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CRITICAL COMMENTARY

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The missing link between core knowledge and language: Review of Elizabeth Spelke's *What babies know, volume 1* (2022)

Barbu Revencu[1] | **Gergely Csibra**[1,2]

[1]Cognitive Development Center, Department of Cognitive Science, Central European University, Vienna, Austria

[2]Department of Psychological Sciences, Birkbeck, University of London, London, UK

Correspondence
Barbu Revencu, Department of Cognitive Science, Central European University, Quellenstraße 51, 1100 Vienna, Austria.
Email: revencu_barbu@phd.ceu.edu

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Spelke's book defends two hypotheses about human cognition. First, humans and other species are endowed with core knowledge systems—innate computational structures that use abstract concepts to represent various aspects of the environment. Second, humans, and only humans, acquire natural languages, whose syntax and compositional semantics allow them to construct new concepts by combining the outputs of core systems. We endorse the first hypothesis but doubt that language acquisition alone explains the productivity of human cognition. In particular, we argue against the claim that infants use aspects of language to develop a new conception of other people.

KEYWORDS
agent concepts, cognitive development, core knowledge, language of thought, natural language

1 | CORE KNOWLEDGE: A CASE STUDY

According to the core knowledge hypothesis (Spelke, 2022), many species start off with several clusters of interconnected abstract concepts, which allow their members to learn relevant aspects of the environment quickly and efficiently. These concepts are universal because they span domains of application that are likely to be present in many ecological niches, and they are selective because each of them applies only to a subset of the entities in the environment and only to a subset of the properties these entities possess.

Consider human adults' intuitive idea of objects as solid bodies that can be tracked through space and time. Mid-sized objects are expected to continue to exist when hidden, to preserve their unity during motion, to move on continuous paths, and to be moved by other objects only upon contact. What are the representations underlying these expectations? Why do they apply to some entities, such as balls, but not others, such as piles of sand? How do these representations come about? Do they interact with representations about other aspects of the environment?

Spelke's proposal of core knowledge systems addresses all of these questions. To mentally represent trackable objects (Chapter 2), adults use a single core system, whose content is built around the concepts of *cohesion*, *continuity*, and *action-on-contact* and whose input consists of perceptual representations. These concepts specify bidirectional principles (e.g., the *action-on-contact* concept includes the *no-action-at-a-distance* principle) that define expectations about what objects are and how they behave. Since, for instance, piles of sand do not move cohesively, they will not fall under the domain of this system, so will not be conceived as trackable objects.

There are several reasons to assume that the core object system is innate. Spelke draws on experiments probing object representations in the first year of life to argue that infants apply the aforementioned concepts to objects in an adult-like way and in an all-or-none fashion at 5 months of age (e.g., Van de Walle et al., 1998). Since there is no direct evidence for a unitary object system at birth, it might be tempting to conclude that the object system requires learning to develop. However, this conclusion would be unwarranted for at least three reasons. First, researchers' ability to tap into infants' cognitive abilities before 3–6 months of age via behavioral measures may be hindered by the slowly developing top-down connections from cortical to motor brain areas (Blumberg & Adolph, 2023). Second, the discrepancy between newborns and 4-month-olds does not preclude a maturational account: The core object system depends on perceptual representations (e.g., motion analyzers) that may not yet be fully formed at birth. Third, as an existence proof that such representational systems can be hard-coded, newborn chicks exhibit an analogous object system in the absence of any visual or tactile experience with solid objects (e.g., Chiandetti & Vallortigara, 2011). Fourth, despite adults' extensive experience with objects, mature object cognition exhibits the same features demonstrated with human infants, which suggests that the core object system is not influenced by learning (see Scholl, 2001, for a review).

The core knowledge hypothesis goes head-on against empiricist views of development, which hold that knowledge accrues slowly and in a bottom-up manner, starting from sensory inputs organized into increasingly abstract representations of objects via domain-general learning. Instead, core knowledge systems are abstract and domain-specific and guide learning in a top-down fashion from the very beginning. This hypothesis also goes against the traditional divide between perception and thought by introducing a layer of representation in between. Unlike perception, the inputs to the object system consist not of sensory information but of representations provided by perceptual systems, and its activation is not automatic but depends on attention. For Spelke, the dependence on attention is an important feature of core systems, as it helps explain why pooling information from several core systems simultaneously is a challenge: Core systems compete for the organism's limited attentional resources.

Objects, however, are not the only kind of entity that various species intuitively grasp from the beginning. Space limitations prevent us from doing justice to Spelke's overview of five more core domains that deal with entities other than trackable objects: navigable spatial layouts (Chapter 3); magnitudes of sets of objects and sequences of events (Chapter 4); shapes and object kinds (Chapter 6); instrumental agents who act efficiently on the environment (Chapter 7); and social beings who engage with one another (Chapter 8). These chapters not only extend the account of core knowledge systems beyond the object system but provide an encyclopedia of

almost half a century of experimental research. Spelke's take on early cognition revolutionized developmental science in its wake and continues to exert a momentous influence on contemporary theories of cognitive development (e.g., Ullman & Tenenbaum, 2020). The core knowledge account singlehandedly provides answers to a variety of questions about the cognitive capacities of human and non-human animals: the mechanisms that support them, their domains and input conditions, their conceptual content, and their ontogeny. This is cognitive science at its best.

2 | BEYOND CORE KNOWLEDGE: LANGUAGE ACQUISITION AND NEW CONCEPTS

In the last two chapters of her book, Spelke seeks to explain why only humans' conceptual repertoire reaches beyond the primitive concepts provided by core knowledge. For her, the limited conceptual repertoire of other animals is easily explainable in terms of two features of core knowledge systems. First, the activation of core knowledge systems is dependent on attention. Second, core knowledge systems are modular—their operation is not influenced by an organism's beliefs about the world. These two features jointly render the core systems unable to exchange information with one another. A creature equipped only with core systems cannot entertain, for instance, a representation with a content such as "Mary broke the five bottles she liked". Such a representation would rely on outputs from several core systems, whose combination would be hindered both by their modularity and by their competition for attention. According to her, while non-human animals can combine representations from distinct core systems by association or by evolved special-purpose mechanisms (pp. 445–446), this ability is neither productive nor systematic. There is no guarantee in the case of non-human animals that being able to represent "X prefers Y" implies being able to represent "Y prefers X" (Fodor & Pylyshyn, 1988).

Humans, on the other hand, acquire concepts that transcend the conceptual primitives of core knowledge as well as use these concepts as building blocks for countless novel thoughts. For Spelke, it is language that provides humans with this capacity. Due to syntax, language can generate complex representations out of individual units; due to compositional semantics, these complex representations are interpretable based only on the meaning of the individual units and on the rules that govern their combination. In addition, Spelke suggests, linguistic expressions may point to core knowledge representations without taking up any attentional resources, which would further simplify the combinatorial process. Importantly, the account Spelke puts forth does *not* involve an innate language of thought (Fodor, 1975), however rudimentary. An innate language of thought would provide infants with a semantics and a syntax that could both underlie natural language acquisition and provide the compositional machinery needed to unlock the modularity of core systems. However, Spelke explicitly rejects this proposal, arguing that an innate language of thought would induce a combinatorial explosion problem: Infants would not know which concepts and beliefs are useful in their culture, which subset of concepts to apply in a given situation, and which propositions are true. Instead, it is only through learning one's native language that the capacity to generate new concepts is achieved.

According to Spelke, human infants are endowed not with compositional machinery but only with capacities for learning natural language (Chapter 9). These capacities include sensitivity to linguistic stimuli and prosodic cues, as well as the ability to distinguish between content words (e.g., nouns, verbs, adjectives) and function words (e.g., prepositions, determiners,

auxiliaries) at a high level of abstraction. Infants activate these learning mechanisms when exposed to speech or sign language, which eventually leads to the acquisition of the syntax and compositional semantics of their native language.

Once the syntactic rules and compositional semantics of their native language are in place, infants can start composing new concepts out of the primitives that core knowledge systems provide. According to Spelke, two new concepts are learned this way toward the first year of life (Chapter 10). At 10 months, infants start viewing people through the lens of a new SOCIAL AGENT concept; at 12 months, infants start viewing people as social agents endowed with phenomenal and intentional MENTAL STATES. Natural language is argued to play a crucial causal role in the creation of both of these concepts, which obviates the need for postulating additional core systems (e.g., shared intentionality: Tomasello, 2022; or communication: Sperber & Wilson, 1995; Csibra & Gergely, 2009). Language does this by allowing infants to combine representations from two core systems: one dedicated to action understanding (representing instrumental agents acting on the environment: Chapter 7), the other dedicated to social cognition (representing people as individuals who engage with one another: Chapter 8). As soon as the composite SOCIAL AGENT concept is in place, infants' word learning accelerates dramatically. They start to understand communicative acts about objects and get Gricean pragmatics (Grice, 1975) for free: Object-directed communicative acts are expected to be efficient (per the agent system) and relevant for social partners (per the social cognition system).

We have several reasons to doubt this account, and we will focus the rest of the discussion on two claims made by Spelke in the ending chapters of the book: (i) that SOCIAL AGENT is the first non-core concept generated at 10 months by composing core knowledge representations and (ii) that this and other compositions are driven by natural language (as opposed to a language of thought). We will argue that theoretical considerations as well as current empirical findings cast doubt on each of these claims.

3 | WHERE THE LANGUAGE ACQUISITION ACCOUNT DOES NOT WORK

The claim that it is only around 10 months that infants begin to treat people as social agents is based on several case studies involving tasks with and without objects, which infants fail before 10 months and pass afterward (e.g., Beier & Spelke, 2012; Thomsen et al., 2011). The problem with this argument is that tasks involving both agents and objects may be more difficult for infants simply because core systems compete for attention, and there are multiple systems that take objects as input. This may mask infants' ability to represent, for instance, object-directed social acts because they have not yet figured out how to rationally allocate attentional resources.

Suppose, however, that the success-failure pattern that has been observed post-10-months and pre-10-months is robust and more than a mere performance issue. Spelke argues that we should attribute this change to the combination of the core agent and social cognition systems, rather than to the emergence of a completely new SOCIAL AGENT concept. First, she writes, the SOCIAL AGENT concept, which drives infants' pragmatic interpretation of object-directed communicative acts, lies precisely at the intersection of the core agent and social cognition systems. As actions, agents' communicative acts are expected to be efficient; as acts of engagement, they are expected to be relevant to the current situation. Spelke attempts to recreate the triadic structure of communication (speaker, audience, referent) by merging the two dyadic relations embedded

in the concepts of instrumental action (actor, object) and social engagement (actor, partner). We doubt that this move is straightforward (Csibra, 2003; Gergely & Jacob, 2012) and that the composition of these two concepts is sufficient to allow infants to ascribe non-natural meaning to communicative acts (Grice, 1957), especially when the intended meaning goes beyond the current situation. Thus, we suspect that the SOCIAL AGENT concept, even when it is expanded with MENTAL STATE concepts at 12 months of age, is not able to serve the function that Spelke assigns to it: moving infants from the interpretation of instrumental action to the extraction of non-natural meaning from communicative action.

A second difference between the composite SOCIAL AGENT concept and other core systems that Spelke puts forth is that social agent concepts do not compete for attention with concepts from other core systems (p. 422). We do not know of any evidence that supports this claim. What we do know is that adults seem to automatically compute the perspective of another agent when engaging in an unrelated dot-estimation task (Samson et al., 2010). What Spelke seems to suggest here is that construing this agent as a *social agent* (not merely as an *agent*) would make the perspective-taking effect disappear: the social agent would no longer be engaging attentional resources, which could now be fully deployed in the dot-estimation task. This is a counterintuitive prediction that, to our knowledge, has not been tested.

Spelke goes on to point out that the SOCIAL AGENT system is not unitary. Even in adults, she notes, agency and intentionality are sometimes dissociated, as in the case of robots (intentional but non-phenomenal agents) or infants (phenomenal but non-intentional beings). This is in contrast to core knowledge systems, which function in an all-or-none fashion. When infants are exposed to an entity that looks like an object but then turns out to not move cohesively, infants no longer expect this entity to move continuously or to persist under occlusion (Huntley-Fenner et al., 2002). However, both adult intuitions and infant data suggest that core systems are not as unitary as they may appear. Just as intentional and phenomenal agency can be dissociated, so can the principles that govern object cognition. Spatiotemporal continuity can be dissociated from cohesion (adults easily understand teleportation in science fiction scenarios) and many objects can be acted on by means of remote controls, violating action-on-contact. As far as we know, this does not make them lesser objects. In addition, Stahl and Feigenson (2015) reported that infants exposed to objects violating different physical laws (e.g., solidity) selectively explored objects depending on the violation observed (e.g., they bang solidity-violating objects against the table). However, allowing for selective violations of object principles should not have occurred under a unitary object cognition system. Instead, infants should have suspended *all* assumptions of objecthood once they witnessed a violation of only one of them. Since unity does not seem to hold even for objects, the lack of unity in the social agent domain cannot be used to rule it out as a single system.

However, even if we accept that the SOCIAL AGENT concept is derived compositionally, it is far from clear that this is the *first* composite representation infants generate. To bolster her claim that infants are unable to combine core representations before the SOCIAL AGENT concept is acquired, Spelke relies on Xu and Carey's (1996) object individuation study, which 10-month-olds fail. After seeing a duck and a truck come out successively from behind an occluding screen before going back in, infants do not expect to see two objects when the occluder is removed. However, infants do succeed in the individuation task when the two objects fall under different core systems, such as a ball and a baby doll (Bonatti et al., 2002; see also Decarli et al., 2020; Surian & Caldi, 2010). How do infants single out the two entities in that case? If they represent two objects within a single composite representation, this would mean that the SOCIAL AGENT concept is not the first one that infants compose. If, on the other hand, infants use separate systems to represent each object—the agent system for the doll and the object system for the ball—it becomes unclear how

the competition for attention between the two systems is solved such that the two outputs, which presumably need to be simultaneously active, can drive successful individuation.

Relatedly, it is not clear to us what criteria one could adopt to judge whether a representation is truly compositional. On the one hand, Spelke grants that there is an associative but limited way of combining core representations, which is available to all animals when they plan specific actions or when they deal with representations that are predictably related. On the other, humans transcend these limits by using language, which allows them to productively combine knowledge in various core systems. This distinction is sensible and likely to capture an important contrast but it is not well-specified enough to discern whether composition has been achieved. What would count as evidence that infants can productively (rather than associatively) compose concepts before 10 months? Conversely, why does the SOCIAL AGENT concept herald true compositionality, instead of simply being the product of an associative combination (efficient agents tend to engage with one another)?

In sum, we do not think that current evidence strongly favors the view that a novel composite conception of agents arises at 10 months. Nevertheless, let us assume it does and ask how language contributes to its emergence. On the one hand, Spelke emphasizes that language exposure guides infants toward useful and relevant concepts, which mitigates the combinatorial explosion problem that an innate language of thought would give rise to. What was unclear in her discussion was whether infants rely on adults for the acquisition of new concepts *before* the emergence of the SOCIAL AGENT concept or only *afterward*, so we will discuss both possibilities. If infants rely on adults' utterances to build a SOCIAL AGENT concept, this would imply that there are sentences in the infants' input that would guide them toward this concept. But, as far as we can tell, there are no natural language expressions that highlight the intersection of the agent and the social cognition systems. This observation points to a more general problem with Spelke's account of how novel concepts are acquired. Spelke needs natural language (as opposed to a language of thought) to combine core representations, but, as she herself acknowledges, core knowledge concepts are taken for granted by everyone, so they are rarely expressed in speech. Moreover, the converse problem also holds, as many linguistic units have no counterpart in core knowledge systems. While the meaning of some function words plausibly originates in the core object system (e.g., prepositions denoting spatial relations: Section 9.8), the link between many other function words and core systems is far from obvious. Absent an internal language of thought that can express a wider range of concepts, the acquisition of logical operators, of tense and aspect morphemes, or of modal verbs would remain a mystery.

One way out of this conundrum would be to allow for the possibility that the output representations of core knowledge systems are in a language-of-thought format from the start. Compositional machinery interfacing with these systems could be added on top of them to derive complex representations built from the outputs of these systems, perhaps augmented with operations absent from the core systems (e.g., conjunction, disjunction, negation). If we read her right, Spelke rejects this account and suggests instead that language is needed to bring all of these systems into a common representational format. But this is not a satisfying solution either. In particular, this account will give rise to an equivocation problem concerning the meaning of "concept", since it would imply that the concepts residing in core knowledge systems are of a different kind from the concepts used as the building blocks of thought. As such, core concepts cannot be straightforwardly used as primitives to learn the concepts that infants allegedly lack. Consequently, Spelke needs an account that goes beyond standard compositional semantics and that can link the two types of concepts envisaged. We did not find such an account in the book.

Returning to the SOCIAL AGENT concept, suppose that infants compose it without relying on external linguistic expressions. This would imply that, in this particular case, concept composition is exclusively driven by infant-internal processes. But then why do infants converge upon the SOCIAL AGENT concept first, as opposed to the myriad other combinations that are possible once composition can be performed? If natural language is productive in the way Spelke claims it to be, her account does not solve the combinatorial explosion problem but only pushes it slightly further in development.

Toward the end of the book, Spelke concedes that exposure to language may not be required for constructing the SOCIAL AGENT concept, since even language-deprived deaf children invent their own gestural language, which allows them to understand others' object-directed communicative acts. If so, she writes, the SOCIAL AGENT concept might depend on the features of language that children can reinvent in the absence of linguistic input (Goldin-Meadow, 2003). Presumably, these features would include the capacity to generate open-ended expressions, but then how could one distinguish these features from a pre-linguistic language of thought, the existence of which Spelke explicitly rejects?

In sum, Spelke argues that core knowledge and language learning capacities are sufficient to explain why humans master seemingly boundless repertoires of concepts. Core knowledge provides the primitives and language provides the tools for their composition. The first learned concept, SOCIAL AGENT, provides the pragmatic assumptions that accelerate word learning and constrain the subsequent formation of novel concepts. We have reasons to doubt the claim that a new SOCIAL AGENT concept emerges at the end of the first year due to the acquisition of a natural language. We are also unconvinced that Spelke's account in its current form can bypass the need for a language of thought. Her account requires bidirectional links between language and core systems, which we do not see to obtain. Function words often have no correspondents in core systems; conversely, the primitive concepts of core systems often have no counterparts in natural language. An innate language of thought would provide the links between infants' internal representations and natural language. Finally, if the SOCIAL AGENT concept is not derived via composition, something beyond core knowledge and natural language will be needed to account for the human-specific path of conceptual development.

4 | CONCLUSION

Spelke's book aims to answer two questions at the heart of the study of human cognitive development: (i) What is built in?; (ii) How do we learn the rest? Spelke draws on beautiful experimental work done by her and her collaborators to provide a clear-cut theoretical answer to the first question. Humans and other animals are endowed with core knowledge systems consisting of abstract concepts that underlie our intuitive understanding of the world in terms of objects, places, numbers, and agents. We could not agree more. In the last part of the book, Spelke outlines her answer to the second question, according to which learning a natural language suffices for breaking the modularity of core knowledge systems and for building novel domains of knowledge. We are not convinced. On the one hand, if only adults' linguistic expressions guide infants toward new concepts, Spelke's account will undergenerate the concepts acquired beyond late infancy, as the interface between core knowledge concepts and natural language expressions is not sufficiently spelled out to account for the human conceptual repertoire. Neither are core concepts expressed often enough in linguistic communication to drive composition nor are many linguistic items to be found a core-systems equivalent. On the other, if the account allows for the SOCIAL AGENT concept to be generated in the absence of external guidance, this move will overgenerate

the concepts we observe beyond late infancy. Until a principled explanation is added for why only the SOCIAL AGENT concept emerges, the account should predict that many more concepts will be constructed by internally driven composition. In our view, therefore, Spelke's account does not yet provide a satisfying answer to the second main question of cognitive development. We are looking forward to a more elaborated version of this account in the second volume.

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There are no data available.

ORCID

Barbu Revencu https://orcid.org/0000-0001-8701-9123
Gergely Csibra https://orcid.org/0000-0002-7044-3056

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