is currently hotly debated, as attested by the BBS treatment of Quilty-Dunn, Porot, and Mandelbaum's (2023) target article on the current status of the language of thought hypothesis. *WBK* gives us further reason as a field to try to bring data to bear on the fundamental issues concerning formats of representation.

Financial support. The research reported here was funded by a James S. McDonnell Foundation Network grant "The Ontogenetic Origins of Abstract Combinatorial Thought". PI: Susan Carey; 16 co-PIs.

References

Beck, J. (2019). Perception is analog: The argument from Weber's Law. *The Journal of Philosophy*, *116*, 319–349.

Block, N. (2022). *The border between thinking and seeing*. Oxford University Press.

Carey, S. (2009). *The origin of concepts*. Oxford University Press.

Feigenson, L., & Carey, S. (2003). Tracking individuals via object files: Evidence from infants' manual search. *Developmental Science*, *6*, 568–584.

Gleitman L. (1990). The structural sources of verb meaning. *Language Acquisition*, *1*, 3–55.

Hesse, J., & Tsao, D. (2020). The macaque face patch system: A turtle's underbelly for the brain. *Nature Review Neuroscience*, *12*, 695–716.

Hochmann, J. R. (2022). Representations of abstract relations in infancy. *Open Mind*, *6*, 291–310.

Hochmann, J. R., Tuerk, A. S., Sanborn, S., Zhu, R., Long, R., Dempster, M., & Carey, S. (2017). Children's representations of abstract relations in relational/array match to sample tasks. *Cognitive Psychology*, *99*, 17–43.

Hochmann, J. R., Zhu, R., & Carey, S. (under review-a). Conceptual combination of mental representations of *same*, *not*, and *all* requires learning the words "same" and "different."

Hochmann, J. R., Zhu, R., Zhu, L., & Carey, S. (under review-b). Learning the words "same" and "different" in the preschool years.

Quilty-Dunn, J., Porot, N., & Mandelbaum, E. (2023). The best game in town: The reemergence of the language-of-thought hypothesis across the cognitive sciences. *Behavioral and Brain Sciences*, *46*, 1–55.

Spelke, E. S. (2022). *What babies know: Core knowledge and composition*. Oxford University Press.

Wasserman, E., Castro, S., & Fagot, K (2017). Relational thinking in animals and humans: From percepts to concepts. In J. Call, G. M. Burgardt, I. M. Pepperberg, C. T. Snowden, & T. Zentall (Eds), *APA handbook of comparative psychology: Perception, learning & cognition* (pp. 359–384). American Psychological Association.

Divisive language

Moira R. Dillon

Department of Psychology, New York University, New York, NY, USA

Corresponding author:
Moira R. Dillon; Email: moira.dillon@nyu.edu

doi:10.1017/S0140525X23003047, e124

Abstract

What language devises, it might divide. By exploring the relations among the core geometries of the physical world, the abstract geometry of Euclid, and language, I give new insight into both the persistence of core knowledge into adulthood and our access to it through language. My extension of Spelke's language argument has implications for pedagogy, philosophy, and artificial intelligence.

As we wander the spaces of the physical world, our experience seems seamless, rich, and unitary, integrating the places we navigate with the visual forms in those places. Nevertheless, a rich series of studies in the psychological, cognitive, and neural sciences – many of which were done by Elizabeth Spelke or her myriad mentees – suggest that different geometric representations underlie our experience of places and forms. In *What Babies Know*, Spelke (2022) argues that these different geometric representations are from different systems of "core knowledge," one system for *places* and another system for *forms*. Although core knowledge of places prioritizes distance and directional information for navigating paths through space, core knowledge of forms prioritizes hierarchically structured shape information for recognizing closed figures and objects. Spelke suggests, moreover, that human language allows the complementary geometries of the place and form systems to combine to support an intuitive abstract geometry that captures Euclidean geometry, a point she will expand on in her second volume, *How Children Learn*. Spelke's proposal is nevertheless committed to the persistence of the separate core systems of geometry throughout the human lifespan, remaining present and active even after older children learn Euclidean geometry, which is unitary in its integration of distance, direction, and shape.

In this commentary, I make two main points. First, I describe new evidence from a recent behavioral experiment in my lab that core knowledge about places and forms is indeed still present and active in educated human adults, consistent with Spelke's proposal (Lin & Dillon, 2023). My evidence complements evidence Spelke has put forward insofar as my tasks, unlike the tasks she reviews, relied only on simple and minimally contrastive linguistic descriptions – with no actual navigation or form analysis – to elicit core geometry of places and forms. Following this point, I then suggest that Spelke's "combined geometries," which are combined in language, can be later *re-isolated* through language, which is neither explicitly predicted by nor outlined in Spelke's proposal. I see my second point as a consistent – but not necessary – extension of Spelke's language argument that has implications for how we think about the relations among core knowledge systems and language more generally.

One pillar of core knowledge is its persistence throughout the lifespan, present – with all its original properties and limits – in human adults long after adults have developed the rich concepts that combine core knowledge. Spelke provides examples of this persistence in her review of each core system. For example, she describes how studies using brain-imaging techniques with adults navigating virtual environments reveal the signature limits of place geometry present in children and nonhuman animals (Doeller & Burgess, 2008; Doeller, King, & Burgess, 2008) and how studies using a two-alternative-forced-choice matching task show that adults, like infants, judge shapes as more similar when those shapes share the same skeletal structure versus the same 3D parts (Ayzenberg & Lourenco, 2019, 2022).

My lab's recent work, led by postdoctoral associate Yi Lin, provides new evidence for the persistence of both place and form geometry in adults, and it does so in a way that is complementary to the examples Spelke provides. In particular, we were able to elicit core geometry in adults for places and forms using simple, minimally contrastive linguistic descriptions and without adults' engaging in any actual navigation or form analysis. In our study, adults watched short videos of two points and two line segments forming an open figure on an otherwise blank screen. These simple figures were described with language that created different spatial contexts. After watching each video, adults were asked to provide a click response. In the *navigation* condition, they were told that they were seeing paths and stops that an agent traveled on a land. They were then asked to click on the next stop. In the *object* condition, they were told that they were seeing edges and corners of one side of an object. They were then asked to click on the next corner.

We wondered what geometry participants would preserve and perpetuate in their clicking responses given the language of their assigned condition. Could this minimal manipulation in language evoke core geometry? In particular, would adults in the navigation condition perpetuate the distance and direction of the figures' initial trajectories? Would those in the object condition instead preserve the initial figures' global shape?

Strikingly, adults produced responses reflecting different sets of geometric representations depending on the condition. In the navigation condition, adults perpetuated the figures' distance and directional information, producing open zig-zag paths. In the object condition, in contrast, they preserved the global shape of the initial figures and produced the third sides of what would be closed parallelograms. The clear and consistent reflections of the different geometries grabbed our attention because the procedure was open-ended and subjective and because the adult participants had been educated in formal geometry. These adults could have imagined a figure with *any* geometry. This task, inspired by other tasks' use of a simple and open-ended tapping procedure (e.g., Firestone & Scholl, 2014), was able to evoke effortlessly the particular geometric representations inherent to places and forms given minimally contrastive descriptions of the spatial context. Our results give new insight into both the persistence of core knowledge into adulthood and our access to it.

The power of language in this paradigm leads to my second point: What language joins it may unjoin. Spelke explains that when 9- and 10-month-old infants, like those in the studies of Xu and Carey (1996) and Xu (2002), see two different objects with two different shapes, like a cup and a shoe, emerge in alternation from either side of an occluder, they fail to predict that there are indeed two objects at play. The physical properties of the display trigger infants' object system and imply the presence of one moving body. This system outcompetes the infants' form system, which, from the spatial properties of the display, signals the presence of two different forms. When each object receives a different noun label upon emerging from its side of the occluder, however, infants can then use the objects' different forms to predict the presence of two objects. Spelke suggests that content words in language, like noun labels, allow for an efficient packaging of the activated core representations in a combined concept: In language, the cup and shoe are each simultaneously a moving body (*object* system) and a distinctive form (*form* system). Depending on the context, infants may choose between these core representations in a way that is relevant and efficient to the task at hand. For example, after hearing two different noun labels, infants may infer that the speaker intends to share with them two different experiences. Infants can then call upon their representation of two forms, from which follows the presence of two objects of different kinds. Older infants, children, and adults already have these combined concepts of cups and shoes as bodies with forms, concepts that were acquired through language, and so unlike younger infants, they do not need this initial labeling step to individuate the objects by their forms.

Content words thereby combine core concepts, as described above. But Spelke sees no evidence that content words express core concepts directly. Moreover, Spelke suggests that short and frequent function words, like *in* and *on*, may capture core knowledge "more directly" because such words express the mechanical relations between objects captured by the core object system (Hespos & Spelke, 2004; Strickland, 2017). She states: "There is no word, in ordinary language, that refers to the objects, places, numerical magnitudes, forms, agents, or social beings revealed by the research on infants; that is why core knowledge is hard to write about." I suggest, however, that some content words are not too far off. After all, Spelke succeeds in writing elegantly about core knowledge! She was right, I think, to talk about *objects* instead of *schmobjects*. Despite the dangers of using ordinary language in scientific theory (Chomsky, 2000), and given that not conflating the ordinary-language combined concept *object* and the core-knowledge concept *object* is a challenge, the ordinary-language word *object* was nevertheless successfully used in Yi's and my experiment to evoke selectively a core inspiration. For example, describing the points, lines, and figures in our stimuli videos as "corners," "edges," and "objects" was enough to evoke the core geometry of the form system when adults were simply asked to click where the next "corner" would be. That this evocation was the geometry of *forms* that comes along with our everyday adult concept of *object*, however, proves both the power and limits of the ordinary language that names such concepts. My study with Yi makes the novel suggestion that at least some content words (or a brief collection of such content words) may also express core knowledge "more directly" – though only ever more or less directly. The re-isolation of core concepts within the medium of their combination reveals the scope and limits that define the combinatorial power of language: Language merges but does not meld (Chomsky, 1995; Chomsky et al., 2023).

So what seem like unitary concepts in ordinary language are never quite so, always already open to different evocations depending on context. If so, this may explain philosophical confusions (Reilly, 2019) and encourage pedagogical innovation. My example here again is geometry. My study with Yi also included an *abstract* condition, in which participants were told that they were seeing "points" and "lines" on an abstract "surface." They were then asked to click on the next point.

Participants in this *abstract* condition produced responses that were strikingly similar to participants' responses in the *navigation* condition. First, if abstract geometry is a combination of place and form geometries, then our findings suggest that this combination is not some *tertium quid*: The core knowledge in merged abstract geometry can be re-isolated through language. Spelke suggests that we lack a deep understanding of "the processes by which infants combine core representations with one another or with language," and I agree. Nevertheless, I suggest that in these combined representations, core concepts remain both intact and evocable through language. Second, abstract concepts in geometry maintain the competition between persistent core systems. In the case of our manipulation, place geometry wins. We suggest that under most conditions, in fact, the geometric representations humans call upon for reasoning about abstract points, lines, and figures may lie in representations we and other animals use for navigation: We wander the abstract world of Euclidean geometry like we wander the physical world of everyday life. Nevertheless, such competition raises the possibility that other manipulations probing abstract geometry, for example, those with different visuals or different language, could instead isolate form geometry over place geometry. These conclusions should inform philosophical debates over the origins of geometry (Husserl, 1970/1954; Kant, 1998/1781), interpretation of past empirical findings (e.g., Izard, Pica, Spelke, & Dehaene, 2011), the development of geometry pedagogies (e.g., Dillon, Kannan, Dean, Spelke, & Duflo, 2017), and the engineering of intelligent machines that aim to think mathematically like we do (McClelland, 2022; Sablé-Meyer, Ellis, Tenenbaum, & Dehaene, 2022).

Is the effect of content words in our study the norm or an exception? After all, Spelke describes how writing her book was a hard-won achievement. And, again, the term we used, *object*, evoked representations from the form system *not* from the object system! Nevertheless, I suggest that our findings call for explorations of whether and how language might isolate other core knowledge in adults' merged experiences, as, for example, our seemingly unified experience of the social world, which may, as Spelke suggests, instead rely on merged core knowledge of agents and social beings (see also Gray, Gray, & Wegner, 2007; Knobe & Prinz, 2008). For example, although our commonsense concept (or word) *person* might seem unified, similarly simple and minimal descriptions in language of people as either agents or social beings might re-isolate these core concepts underlying *person*. As for geometry, so for ethics. Spelke's core knowledge and language hypotheses, in combination, promise to be generative indeed in education and economics, philosophy and psychology, allowing us to probe the core of these domains.

Acknowledgments. The author thanks Elizabeth Spelke for her mentorship, support, and the opportunity to probe further just *What Babies Know*. The author thanks also Brian J. Reilly for his comments on the article.

Financial support. This work was supported by a National Science Foundation CAREER Award (DRL-1845924; to M. R. D.).

Competing interests. None.

References

Ayzenberg, V., & Lourenco, S. (2022). Perception of an object's global shape is best described by a model of skeletal structure inhuman infants. *eLife*, *11*, e74943. doi:10.7554/eLife.74943

Ayzenberg, V., & Lourenco, S. F. (2019). Skeletal descriptions of shape provide unique perceptual information for object recognition. *Scientific Reports*, *9*, 1–12. doi: doi.org/10.1038/s41598-019-45268-y

Chomsky, N. (1995). *The minimalist program*. MIT Press.

Chomsky, N. (2000). *New horizons in the study of language and mind*. Cambridge University Press.

Chomsky, N., Seely, T. D., Berwick, R. C., Fong, S., Huybregts, M. A. C., Kitahara, H., … Sugimoto, Y. (2023). *Merge and the strong minimalist thesis*. Cambridge University Press.

Dillon, M. R., Kannan, H., Dean, J. T., Spelke, E. S., & Duflo, E. (2017). Cognitive science in the field: A preschool intervention durably enhances intuitive but not formal mathematics. *Science (New York, N.Y.)*, *357*, 47–55. doi: doi.org/10.1126/science.aal4724

Doeller, C. F., & Burgess, N. (2008). Distinct error-correcting and incidental learning of location relative to landmarks and boundaries. *Proceedings of the National Academy of Sciences of the United States of America*, *105*, 5909–5914. doi: doi.org/10.1073/pnas.0711433105

Doeller, C. F., King, J. A., & Burgess, N. (2008). Parallel striatal and hippocampal systems for landmarks and boundaries in spatial memory. *Proceedings of the National Academy of Sciences of the United States of America*, *105*, 5915–5920. doi: doi.org/10.1073/pnas.0801489105

Firestone, C., & Scholl, B. J. (2014). "Please tap the shape, anywhere you like" shape skeletons in human vision revealed by an exceedingly simple measure. *Psychological Science*, *25*, 377–386. doi: doi.org/10.1177/0956797613507

Gray, H. M., Gray, K., & Wegner, D. M. (2007). Dimensions of mind perception. *Science (New York, N.Y.)*, *315*, 619. doi: doi.org/10.1126/science.1134475

Hespos, S. J., & Spelke, E. S. (2004). Conceptual precursors to language. *Nature*, *430*, 453–456. doi: doi.org/10.1038/nature02634

Husserl, E. (1970). *The crisis of European sciences and transcendental phenomenology* (D. Carr, Trans.). Northwestern University Press. (Original work published 1954).

Izard, V., Pica, P., Spelke, E. S., & Dehaene, S. (2011). Flexible intuitions of Euclidean geometry in an Amazonian indigene group. *Proceedings of the National Academy of Sciences of the United States of America*, *108*, 9782–9787. doi: doi.org/10.1073/pnas.1016686108

Kant, I. (1998). *Critique of pure reason* (P. Guyer & A. W. Wood, Trans. and Eds.). Cambridge University Press. (Original work published 1781).

Knobe, J., & Prinz, J. (2008). Intuitions about consciousness: Experimental studies. *Phenomenology and the Cognitive Sciences*, *7*(1), 67–83. doi: doi.org/10.1007/s11097-007-9066-y

Lin, Y., & Dillon, M. R. (2023). We are wanderers: Abstract geometry reflects spatial navigation. *Journal of Experimental Psychology: General*. doi:10.1037/xge0001504

McClelland, J. L. (2022). Capturing advanced human cognitive abilities with deep neural networks. *Trends in Cognitive Sciences*, *26*, 1047–1050. doi: doi.org/10.1016/j.tics.2022.09.018

Reilly, B. J. (2019). *Getting the blues: Vision and cognition in the middle ages*. Peter Lang.

Sablé-Meyer, M., Ellis, K., Tenenbaum, J., & Dehaene, S. (2022). A language of thought for the mental representation of geometric shapes. *Cognitive Psychology*, *139*, 101527. doi: doi.org/10.1016/j.cogpsych.2022.101527

Spelke, E. S. (2022). *What babies know: Core knowledge and composition*. Oxford University Press.

Strickland, B. (2017). Language reflects "core" cognition: A new theory about the origin of cross-linguistic regularities. *Cognitive Science*, *41*, 70–101. doi: doi.org/10.1111/cogs.12332

Xu, F. (2002). The role of language in acquiring object kind concepts in infancy. *Cognition*, *85*, 223–250. doi: doi.org/10.1016/S0010-0277(02)00109-9

Xu, F., & Carey, S. (1996). Infants' metaphysics: The case of numerical identity. *Cognitive Psychology*, *30*, 111–153. doi: doi.org/10.1006/cogp.1996.0005

Is there only one innate modular system for spatial navigation?

Alexandre Duval*

School of Philosophy, Australian National University, Canberra, ACT, Australia
alexandre.duval@anu.edu.au

*Corresponding author.

doi:10.1017/S0140525X23003114, e125

Abstract

Spelke convincingly argues that we should posit six innate modular systems beyond the periphery (i.e., beyond low-level perception and motor control). I focus on the case of spatial navigation (Ch. 3) to claim that there remain powerful considerations in favor of positing additional innate, nonperipheral modules. This opens the door to stronger forms of nativism and nonperipheral modularism than Spelke's.

A central thesis of *What Babies Know* (Spelke, 2022) is that there are (at least) six innate modular cognitive systems beyond the periphery of the mind, one for each of the following domains: objects, places, numbers, forms, agents, and social beings. Moreover, it seems clear from previous works (e.g., Spelke & Kinzler, 2007) and various discussions in the book that Spelke thinks that there are only a handful of systems that will turn out to be innate and/or nonperipheral modules – either exactly six or only slightly above six – and that research on core knowledge systems will therefore support *moderate* forms of both nativism and nonperipheral modularism.

My view on the book is that it does an excellent job of arguing for a *lower bound* on the number of such systems, but that it doesn't give strong reasons why we should stop at six and thus eschew stronger forms of nativism and nonperipheral modularism. It helps to distinguish two questions here: Are there additional innate modules operating *within* the six domains discussed in the book? Are there additional innate modules operating in *other* domains? I will make my case by focusing on the first question, and I will do so by taking spatial navigation (Ch. 3) as a case study. (Terminological note: In what follows, I