.60-0.71]).

For the inanimate beings included in this study, there was a high degree of consensus among adults that such entities had virtually no physiological or social-emotional abilities (mean *BODY* score: 0.04, 95% CI: [0.01-0.08]; mean *HEART* score: 0.03, 95% CI: [0.00-0.07]). In contrast, both groups of children, in the aggregate, granted low to moderate abilities to inanimate beings in both the BODY domain (mean *BODY* score among older children: 0.19, 95% CI: [0.13-0.25]; among younger children: 0.28, 95% CI: [0.20-0.37]) and the HEART domain (mean *HEART* score among older children: 0.27, 95% CI: [0.19-0.37]; among younger children: 0.31, 95% CI: [0.23-0.40]). All three age groups, in the aggregate, granted middling perceptual-cognitive abilities to these inanimate characters (which included two "intelligent" technologies; mean *MIND* score among adults: 0.33, 95% CI: [0.23-0.43]; among older children: 0.47, 95% CI: [0.38-0.58]; among younger children: 0.34, 95% CI: [0.25-0.43]).

A series of Bayesian regression analyses confirmed these general impressions of differences across age groups (see Table 5.3).

Neither older nor younger children's *BODY* scores were generally higher than adults', but in both groups of children the difference in *BODY* scores between animate vs. inanimate characters was attenuated, relative to adults (i.e., both interaction terms were non-zero). Meanwhile, in the *HEART* domain, both older and younger children's *HEART* scores were generally higher than adults', but this difference did not vary substantially across target characters. Finally, in the *MIND* domain, younger children's (but not older children's) *MIND* scores were substantially lower than adults'. In addition, in both groups of children the difference in *MIND* scores between animate vs. inanimate characters was attenuated, relative to adults.

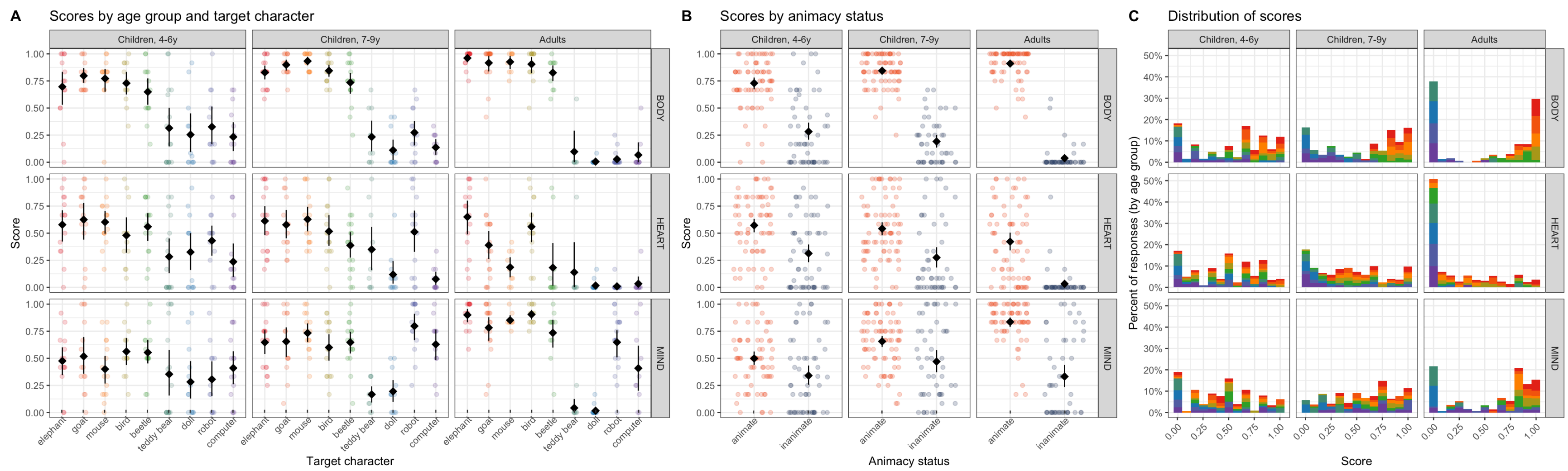

Figure 5.3: Attributions of BODY, HEART, and MIND among younger children (4-6y), older children (7-9y), and adults in Study 3. For each conceptual unit, scores could range from 0-1. Plots include (A) scores by target character, (B) animacy status, and (C) distributions of scores. Individual participants are plotted as small, translucent circles, and mean scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals.

Table 5.3: Regression analyses of age group differences in BODY, HEART, and MIND scores among the 4- to 6-year-old children, 7- to 9-year-old children, and adults in Study 3 (scored using adults' scales, as presented in Chapter IV). For each conceptual unit, the table presents a Bayesian regression with 4 fixed effect parameters: (1) the intercept, which is an index of attributions of that conceptual unit among adults; (2) the overall difference in scores for the animate characters compared to the grand mean ('GM') among adults; (3) the difference between children's and adults' scores, collapsing across target characters; and (4) the interactive effect of age group and animacy status. Age effects are highlighted in bold, because they are the primary parameters of interest for these analyses. In addition to the fixed effects listed here, these regressions included random intercepts for individual target characters (n=9). For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	BODY			HEART			MIND		
Parameter	**b**	**95% CI**		**b**	**95% CI**		**b**	**95% CI**	
Intercept (adults)	0.47	[0.44, 0.51]	*	0.23	[0.17, 0.28]	*	0.58	[0.53, 0.64]	*
Animate characters vs. GM (adults)	0.44	[0.40, 0.47]	*	0.20	[0.14, 0.25]	*	0.25	[0.20, 0.30]	*
Older children (7-9y) vs. adults	**0.04**	**[-0.01, 0.10]**		**0.18**	**[0.11, 0.26]**	*	**-0.02**	**[-0.09, 0.05]**	
Younger children (4-6y) vs. adults	**0.03**	**[-0.02, 0.08]**		**0.22**	**[0.14, 0.29]**	*	**-0.16**	**[-0.24, -0.09]**	*
Interaction: Older children (7-9y) vs. adults	**-0.11**	**[-0.16, -0.06]**	*	**-0.06**	**[-0.14, 0.01]**		**-0.16**	**[-0.23, -0.09]**	*
Interaction: Younger children (4-6y) vs. adults	**-0.21**	**[-0.27, -0.16]**	*	**-0.07**	**[-0.14, 0.01]**		**-0.17**	**[-0.25, -0.10]**	*

Table 5.4: Regression analyses of age-related differences in BODY, HEART, and MIND scores among the 4- to 9-year-old children in Study 3 (scored using adults' scales, as presented in Chapter IV). For each conceptual unit, the table presents a Bayesian regression with 4 fixed effect parameters: (1) the intercept, which is an index of attributions of that conceptual unit, collapsing across target characters, at the mean age for this sample (6.73y); (2) the overall difference in scores for the animate characters compared to the grand mean ('GM'), at the mean age for this sample (6.73y); (3) the overall effect of age on scores, collapsing across target characters; and (4) the interactive effect of age and animacy status. The last two effects are highlighted in bold, because they are the primary parameters of interest for these analyses. In addition to the fixed effects listed here, these regressions included random intercepts for individual target characters (n=9). For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	BODY			**HEART**			**MIND**		
Parameter	**b**	**95% CI**		**b**	**95% CI**		**b**	**95% CI**	
Intercept	0.52	[0.45, 0.57]	*	0.43	[0.34, 0.51]	*	0.49	[0.41, 0.57]	*
Animate characters vs. GM	0.27	[0.22, 0.33]	*	0.13	[0.04, 0.22]	*	0.09	[0.00, 0.18]	*
Exact age (centered)	**0.01**	**[-0.01, 0.02]**		**-0.01**	**[-0.03, 0.01]**		**0.05**	**[0.03, 0.07]**	*
Interaction	**0.03**	**[0.01, 0.04]**	*	**0.00**	**[-0.02, 0.02]**		**0.00**	**[-0.02, 0.02]**	

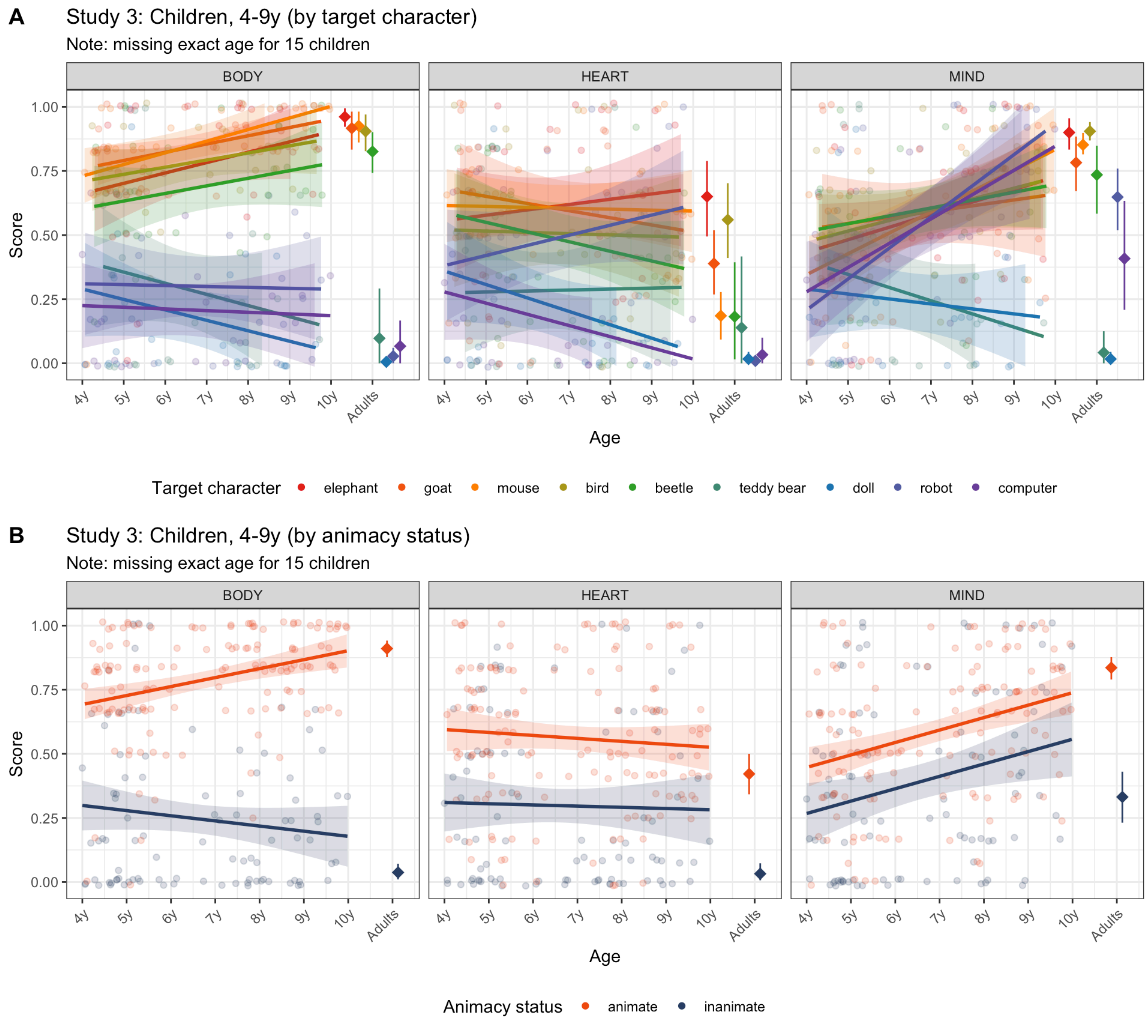

Figure 5.4: Changes in attributions of BODY, HEART, and MIND among 4- to 9-year-old children in Study 3. For each conceptual unit, scores could range from 0-1. Individual children are plotted as small, translucent circles; mean scores among adults are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. Lines correspond to simple linear regressions (formula: score ~ age).

Age-related differences between 4-9y

Here, I shift from the “snapshot” age group comparisons of the previous section to an examination of age-related differences within the child sample: How might children’s attributions to these target characters change between 4-9y of age?

As I argued for Study 2, if the age group differences just described reflect *developmental* differences, I would expect that, with increasing age, children’s responses would become increasingly adult-like. In this case, this would mean that age would be associated with increased differentiation of animate vs. inanimate characters in children's *BODY* scores; lower *HEART* scores (regardless of target character); and higher *MIND* scores, particularly for animate beings.

Some, but not all, of these predictions were born out among the 4- to 9-year-old children in this study (see Table 5.4 and Figure 5.4).

Age-related differences in the BODY domain conformed to the developmental story suggested by the group differences in the previous section: *BODY* scores were generally higher among children who assessed one of the animate target characters (elephant, goat, mouse, bird, or beetle) than among children who assessed one of the inanimate target characters (teddy bear, doll, robot, or computer), and this difference increased with age (i.e., the interaction term was non-zero). Visual inspection of Figure 5.4, panel A, suggests that these general trends held true for all animate vs. inanimate target characters. A regression analysis did not reveal any reliable overall differences (collapsing across characters) in *BODY* scores over the age range.

The group differences in the previous section suggested that attributions of HEART should decrease with age. I did not observe evidence of this within this sample of children. As in the BODY domain, *HEART* scores were generally higher among children who assessed one of the animate target characters than among those who assessed one of the inanimate target characters, but there were no reliable age-related changes in children's *HEART* scores. Visual inspection of Figure 5.4, panel B, suggests that this may reflect variability across specific target characters: For some characters (most notably, the robot) attributions of HEART appeared to increase over this age range, while for other characters (most notably, the beetle, the doll, and the computer) attributions appeared to decrease; and for many of the target characters included in this study there appeared to be no systematic age-related differences in attributions of HEART.

Finally, in line with the group differences in the previous section, *MIND* scores generally increased with age. As in the BODY and MIND domains, *MIND* scores were generally higher among children who assessed one of the animate target characters than among those who assessed one of the inanimate target characters—but although group differences suggested that this difference should increase with age, there was no evidence for this interaction among children. However, visual inspection of Figure 5.4, panel C, suggests that there were two target characters for whom attributions of MIND did *NOT* increase with age: namely, the two inert toys (the teddy bear and the doll). Interestingly, this plot suggests that the two technologies (the robot and the computer) appear to be among the characters for whom age-related changes in attributions of MIND may have been most dramatic—but this general trend of increasing attributions of MIND also appears to have applied to all of the animate characters.

Discussion

As in Study 2, adults in Study 3 distinguished very strongly between animate beings (the elephant, goat, mouse, bird, and beetle) vs. inanimate objects (the teddy bear, doll, robot, and computer) in terms of their capacities in the BODY domain: They were nearly unanimous in their denial of physiological sensations to inanimate objects, while all of the animate beings were granted a fairly high degree of BODY abilities (on average). Likewise, in the HEART domain, adults were nearly unanimous in their denial of social-emotional abilities to inanimate objects, while animate beings were perceived to vary in their HEART abilities. Finally, echoing Study 1, adults did not outright deny the possibility that some inanimate objects could have a fair degree of perceptual-cognitive abilities—but they did grant relatively *more* MIND abilities to animate beings.

Study 3 aligned with Study 2 in providing further evidence for a robust distinction between animates vs. inanimates in the BODY domain among 7- to 9-year-old children, and extended this distinction back to younger (4- to 6-year-old children). As in Study 2, however, this distinction appears to have increased with age within this sample of children—in this case, driven both by decreases in *BODY* scores for inanimate objects (as in Study 2) and by *increases* in *BODY* scores for animate beings.

Again echoing Study 2, the biggest differences between children and adults in Study 3 were in the HEART domain. In this case, it was children's attributions of social-emotional abilities to inanimate objects—and in particular, the robot—that marked them as different from adults in this study. Interestingly, this difference between "snapshots" of older and younger children vs. adults was *not* reflected in age-related differences *within* the child sample: If anything, *HEART* scores among the relatively small sample of children (n = 25) who assessed the robot appeared to have *increased* with age (see Figure

5.4, panel A, center plot). Together with the results of Study 2, this provides some intriguing evidence that children (at least children in the San Francisco Bay Area) may have qualitatively different beliefs than adults about the possibility of social-emotional abilities in robots, perhaps reflecting cohort differences as well as any developmental changes.

Finally, in contrast to Study 2, Study 3 also suggested substantial ongoing development in children's attributions of MIND, characterized by dramatic increases in MIND scores with age. Like adults in this study (and like adults and 7- to 9-year-old children in Study 2), children of all ages seemed to be willing to attribute a fair degree of perceptual-cognitive abilities to inanimate beings. Age-related differences were driven not only by increases in these attributions (which run counter-typical to the broadest or bluntest version of a general "animate-inanimate" distinction), but also by increases in attributions of MIND to animate beings (see Figure 5.4).

Study 4: A focus on early childhood (4-5y)

Note: At the time of the submission of this dissertation, the sample of 4- to 5-year-old children for Study 4 was only partially complete. All results using this sample should thus be considered preliminary and not conclusive.

Study 4 builds on Study 3 by providing a targeted investigation of representations of mental life in the preschool years (4-5y). In this chapter, I again focus on what this study can reveal about attributions of BODY, HEART, and MIND at the earliest point in development that I have examined so far, and compare the deployment of this concept among young children vs. adults.

To review, in Study 4, 104 US adults and 43 US children between the ages of 4.02-5.59 years (median: 4.73y) each assessed two target characters on 18 mental capacities, with all aspects of the experimental design tailored to be appropriate for this youngest age group. This study employed the "edge case" variant of the general approach, with participants assessing both a beetle or a robot in sequence (with order counterbalanced across participants). (See Chapter II for detailed methods.)

Special notes on data processing and analysis

As in Studies 2 and 3, to facilitate comparison between children and adults in Study 4, I use adults' *BODY*, *HEART*, and *MIND* scales (as described in Chapter IV) to analyze both age groups.

Results

Children vs. adults

See Figure 5.5, panel A, for *BODY*, *HEART*, and *MIND* scores for both target characters among the 4- to 5-year-old children and adults in Study 4. On the whole, participants' assessments of these two "edge cases" in Study 4 were similar to those of adults' and 7- to 9-year-old children in Study 2.

As in Study 2, in the aggregate, both children and adults seem to have considered the beetle (the animate character) to be a being with a moderately high degree of physiological sensations (mean *BODY* score among adults: 0.77, 95% CI: [0.72-0.83]; among children: 0.73, 95% CI: [0.66-0.80]) and perceptual-cognitive capacities (mean *MIND* score among adults: 0.61, 95% CI: [0.55-0.66]; among children: 0.56, 95% CI: [0.47-0.65]). Adults granted relatively little in the way of social-emotional abilities to the beetle (mean *HEART* score among adults: 0.23, 95% CI: [0.17-0.29]), but—as with the older children in Study 2—children's *HEART* scores tended to hover around the midpoint of the scale (mean: 0.46, 95% CI: [0.38-0.55]).

For the robot (the inanimate character) both adults and children, in the aggregate, indicated a moderate degree of perceptual-cognitive abilities (mean *MIND* score among adults: 0.62, 95% CI: [0.56-0.68]; among children: 0.55, 95% CI: [0.47-0.63]), and appeared to agree that the robot had less in the way of physiological sensations and social-emotional abilities than the beetle. However, echoing the results of Study 2, the two age groups appear to have diverged in their assessments of the absolute degree of BODY and HEART that they were willing to grant the robot: Adults granted very little in either domain (mean *BODY* score: 0.05, 95% CI: [0.03-0.07]; mean *HEART* score: 0.05, 95% CI: [0.02-0.08]), while children granted middling abilities in both domains (mean *BODY* score: 0.36, 95% CI: [0.28-0.44]; mean *HEART* score: 0.43, 95% CI: [0.35-0.51]).

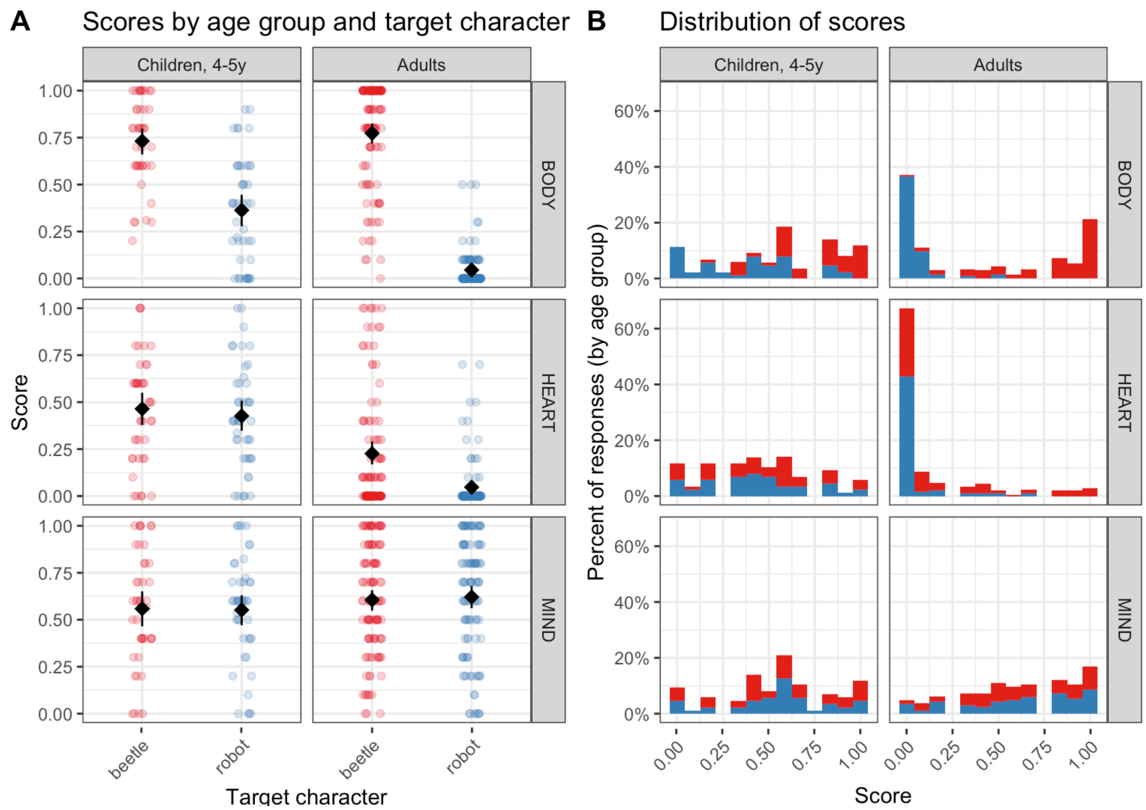

Figure 5.5: Attributions of BODY, HEART, and MIND among children (4-5y) and adults in Study 4. For each conceptual unit, scores could range from 0-1. Plots include (A) scores by target character, and (B) distributions of scores. Individual participants are plotted as small, translucent circles, and mean scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals.

Table 5.5: Regression analyses of age group differences in BODY, HEART, and MIND scores among to 4- to 5-year-old children and adults in Study 4 (scored using adults' scales, as presented in Chapter IV). For each conceptual unit, the table presents a Bayesian regression with 4 fixed effect parameters: (1) the intercept, which is an index of attributions of that conceptual unit among adults; (2) the overall difference in scores for the beetle compared to the grand mean ('GM') among adults; (3) the difference between children's and adults' scores, collapsing across target characters; and (4) the interactive effect of age group and target character. Age effects are highlighted in bold, because they are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	BODY			HEART			MIND		
Parameter	**b**	**95% CI**		**b**	**95% CI**		**b**	**95% CI**	
Intercept (adults)	0.41	[0.38, 0.44]	*	0.14	[0.10, 0.17]	*	0.61	[0.57, 0.65]	*
Beetle vs. GM (adults)	0.36	[0.33, 0.39]	*	0.09	[0.05, 0.12]	*	-0.01	[-0.05, 0.03]	
Children vs. adults	**0.14**	**[0.08, 0.20]**	*	**0.31**	**[0.24, 0.37]**	*	**-0.06**	**[-0.13, 0.02]**	
Interaction	**-0.18**	**[-0.24, -0.12]**	*	**-0.07**	**[-0.14, -0.01]**	*	**0.01**	**[-0.06, 0.09]**	

Table 5.6: Regression analyses of age-related differences in BODY, HEART, and MIND scores among the 4- to 5-year-old children in Study 4 (scored using adults' scales, as presented in Chapter IV). For each conceptual unit, the table presents a Bayesian regression with 4 fixed effect parameters: (1) the intercept, which is an index of attributions of that conceptual unit, collapsing across target characters, at the mean age for this sample (4.73y); (2) the overall difference in scores for the beetle compared to the grand mean ('GM'), at the mean age for this sample (4.73y); (3) the overall effect of age on scores, collapsing across target characters; and (4) the interactive effect of age and target character. The last two effects are highlighted in bold, because they are the primary parameters of interest for these analyses. In addition to the fixed effects listed here, these regressions included random intercepts for participants to account for the within-subjects design of this study. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	BODY			HEART			MIND		
Parameter	**b**	**95% CI**		**b**	**95% CI**		**b**	**95% CI**	
Intercept	0.55	[0.48, 0.61]	*	0.45	[0.38, 0.51]	*	0.56	[0.49, 0.63]	*
Beetle vs. GM	0.19	[0.14, 0.23]	*	0.02	[-0.04, 0.08]		0.00	[-0.05, 0.06]	
Exact age (centered)	**0.11**	**[-0.05, 0.27]**		**0.03**	**[-0.13, 0.19]**		**0.10**	**[-0.07, 0.27]**	
Interaction	**0.12**	**[0.01, 0.22]**	*	**-0.04**	**[-0.17, 0.10]**		**0.08**	**[-0.06, 0.21]**	

A series of Bayesian regression analyses confirmed these overall impressions, yielding remarkably similar results to the parallel comparison between 7- to 9-year-old children and adults in Study 2 (see Table 5.5).

As in Study 2, children's *BODY* scores were generally higher than adults'. This appears to have been particularly true for the robot; as a result, the difference between the beetle and the robot was attenuated among children, relative to adults (i.e., the interaction term was non-zero). Again, as in Study 2, children's *HEART* scores were also higher than adults'. In Study 4, this difference between children and adults was slightly more pronounced for the robot than the beetle. And yet again, as in Study 2, there were no substantial differences between children and adults in their *MIND* scores.

Age-related differences between 4-5y

Here, I explore age-related differences within the child sample: How might children's attributions change over the age range included in this study? Unlike Studies 2-3, which each included a relatively wide age range (7-9y in Study 2; 4-9y in Study 3), the age range included in Study 4 was relatively narrow, rendering it less likely to observe age-related differences. Nonetheless, based on the age group comparisons discussed in the previous sections, I expected that the most likely age-related differences to emerge would be for increases in age to be associated with lower *BODY* scores, particularly for the robot; and with lower *HEART* scores for both target characters.

Figure 5.6: Changes in attributions of BODY, HEART, and MIND among 4- to 5-year-old children in Study 4. For each conceptual unit, scores could range from 0-1. Individual children are plotted as small, translucent circles; mean scores among adults are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. Lines correspond to simple linear regressions (formula: score ~ age).

However, neither of these differences was present in this sample of children. Instead, the only reliable age-related difference to emerge was an increasing differentiation of the beetle and the robot in the BODY domain, driven—surprisingly—by an *increase* in *BODY* scores for the beetle (rather than a decrease in *BODY* scores for the robot). See Figure 5.6, and see Table 5.6 for the full results of these regression analyses.

Discussion

Adults' attributions of BODY, HEART, and MIND to the two "edge cases" included in Study 4 were very similar to their attributions in Study 2. As in previous studies, the difference between animates vs. inanimates was dramatic in the BODY domain, smaller in the HEART domain, and in this case non-existent in the MIND domain.

Study 4 aligned with Study 3 in providing evidence for a distinction between animate vs. inanimate characters in BODY attributions within the youngest sample tested in these studies (4- to 5-year-old children). As in previous studies, this distinction appears to have increased with age—but in contrast to previous studies, this appears to have been driven primarily by increases in *BODY* scores for the animate character (the beetle).

Like children in Studies 2 and 3, the 4- to 5-year-old children in this study generally attributed greater social-emotional abilities (HEART) to these characters, relative to adults. Finally, like the 7- to 9-year-old children in Study 2 (who also assessed these "edge cases"), the 4- to 5-year-old children demonstrated rather adult-like attributions in the MIND domain. The lack of age-related differences within the child sample in the domains of HEART and MIND should be interpreted with some caution, given the smaller sample size and more limited age range of children in Study 4 compared to Studies 2 and 3.

General discussion

In this chapter, I focused on a third aspect of the development of conceptual representations of mental life: the deployment of these representations in assessments of particular beings in the world. I focused in particular on analyses that might bring to light how representations of mental life interact with distinctions between animate beings vs. inanimate objects.

An adult endpoint

Taken together, these studies shed new light on the role of attributions of mental life in adults' distinction between animate beings and inanimate objects. These findings are perhaps easiest to understand in terms of the visualizations of *BODY*, *HEART*, and *MIND* scores for animate vs. inanimate characters presented in Figures 5.8 and 5.9.

First, in the aggregate, the largest and most robust animate-inanimate distinctions among adults in these studies were in the BODY domain, for which the difference between animate vs. inanimate characters spanned at least half of the 0-1 scale across all of the studies included in this dissertation (see Figure 5.7, top row). A regression analysis confirmed that adult participants distinguished strongly between animate vs. inanimate characters in their *BODY* scores; collapsing across studies this distinction was still present, but substantially diminished, in the HEART and MIND domains. Visual inspection of Figure 5.7 (top row) suggests that the difference between animate and inanimate characters in *BODY* scores was quite consistent across studies, while differences in *HEART* and *MIND* scores varied rather dramatically. (See also the "Robot vs. GM" and "Animate characters vs. GM" rows in Tables 5.1, 5.3, and 5.5 for differences between animate vs. inanimate characters among adults each study separately.)

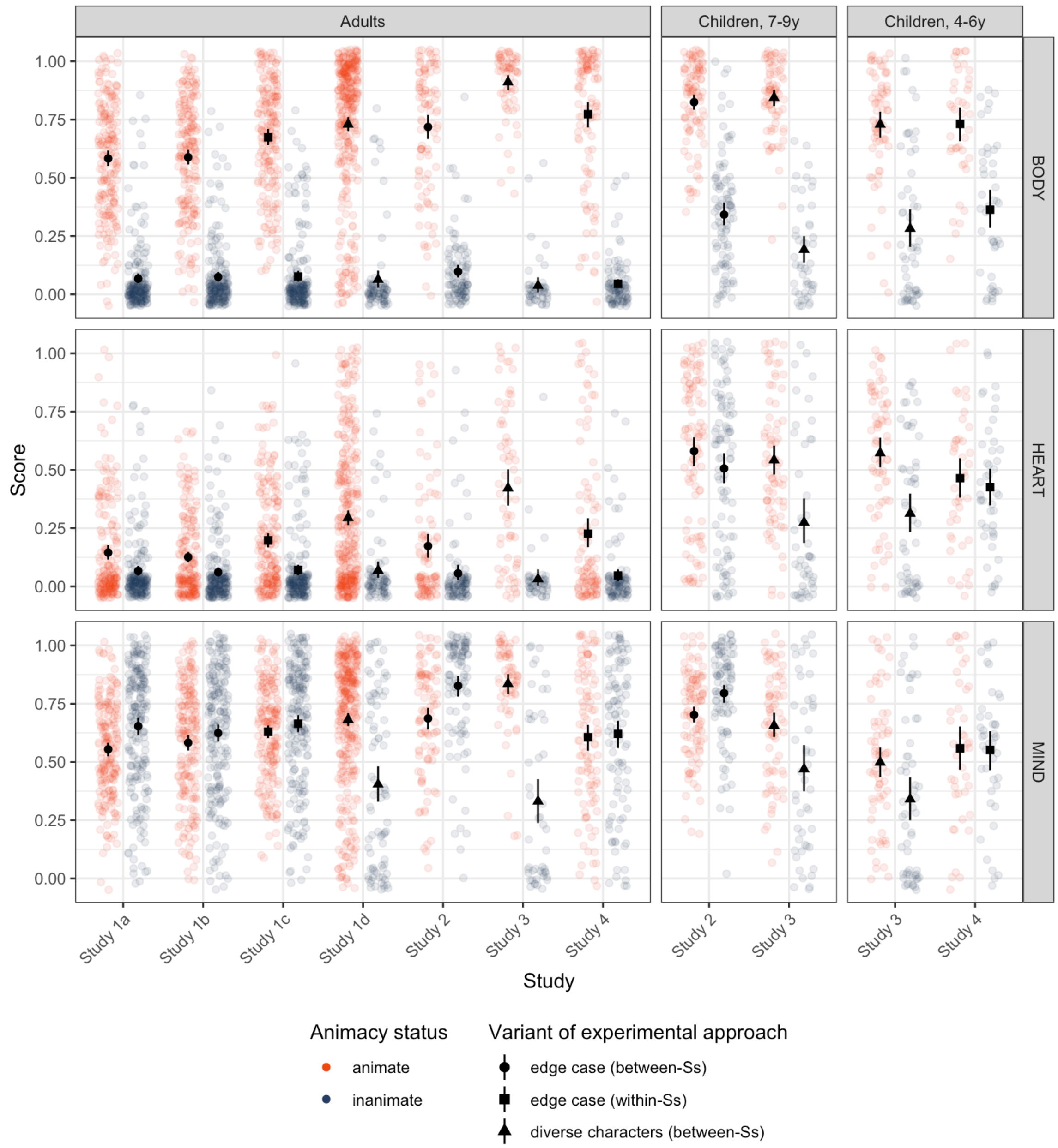

Figure 5.7: Differentiation of animate vs. inanimate characters in participants' endorsements of BODY, HEART, and MIND across studies and age groups, using adults' BODY, HEART, and MIND scales for all samples. In Studies 1a, 1b, and 2, each participant assessed either an animate 'edge case' (a beetle) or an inanimate edge case (a robot). In Study 1c and Study 4, each participant assessed both an animate and an inanimate 'edge case' (a beetle and a robot). In Study 1d, each participant assessed either one of 17 animate beings (adult, child, infant, person in a persistent vegetative state, fetus, chimpanzee, elephant, dolphin, bear, dog, goat, mouse, frog, blue jay, fish, beetle, or microbe) or one of four inanimate objects (robot, computer, car, stapler); similarly, in Study 3, each participant assessed either one of five animate characters (elephant, goat, mouse, bird, or beetle) or one of four inanimate characters (teddy bear, doll, robot, or computer). For each conceptual unit, scores could range from 0-1. Individual participants are plotted as translucent circles, and mean scores are plotted as larger, solid black points. Error bars are 95% bootstrapped confidence intervals.

Table 5.7: Regression analysis of distinctions between animate vs. inanimate target characters in attributions of BODY, HEART, and MIND among US adults, 7- to 9-year-old children, and 4- to 6-year-old children in Studies 2-4. In terms of fixed effects, this Bayesian regression included all main effects and interactions between factor (dummy-coded for comparisons to the BODY domain as a baseline), age group (dummy-coded for comparisons to adults as a baseline), and animacy status (effect-coded for comparisons of animate characters to the grand mean collapsing across characters). The animate-inanimate comparisons (including interactions with age group) are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

Parameter	**b**	**95% CI**	
BODY			
BODY, among adults (intercept)	-0.09	[-0.29, 0.18]	
BODY, older children (7-9y) vs. adults (main effect)	0.13	[0.09, 0.17]	*
BODY, younger children (4-6y) vs. adults (main effect)	0.12	[0.08, 0.17]	*
BODY, animates vs. inanimates, among adults (main effect)	**0.45**	**[0.38, 0.52]**	*
BODY, animates vs. inanimates, older children vs. adults (2-way interaction)	**-0.11**	**[-0.14, -0.07]**	*
BODY, animates vs. inanimates, younger children vs. adults (2-way interaction)	**-0.19**	**[-0.23, -0.15]**	*
HEART			
HEART vs. BODY, among adults (main effect)	-0.27	[-0.30, -0.25]	*
HEART vs. BODY, older children (7-9y) vs. adults (2-way interaction)	0.21	[0.17, 0.25]	*
HEART vs. BODY, younger children (4-6y) vs. adults (2-way interaction)	0.20	[0.15, 0.24]	*
HEART vs. BODY, animates vs. inanimates, among adults (2-way interaction)	**-0.26**	**[-0.28, -0.23]**	*
HEART vs. BODY, animates vs. inanimates, older children vs. adults (3-way interaction)	**0.05**	**[0.01, 0.10]**	*

Parameter	b	95% CI	
HEART vs. BODY, animates vs. inanimates, younger children vs. adults (3-way interaction)	**0.13**	**[0.09, 0.18]**	*
MIND			
MIND vs. BODY, among adults (main effect)	0.24	[0.22, 0.27]	*
MIND vs. BODY, older children (7-9y) vs. adults (2-way interaction)	-0.12	[-0.16, -0.08]	*
MIND vs. BODY, younger children (4-6y) vs. adults (2-way interaction)	-0.29	[-0.34, -0.24]	*
MIND vs. BODY, animates vs. inanimates, among adults (2-way interaction)	**-0.34**	**[-0.36, -0.31]**	*
MIND vs. BODY, animates vs. inanimates, older children vs. adults (3-way interaction)	**0.06**	**[0.02, 0.11]**	*
MIND vs. BODY, animates vs. inanimates, younger children vs. adults (3-way interaction)	**0.17**	**[0.13, 0.22]**	*

Table 5.8: Summary statistics for BODY, HEART, and MIND scores in Studies 2-4, organized by the age group of participants and the animacy status of target characters.

		BODY (B)		HEART (H)		MIND (M)		Correlations (Pearson's r)		
Animacy status	**Age group**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**B vs. H**	**B vs. M**	**H vs. M**
Study 2										
animate	Adults	0.22	0.27	-0.33	0.27	0.19	0.24	0.38	0.68	0.43
	Children, 7-9y	0.32	0.17	0.08	0.33	0.20	0.18	0.28	0.38	0.20
inanimate	Adults	-0.40	0.14	-0.44	0.17	0.33	0.23	0.69	0.25	0.08

		BODY (B)		HEART (H)		MIND (M)		Correlations (Pearson's r)		
Animacy status	**Age group**	**mean**	**sd**	**mean**	**sd**	**mean**	**sd**	**B vs. H**	**B vs. M**	**H vs. M**
	Children, 7-9y	-0.16	0.24	0.01	0.33	0.30	0.19	0.64	0.24	0.22
Study 3										
animate	Adults	0.41	0.14	-0.08	0.33	0.34	0.18	0.29	0.68	0.46
	Children, 7-9y	0.34	0.15	0.04	0.28	0.16	0.24	0.39	0.36	0.16
	Children, 4-6y	0.23	0.23	0.07	0.28	0.00	0.27	0.54	0.45	0.39
inanimate	Adults	-0.46	0.12	-0.47	0.13	-0.17	0.36	0.89	0.20	0.01
	Children, 7-9y	-0.31	0.20	-0.23	0.33	-0.03	0.35	0.65	0.29	0.23
	Children, 4-6y	-0.22	0.32	-0.19	0.31	-0.16	0.34	0.80	0.62	0.71
Study 4										
animate	Adults	0.27	0.28	-0.27	0.32	0.11	0.29	0.42	0.75	0.58
	Children, 4-6y	0.23	0.23	-0.04	0.29	0.06	0.30	0.31	0.43	0.51
inanimate	Adults	-0.45	0.10	-0.45	0.14	0.12	0.31	0.63	0.24	0.23
	Children, 4-6y	-0.14	0.28	-0.07	0.27	0.05	0.28	0.59	0.56	0.56

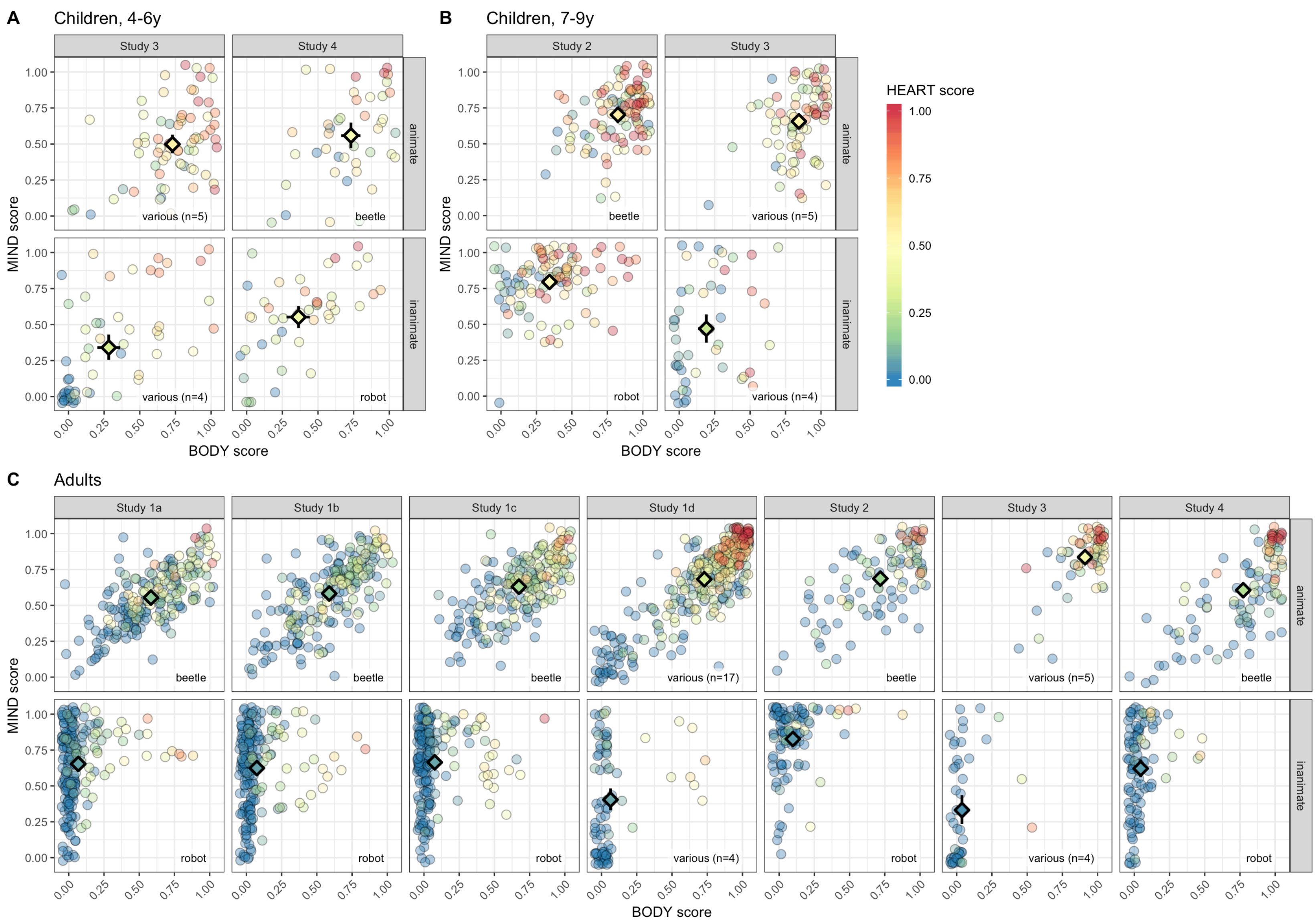
A
Children, 4-6y
B
Children, 7-9y
C
Adults
Study 1a
Study 1b
Study 1c
Study 1d
Study 2
Study 3
Study 4
animate
inanimate
beetle
robot
various (n=5)
various (n=4)
various (n=17)
MIND score
BODY score
HEART score
0.00
0.25
0.50
0.75
1.00

Figure 5.8: Participants' endorsements of BODY, HEART, and MIND for animate vs. inanimate characters, using adults' BODY, HEART, and MIND scales for all samples. (A) 4- to 6-year-old children in Studies 3 and 4. (B) 7- to 9-year-old children in Studies 2 and 3. (C) Adults in Studies 1-4. In Studies 1a, 1b, and 2, each participant assessed either an animate 'edge case' (a beetle) or an inanimate edge case (a robot). In Study 1c and Study 4, each participant assessed both an animate and an inanimate 'edge case' (a beetle and a robot). In Study 1d, each participant assessed either one of 17 animate beings (adult, child, infant, person in a persistent vegetative state, fetus, chimpanzee, elephant, dolphin, bear, dog, goat, mouse, frog, blue jay, fish, beetle, or microbe) or one of four inanimate objects (robot, computer, car, stapler); similarly, in Study 3, each participant assessed either one of five animate characters (elephant, goat, mouse, bird, or beetle) or one of four inanimate characters (teddy bear, doll, robot, or computer). For each conceptual unit, scores could range from 0-1. Individual participants are plotted as translucent circles, and mean scores are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals.

Beyond this, there appear to be have been differences between animate vs. inanimate characters in the *variability* of adults' BODY, HEART, and MIND attributions. In each study, adults' attributions to animate beings varied widely along all three dimensions: BODY, HEART, and MIND (see Figure 5.7, top row; Figure 5.8, panel C, top row; and Table 5.8 for standard deviations across study, animacy status, and domain). This variability has several possible sources, including differences in opinions or beliefs across individual participants (especially relevant for attributions to the animate "edge case"—the beetle—in Studies 1a, 1b, 1c, 2, and 4), as well as differences in the (perceived) mental capacity profiles of different animate beings (especially relevant for attributions to the "diverse characters" featured in Study 1d and Study 3).

Moreover, these attributions appear to have varied in tandem (see Figure 5.8 and Table 5.8). *BODY* and *MIND* scores for animate beings were particularly strongly correlated (Pearson's r = 0.68-0.75 across Studies 2-4), and scores for each of these more "basic" conceptual units (per Chapter IV) were also correlated quite strongly with *HEART* scores (BODY vs. HEART: r = 0.29-0.42; MIND vs. HEART: r = 0.43-0.58). Indeed—to pick up on a thread from the General Discussion in Chapter IV—attributions of HEART to animate beings appear to have been *jointly* dependent on attributions of *both* BODY and MIND; see Figure 5.8, panel C, in which strong *HEART* scores are present only among participants who received strong *BODY* and *MIND* scores—i.e., reddish points are only present in the upper right corner of the plot.

Meanwhile, adults' attributions to inanimate objects (Figure 5.8, panel C, bottom row) varied particularly strongly in the MIND domain, but seemingly less in the domains of BODY and HEART (see also Table 5.8). Among inanimate objects, *BODY* and *HEART* scores were particularly strongly correlated (Pearson's r = 0.63-0.89 across

Studies 2-4)—but high scores in either of these two domains were quite rare. Scores for the two more "basic" conceptual units (per Chapter IV), *BODY* and *MIND*, were only weakly correlated (Pearson's r = 0.20-0.25 across Studies 2-4), and *MIND* and *HEART* scores were virtually independent (MIND vs. HEART: r = 0.01-0.23).

In sum, these studies suggest that—in addition to biological properties like having blood, digesting food, growing, reproducing, and dying—US adults distinguish animate beings from inanimate objects by their high degree of perceived physiological sensations (BODY)—and, to a lesser degree, their superior social-emotional abilities (HEART) and perceptual cognitive abilities (MIND). Above and beyond perceiving animates vs. inanimates to differ in their "average" mental capacities, adults in these studies also appeared to conceptualize animate beings as entities who *vary* quite dramatically in all three aspects of mental life, and for whom these different aspects of mental life may be closely related. In contrast, in this consensus view inanimate objects appear to be seen as entities that vary mostly in their perceptual-cognitive abilities (MIND), with consistently little of the physiological sensations or social-emotional abilities of the BODY and HEART.

A developmental trajectory

As among adults, the largest and most robust animate-inanimate distinctions among children in these studies were also in the BODY domain—but these distinctions were not quite as dramatic among children as they were among adults (see Figure 5.7, center and right columns). The regression analysis reported in the previous section confirmed that the difference in *BODY* scores between animate vs. inanimate characters was smaller both among older children (7-9y) and particularly among younger children (4-6y) than it was among adults (see Table 5.7). This appears to have been driven primarily by children over-attributing BODY to inanimate characters: While adults' *BODY* scores were near zero for inanimate beings, children's *BODY* scores for inanimate characters hovered, on average, around 0.25 on a scale from 0 to 1 (see Figure 5.7).

In line with an attenuated animate-inanimate distinction in the BODY domain, the differences in the strength of the animate-inanimate distinction across domains were substantially attenuated, both among older children and particularly among younger children, as compared to adults.

In terms of variability, both older and younger children appear, if anything, to have demonstrated the reverse pattern to that of adults: *BODY* scores appear to have been more variable for *inanimate* than animate characters, and *HEART* and *MIND* scores appear to have been roughly equally variable for animate and inanimate characters among children. Moreover, covariance relationships among these three aspects of mental life appeared to be no clearer or stronger among animates than they were among inanimates. In my view, there were no clear indications of substantial development between early and middle childhood in these aspects of the deployment of conceptual representations of mental life, suggesting that this kind of fine tuning might be ongoing well into middle childhood—perhaps into adolescence or beyond. (See Table 5.8 for all standard deviations and correlations.)

In sum, while I characterized adults as conceptualizing animate beings as entities who vary more dramatically in their BODY and HEART capacities than inanimate objects (and for whom all three aspects of mental life are more closely related), I do not consider Studies 2-4 to offer strong evidence that differences in perceived variability in mental capacities or differences in perceived relationships among different aspects of mental life are important parts of children's animate-inanimate distinction. Instead, these studies suggest that the primary role of the animate-inanimate distinction in 4- to 9-year-old children's attributions of mental life seems to be governing their "average" attributions of physiological sensations (BODY)—and to a lesser degree, social-emotional (HEART) and perceptual cognitive abilities (MIND)—to various entities in their world.

Beyond the animate-inanimate distinction, there were more general age-related differences that emerged from this analysis of the deployment of conceptual representations of mental life to various beings in the world. (See Figure 5.7 for a summary of comparisons across age groups in all studies.) The most striking and consistent was in the HEART domain: Across all child samples in Studies 2-4, both older and younger children tended to grant both animate and inanimate characters more HEART abilities than did adults. In Study 2 and Study 4 children in both age groups also granted both "edge cases" (beetles and robots) more BODY abilities than did adults, but this general age-related difference did not extend to the wider set of "diverse characters" featured in Study 3 (instead, in this study, children appeared to *under*-attribute BODY to animate characters, while continuing to over-attribute BODY to inanimate characters). Across studies, these over-attributions of HEART and (when relevant) BODY declined with age (i.e., became more adult-like). Finally, there were some hints that 4- to 6-year-old children might have *under*-attributed MIND to both animate and inanimate characters, relative to adults (Study 3; but cf. Study 4), and, relatedly, that both 4- to 6-year-old and 7- to 9-year-old children's attributions of MIND to animate and inanimate characters increased (i.e., became more adult-like) with age (Studies 2 and 3; but cf. Study 4).

Chapter conclusion

In this chapter, I explored a third aspect of conceptual representations of mental life among US children and adults: The *deployment* of these representations in reasoning about particular entities in the world. I focused in particular on the role of the classic distinction between "animate beings" (primarily, humans and other biological animals) and "inanimate objects" (in this case, technologies as well as inert objects) in attributions of BODY, HEART, and MIND.

These studies are consistent with the following theory: By the preschool years, US children's animate-inanimate distinction includes an awareness that animate beings are more likely than inanimate objects to have physiological sensations like hunger, pain, and fatigue (what I have called BODY). This continues to be the primary axis of the distinction between the mental lives of animates vs. inanimates throughout development, increasing in size and reliability over early and middle childhood (and perhaps beyond); ultimately, US adults perceive the BODY domain to be the site of the most dramatic and robust differences in the mental lives of animate beings vs. inanimate objects.

At all ages, animates and inanimates are also perceived to differ in their social-emotional abilities (HEART) and perceptual-cognitive capacities (MIND), but among children as well as adults these differences are smaller and more variable across the particular beings in question.

Finally, at some point in later childhood or adolescence, US children come to acquire adults' intuition that animate beings are distinct from inanimate objects not only in that their mental capacities are, on average, superior (especially in the BODY domain)—but also in that their mental capacities are more *variable* across specific entities and more *correlated* across domains (BODY, HEART, and MIND). These nuances—which might be characterized as "over-hypotheses" about the mental lives of animates vs. inanimates (Goodman, 1955)—appear not to have emerged by the age of 7-9y and may instead develop later in childhood or adolescence.

In addition to this emergent theory of the refinement of mental capacity attributions to animate vs. inanimate beings, these studies also suggest that—regardless of animacy status—children may have a tendency to over-attribute both the physiological sensations of the BODY and especially the social-emotional abilities of the HEART to many entities in the world, coupled with a (weaker) tendency to *under*-attribute the perceptual-cognitive abilities of the MIND. The tendency to over-attribute HEART is particularly striking—it emerged robustly in all studies, and while attributions of HEART did appear to decline with age, they did not appear to reach "adult-like" levels even among the oldest children in these studies. This finding is consistent with the possibility that, well into middle childhood, children may maintain a general openness to untraditional social partners (both animate and inanimate).

As in previous chapters, these are not the only possible interpretation of the patterns of results presented here; I have intentionally stated these hypotheses in their strongest form, to facilitate confirmatory tests in future research. The primary role of the studies and analyses discussed here has been to inspire the hypothesis stated in the previous paragraph and to lay the foundation for these future studies.

This marks the end of my exploration of the large, rich datasets emerging from Studies 1-4. In the next and final chapter, I step back to reflect on what these three "passes" at analysis have revealed about conceptual development in this domain, how these three aspects of conceptual development (conceptual units, relational organization, and deployment) might be related to one other, and what this case study of representations of mental life might reveal about conceptual development more broadly.

CHAPTER VI: SYNTHESIS AND DISCUSSION

How do ordinary people conceptualize mental life, and how do these conceptual representations emerge and change across development? The goal of this dissertation was to explore the development of conceptual representations of mental life over early and middle childhood in the modern US context. In the preceding chapters, I argued that a simple empirical approach—asking children straightforward questions about whether familiar entities possessed specific mental capacities (e.g., “Can a beetle feel happy?”)—can offer deep insights into the cognitive architecture that supports children’s understanding of mental life. In particular, I provided an in-depth analysis of three aspects of conceptual development in this domain: (1) the conceptual units that anchor representations of mental life; (2) the organization of these conceptual units with respect to one another; and (3) the deployment of these representations in reasoning about animate beings vs. inanimate objects. Together, these analyses sketch a picture of a developmental “endpoint” for these representations among US adults and provide the first glimpse of a developmental trajectory between 4-9y of age as US children learn to reason like the adults in their cultural context.

Here I step back to synthesize what these studies have revealed about conceptual development in this domain, and to speculate about the implications of these findings for social development.

An emerging theory of conceptual units, their organization, and their deployment

To recap the findings of Chapters III-VI, the current studies are consistent with the following theory of the development of representations of mental life among US children. As I have noted elsewhere, this is far from the only possible interpretation of the pattern of results presented in this dissertation—I intentionally state a bold version of the theory here in order to lay a clear foundation for future tests of these hypotheses (and, no doubt, refinements and revisions of this theory). Figure 6.1 provides a visual depiction of this theory.

US adults’ representations of mental life are anchored by three conceptual units: BODY, HEART, and MIND. Early in life, children have access to a more limited set of conceptual units; by the preschool years, they make a broad distinction between the more visceral sensations of the BODY and the more cognitive abilities of the MIND, but have no notion of social-emotional abilities as a third, unified class of mental states. Over the course of early childhood, the set of conceptual units available to children expands in number as HEART emerges as a distinct construct; each of these conceptual units also undergoes further refinements in its content and size. The set of conceptual units reaches an adult-like state some time in the early elementary school years (i.e., early enough to appear "mature" in a snapshot of 7- to 9-year-old children).

Even by the preschool years, however—well before these conceptual units are fully mature—children already consider physiological sensations (BODY) to be particularly basic or fundamental aspects of mental life, and they quickly come to see perceptual-cognitive abilities (MIND) as roughly equally "basic." The social-emotional abilities of the HEART are already perceived to be less basic, i.e., to occupy a different position in the hierarchical structure that characterizes this conceptual domain (even though they are not yet perceived as constituting a unified third construct distinct from BODY and MIND). Over the course of early and middle childhood (and likely into adolescence), these hierarchical relationships become increasingly stark, applying more universally to any kind of "being" in the world, and the degree of consensus across individuals increases. In its "mature" state, this hierarchical structure admits of virtually no exceptions: It governs mental capacity attributions to all kinds of target entities among all individual people.

The final element of this relational structure to emerge—perhaps at some point in adolescence—is that HEART comes to be seen as not only dependent on both BODY and MIND, but *jointly* dependent on their combination. This understanding of joint dependency may emerge from one or more intuitive theories, such as a theory of how emotions work (e.g., that affective experiences have both physiological and cognitive components), or an understanding of emotions as fundamentally social phenomena (e.g., that the only entities capable of emotional experiences are social beings, and the only entities capable of social relationships are living beings with a certain degree of "intelligence").

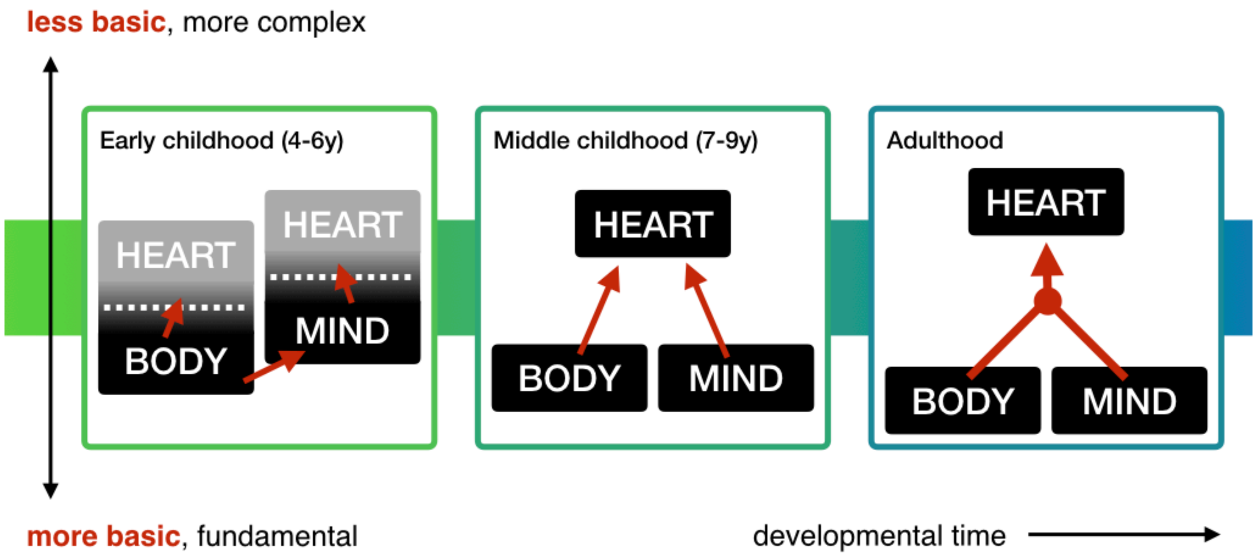

Figure 6.1: A visual depiction of my working theory of conceptual development in representations of mental life in the modern US context, featuring snapshots of this conceptual structure at three points in development. Conceptual units are depicted as black boxes. Hierarchical relationships are depicted as red arrows, with the arrowhead pointing to the less "basic" unit. The red node that these arrows pass through in the "Adulthood" snapshot represents the perceived joint dependency of HEART on both of the more basic units (BODY and MIND).

Related to this question of which entities in the world possess or participate in which aspects of mental life, from early in childhood, children's distinction between animate beings vs. inanimate objects includes an understanding—shared with adults in their cultural context—that animate beings are generally more likely to have any kind of mental capacities than inanimate objects. The BODY, in particular, is the primary axis of this distinction throughout childhood and in adulthood, with this distinction increasing in size and reliability over early and middle childhood (and perhaps beyond).

At some point in later childhood or perhaps adolescence, children come to believe that only animates, but not all animates, have social-emotional abilities—i.e., that biological animacy is necessary, but not sufficient, for HEART. Likewise, children eventually come to believe that most animates, but also some inanimates, have perceptual-cognitive abilities—i.e., that biological animacy is broadly sufficient, but not necessary, for MIND. These adjustments to the conceptual connections between mental life and animacy result in general decreases in attributions of HEART, and increases in attributions of MIND.

Finally, at some point in later childhood or adolescence, children come to share adults' intuitions (which might be considered "over-hypotheses"; Goodman, 1955) that animate beings are distinct from inanimate objects not only in that their mental capacities are, on average, superior (especially in the BODY domain)—but also in that their mental capacities are more variable across specific entities, and more correlated across domains (BODY, HEART, and MIND).

Testing and refining this emerging theory will require extensive follow-up studies with children in the current age range (4-9y) as well as older children and adolescents. Particularly useful would be studies that employ truly *experimental* designs testing specific hypotheses. To give just a few examples:

1. To test the hypothesis that preschool-age children consider physiological sensations to be more similar to social-emotional abilities than do older children (as indicated by the EFA solutions reported in Chapter III), one might ask children to make inductive inferences from one mental capacity to another (e.g., to make guesses about the mental capacities of an unfamiliar entity that is known to have a capacity for, say, hunger), with the prediction that inferences from physiological sensations to social-emotional abilities (and vice versa) will decline in strength between 4-9y of age.
2. To test the hypothesis that adults consider the physiological sensations of the BODY and the perceptual-cognitive abilities of the MIND to be more "basic" or "fundamental" than the social-emotional abilities of the HEART (as indicated by the analyses of asymmetries in mental capacity attributions reported in Chapter IV), one could provide adult participants with some operational definition of "basic" and ask adults to rate the "basic-ness" of a wide range of mental capacities, with the prediction that the mental capacities associated with HEART in the current studies would be rated as less "basic" than the capacities associated with BODY or MIND.
3. To test the hypothesis that, sometime between middle childhood and adulthood, children come to think of biological animacy as necessary but not sufficient for the social-emotional abilities of the HEART (as suggested by the differences between children and adults in their attributions of HEART to

animates vs. inanimates reported in Chapter V), one might ask children and adolescents (covering a wide age range, e.g., 7-17y) explicit questions about the relationship between animacy and social-emotional experience. For example, one could ask broad questions about the general relationship between animacy and HEART (e.g., "Is there anything that's not alive but still as emotions?"), or more pointed questions about specific beings that might plausibly be considered to have HEART without being a living thing (e.g., "What about a really advanced kind of robot, do you think it could ever have any kind of emotions?"; "What about something like a spirit or a ghost—do you think that could be real, and if it were real, do you think it could ever have any kind of emotions?"). If the differences documented in Chapter V are truly *developmental* differences, one would predict that answers to these questions would become more negative with age over the course of later childhood and adolescence; if any of these differences were reflective of cohort differences, rather than development, one would predict that even adolescents might answer these questions more positively than adults.

These are just a few of the ways in which specific aspects of this theory could be probed in more focused confirmatory tests. In addition to this, examining snapshots of a larger number of narrower age ranges between early childhood and adulthood; developing analyses that aim to capture these aspects of conceptual development more continuously, rather than binning children into age groups; and designing longitudinal studies to capture conceptual change at the level of the individual, rather than in the aggregate, could all provide converging evidence or could challenge the theoretical framework I have proposed.

"Edge cases" vs. "diverse characters" approaches

Across the current studies, I employed two strategies for gauging conceptual representations of mental life through variability in participants' mental capacity attributions: (1) asking participants to assess the mental capacities of two selected "edge cases" in social reasoning, whose mental lives I presumed would elicit different responses across individual participants (a beetle and a robot; Studies 1a-1c, 2, and 4); and (2) asking participants to assess a diverse range of target characters (e.g., humans and a wide variety of other animals, technologies, inert objects), whose mental lives I presumed would be perceived to differ (Study 1d and Study 3). These two "variants" of my experimental approach were introduced in Chapter II; here I discuss the extent to which they provided converging or diverging evidence about conceptual units, their organization, and the deployment of representations of mental life over development.

The two studies with younger children (Study 3, "diverse characters" variant; Study 4, "edge case" variant) varied along so many dimensions—the set of mental capacities included; the physical setup, experimental setting, experimenter's script, and the amount of scaffolding provided for using the response scale; the between- vs. within-subjects design; the average age of participants—that differences between studies cannot reasonably be interpreted as arising from differences in the variant of the experimental approach alone. Given this, I focus my comparisons of these two variants on adults (seven samples: Studies 1a-1d, 2, 3, and 4) and 7- to 9-year-old children (two samples: Study 2 and Study 3).

Conceptual units

In terms of conceptual units (Chapter III), the "edge case" and "diverse characters" variants appear to have yielded very similar results.

Among adults, all seven datasets were well accounted for by a three-factor exploratory factor analysis solution featuring conceptual units corresponding to BODY, HEART, and MIND. There was only one adult sample—in Study 2, one of the five studies with adults to employ the "edge case" variant of the approach—for which there was any compelling evidence for a more complex solution (featuring four or more factors), and no adult samples for which there was any indication of a simpler underlying structure (featuring fewer than three factors; see Chapter III, Table 3.1). The BODY, HEART, and MIND factors were qualitatively very similar across adult samples, and accounted for similar proportions of the shared variance in each EFA solution (see Chapter III, Figure 3.5, panel C).

The two studies with 7- to 9-year-old children (Study 2, "edge case" variant; Study 3, "diverse characters" variant) also converged in their EFA results: Both studies provided strong evidence for a three-factor solution (see Chapter III, Table 3.1), with qualitatively similar BODY, HEART, and MIND factors. The proportion of the shared variance explained by each of these three factors appeared to be more variable across these two studies, among older children, with the HEART factor explaining a disproportionately large amount of variance in mental capacity attributions to the edge cases featured in Study 2, but not to the diverse characters featured in Study 3 (see Chapter III, Figure 3.5, panel C). This is particularly interesting given how dramatically children in this study over-attributed capacities related to the HEART to both of these edge cases, relative to adults (see Chapter VI)—but Studies 2 and 3 also differed substantially in the number of mental capacities included in their design (40 mental capacities in Study 2 vs. 20 mental capacities in Study 3), making it difficult to determine (without further studies) whether the variant of the experimental approach had an impact on the estimated size of conceptual units. In any case, the broad picture of three conceptual units, which correspond closely to the BODY, HEART, and MIND units of adults, was quite similar across these two studies with 7- to 9-year-old children.

In sum, for both adults and 7- to 9-year-old children, the suites of mental capacities that tended to "hang together" when individual participants disagreed in their assessments of the mental lives of "edge cases" were strikingly similar to the suites of mental capacities that tended to "hang together" when target characters were perceived to vary in their mental capacity profiles. Although these two variants of the experimental approach relied to varying degrees on different sources of variability—individual differences in opinion vs. (perceived) differences between target characters—both yielded correlation structures that quite plausibly reflect a common set of latent constructs: the conceptual units that I have called BODY, HEART, and MIND.

Organization

In terms of the organization of these conceptual units (Chapter IV), the "edge case" and "diverse characters" approaches both appear to have captured the more stable aspects of the relationships between BODY, HEART, and MIND (namely, that BODY and MIND appear to be more "basic" than HEART), while each also revealing somewhat different aspects of the finer details of this relational structure (including the nature of the relationship between BODY and MIND, as well as the strength of the correlations among all three conceptual units).

Among adults, the asymmetries in scores on the *BODY* vs. *HEART* scales were strikingly consistent across studies: Virtually all adult participants, in all studies, endorsed BODY abilities at least as strongly as, and often more strongly than, HEART abilities—regardless of which character they assessed (and, by extension, regardless of which variant of the experimental paradigm was employed in that study). The same could be said of the asymmetries in scores on the *MIND* vs. *HEART* scales: Virtually all adult participants, in all studies, endorsed MIND abilities at least as strongly as, and often more strongly than, HEART abilities. The MIND vs. HEART asymmetry appears to have been estimated to be slightly smaller in the two adult samples from studies that used the "diverse characters" variant (Study 1d and Study 3) than in the samples from studies that used the "edge cases" variant (Studies 1a-1c, 2, and 4), but the asymmetry was clearly present in all adult samples. In Chapter IV I took these reliable asymmetries to be evidence that BODY and MIND are more basic, fundamental aspects of mental life, while HEART is more complex and contingent on the presence of BODY and MIND. The "edge case" and "diverse characters" variants of the experimental approach both provided strong evidence for this aspect of the relational structures among conceptual units among adults.

Among 7- to 9-year-old children it also seems to be true that both variants of the experimental approach yielded similar pictures of the relationships between BODY vs. HEART and MIND vs. HEART: The asymmetries between the more "basic" units (BODY and MIND) vs. HEART were generally similar across the two samples of older children, regardless of which variant of the experimental approach was employed. The only exception to this was that in Study 2 ("edge case" variant), the asymmetry in 7- to 9-year-old children's *BODY* vs. *HEART* scores appears to have been smaller than the corresponding asymmetry in Study 3 ("diverse characters" variant); after accounting for other aspects of the experimental design this asymmetry was not differentiable from zero.

Meanwhile, the "edge case" and "diverse characters" variants of the experimental approach yielded much more variable pictures of the relationship between the two more "basic" units—BODY and MIND, both among adults and among 7- to 9-year-old children.

Among adults, all five of the studies that featured edge cases as target characters suggested that adults tended to endorse MIND more strongly than BODY (albeit not with the same strictness as in the BODY vs. HEART and MIND vs. HEART asymmetries just described); indeed, these studies estimated this asymmetry to be roughly as strong as the asymmetry between BODY vs. HEART. The two studies that featured diverse characters, however, appear to have estimated this asymmetry in adults' *BODY* vs. *MIND* scores to be much smaller and more variable across target characters, with some target characters eliciting asymmetries in the opposite direction (stronger endorsements of BODY than MIND).

This same pattern holds true among 7- to 9-year-old children: In Study 2 ("edge case" variant), children tended to endorse MIND more strongly than BODY on average, while in Study 3 ("diverse characters" variant), there was no systematic asymmetry in children's *BODY* vs. *MIND* scores, which reflected the fact that this asymmetry ran in opposite directions for different target characters.

A final aspect of the relationships among conceptual units that I explored in Chapter IV was the correlations among scores on *BODY*, *HEART*, and *MIND* scales. In general, scores on all three scales were positively correlated, as I would expect if all three scales tapped into different aspects of the same more general phenomenon (what I have called "mental life"). However, among both adults and 7- to 9-year-old children, the correlations between BODY vs. MIND appear to have been much stronger in studies that employed the "diverse characters" variant of the approach (Study 1d and Study 3) than in studies that employed the "edge cases" variant (Studies 1a-1c, 2, and 4). A post-hoc visual inspection of Figure 4.1, panel D2, and Figure 4.6, panel A2, suggests that this may be due to the inclusion of more animate than inanimate characters: In both cases, the correlations between BODY vs. MIND appears to have been quite strong among animate characters, and closer to zero among inanimate characters, and the preponderance of animate characters in these studies (17 animates vs. 4 inanimates in Study 1d; 5 animates vs. 4 inanimates in Study 3) may have tipped the balance toward stronger correlations in these cases. Whether these are inflated estimates of the BODY-MIND relationship (because of this imbalance in experimental design), or more accurate estimates (because this imbalance favors the kinds of entities that are the primary targets of reasoning about mental life in the course of most people's ordinary lives) is a difficult judgment to make.

In sum, for both adults and 7- to 9-year-old children, the relationships among BODY and MIND, on the one hand, and HEART, on the other, were generally similar across the two variants of the experimental approach, both in the strength of the positive correlations across conceptual units (if a target was judged to have BODY or MIND abilities, it was more likely to be judged to have HEART abilities) and in the asymmetries between more "basic" vs. less "basic" units (targets were generally judged to have more BODY and MIND abilities than HEART abilities). In contrast, correlations and asymmetries between these two more basic conceptual units, BODY and MIND, appear to have been varied more in their manifestations across the "edge case" vs. "diverse characters" approaches—seemingly because the nature of these relationships seems to have varied across target characters and animacy status. This would not have been clear if I had only conducted studies that employed the "edge case" variant of the experimental approach.

Deployment

In terms of the deployment of these conceptual representations (Chapter V), the "edge case" and "diverse characters" approaches again both appear to have captured the most stable and striking aspects of participants' use of BODY, HEART, and MIND in their reasoning about various entities in the world, while also revealing somewhat different aspects of the finer details of this application of the concept in question.

Among adults, both variants of the experimental approach highlighted the BODY domain as the primary site of distinction between animate vs. inanimate target charters. Both variants also revealed a distinction between animates vs. inanimates in adults' attributions of HEART (like BODY, adults tended to attribute more HEART to animates than to inanimates), but these differences were largest in the studies that employed the "diverse characters" variant (Study 1d and Study 3). Likewise, adults' distinction between animates vs. inanimates in the MIND domain was much greater using the "diverse characters" variant—and, if anything, seemed to run in the opposite direction when using the "edge cases" variant (with adults tending to attribute slightly more MIND to inanimate robots than to animate beetles in Studies 1a-1c, 2, and 4). All of these observations also held true for 7- to 9-year-old children in Study 2 ("edge case" variant) vs. Study 3 ("diverse characters" variant); see Figure 5.7.

In terms of general age-related differences in attributions beyond the animate-inanimate distinction, the seemingly largest and most robust of these general age-related trends—over-attributions of HEART—was clear across Studies 2-4, regardless of which variant was employed; the "edge case" variant (employed in Study 2 and Study 4) appears to have drawn particular attention to this tendency, but it was also apparent among the "diverse characters" featured in Study 3. The weaker age-related trends—possible tendencies to over-attribute BODY and to under-attribute MIND, relative to adults—were more contingent on which target characters were included in the study; see Figure 5.7.

In my view, this particular aspect of conceptual representations of mental life—what I have called their "deployment" or application to specific real-world cases—is best captured by the "diverse characters" variant of the experimental approach. I believe including a wider range of target characters provides a more comprehensive and ecologically valid picture of the deployment of this conceptual structure, because it includes more of the range of entities that are the primary targets of reasoning about mental life in the course of most people's ordinary lives. If anything I would suggest that future studies with children aim to include an even more "diverse" and representative set of characters, such as inert objects that are not anthropomorphic, natural non-living things, plants (see, e.g., Inagaki, 1996; Ojalehto, Medin, & García, 2017), and a wider range of animates, including a variety of humans.

Three *interconnected* aspects of conceptual development?

Throughout this dissertation, I have considered the development of conceptual units, their organization, and their deployment independently, one by one—but of course, these three passes at analysis and interpretation made use of the same datasets, and the theory that is emerging from this work suggests that several different conceptual changes are unfolding simultaneously or in overlapping time courses. How might these aspects of development in this domain relate to or inform each other?

Again, my comments on this topic are highly speculative, and I share them here with the purpose of laying the groundwork for future tests, refinements, and revisions.

First, I would like to highlight the possibility of a dynamic interplay between the development of conceptual units (Chapter III) and their organization (Chapter IV). In the current studies, there were examples of children demonstrating adult-like sensitivities to hierarchical relationships among mental capacities *before* demonstrating adult-like distinctions among conceptual units: For example, in the aggregate even 4- to 6-year-old children appeared to treat the physiological sensations of the BODY as more "basic" than the social-emotional abilities of the HEART (Chapter IV, Study 3 and Study 4), although as a group these children did not clearly distinguish between BODY and HEART (Chapter III, Study 3 and Study 4). At the same time, there were also examples of children's sense of hierarchical relationships being refined well after they appeared to have mastered the distinctions among conceptual units: For example, in the aggregate 7- to 9-year-old children's distinctions between BODY, HEART, and MIND appeared to be very robust and adult-like (Chapter III, Study 2 and Study 3), but the asymmetries in their attributions of BODY and MIND, on the one hand, and HEART, on the other, were not nearly as pronounced or as strict as the corresponding asymmetries among adults (among whom there were virtually no exceptions to the rule that *BODY* and *MIND* scores should always be at least as high, if not higher, than *HEART* scores; Chapter IV, Studies 1-3). In other words, an emerging sense of hierarchical relationships seems to be a precursor of more robust and adult-like distinctions among conceptual units in early childhood—but these hierarchical relationships continue to be refined (in this case, strengthened) well after the point at which children appear to have mastered these distinctions among conceptual units. Taken together, this suggests that these two aspects of conceptual development might mutually inform each other in a sort of feedback cycle over early and middle childhood.

Meanwhile, I have come to see the age-related differences in the *deployment* of these conceptual representations—in particular, children's over-attribution of HEART, relative to adults, which appears to extend well into middle childhood—as possible relics of earlier shifts in conceptual units and their organization. Even the oldest children in these studies attributed markedly more in the way of HEART, to both animate and inanimate beings, than did adults—even though these same children appeared to share adults' sense of BODY, HEART, and MIND, the general organizational structure of these three conceptual units, and even the ways in which animates vs. inanimates might vary in these three domains. Could it be the case that these over-attributions of HEART are rooted in the fact that these social-emotional abilities were only distinguished as a third aspect of mental life relatively recently? Could the "liberation" of HEART from BODY and MIND result in a period of over-zealousness about which beings in the world might have capacities in this domain, with social-emotional abilities attributed even to beings with limited BODY abilities (like robots), or limited MIND abilities (like beetles)? How might this kind of account apply to children's earlier over-attributions of BODY, or to the more subtle under-attributions of MIND?

In my view, rigorous explorations these possibilities would require adopting experimental methods and analyses that are capable of diagnosing conceptual units, their organization, and their deployment at the level of an individual child—the current studies and analyses are not sufficient. But they have opened the door to these kinds of questions, which I hope to explore in future work.

BODY, HEART, and MIND as "lenses" through which to view a being

In discussing BODY, HEART, and MIND as "conceptual units" that anchor representations of mental life, I have drawn on the language and mindset of ontology, presenting these three aspects of mental life as component parts of a larger concept, or as categories of mental capacities.

Here, I would like to propose another way of thinking about BODY, HEART, and MIND: as distinct *modes of social reasoning*. I will draw on the metaphor of BODY, HEART, and MIND as offering different "lenses" through which an observer might "view" another being's behavior—each lens being associated with a different set of knowledge, concepts, and theories about one aspect of a being's existence and identity, thereby making available to the observer specific ways of interacting with that being.[2]

Consider first: BODY. In the current studies with adults and 7- to 9-year-old children, this conceptual unit was identified by a strongly correlated suite of physiological sensations corresponding to biological needs (e.g., hunger, pain, fatigue),

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[2] This paragraph and the following three paragraphs are adapted from a manuscript currently in revision. See also Weisman et al. (2017) for an earlier take on the resonance between BODY, HEART, and MIND, on the one hand, and lay biology, social partnership, and representational theory of mind, on the other.

but also included basic affective responses related to physical survival (e.g., fear, pleasure) as well as mental capacities that support the self-initiated behaviors required to meet those needs (e.g., desire, free will; see Chapter III, as well as Weisman et al., 2017). Taken together, this suite of mental capacities calls to mind previous work on "folk biology," a conceptual system hypothesized to support an observer's reasoning about living creatures who are subject to biological needs and are motivated to action to satisfy these needs (e.g., Carey, 1985; Wellman & Gelman, 1992). Viewing another being as a living creature might focus an observer's attention on the more embodied aspects of that being's mental life, and might lead this observer to interact with the being in ways typically reserved for animals.

But the "living creature" lens is just one way to think about another being. Consider next the conceptual unit that I have called HEART. In the current studies, this unit was exemplified by both basic emotional experiences (e.g., happiness, sadness) and many more complex social emotions (e.g., pride, guilt), as well as mental capacities that support moral agency (e.g., an understanding of right and wrong, self-restraint). This calls to mind work on the conceptual underpinnings of social cognition, including reasoning about the interactions, affiliations, and moral status of social partners (e.g., Hamlin, 2013; Hamlin et al., 2013; Spelke, Bernier, & Skerry, 2013; Spelke & Kinzler, 2007). Viewing another being as a social partner might focus an observer's attention on the more affective or emotional aspects of that being's mental life, and might lead this observer to interact with the being in ways typically reserved for friends, family members, and other social partners.

Finally, consider the third conceptual unit that emerged from the current studies: MIND. In the current studies, this unit was identified by a functionally related suite of mental capacities that encompasses perceptual experiences (e.g., vision, hearing), cognitive abilities (e.g., memory), and goal pursuit (e.g., planning, making choices). This calls to mind the extensive literature on the more representational aspects of "theory of mind" (e.g., Wellman & Gelman, 1992; Wellman & Woolley, 1990)—the domain of reasoning that deals with planful, intentional agents who take in, store, and make use of information about their surroundings in order to achieve certain goals or end-states. Viewing another being as a goal-directed agent might focus an observer's attention on that being's perceptions, thoughts, beliefs, and plans, and might lead this observer to interact with the being in ways typically reserved for intelligent beings.

On this account, in any given interaction an observer might draw on one or more of these lenses to form interpretations, explanations, and predictions about another being's behaviors. Indeed, another gloss on this proposal would be that BODY, HEART, and MIND pick out three parallel lay theories of motivated action, akin to the "BELIEF + DESIRE = ACTION" framework that is so fundamental to many psychological theories, both in cognitive psychology and cognitive development (e.g., Schank & Abelson, 1975; Wellman & Woolley, 1990), and also in social psychology and affective science (Dweck, 2017; Gross, 2015).

In addition to suggesting three distinct "lenses"—or three parallel "theories"—that may play particularly important roles in the reasoning of US adults, the current work also suggests that some of these lenses or theories might be more fundamental (and perhaps more widely shared across ages and cultural contexts), while others—namely, the "social partner" lens/theory corresponding to the conceptual unit HEART—may be acquired, distinguished, or refined over an extended period of experience with the world, likely involving socialization and extensive social-cultural input. For the US children in the current studies, the finding that the social-emotional abilities may only gradually be distinguished from physiological sensations (BODY) and perceptual-cognitive abilities (MIND) over the course of early childhood suggests, for example, that preschool-age children may not have access to a distinct lens/theory for making sense of others as social partners, and instead rely on more fundamental theories of agents (MIND) and animals (BODY) to navigate the social world (each of which might incorporate more about social-emotional abilities than the corresponding MIND and BODY lenses/theories of US adults).

I highlight these speculations and connections to previous work not only because I find them interesting in their own right, but also because I see them as a bridge between the current project—which has been focused mainly on describing a *lay ontology* of mental life—and the ongoing fascination in cognitive science and developmental psychology with the *lay theories* that guide people's inferences, predictions, explanations, and behaviors. In my view it would be deeply rewarding to bring the current ontological project "to life" by connecting it to this rich tradition of work on lay theories—and, likewise, to ground ongoing work on "lay psychology" and "theory of mind" in the ecologically valid picture of children's developing ontologies of mental life that has emerged from the studies in this dissertation.

Appendix A: Additional EFA solutions

Appendix overview

In this appendix, I report additional exploratory factor analysis (EFA) results that were excluded from the main text of Chapter III, including: (a) unrotated versions of all of the EFA solutions reported in Chapter III; (b) oblimin-transformed (rather than varimax-rotated) versions of all of the EFA solutions reported in Chapter III; and (c) additional varimax-rotated EFA solutions not reported in full in Chapter III because I deemed to be redundant with the reported solutions.

Unrotated solutions

Throughout this dissertation, beginning in Chapter III, I have reported EFA solutions after applying varimax rotation. This rotation, which maximizes the sum of the variances of the squared factor loadings, is intended to make factors more interpretable by producing "simple structure" (Thurstone, 1949). Here, for completeness, I present unrotated EFA solutions for all of the EFAs reported in Chapter III.

Oblimin-transformed solutions

Throughout this dissertation, I have opted to focus on varimax-rotated EFA solutions, in which factors are constrained to be orthogonal (i.e., inter-factor correlations are 0). In my (admittedly anecdotal) experience, this rotation has tended to produce solutions that are more replicable when studies are repeated exactly, more similar across variants of the empirical approach, and easier to make factor retention decisions about. Orthogonal solutions also lend themselves more naturally to "scoring" individual participants on each of the underlying constructs because factors are, by definition, maximally distinct from one another. Since comparing EFA solutions across studies and age groups (Chapter III) and using these solutions to "score" participants on their assessments of the mental lives of different target characters (Chapter V) are two of the main goals of this dissertation, varimax rotations seemed to me to be appropriate for my current purposes.

Study 1

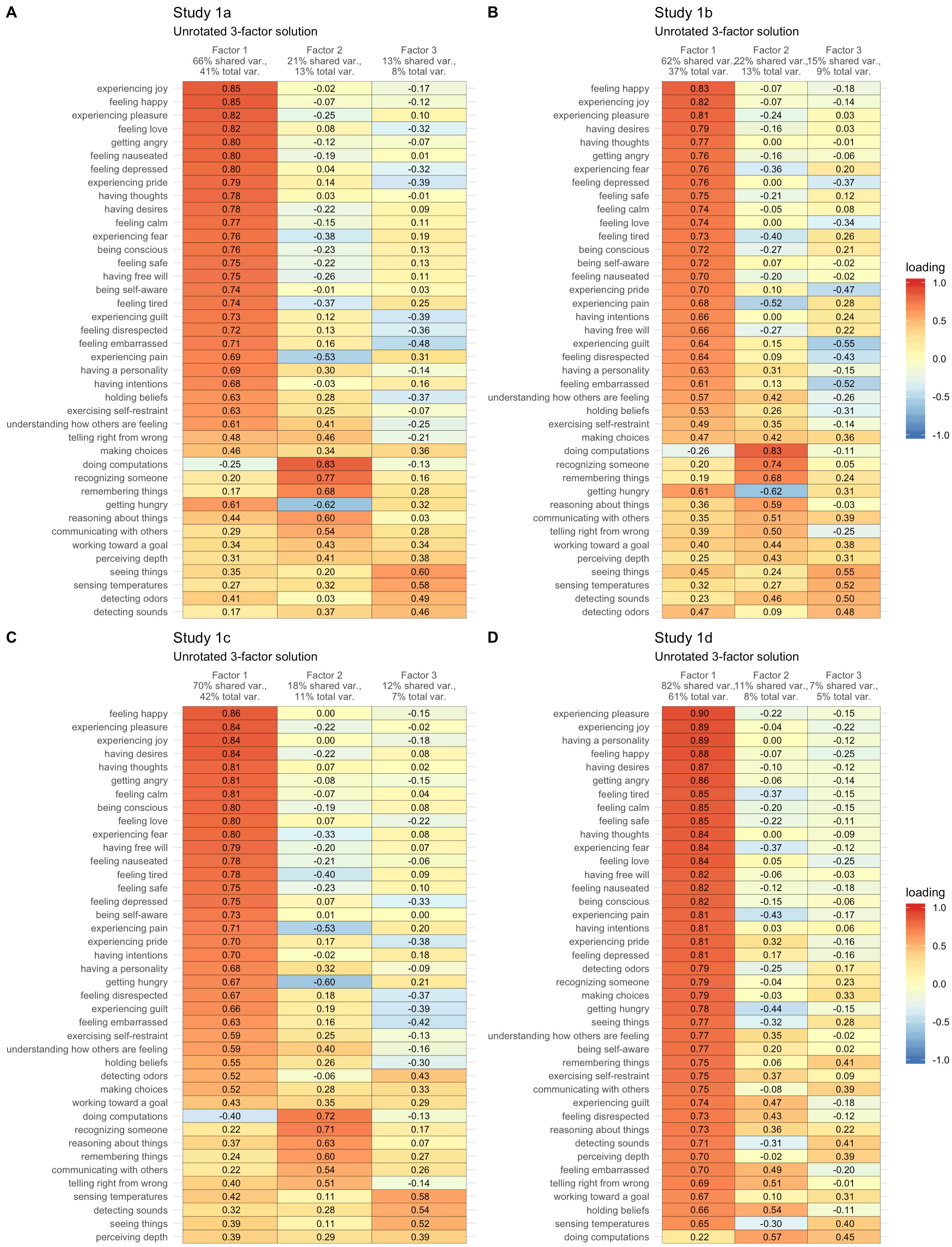


Figure A.1: Factor loadings from exploratory factor analyses of Study 1 (as reported in Chapter III), before rotation. All results are from US adult samples; see Chapter II for methods. (A) Study 1a. (B) Study 1b. (C) Study 1c. (D) Study 1d. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Study 2

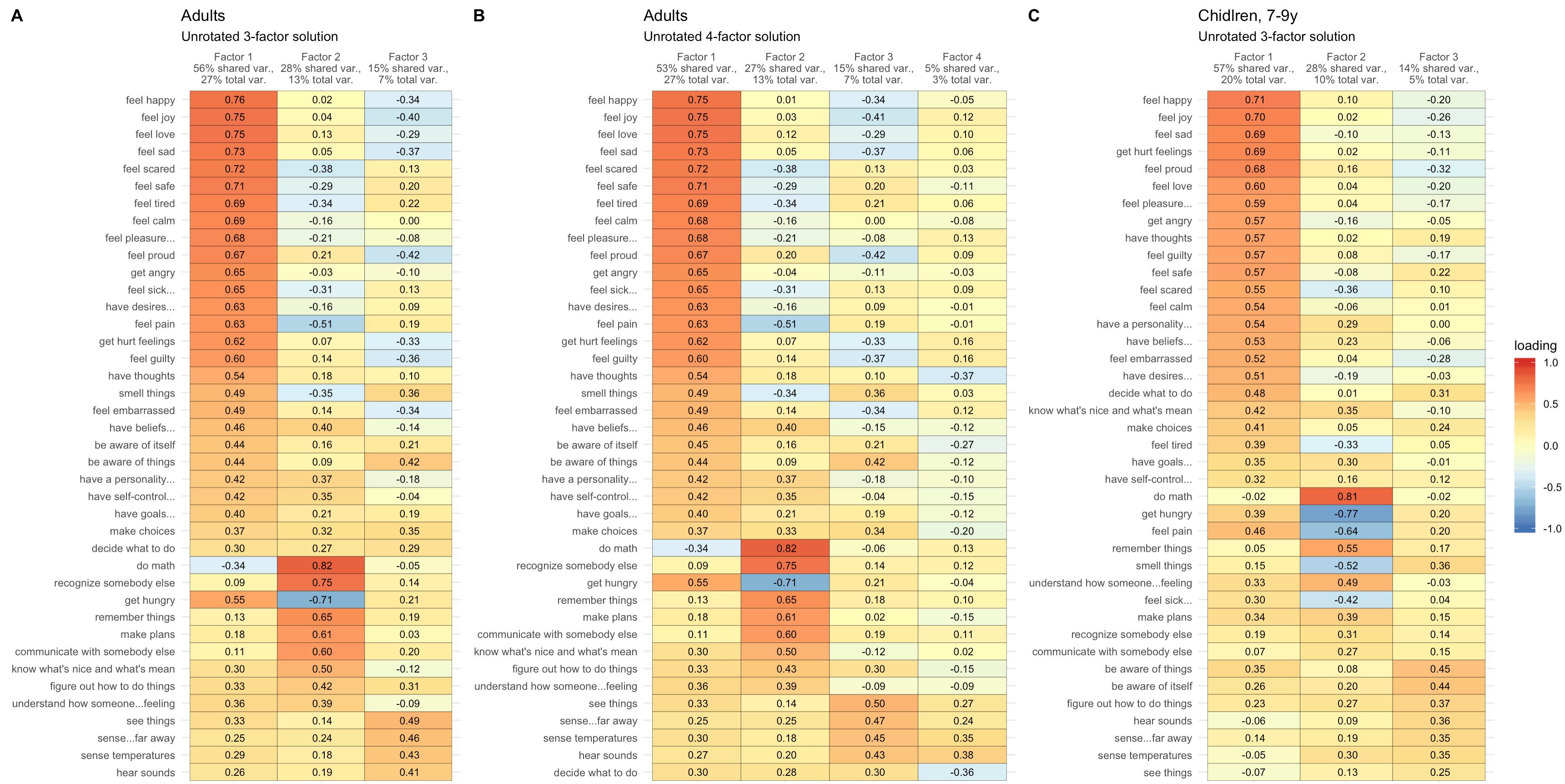


Figure A.2: Factor loadings from exploratory factor analyses of Study 2 (as reported in Chapter III), before rotation. (A) Results for US adults, retaining three factors. (B) Results for US adults, retaining four factors. (C) Results for US children ages 7-9y. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Study 3

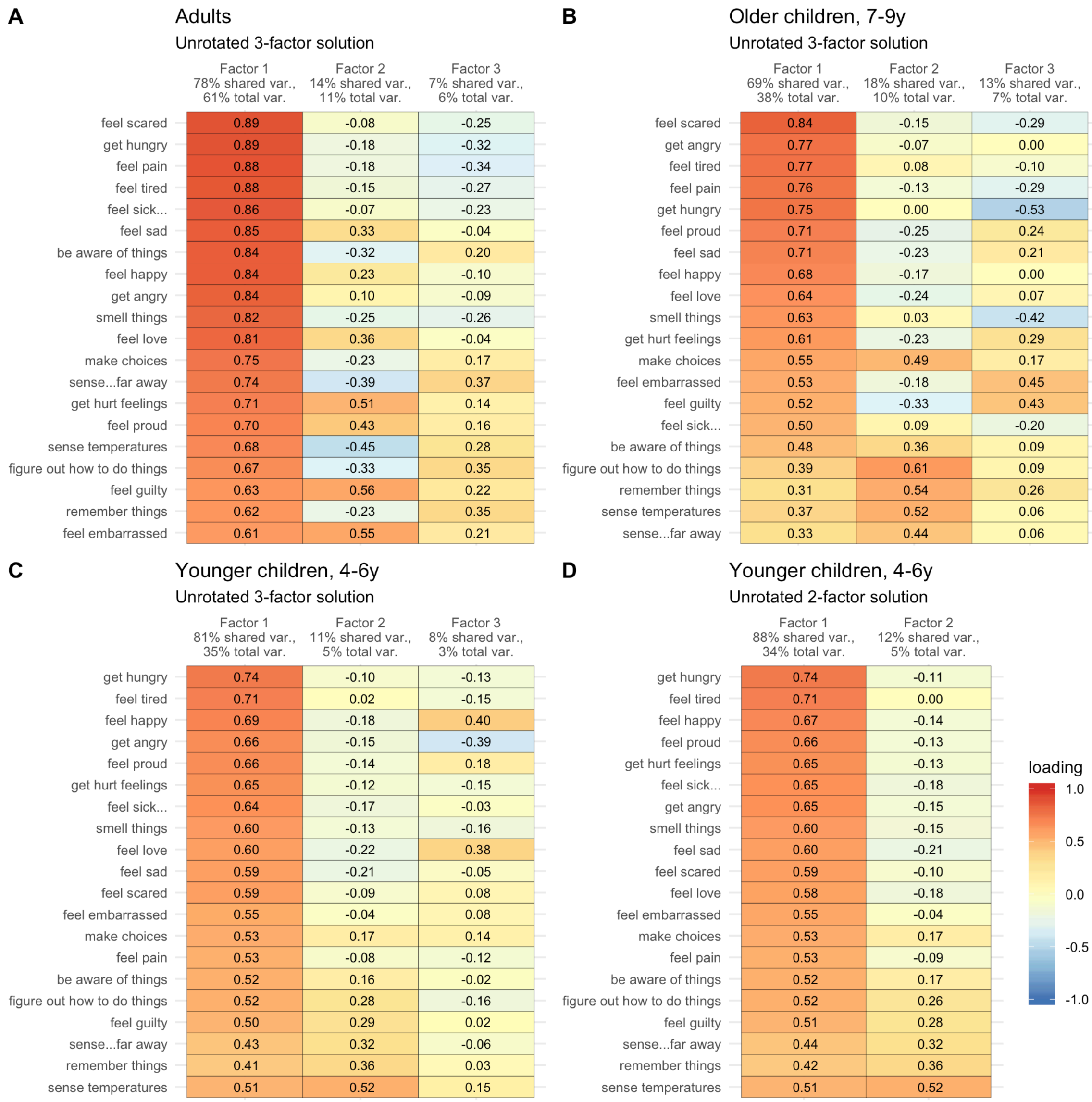


Figure A.3: Factor loadings from exploratory factor analyses of Study 3 (as reported in Chapter III), before rotation. (A) Results for US adults. (B) Results for US children ages 7-9y. (C) Results for US children ages 4-6y, retaining three factors. (D) Results for US children ages 4-6y, retaining two factors. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Study 4

Figure A.4: Factor loadings from exploratory factor analyses of Study 4 (as reported in Chapter III), before rotation. (A) Results for US adults. (B) Results for US children ages 4-5y, retaining two factors. (C) Results for US children ages 4-5y, retaining three factors. (D) Results for US children ages 4-5y, retaining four factors. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

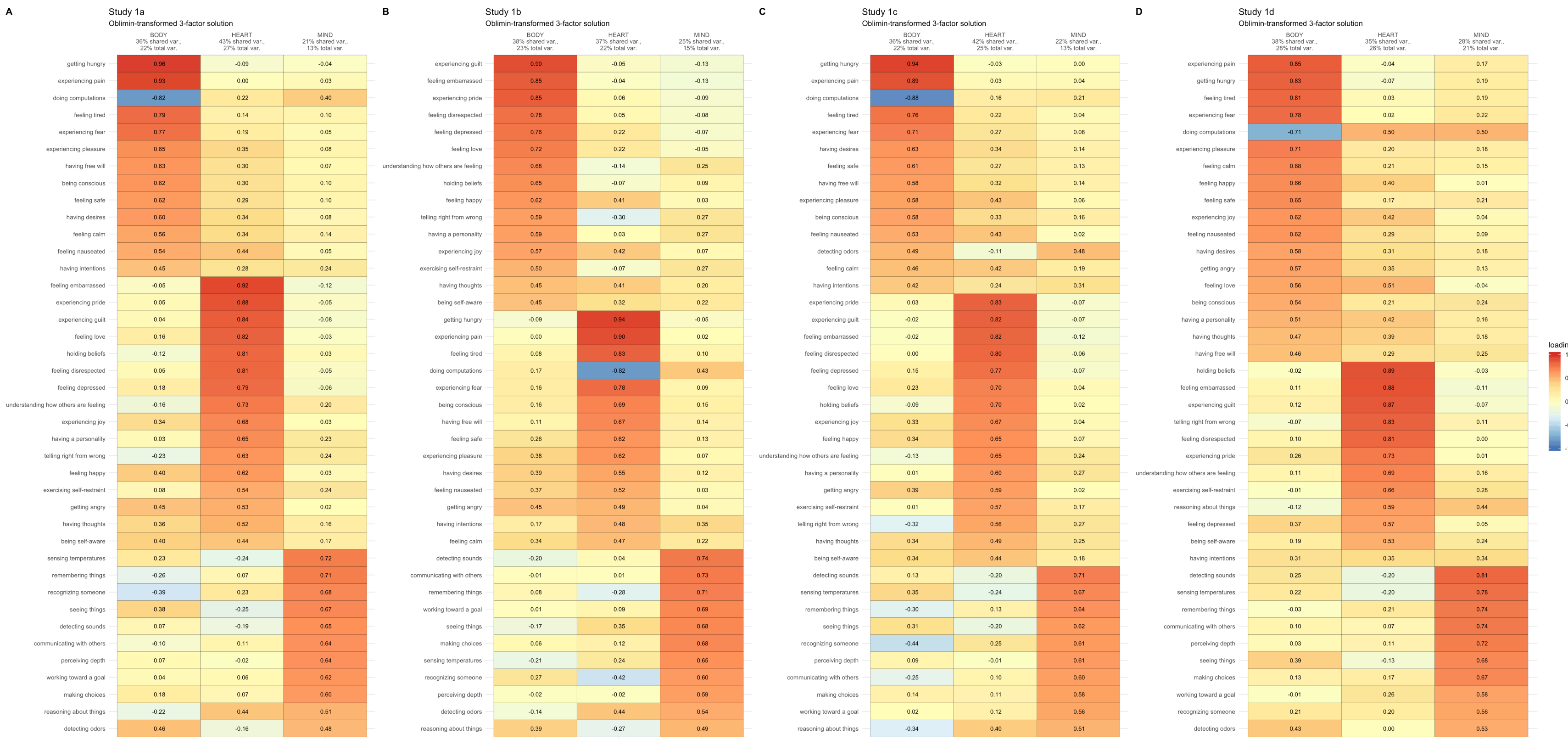
However, “oblique” transformations, such as the “oblimin” transformation, also confer many advantages in using EFA to identify constructs of theoretical interest (for discussion, see Revelle, 2018, Chapter 6). In contrast to orthogonal rotations, oblique transformations allow factors to correlate with each other. In removing the orthgonality constraint, oblique transformations thus reveal relationships between variables (in my case, mental capacities) and factors (conceptual units) that might be considered more “natural”; they might also reveal new aspects of the relationships among factors themselves (pertinent to my goals in Chapter V).

In the interest of adding nuance to my primary discussions of the conceptual units identified by EFA (Chapter III) and the relationships among these units (Chapter V), here I present oblimin-transformed EFA solutions for all studies.

Study 1

EFA solutions

Different factor retention protocols suggested retaining between 3-5 factors for Studies 1a-1d. Here, I report 3-, 4-, and 5-factor solutions for all of these studies. When these factors seem similar to the BODY, HEART, and MIND factors presented in Chapter III, I have labeled them accordingly.



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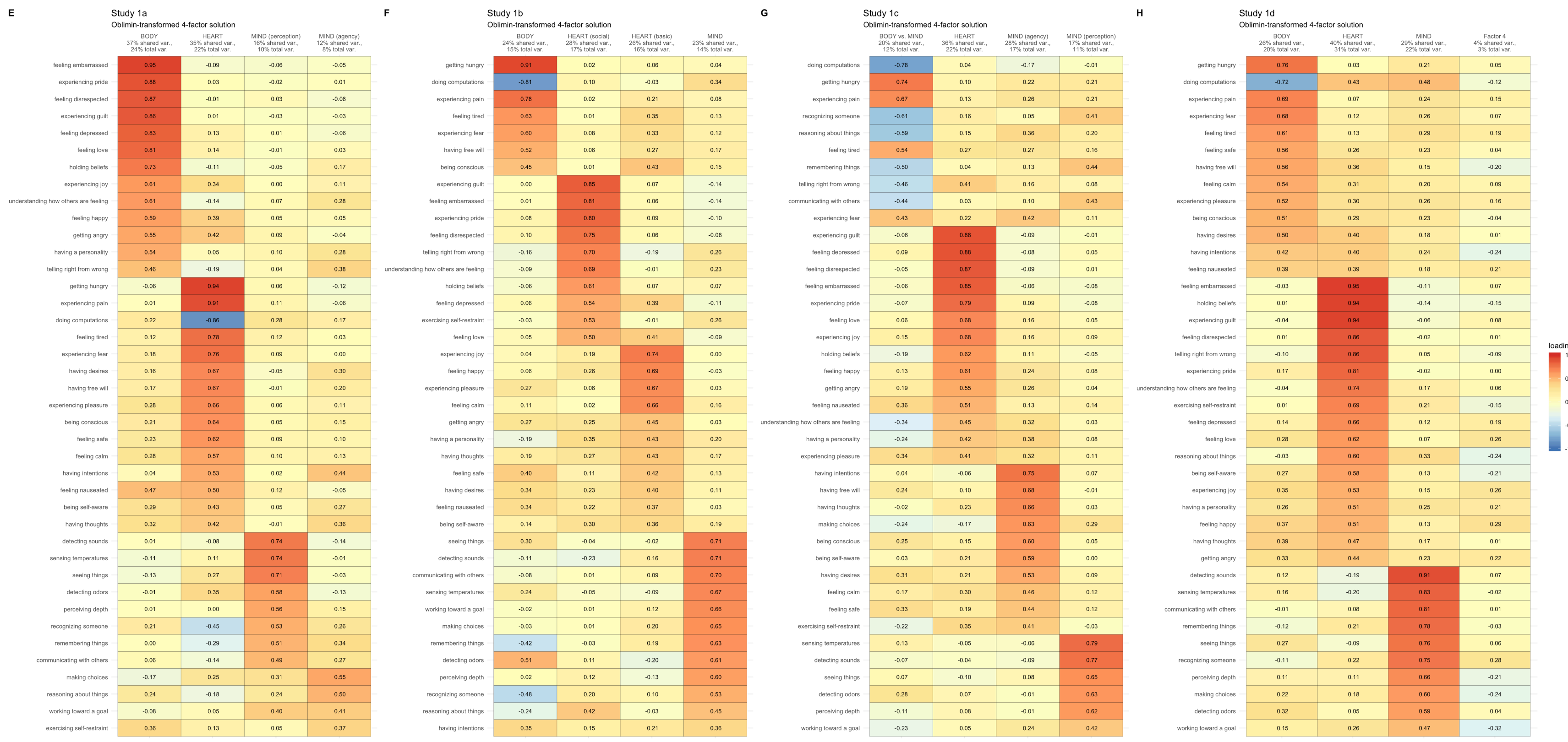

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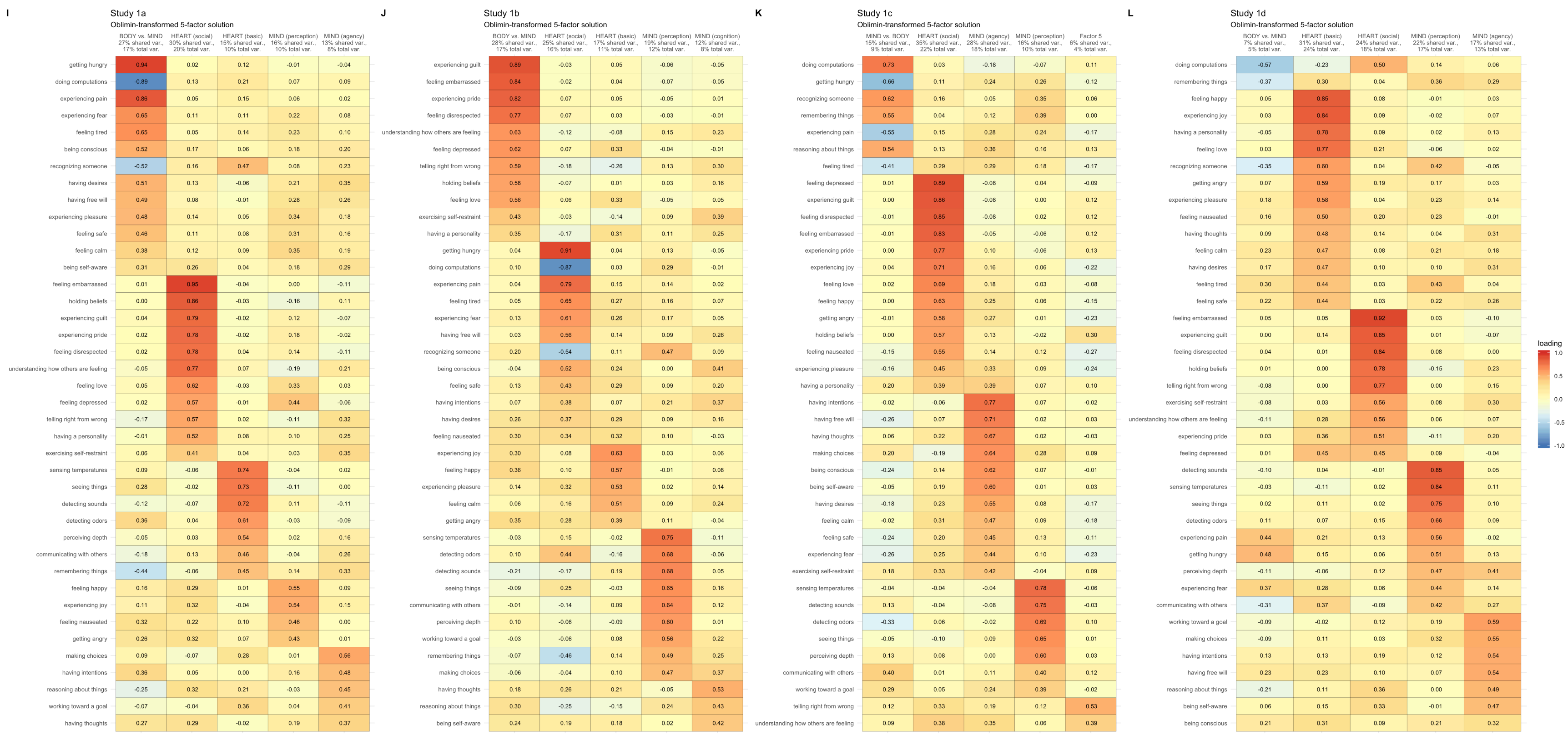

(continued from previous page)

Figure A.5: Factor loadings from exploratory factor analyses of Study 1 after oblimin transformation. All results are from US adult samples; see Chapter II for methods. (A) Study 1a. (B) Study 1b. (C) Study 1c. (D) Study 1d. In this and all figures portraying factor loadings, factors have been plotted in the same order (BODY, HEART, MIND), when applicable, to facilitate comparison across studies. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Inter-factor correlations

Here I present inter-factor correlations for all of the above EFA solutions for Studies 1a-1d.

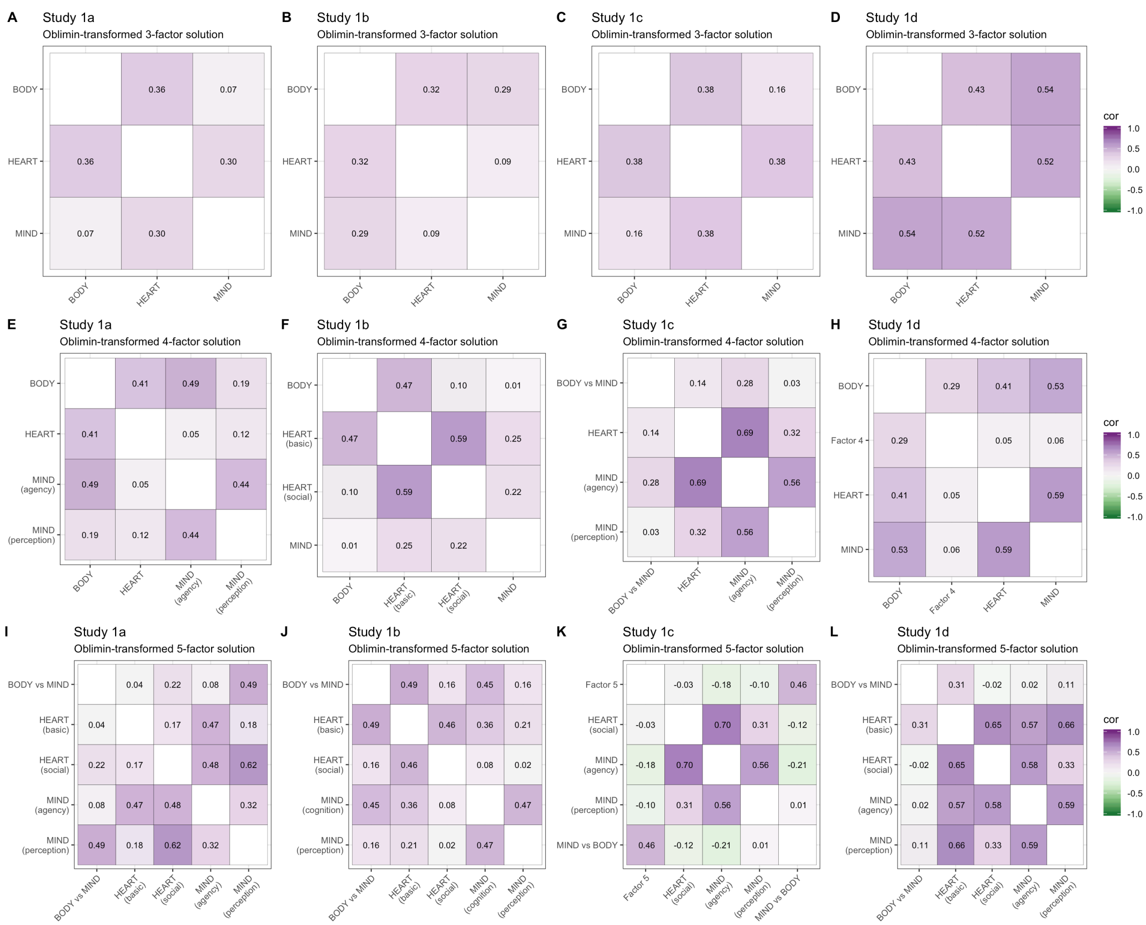

Figure A.6: Inter-factor correlations from exploratory factor analyses of Study 1 after oblimin transformation. All results are from US adult samples; see Chapter II for methods. (A) Study 1a. (B) Study 1b. (C) Study 1c. (D) Study 1d. Factors have been labeled with the labels 'BODY,' 'HEART,' and 'MIND,' when applicable, to facilitate comparison across studies.

Study 2

EFA solutions

Different factor retention protocols suggested retaining either 3 or 4 factors for adults in Study 2; all protocols suggested retaining 3 factors for children (ages 7-9y). Here, I report 3-, and 4-factor solutions for adults and the 3-factor solution for children. When these factors seem similar to the BODY, HEART, and MIND factors presented in Chapter III, I have labeled them accordingly.

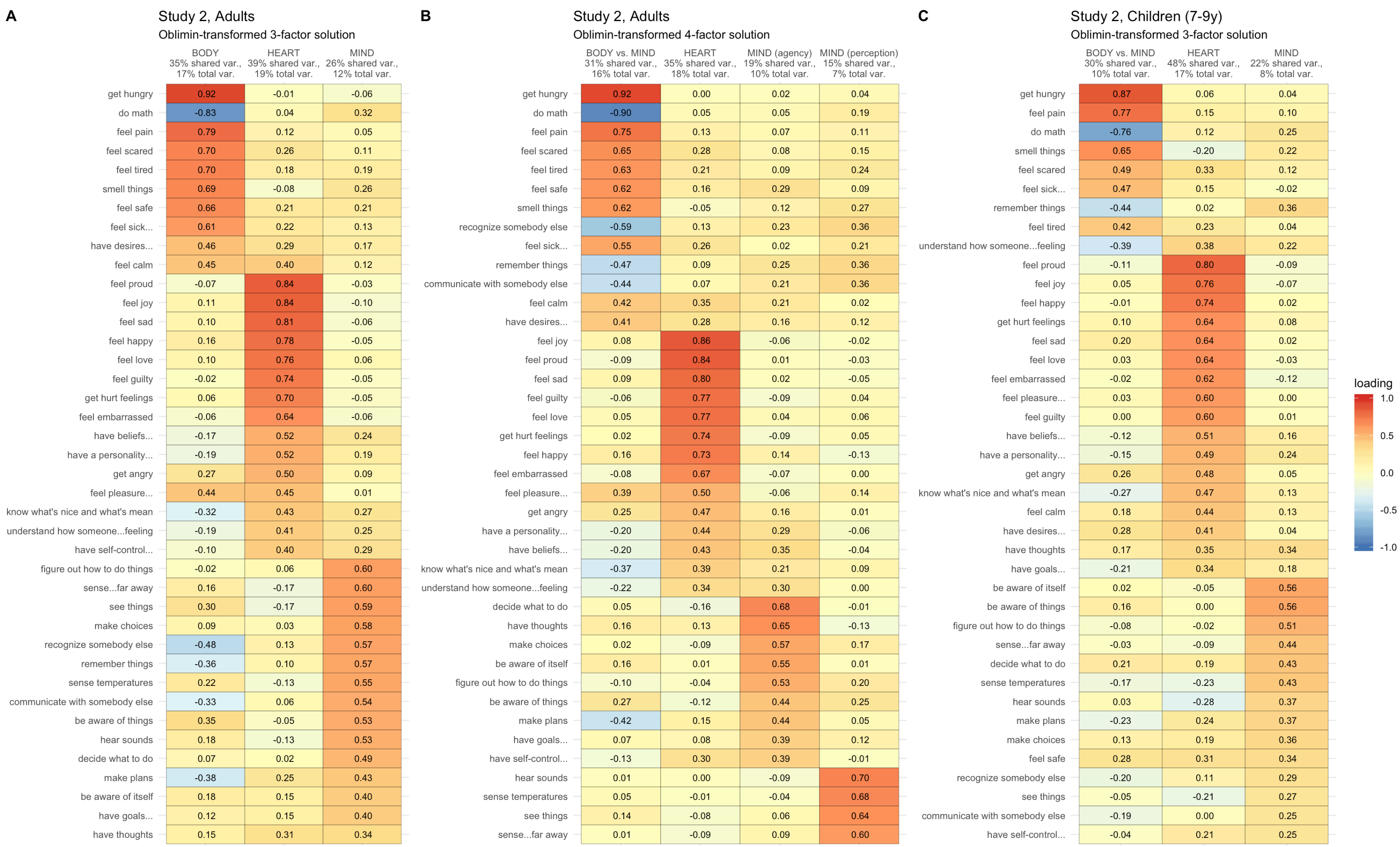

Figure A.7: Factor loadings from exploratory factor analyses of Study 2 after oblimin transformation. See Chapter II for methods. (A) US adults, 3-factor solution. (B) US adults, 4-factor solution. (C) US children ages 7-9y. In this and all figures portraying factor loadings, factors have been plotted in the same order (BODY, HEART, MIND), when applicable, to facilitate comparison across studies. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Inter-factor correlations

Here I present inter-factor correlations for all of the above EFA solutions for Study 2.

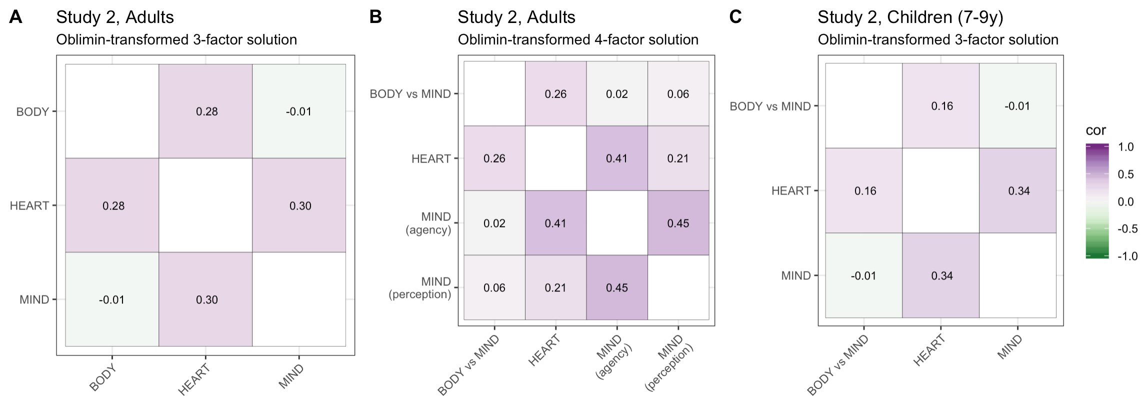

Figure A.8: Inter-factor correlations from exploratory factor analyses of Study 2 after oblimin transformation. See Chapter II for methods. (A) US adults, 3-factor solution. (B) US adults, 4-factor solution. (C) US children ages 7-9y. Factors have been labeled with the labels 'BODY,' 'HEART,' and 'MIND,' when applicable, to facilitate comparison across studies.

Study 3

EFA solutions

Various factor retention protocols suggested retaining either 3 or 4 factors for adults in Study 3; 3 factors for older children (ages 7-9y); and either 1, 3, or 4 factors for younger children (ages 4-6y). Here, I report 3-, and 4-factor solutions for adults, the 3-factor solution for older children, and the 1-, 3-, and 4-factor solutions for younger children. When these factors seem similar to the BODY, HEART, and MIND factors presented in Chapter III, I have labeled them accordingly.

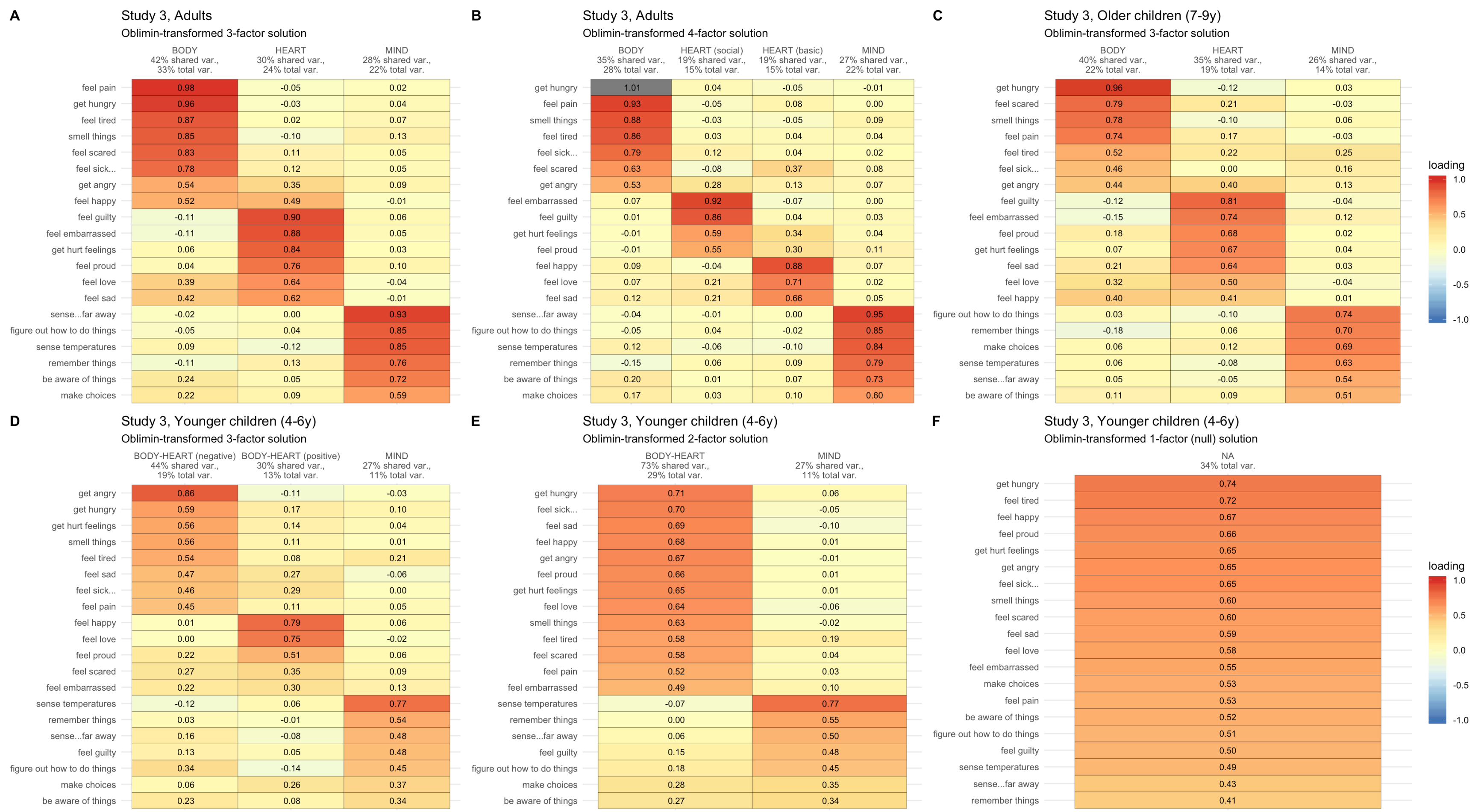

Figure A.9: Factor loadings from exploratory factor analyses of Study 3 after oblimin transformation. See Chapter II for methods. (A) US adults, 3-factor solution. (B) US adults, 4-factor solution. (C) US children ages 7-9y. (D) US children ages 4-6y, 3-factor solution. (E) US children ages 4-6y, 2-factor solution. (F) US children ages 4-6y, 1-factor (null) solution. In this and all figures portraying factor loadings, factors have been plotted in the same order (BODY, HEART, MIND), when applicable, to facilitate comparison across studies. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Inter-factor correlations

Here I present inter-factor correlations for all of the above EFA solutions for Study 3 (with the exception of the 1-factor null solution for younger children).

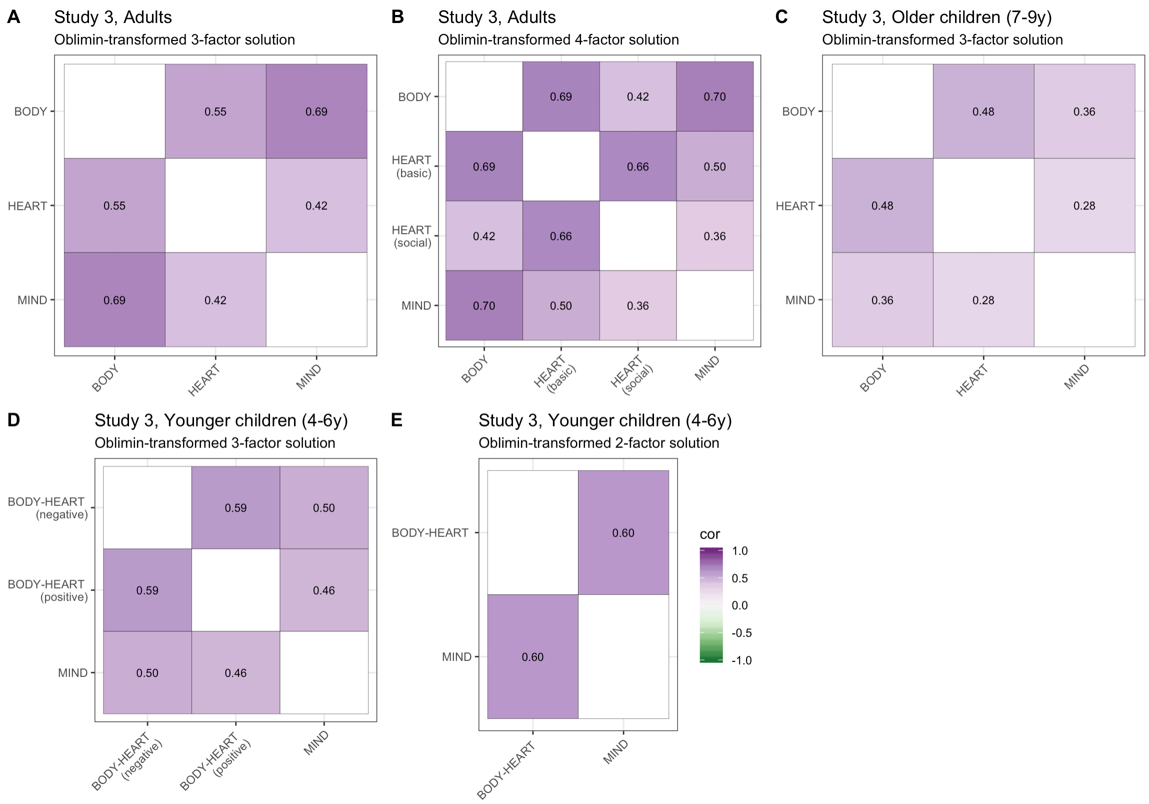

Figure A.10: Inter-factor correlations from exploratory factor analyses of Study 3 after oblimin transformation. See Chapter II for methods. (A) US adults, 3-factor solution. (B) US adults, 4-factor solution. (C) US children ages 7-9y. (D) US children ages 4-6y, 3-factor solution. (E) US children ages 4-6y, 2-factor solution. Factors have been labeled with the labels 'BODY,' 'HEART,' and 'MIND,' when applicable, to facilitate comparison across studies.

Study 4

EFA solutions

All factor retention protocols suggested retaining 3 factors for adults in Study 4; different protocols suggested retaining either 1, 3, or 4 factors for children (ages 4-5y). Here, I report the 3-factor solution for adults, and the 1-, 3-, and 4-factor solutions for children. When these factors seem similar to the BODY, HEART, and MIND factors presented in Chapter III, I have labeled them accordingly.

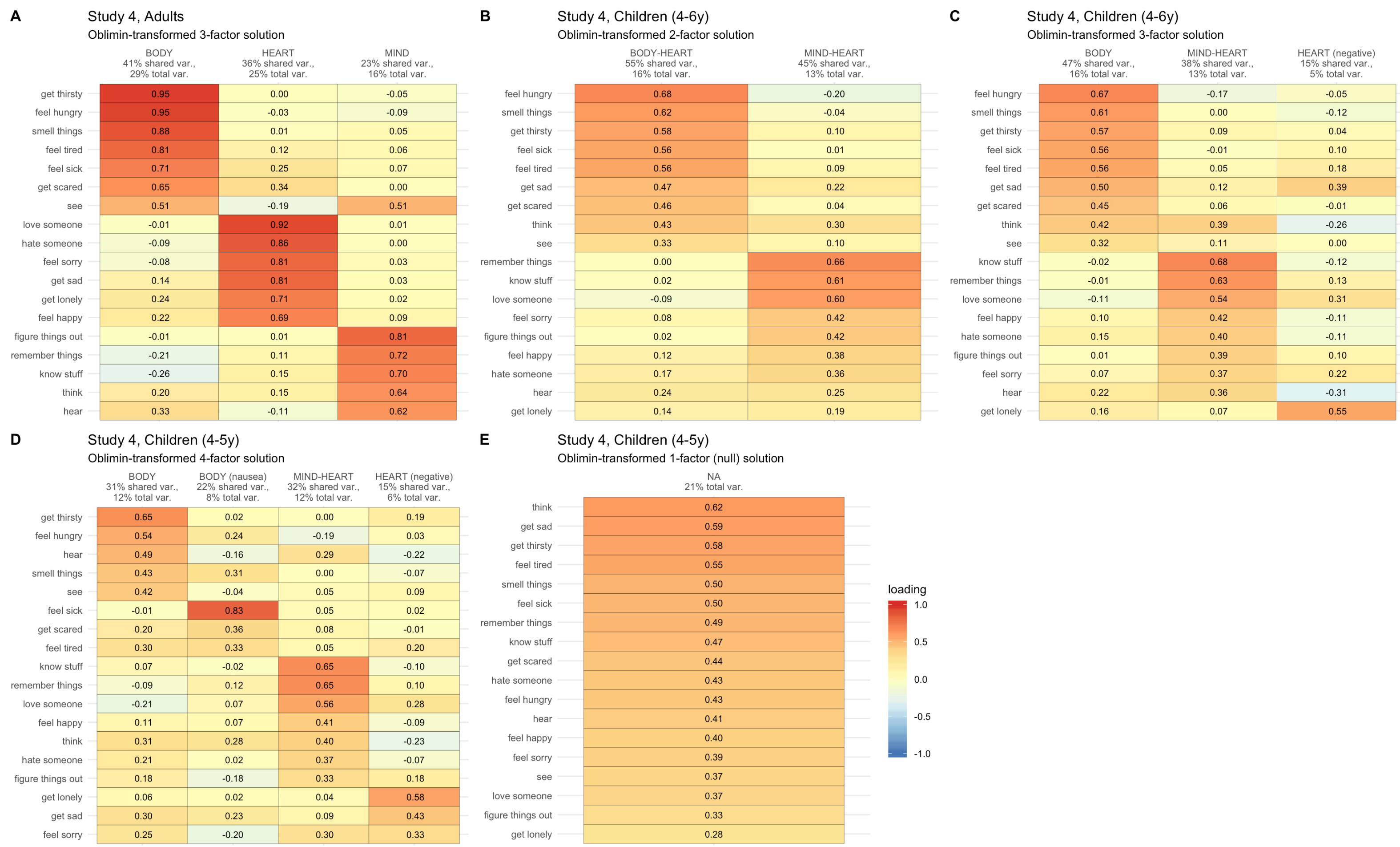

Figure A.11: Factor loadings from exploratory factor analyses of Study 4 after oblimin transformation. See Chapter II for methods. (A) US adults. (B) US children ages 4-5y, 2-factor solution. (C) US children ages 4-5y, 3-factor solution. (D) US children ages 4-5y, 4-factor solution. (E) US children ages 4-5y, 1-factor (null) solution. In this and all figures portraying factor loadings, factors have been plotted in the same order (BODY, HEART, MIND), when applicable, to facilitate comparison across studies. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Inter-factor correlations

Here I present inter-factor correlations for all of the above EFA solutions for Study 4 (with the exception of the 1-factor null solution for children).

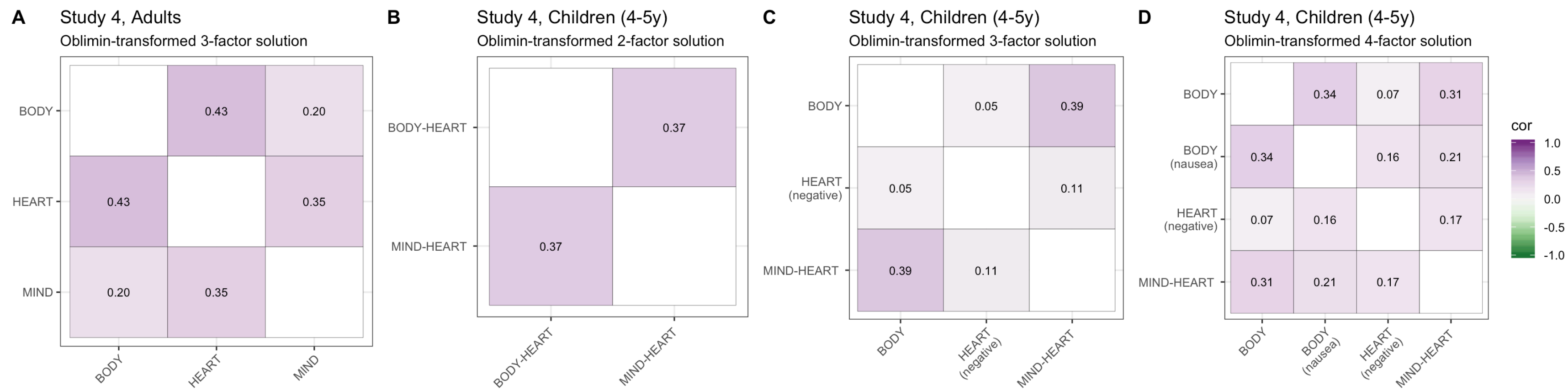

Figure A.12: Inter-factor correlations from exploratory factor analyses of Study 4 after oblimin transformation. See Chapter II for methods. (A) US adults. (B) US children ages 4-5y, 2-factor solution. (C) US children ages 4-5y, 3-factor solution. (D) US children ages 4-5y, 4-factor solution. Factors have been labeled with the labels 'BODY,' 'HEART,' and 'MIND,' when applicable, to facilitate comparison across studies.

Varimax-rotated solutions previously deemed redundant

In Chapter III, I focused my interpretation on a subset of the EFA solutions suggested by the three factor retention protocols, excluding those solutions in which additional factors were redundant with the 3-factor (BODY-HEART-MIND) solution. These additional factors tend to explain very little of the shared variance; tend not to be the dominant factor (the factor with the strongest absolute factor loading) for many, if any, mental capacities; and tend to have very weak factor loadings. I include them here for completeness.

Study 1

The factor retention criteria employed in Weisman et al. (2017) suggested retaining 3 factors for all of the studies included in Study 1; see Chapter III. In contrast, parallel analysis suggested retaining 4 factors (instead of 3) for Studies 1b and 1d; minimizing BIC suggested retaining 4 factors (instead of 3) for Study 1c, and 5 factors (instead of 3) for Studies 1a, 1b, and 1d. See Figure A.13.

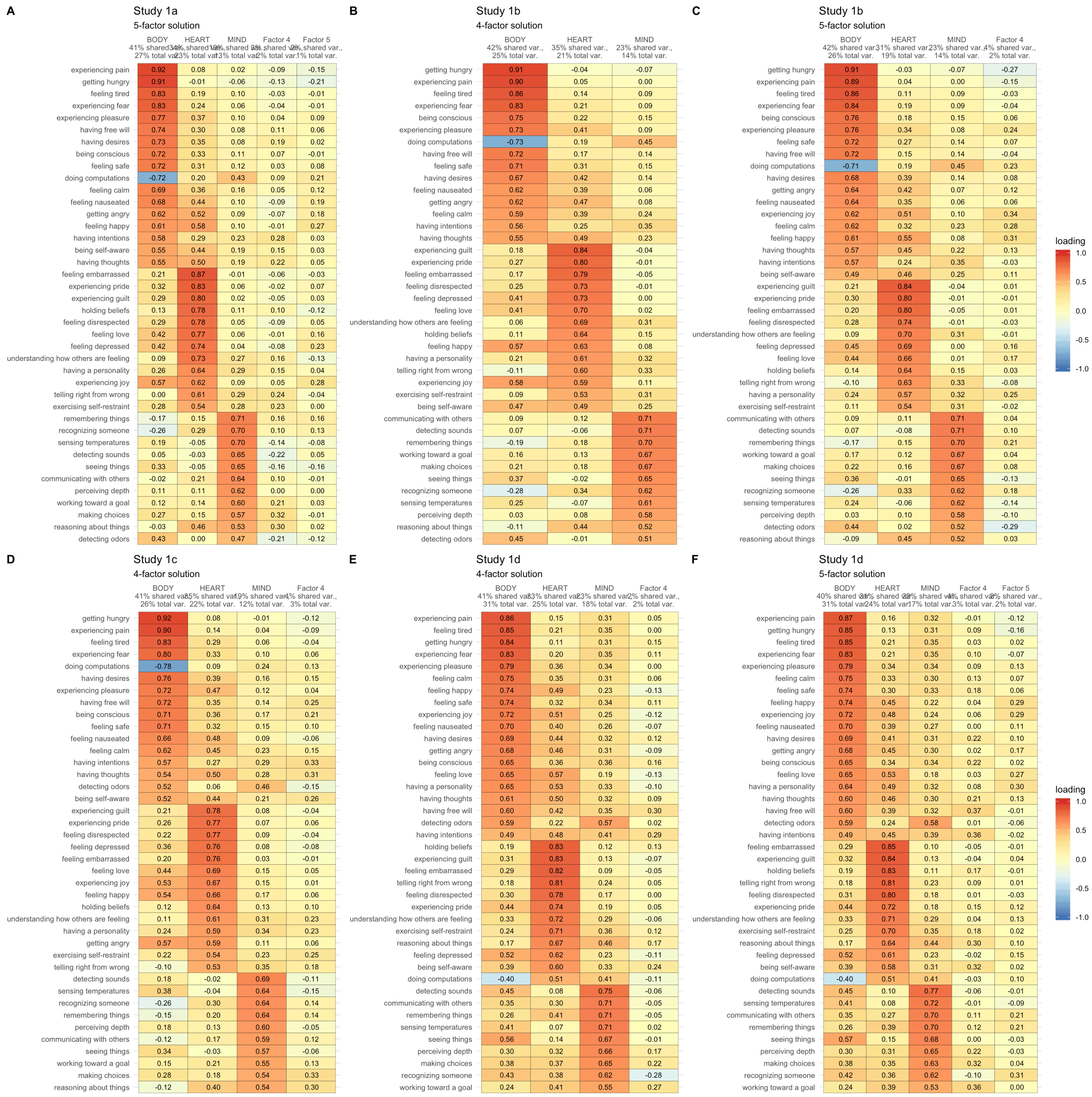

Figure A.13: Factor loadings from additional exploratory factor analyses of Study 1, not reported in Chapter III. All results are from US adult samples; see Chapter II for methods. (A) Study 1a, solution suggested by minimizing BIC. (B) Study 1b, solution suggested by parallel analysis. (C) Study 1b, solution suggested by minimizing BIC. (D) Study 1c, solution suggested by minimizing BIC. (E) Study 1d, solution suggested by parallel analysis. (F) Study 1d, solution suggested by minimizing BIC. In this and all figures portraying factor loadings, factors have been plotted in the same order (BODY, HEART, MIND), when applicable, to facilitate comparison across studies. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Study 2

All of the EFA solutions suggested by the three factor retention protocols are reported in full in Chapter III.

Study 3

The factor retention criteria employed in Weisman et al. (2017) suggested retaining 3 factors for all of the age groups included in Study 3; see Chapter III. In contrast, parallel analysis suggested retaining 2 factors (instead of 3) for younger children; and minimizing BIC suggested retaining 4 factors (instead of 3) for adults, and 1 factor (i.e., a "null" solution) for younger children (ages 4-6y). See Figure A.14.

Study 4

All of the EFA solutions suggested by the three factor retention protocols are reported in full in Chapter III, with the exception of the 1-factor ("null") solution suggested by minimizing BIC for younger children (4-5y). See Figure A.15.

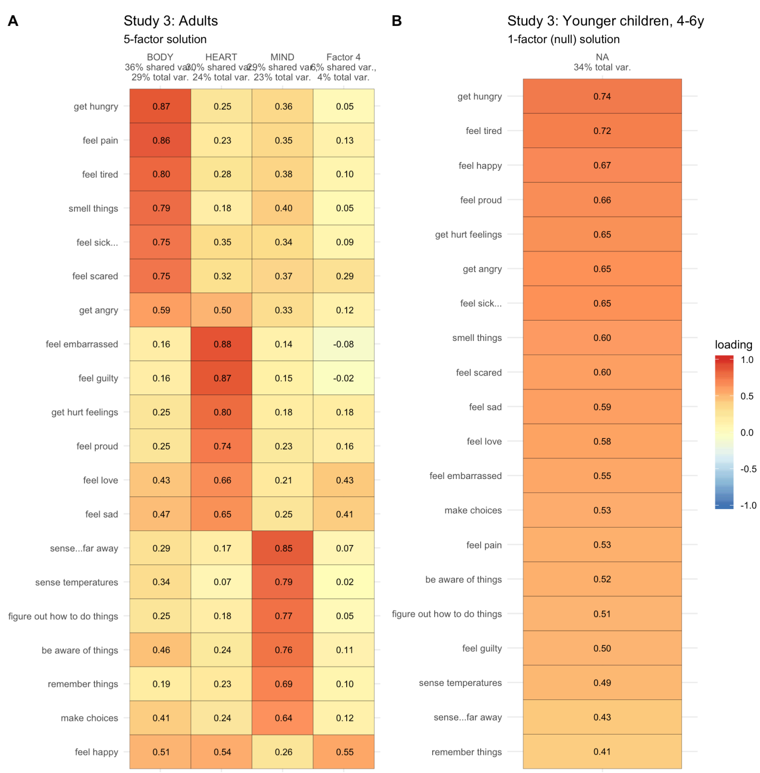

Figure A.14: Factor loadings from additional exploratory factor analyses of Study 3, not reported in Chapter III. See Chapter II for methods. (A) Adults, solution suggested by minimizing BIC. (B) Younger children (4-6y), 'null' solution suggested by minimizing BIC. In this and all figures portraying factor loadings, factors have been plotted in the same order (BODY, HEART, MIND), when applicable, to *facilitate comparison across studies. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.*

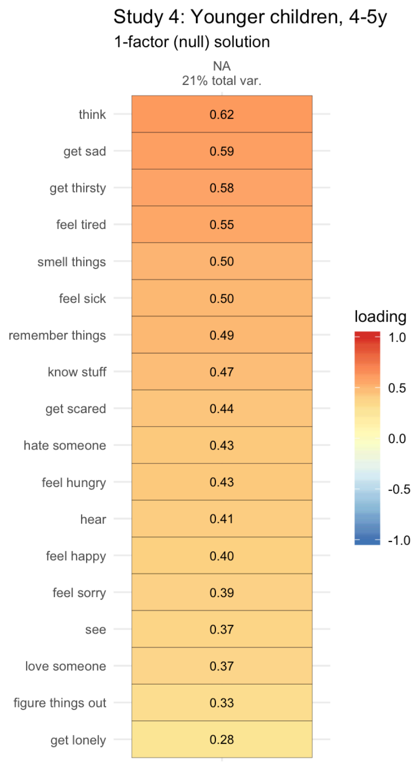

Figure A.15: Factor loadings from the 'null' solution suggested by minimizing BIC for younger children (4-5y) in Study 4. See Chapter II for methods, and Chapter III for other EFA solutions for this study. A factor loading of +1 indicates a perfectly positive relationship between mental capacity and underlying construct; a loading of -1 indicates a perfectly negative relationship.

Appendix B: Additional explorations of organization

Appendix overview

In this appendix, I report additional exploratory analyses of the organization of the sets of "conceptual units" that were excluded from the main text of Chapter IV, including: (a) Visualizations and analyses of the relationships among conceptual units using scales derived from EFA of children's own responses, rather than adults' responses, for 7- to 9-year-old children in Study 3, and 4- to 6-year-old children in Study 3; (b) Visualizations and analyses of age-related changes in difference scores between conceptual units (scored using adults' scales) for 7- to 9-year-old children in Study 2, 4- to 9-year-old children in Study 3, and 4- to 5-year-old children in Study 4; and (c) Visualizations of the joint dependency of HEART on both BODY and MIND.

Relationships among conceptual units using scales derived from children's EFAs

In Chapter IV, I used adults' EFA solution to construct BODY, HEART, and MIND scales and used these scales to assess the organization of these adult-like conceptual units among both adult and child samples. For Study 2, I also used 7- to 9-year-old children's own EFA solution to construct a separate set of scales based on children's own conceptual units and conducted a separate set of analyses of the organization of these "child-like" conceptual units. Here I present a parallel set of analyses using children's own EFA solutions (rather than adults') to assess the organization of conceptual units among both older children (7-9y of age) and younger children (4-6y of age) in Study 3.

Study 3

Older children (7-9y), using their own scales

Scale construction

Following the steps described in "General analysis plan," above, yielded *BODY*, *HEART*, and *MIND* scales of 6 items each; see Table B.1.

Visualization and analysis of asymmetries

Visualizations of relationships among 7- to 9-year-old children's scores on the *BODY*, *HEART*, and *MIND* scales are provided in Figure B.1, row A.

On the whole, these results (using *BODY*, *HEART*, and *MIND* scales derived from EFA 7- to 9-year-old children's responses) are very similar to those presented in the main text of Chapter IV (using adults' *BODY*, *HEART*, and *MIND* scales): Children systematically endorsed *BODY* and *MIND* items more strongly than *HEART* items, but showed no systematic asymmetry between BODY and MIND. This is unsurprising, since children's and adults' scales were so similar to each other (see Table B.1).

Younger children (4-6y), using their own scales (three-factor solution)

Scale construction

Following the steps described in "General analysis plan," above, yielded *BODY**, *HEART**, and *MIND* scales of 5 items each; see Table B.1.

Visualization and analysis of asymmetries

Visualizations of relationships among 4- to 6-year-old children's scores on the *BODY**, *HEART**, and *MIND* scales are provided in Figure B.1, row B.

As in the results presented in the main text of Chapter IV (using adults' *BODY*, *HEART*, and *MIND* scales), 4- to 6-year-old children systematically endorsed *BODY** items more strongly than *MIND* items. This is further evidence of a markedly un-adult-like intuition that BODY may be a more basic conceptual unit than MIND.

In contrast to the results presented in the main text of Chapter IV, 4- to 6-year-old children's *BODY** vs. *HEART** difference scores were indistinguishable from zero, and they systematically endorsed *HEART** items more strongly than *MIND* items. Both of these observations render 4- to 6-year-old children's conceptual organizations even less adult-like than those reported in Chapter IV.

Younger children (4-6y), using their own scales (two-factor solution)

Scale construction

Following the steps described in "General analysis plan," above, yielded *BODY-HEART* and *MIND* scales of 6 items each; see Table B.1.

Visualization and analysis of asymmetries

Visualizations of relationships among 4- to 6-year-old children's scores on the *BODY-HEART* and *MIND* scales are provided in Figure B.1, row C.

The main takeaway of this analysis is that 4- to 6-year-old children reliably endorsed *BODY-HEART* items more strongly than *MIND* items.

Table B.1: Scales for each of the conceptual units identified by EFA for US Adults, older children, and younger children in Study 3 (see Chapter III). For younger children, this includes scales for both three- and two-factor EFA solutions. A checkmark indicates that a mental capacity was included in a scale for a particular sample. The conceptual units of younger children differed substantially from those of older children and adults, such that some mental capacities were included in different scales across age groups (e.g., feel scared was part of the BODY scale for older children and adults, but part of the HEART scale for younger children). In these cases, the name of the scale is provided (rather than a checkmark).*

			Younger children, 4-6y	
Capacity	**Adults**	**Older children, 7-9y**	**3-factor solution**	**2-factor solution**
BODY scale				
feel pain	✓	✓		
get hungry	✓	✓	✓	BODY-HEART
feel tired	✓	✓	✓	
smell things	✓	✓	✓	
feel scared	✓	✓	HEART*	
feel sick...	✓			BODY-HEART
get angry		✓	✓	BODY-HEART
HEART scale				
feel happy			✓	BODY-HEART
feel guilty	✓	✓	MIND	MIND
get hurt feelings	✓	✓	BODY*	
feel embarrassed	✓	✓	✓	
feel proud	✓	✓	✓	BODY-HEART
feel love	✓	✓	✓	
feel sad	✓	✓		BODY-HEART
MIND scale				
sense...far away	✓	✓	✓	✓

sense temperatures	✓	✓	✓	✓
figure out how to do things	✓	✓	✓	✓
be aware of things	✓	✓		
remember things	✓	✓	✓	✓
make choices	✓	✓		✓

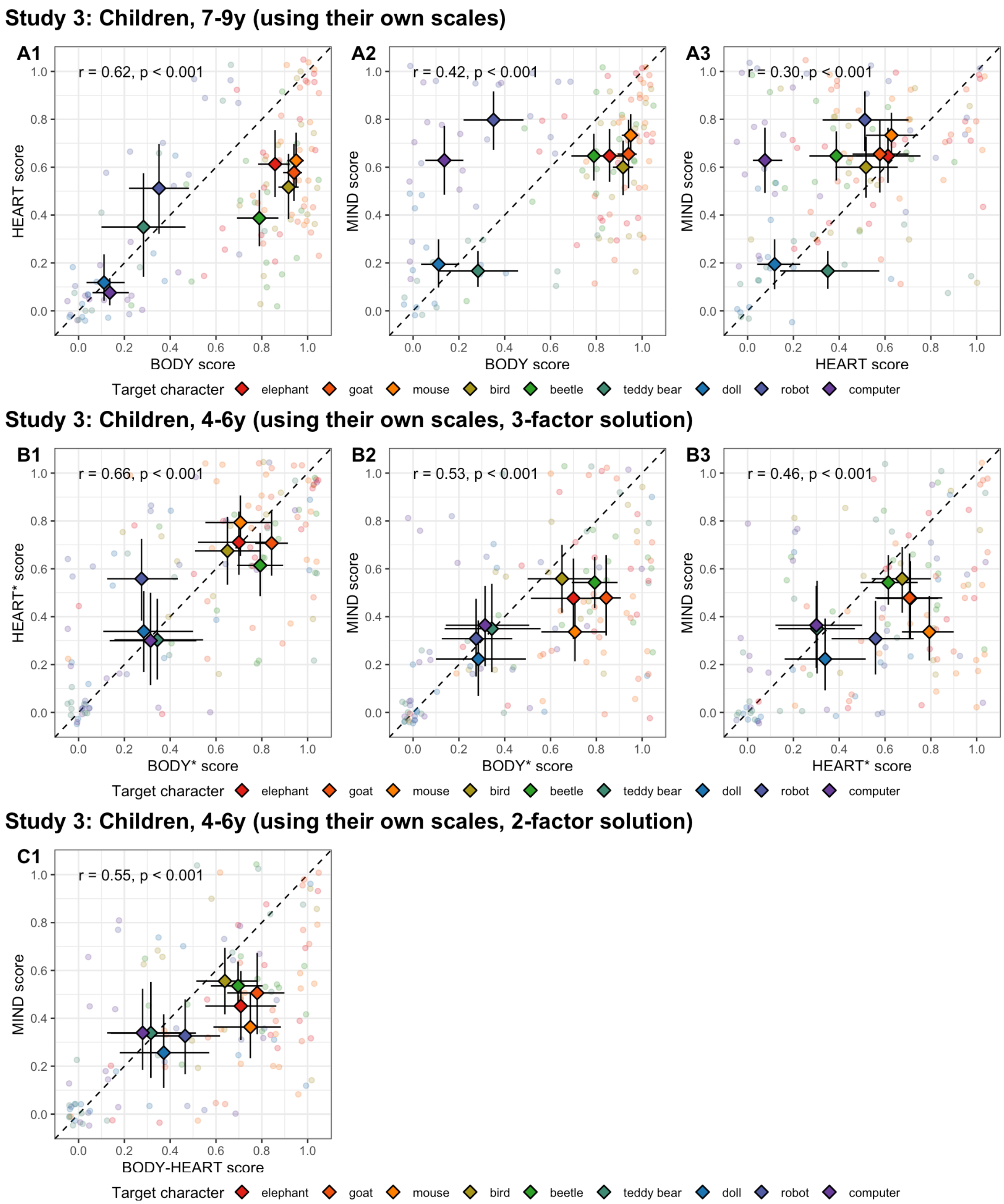

Figure B.1: Relationships among older and younger children's attributions of conceptual units in Study 3, scored using their own scales (see Table B.1). For younger children (4-6y of age), two sets of scores are presented: using a three-factor EFA solution (B1-B3) and using a two-factor EFA solution (C1). Plots are organized by sample and scale used (rows) and by pair of conceptual units (columns). For each conceptual unit, scores could range from 0-1. Individual participants are plotted as small, translucent circles, and mean scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. The dotted line corresponds to equal endorsements of the two conceptual units plotted.

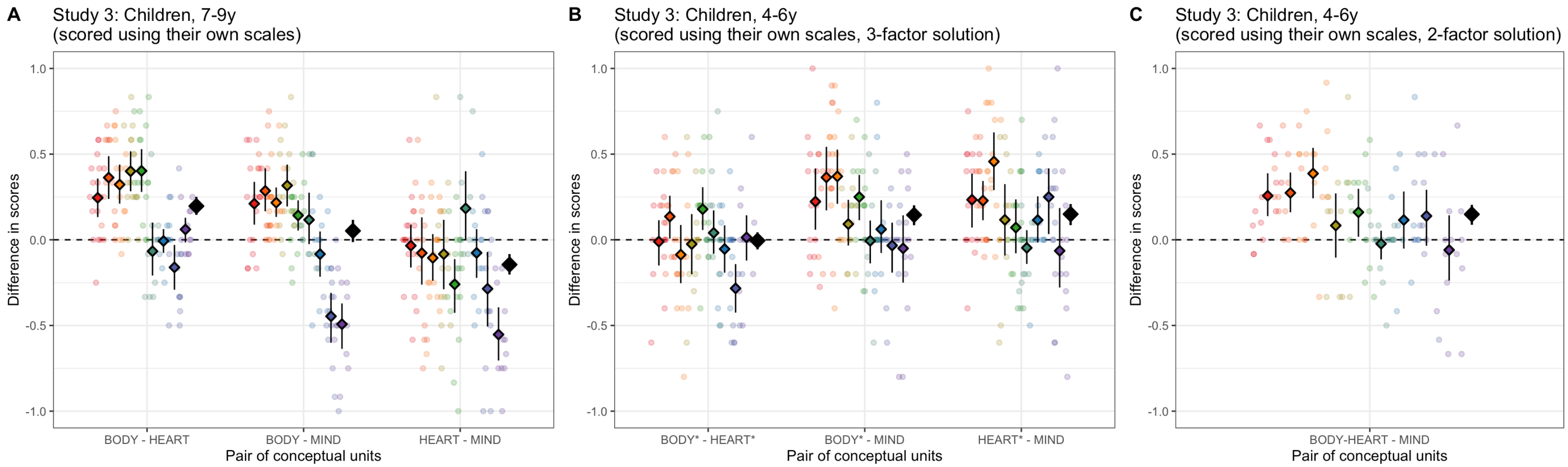

Figure B.2: Difference scores between conceptual units among 7- to 9-year-old children and 4- to 6-year-old children in Study 3, using their own scales. For younger children (4-6y of age), this includes difference scores using the three-factor EFA solution (panel B) and difference scores using the two-factor solution (panel C; see Table B.1). For each conceptual unit, scores could range from 0-1, such that difference scores could range from -1 to +1. Individual participants are plotted as small, translucent circles, and mean difference scores by character are plotted as larger, solid diamonds. Error bars are 95% bootstrapped confidence intervals. The dotted line corresponds to equal endorsements of the two conceptual units plotted (i.e., a difference score of 0).

Age-related changes in difference scores between conceptual units

In Chapter IV, I conducted separate analyses of difference scores for different age groups, as well as formal comparisons across age groups. These analyses aligned with the "snapshot" approach that I utilized in Chapter III to identify conceptual units at different points in development, and allowed for the kinds of visualizations of visualizations of relationships among *BODY*, *HEART*, and *MIND* scores that anchored my analyses and discussion of the organization of conceptual units in Chapter IV. This approach suggested that across the three age groups under consideration in this study (roughly, 4-6y of age, 7-9y of age, and adulthood), the asymmetries in participants' responses grew increasingly stronger, more reliable across studies and participants, and generally more "adult-like."

Here, I supplement this "snapshot" approach to studying development with one that respects how development actually unfolds: continuously. For Studies 2, 3, and 4, I present Bayesian regressions of difference scores—modeled exactly on the analyses presented in Chapter IV—that include exact age and interactions with age as predictors.

Study 2

In Study 2, children ranged in age from 7.01-9.99 years (median: 8.31y; mean: 8.36y). As a group, these children tended to endorse *BODY* and *MIND* items more strongly than *HEART* items, and *MIND* items more strongly than *BODY* items—but all of these asymmetries were weaker among children than among adults in this study. Here, I re-analyze children's difference scores, including exact age (centered at the mean) and interactions with age as predictors.

The main takeaways of these analyses are that, among 7- to 9-year-old children in Study 2, *BODY* vs. *HEART* difference scores did not vary systematically with age, but both *BODY* vs. *MIND* and *HEART* vs. *MIND* difference scores became increasingly adult-like with age. See "Exact age (centered)" rows in Table B.3, and see Figure B.3 for a visualization of difference scores over age.

Study 3

In Study 3, children ranged in age from 4.00-9.98 years (median: 6.72y; mean: 6.73y). As a group, the older children in this study (7-9y of age) tended to endorse *BODY* and *MIND* items more strongly than *HEART* items—but both of these asymmetries were weaker among children than among adults in this study. Meanwhile, the younger children

(4-6y) tended to endorse *BODY* items more strongly than both *HEART* and *MIND* items. Here, I combine these two age groups and re-analyze children's difference scores, including exact age (centered at the mean) and interactions with age as predictors. (Note: At the time of writing, exact age was missing for 15 children in Study 3.)

Table B.3: Regression analyses of difference scores among children (7-9y of age) in Study 2, including effects of exact age. The table presents results from separate Bayesian regressions of each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND). Each regression included four fixed effect parameters: (1) the intercept, which I treat as an index of the asymmetry in attributions of the two conceptual units in question; (2) the exact age of participants (centered at the mean); (3) the difference between target characters (in this case, the difference between the robot and the grand mean, 'GM'); and (4) the interaction between age and target character. Effects having to do with age are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

Parameter	b	95% CI	
BODY vs. HEART			
Intercept	0.04	[0.00, 0.08]	
Exact age (centered)	**0.04**	**[-0.02, 0.09]**	
Robot vs. GM	-0.20	[-0.25, -0.16]	*
Interaction	**-0.02**	**[-0.07, 0.03]**	
BODY vs. MIND			
Intercept	-0.17	[-0.20, -0.13]	*
Exact age (centered)	**-0.08**	**[-0.11, -0.04]**	*
Robot vs. GM	-0.29	[-0.32, -0.26]	*
Interaction	**-0.05**	**[-0.09, -0.01]**	*
HEART vs. MIND			
Intercept	-0.21	[-0.26, -0.16]	*
Exact age (centered)	**-0.11**	**[-0.17, -0.06]**	*
Robot vs. GM	-0.09	[-0.13, -0.04]	*
Interaction	**-0.03**	**[-0.09, 0.03]**	

Table B.4: Regression analyses of difference scores among children (4-9y of age) in Study 3, including effects of exact age. The table presents results from separate Bayesian regressions of each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND). Each regression included 18 fixed effect parameters: (1) the intercept, which I treat as an index of the asymmetry in attributions of the two conceptual units in question; (2) the exact age of participants (centered at the mean); (3-10) the difference between target characters and the grand mean ('GM'); and (11-18) the interactions between age and target character. Effects having to do with age are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

Parameter	b	95% CI	
BODY vs. HEART			
Intercept	0.11	[0.07, 0.14]	*
Exact age (centered)	**0.02**	**[0.00, 0.04]**	*
Elephant vs. GM	0.05	[-0.03, 0.13]	
Goat vs. GM	0.14	[0.05, 0.22]	*
Mouse vs. GM	0.14	[0.06, 0.23]	*
Bird vs. GM	0.18	[0.09, 0.26]	*
Beetle vs. GM	0.09	[0.01, 0.17]	*
Teddy bear vs. GM	-0.11	[-0.20, -0.02]	*
Doll vs. GM	-0.14	[-0.23, -0.06]	*
Robot vs. GM	-0.29	[-0.38, -0.21]	*
Age * Elephant vs. GM	**0.00**	**[-0.05, 0.05]**	
Age * Goat vs. GM	**0.04**	**[-0.01, 0.09]**	
Age * Mouse vs. GM	**0.03**	**[-0.01, 0.07]**	
Age * Bird vs. GM	**0.01**	**[-0.04, 0.06]**	
Age * Beetle vs. GM	**0.05**	**[0.00, 0.09]**	*
Age * Teddy bear vs. GM	**-0.07**	**[-0.13, -0.02]**	*
Age * Doll vs. GM	**-0.01**	**[-0.06, 0.04]**	
Age * Robot vs. GM	**-0.06**	**[-0.11, -0.02]**	*
BODY vs. MIND			
Intercept	0.05	[0.02, 0.08]	*

Parameter	b	95% CI	
Exact age (centered)	**-0.03**	**[-0.05, -0.02]**	*
Elephant vs. GM	0.16	[0.07, 0.25]	*
Goat vs. GM	0.21	[0.12, 0.30]	*
Mouse vs. GM	0.24	[0.14, 0.33]	*
Bird vs. GM	0.15	[0.05, 0.24]	*
Beetle vs. GM	0.04	[-0.06, 0.12]	
Teddy bear vs. GM	-0.03	[-0.13, 0.07]	
Doll vs. GM	-0.11	[-0.21, -0.02]	*
Robot vs. GM	-0.29	[-0.38, -0.20]	*
Age * Elephant vs. GM	**0.03**	**[-0.03, 0.08]**	
Age * Goat vs. GM	**0.04**	**[-0.01, 0.10]**	
Age * Mouse vs. GM	**0.00**	**[-0.04, 0.04]**	
Age * Bird vs. GM	**0.02**	**[-0.04, 0.07]**	
Age * Beetle vs. GM	**0.03**	**[-0.02, 0.08]**	
Age * Teddy bear vs. GM	**0.04**	**[-0.02, 0.10]**	
Age * Doll vs. GM	**0.01**	**[-0.04, 0.07]**	
Age * Robot vs. GM	**-0.09**	**[-0.14, -0.04]**	*
HEART vs. MIND			
Intercept	-0.05	[-0.09, -0.02]	*
Exact age (centered)	**-0.05**	**[-0.08, -0.03]**	*
Elephant vs. GM	0.10	[0.00, 0.21]	*
Goat vs. GM	0.07	[-0.03, 0.17]	
Mouse vs. GM	0.10	[-0.01, 0.20]	
Bird vs. GM	-0.03	[-0.13, 0.08]	
Beetle vs. GM	-0.06	[-0.16, 0.05]	

Parameter	b	95% CI	
Teddy bear vs. GM	0.08	[-0.04, 0.20]	
Doll vs. GM	0.03	[-0.08, 0.14]	
Robot vs. GM	0.00	[-0.11, 0.11]	
Age * Elephant vs. GM	**0.03**	**[-0.03, 0.08]**	
Age * Goat vs. GM	**0.00**	**[-0.05, 0.06]**	
Age * Mouse vs. GM	**-0.03**	**[-0.08, 0.02]**	
Age * Bird vs. GM	**0.01**	**[-0.06, 0.07]**	
Age * Beetle vs. GM	**-0.01**	**[-0.07, 0.04]**	
Age * Teddy bear vs. GM	**0.11**	**[0.04, 0.18]**	*
Age * Doll vs. GM	**0.02**	**[-0.04, 0.08]**	
Age * Robot vs. GM	**-0.03**	**[-0.08, 0.03]**	

The main takeaways of these analyses are that, among 4- to 9-year-old children in Study 3, all three difference scores (*BODY* vs. *HEART*, *BODY* vs. *MIND*, and *HEART* vs. *MIND*) became increasingly adult-like with age. See “Exact age (centered)” rows in Table B.B, and see Figure B.3 for a visualization of difference scores over age.

Study 4

In Study 4, children ranged in age from 4.02-5.59 years (median: 4.73y; mean: 4.73y). As a group, these children tended to endorse *BODY* items more strongly than *HEART* items, and (unlike adults) *HEART* items more strongly than *MIND* items, but showed no systematic asymmetry in their endorsement of *BODY* vs. *MIND* items. Here, I re-analyze children’s difference scores, including exact age (centered at the mean) and interactions with age as predictors, and random intercepts for participants to account for the within-subjects design of this study.

Table B.5: Regression analyses of difference scores among children (4-5y of age) in Study 4, including effects of exact age. The table presents results from separate Bayesian regressions of each pair of conceptual units (BODY vs. HEART, BODY vs. MIND, and HEART vs. MIND). Each regression included four fixed effect parameters: (1) the intercept, which I treat as an index of the asymmetry in attributions of the two conceptual units in question; (2) the exact age of participants (centered at the mean); (3) the difference between target characters (in this case, the difference between the robot and the grand mean, 'GM'); and (4) the interaction between age and target character. Effects having to do with age are highlighted in bold, because these are the primary parameters of interest for these analyses. For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

Parameter	b	95% CI	
BODY vs. HEART			
Intercept	0.10	[0.04, 0.16]	*
Exact age (centered)	**0.07**	**[-0.07, 0.22]**	
Robot vs. GM	-0.17	[-0.23, -0.11]	*
Interaction	**-0.16**	**[-0.31, -0.01]**	*
BODY vs. MIND			
Intercept	-0.01	[-0.07, 0.05]	
Exact age (centered)	**0.00**	**[-0.15, 0.15]**	
Robot vs. GM	-0.18	[-0.24, -0.12]	*
Interaction	**-0.05**	**[-0.20, 0.10]**	
HEART vs. MIND			
Intercept	-0.11	[-0.17, -0.04]	*
Exact age (centered)	**-0.07**	**[-0.22, 0.09]**	
Robot vs. GM	-0.02	[-0.07, 0.04]	
Interaction	**0.12**	**[-0.01, 0.25]**	

The main takeaways of these analyses are that, among 4- to 5-year-old children in Study 4, difference scores did not vary systematically with age. This is not entirely surprising given the smaller sample size and more restricted age range included in this study. See "Exact age (centered)" rows in Table B.5, and see Figure B.3 for a visualization of difference scores over age.

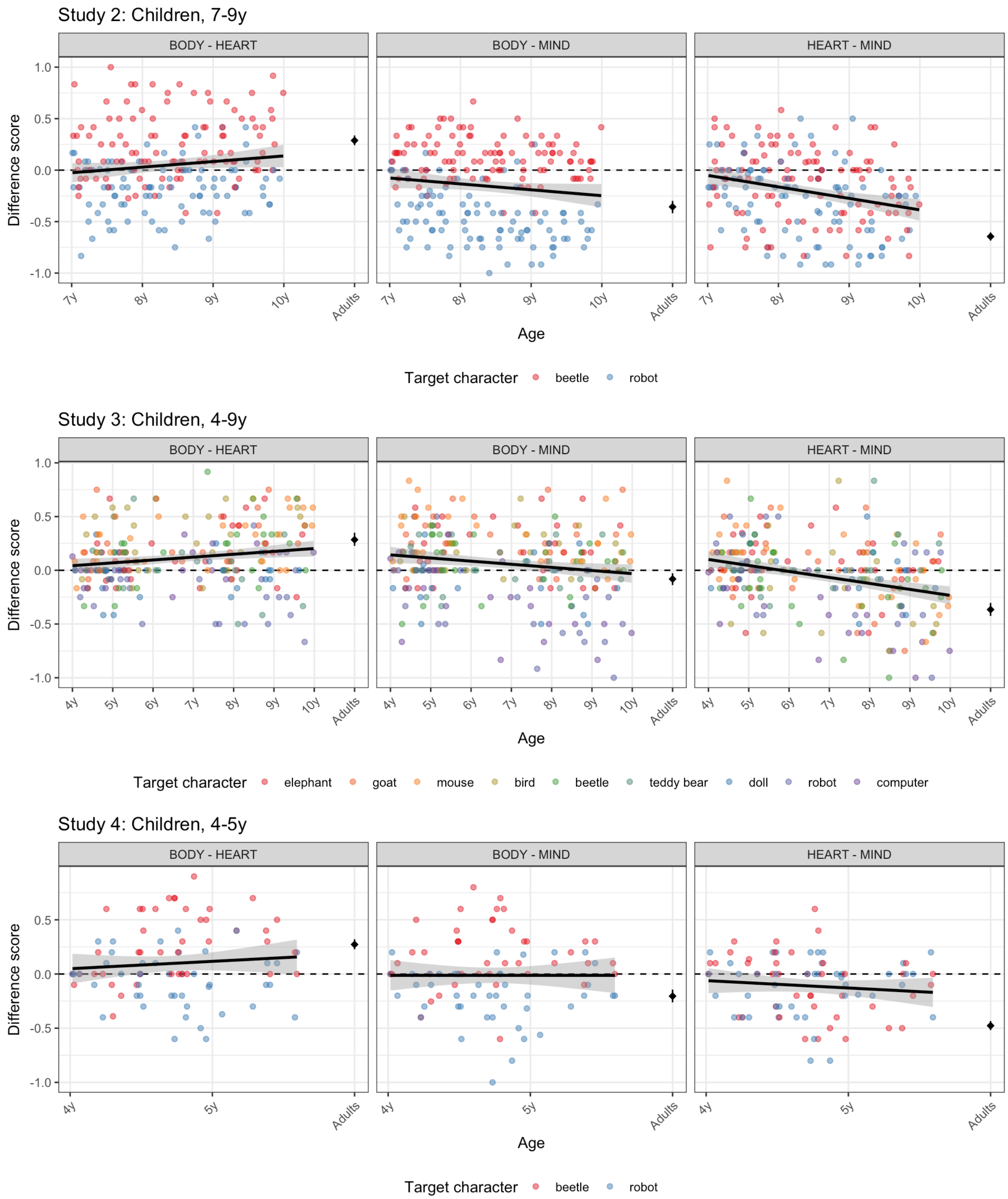

Figure B.3: Changes in difference scores with age among (A) 7- to 9-year-old children in Study 2, (B) 4- to 9-year-old children in Study 3, and (C) 4- to 5-year-old children in Study 4. Plots are organized by sample and scale used (rows) and by pair of conceptual units (columns). All difference scored were calculating using adults' scales for that study; adults' mean difference score (collapsing across target characters) is plotted on the far right of each plot (error bars are 95% bootstrapped confidence intervals).

The joint dependency of HEART on both BODY and MIND

A particularly robust and reliable finding reported in the main text of Chapter IV was that US adults virtually never endorsed HEART more strongly than either BODY or MIND. (US children between the ages of 4-9y also demonstrated increasingly adult-like asymmetries in their BODY, HEART, and MIND attributions with age.) I argued in that chapter that this pattern of findings is consistent with the possibility that adults' mental capacity attributions are governed by an intuitive theory of mental life specifying that, in order for a being to have the social-emotional abilities of the HEART, it must also have the physiological sensations of the BODY *and* the perceptual-cognitive abilities of the mind.

I illustrated support for this hypothesis with a visualization of participants' *BODY*, *HEART*, and *MIND* scores, which demonstrated that, among adults in Studies 1-4, strong endorsements of *HEART* abilities only occurred among participants who also gave strong endorsements of *both BODY* and *MIND* abilities (see Figure 4.11, top row). These tendencies appeared to be weaker among children (middle and bottom rows).

Here I provide a formal analysis of joint dependency in each age group separately, and a formal comparison of these tendencies across age groups. These analyses were conducted using data pooled across all samples (i.e., Studies 1-4 for adults, Studies 2 and 3 for 7- to 9-year-old children, and Studies 3 and 4 for 4- to 6-year-old children). The primary parameter of interest in these analyses is the interaction between *BODY* and *MIND* scores: If attributions of HEART are jointly dependent on attributions of both BODY and MIND, then the interaction between *BODY* and *MIND* scores should be a strong predictor of *HEART* scores, above and beyond either *BODY* scores or *MIND* scores on their own. In addition to using *BODY* scores (when *MIND* scores are at zero), *MIND* scores (when *BODY* scores are at zero), and the interaction between *BODY* and *MIND* scores to predict *HEART* scores, these models also include random intercepts for participants, nested within studies, and random intercepts for target characters.

Among adults, the interaction between *BODY* and *MIND* scores was clearly differentiable from zero, lending further support to the claim that HEART is jointly dependent on both BODY and MIND among US adults. In contrast, the interaction between *BODY* and *MIND* scores was not differentiable from zero among either 7- to 9-

year-old or 4- to 6-year-old children (see “BODY * MIND” row in Table B.6), suggesting that this joint dependency is not present in the aggregate for either of these age groups. A formal comparison across age groups further confirmed these apparent developmental differences: The interactive effect was substantially attenuated among both older children and younger children, relative to adults (see “BODY & MIND” rows in Table B.7).

Table B.6: Regression analyses of the joint dependency of HEART on both BODY and MIND. The table presents results from a series of Bayesian regressions using pooled data from all samples within an age group (i.e., Studies 1-4 for adults, Studies 2 and 3 for 7- to 9-year-old children, and Studies 3 and 4 for 4 - to 6-year-old children. These regressions each included 4 fixed effect parameters: (1) the intercept, which is an index of HEART scores when BODY and MIND scores were both zero; (2) the effect of BODY scores on HEART scores (when MIND scores were zero); (3) the effect of MIND scores on HEART scores (when BODY scores were zero); and (4) the interactive effect of BODY and MIND scores on HEART scores. This last effect is highlighted in bold, because it is the primary parameter of interest for these analyses. In addition to the fixed effects listed here, these regressions included random intercepts for participants, nested within studies, for adults and for 4- to 6-year-old children; random intercepts for studies for 7- to 9-year-old children (since neither study with this age group featured a within-subjects design); and random intercepts for target characters (n = 21 for adults, n = 9 for both 7- to 9-year-old and 4- to 6-year-old children). For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

	Adults			**Children, 7-9y**			**Children, 4-6y**		
Parameter	**b**	**95% CI**		**b**	**95% CI**		**b**	**95% CI**	
Intercept	0.01	[-0.06, 0.08]		0.13	[-3.06, 3.76]		-0.07	[-5.01, 4.44]	
BODY	0.13	[0.05, 0.21]	*	0.68	[0.38, 0.99]	*	0.48	[0.30, 0.66]	*
MIND	-0.04	[-0.08, 0.00]	*	0.14	[-0.12, 0.41]		0.41	[0.22, 0.60]	*
BODY:MIND	**0.42**	**[0.34, 0.51]**	*	**-0.12**	**[-0.52, 0.30]**		**-0.13**	**[-0.43, 0.18]**	

Table B.7: Developmental comparisons of the joint dependency of HEART on both BODY and MIND. The table presents results from a single Bayesian regression using pooled data from all samples in all studies. This regression included 12 fixed effect parameters: (1) the intercept (for adults), which is an index of HEART scores among adults when BODY and MIND scores were both zero; (2-3) the differences between older children vs. adults and younger children vs. adults in their HEART scores when BODY and MIND scores were both zero; (4-6) the effect of BODY scores on HEART scores for adults, and differences from adults in this effect for older and younger children; (7-9) the effect of MIND scores on HEART scores for adults, and differences from adults in this effect for older and younger children; (10-11) the interactive effect of BODY and MIND scores on HEART scores for adults, and differences from adults in this interactive effect for older and younger children. These last three effects are highlighted in bold, because these are the primary parameters of interest for these analyses. In addition to the fixed effects listed here, the regression included random intercepts for participants, nested within studies, and random intercepts for characters (n = 24). For each parameter, the table includes the estimate (b) and a 95% credible interval for that estimate. Asterisks indicate 95% credible intervals that do not include 0.

Parameter	b	95% CI	
HEART scores when BODY scores and MIND scores = 0			
Intercept	0.00	[-0.07, 0.07]	
Older children vs. adults	0.02	[-0.09, 0.12]	
Younger children vs. adults	0.02	[-0.05, 0.10]	
The effect of BODY scores on HEART scores when MIND scores = 0			
BODY	0.13	[0.04, 0.22]	*
BODY * Older children vs. adults	0.54	[0.34, 0.73]	*
BODY * Younger children vs. adults	0.45	[0.29, 0.62]	*
The effect of MIND scores on HEART scores when BODY scores = 0			
MIND	-0.06	[-0.10, -0.01]	*
MIND * Older children vs. adults	0.31	[0.16, 0.46]	*
MIND * Younger children vs. adults	0.45	[0.29, 0.60]	*
The interactive effect of BODY scores and MIND scores on HEART scores			
BODY * MIND	**0.44**	**[0.34, 0.54]**	*
BODY * MIND * Older children vs. adults	**-0.62**	**[-0.88, -0.35]**	*
BODY * MIND * Younger children vs. adults	**-0.63**	**[-0.91, -0.36]**	*

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