Philosophical Psychology
Vol. 21, No. 2, April 2008, pp. 241–250

Routledge
Taylor & Francis Group

Space—The Primal Frontier? Spatial Cognition and the Origins of Concepts

Frank C. Keil

The more carefully we look, the more impressive the repertoire of infant concepts seems to be. Across a wide range of tasks, infants seem to be using concepts corresponding to surprisingly high-level and abstract categories and relations. It is tempting to try to explain these abilities in terms of a core capacity in spatial cognition that emerges very early in development and then gets extended beyond reasoning about direct spatial arrays and events. Although such a spatial cognitive capacity may indeed form one valuable basis for later cognitive growth, it seems unlikely that it can be the sole or even primary explanation for either the impressive conceptual capacities of infants or the ways in which concepts develop.

Keywords: Cognitive Development; Concepts; Conceptual Change; Spatial Cognition

Few problems are more challenging than those surrounding the origins of concepts. Common sense suggests that children really cannot come into the world with the full complement of concepts that adults have, but as Fodor and others have pointed out, it is difficult to find convincing stories about how the full adult set might originate out of a simpler set through some sort of compositional apparatus (Fodor, 1998). Mandler (2008, this issue) argues that there is a solution, one that bypasses Fodor's concerns by rejecting notions of concept acquisition as hypothesis testing, while not making recourse to concepts arising from latent pre-existing structure. If this account could work for the full range of concepts, it would offer a dramatic solution.

Frank C. Keil is a Professor at the Yale Psychology Lab of Cognition and Development. Correspondence to: Frank C. Keil, Department of Psychology, Yale University, 2 Hillhouse Avenue, P.O. Box 208205, New Haven, CT 06520-8205, USA. Email: frank.keil@yale.edu

ISSN 0951-5089 (print)/ISSN 1465-394X (online)/08/020241-10 © 2008 Taylor & Francis
DOI: 10.1080/09515080801980203

The core of Mandler's account is the idea that the earliest forms of thought are built out of visual-spatial components—'image-schemas'—which are more than just images, and represent relational notions in a nonpropositional way. This assumption leads to several other proposals: (1) that conceptual development goes from the abstract to the concrete, (2) that image-schemas are surprisingly powerful underpinnings of adult cognition through analogy and metaphor, (3) that it is possible to tell a smooth continuous developmental story from infancy onwards, and (4) that, taken together, these proposals offer a way out of Fodor's pessimism about how adult concepts could be built up out of a much smaller primitive set in infants. There is much to like here. Mandler's work represents one of the most extensive proposals about how concepts might initially emerge and then grow into their adult form. Moreover, some of her proposals capture phenomena that are central to conceptual development, but which have been largely ignored, denied or repressed until quite recently. In the end, however, we may still have the same puzzle of where most concepts come from.

1. Non–propositional Origins

Consider first the idea that infant cognition consists largely of image-schemas and associations and that most, if not all, infant behavioral data can be explained by such cognitions. Mandler suggests that early concepts are composed from elements of spatial information, especially movements in space. She thinks of these as 'conceptual primitives'. She argues that these primitives are not atomic and unanalyzable. Instead, she suggests that they have an internal structure. One such example is CONTAINER, which has a necessary structural relationship between an inside and an outside. Most concepts consist of more than one such primitive. Motion is argued to be especially salient, especially to young infants who cannot make fine-grained distinctions based on perceptual appearance. Thus, paths of motion and self-generated motion are thought to be some of the most foundational forms of information that are represented.

The engine of early conceptual development is largely a process called 'Perceptual Meaning Analysis', which 'reformats' spatial information into a new format. Thus, when an infant sees an apple put into a bowl, Mandler says that the infants see 'THING INTO CONTAINER'. At some level this must be true. If an adult lands in a strange culture and sees an unfamiliar object placed into the interior of another unfamiliar object, she can do little more than encode the event as 'THING INTO CONTAINER'. What seems to be central here is the idea that this level of analysis is the most primitive and psychologically immediate and the default when one has minimal background knowledge. Perceptual Meaning Analysis can be thought of as a data summarization device that takes rich perceptual information and puts it into a much sparser code that is dictated by a limited set of primitives and rules governing their combination. Image-schemas, which are said to be analog, 'kinetic' and unconscious, seem to be that code, although the rules of combination are never spelled out. Image-schemas also

seem to be a launching pad both for adult-like concepts and for mental images. In short, they are very powerful cognitive primitives indeed.

Consider for a moment, some of the image-schema primitives: PATH, START, CONTACT, and LINK. These notions are said to be powerful bases for many high level categories. In addition, certain perceptual patterns (not image-schemas) may be associated with image-schemas or spatial redescriptions so as to offer additional discrimination information. One curious primitive is NO CONTACT. It is not clear if this implied a distinct NO primitive as well or whether the infant treats NO CONTACT and CONTACT as completely unrelated concepts. If NO is a primitive, how is negation related to image-schemas? If it is not, when does the obvious relationship between CONTACT and NO CONTACT emerge in development and how? Despite the list of primitives offered, many questions remain about their nature and about principles governing their interactions.

In all this, one worries about how the account might derail in children who have radically different early experiences. Congenitally blind children are an obvious case. Although they clearly could learn about motion, paths and spatial relations without vision and through such means as touch, it would certainly seem that they should have far more limited access to patterns that bear on attaching image-schemas to real world categories. Yet, as best we know, blind infants do not show any dramatic differences in categorization or conceptual development (e.g., Landau & Gleitman, 1985). Does this mean that the image-schemas and their relationships are so innately predetermined that no visual experience is necessary? Such a conclusion seems not to fit with Mandler's account. If one puts the primary emphasis on visual-spatial constructs in linking up early cognition to experience, one needs to confront in detail how blind children could acquire concepts in a manner that is largely similar to that of sighted children. Mandler does argue that image-schemas are intermodal in nature and can have motoric components, but that concession does not diminish the apparent conflict between the early centrality of visual-spatial information and the relatively normal conceptual development of blind children (Zlatev, 2005).

A second issue concerns whether the conceptual space offered by image-schemas is large enough to accommodate the cognitions of preverbal infants. As researchers uncover wider and wider ranges of cognitions in infants, one may have to stretch the notion of image-schema so far that it starts to lose any specificity and predictive value. Consider, for example, recent studies demonstrating that preverbal infants seem to have a clear concept of malevolence. In a series of studies involving both looking time measures (Kuhlmeier, Wynn, & Bloom, 2003) and reaching preferences (Hamlin, Wynn, & Bloom, 2007), infants as young as 6 months prefer animate agents, who are helpful as opposed to malevolent as represented by simple geometric solids that either 'help' or 'hinder' other solids that climb a ramp. One might be able to use image-schemas to encode helping and hindering of motion (although even here the details will be tricky), but it is much harder to see how helping and hindering then get linked to an apparent notion of a good *versus* a bad agent. How do image-schemas encode categorizations of some agents as malicious and others as kind?

Other early notions also seem to pressure the image-schema meanings to become too broad. Consider, for example, randomness and the ways that infants seem to link this idea to intentionality. In a series of studies with infants as young as 9 months, it appears that there are strong expectations that only intentional agents can take a set of objects from disorder to order, while both intentional and unintentional agents can take displays from order to disorder (Newman, Kuhlmeier, Keil, & Wynn, 2005). How is this to be explained in terms of image-schemas? How does the notion of an ordered array emerge when its local instantiations can vary so dramatically (e.g., things can be ordered along various dimensions such as color, spatial alignment, or shape)?

Similarly, infants categorize some things as 'mine' others as 'not mine'. How are ownership categories related to image-schemas? We do not yet know how early these notions are but there are strong suggestions that, at least by 14 months, infants think about things that they own and do not own (Fasig, 2000; Rodgon & Rashman, 1976).

Given that capuchin monkeys show economic endowment effects (Chen, Lakshminaryanan, & Santos, 2006), it seems quite plausible that ownership can be understood in nonverbal ways that might well be available to much younger human infants. There is no obvious direct application of image-schemas to capture the meaning of 'mine'. One can come to own things through buying, through receiving a gift, through labor exerted on a found object, and through having an idea ('it is my story'). In what ways could this array of situations to be captured by image-schemas?

It might be possible to stretch the account of image-schemas so that they can be said to model these sorts of behavioral phenomena, but as the range of cognitions available to young infants increases, the specificity of image-schemas seems to evaporate into an unconstrained idea of some kind of internal mental representation that goes beyond the perceptual. If image-schemas are to have substance, then they should predict what sorts of concepts a toddler is unlikely to have because those concepts cannot be easily captured in terms of image-schemas. Of course, we do not expect infants to have concepts of hedge funds or double jeopardy, but it does not seem too far-fetched to grant them some notions of ownership and fairness. Mandler thinks it patently absurd to think of an infant as having a concept of justice, but related notions of fairness and equity seem more plausible. Are there other universal concepts in adults that are nonetheless beyond the ken of infants and toddlers, because of how they are limited by image-schemas? Without such a set of excluded concepts, the notion of image-schema runs of the risk of becoming empty.

2. Abstract to Concrete and Back Again

There is considerable support for Mandler's proposal that much of development goes from the abstract to the concrete rather than the other way around. She makes strong principled arguments for this idea as well as providing excellent empirical support in

several of her clever studies on induction and imitation. In our own lab, we have repeatedly made similar suggestions (Keil, 2006; Keil et al., 1998; Newman & Keil, in press; Simons & Keil, 1995) and the work of many others can be interpreted in this way (e.g., Inagaki & Hatano, 2004). Mandler sees this pattern as intimately connected to the early presence of highly simplified interpretations such as image-schema, which can only pick out object categories at levels like vehicles and furniture. This is an intriguing claim, but image-schemas may not be an especially privileged way of explaining the full range of cases where earlier thought seems to be more abstract.

Abstract categories generally have a much wider scope than concrete ones, as in the class of furniture compared to the class of chairs. This criterion alone, however, does not usually suffice. A young child, for example, might lock onto one highly concrete perceptual feature, such as furriness, and then treat all furry things as a common category, whether they are mammals, fur coats, or even a kind of fiberglass insulation. We can sometimes see this in overextensions that children make with early words. But these cases are less interesting and do not really represent a general pattern as young children can also under extend early words (Kay & Anglin, 1982). Abstract categories are truly abstract when they do not seem to rely on an arbitrary perceptual feature that clusters entities together. Rather, abstract categories pick out a superordinate category and ideally all members of that category by referring to nonperceptual relations. An infant that has the category of furniture should apply it primarily to furniture and little else, so also for vehicles. Image-schemas are interesting here because they seem to provide a means of capturing this phenomenon. Vehicles are something like containers that carry things (perhaps mostly animate) inside their container parts. Given the full range of furniture or vehicles, it is difficult to imagine an invariant perceptual feature that could do the trick.

But young children and infants seem to be aware of other sorts of abstractions that do not follow from image-schemas. In terms of categorization, we have already discussed the case of malevolent beings. Other early categories include living things, as defined by a vital force (Inagaki & Hatano, 2002, 2004) and substances *versus* solids (Kemp, Perfors, & Tenenbaum, 2007). In neither case are object schemas the most obvious explanation for early facility with these categories. Vitalism, the idea of a vital force that drives both growth and movement, does not seem to be easily translatable into an image-schema. The biases to emphasize shape for objects and composition for substances have been long debated as to their origins in infancy, but above and beyond those debates is the presence of many models that make no reference to image-schemas, including recent Bayesian approaches that are able to frequently discover abstract relations earlier than concrete ones (Kemp et al., 2007). Similar demonstrations have been made in connectionist networks. Indeed, Mandler cites Rogers and McClleland's (2004) very interesting work along these lines on the animate/inanimate distinction, acknowledging that their approach seems to work without image-schemas. But this raises a problem: What reason is there to favor image-schemas as the means for modeling abstract to concrete progressions? They offer one interesting way of accounting for such progressions, but if they

are used to try to model all such progressions, they again run the risk of becoming too vague to be useful.

3. Causation and Conception

Mandler rightly focuses on Michotte's launching phenomena as providing a powerful and immediate sense of causation, in particular, that of one object launching another. This process has been studied in depth and may well reflect a dedicated processing system that automatically outputs a sense of cause in the same way that some perceptual 2-D illusions output a sense of depth (Choi & Scholl, 2006; Scholl & Tremoulet, 2000). But the power of this phenomenon may not be a good reason for concluding that it is the foundation behind all early notions of causation. For one thing, there may be other perceptually induced senses of causation quite different from launching, with suggestions that simple visual events can trigger senses of causal pulling and bursting among others (White & Milne, 1999). Launching may not, therefore, be so privileged.

More importantly, there seem to be other early senses of cause that are quite different from causation as activated by dynamic perceptual events. One of the most surprising may be support. Mandler mentions support but seems to think of it as a late-emerging and somewhat derivative concept. Yet, the research suggests the existence of a concept of support in infants as young as 3 months old, a concept that would seem to be intrinsically causal. Mandler discusses infants having a gradually emerging sense of the nuances of causal relations among objects (Baillargeon, 1994; Baillargeon, Kotovsky, & Needham, 1995), but does not dwell on findings that even 3-month-olds seem to know that completely unsupported objects should fall. But how could this work with image-schemas? It seems plausible that when infants see a large object balanced on top of a column, they see the object as supporting the column even though nothing is moving. One can therefore, see causality at work when objects are at rest. When the support is moved away at a very slow rate—that is, at a rate inconsistent with the Michottean notion of cause—3-month-olds are still surprised when the object remains hovering in the air. Mandler might argue that the infant is envisioning a path to the ground that is blocked by the support, but how is this done without ever seeing the path?

Later notions of causation certainly do not all seem to arise out of launching phenomena or dynamic events. Consider the notion of function and the accompanying idea that certain properties are present for a causal reason. Sometime during the preschool years, and possibly quite a bit earlier, children are able to learn about the functions of properties for objects. Fur is for keeping an animal warm, eyes are for seeing, batteries are for giving a flashlight power. Children grasp these causal functional relationships with ease, but it is difficult to see how they could be extensions of image-schema accounts. Similarly, young children seem drawn to the idea that a microstructural essence is causally responsible for phenomenal features (Gelman, 2003). Such a causal belief seems to emerge without reference to dynamic events

related to the interactions of bounded objects. Even 14-month-olds believe that distinctively colored insides are more likely to be causally related to particular motions of an animal than distinctively colored hats (Newman, Herrmann, Wynn, & Keil, in press). One can attempt to translate image-schemas into goal structures in the way that Mandler does for other studies showing that infants encode goals, but such efforts again run the serious risk of diluting the meaning of 'image-schema' so much as to lose explanatory and predictive value.

4. Can You Get Here from There?

Mandler has repeatedly said that her account is not one of how infants go from being perceptual creatures to conceptual ones. She seems to endorse the idea that one finds both concepts and percepts all the way down in development. I agree and think this is a foundational point often overlooked or neglected. However, I am not sure it solves the problem of how we get adult concepts from infant concepts. Even the most elaborated image-schemas and the most sophisticated perceptual meaning analysis system seem to yield analog representations that are then somehow brought into consciousness through either imagery or language. It seems, then, that the prelinguistic child can only have conscious awareness via imagery. This is an extremely strong and unjustified conclusion. Infants do seem to engage in inferences suggesting the presence of propositional thought prior to language. In this view, language does not create propositional thought; it merely attaches to it and greatly amplifies its power. The prelinguistic infant may have in place a language of thought that is propositional in nature and must exist prior to the acquisition of language, so that language can appropriately attach to it (Fodor, 1975). Mandler has wryly commented that 'babies think before they speak' (Mandler, 1998, p. 116), but that thought may critically rely on a language of thought that involves symbols and their manipulation in a propositional manner. One can try to do away with propositional thought by arguing that all the heavy lifting is done at a 'subsymbolic' level such as in connectionist systems, but such approaches have repeatedly encountered serious problems when they try to capture the recursive and generative nature of early cognition (Marcus, 2001).

Mandler does not seem to want to relegate propositional thought to a marginal status in adults; but to acknowledge its role in adults is to create in turn a demand for explaining how that thought could be acquired from something else. There is, to date, no consensus on how language could create propositional thought (see Carruthers, 2002 and ensuing commentaries for some flavor of the controversies). Because no widely accepted developmental account has been presented, many think that some kind of language of thought must be part of the original neonatal equipment package. There is no need here to wade into that debate beyond noting that image-schemas do not seem to offer an easy mechanism for building propositional thought out of something else and therefore do not really help us explain how infant minds get to here from there.

There is a clear legacy of something like image-schemas in adults. I am repeatedly impressed by recent demonstrations of the heavy engagement of visual-spatial thought in some kinds of abstract reasoning (Barsalou, 2008) and thought about causality (Wolff, 2007); seeing the enduring presence of that kind of thought as one part of a much larger system of diverse cognitive faculties, however, is not at all the same as seeing it as the primary launch pad for higher-level cognition.

5. Conclusions

Mandler's work is of fundamental importance to the field of cognitive development and to cognitive science as a whole. She has had a dramatic influence on how all of us view infant cognition and on how we see later cognition emerging from infancy. She has shown that infants often grasp high-level and surprisingly abstract categories long before they grasp subordinate ones. Moreover, she has shown that they do so not on the basis of noticing perceptual features, but rather on the basis of more conceptual relations and properties. The finding that infants may understand vehicles and furniture before they understand cars and chairs is a landmark discovery and supports the view that concepts are not built up out of concatenations of perceptual features, no matter how sophisticated and massively parallel that concatenation machinery might be. Mandler has also taken an influential idea in cognitive linguistics, image-schemas, and shown how it has very early roots in infancy. She has further shown how image-schemas should not have been seen as perceptually grounded, but as going beyond perception in ways that distill out powerful relationships such as CONTAINER, PATH, and CONTACT. In addition, she has confronted the critical problem of how all of us achieve some kind of economy of representation of an otherwise overwhelmingly complex world, a problem that is one of the core issues in cognitive science (Keil, 2003). Finally, she is to be applauded for trying to tell an overall account of where concepts come from, one that attempts to form a bridge from what she sees as the nonconscious, nonpropositional thought of early infancy to the conscious propositional thought of adults and older children. It is this last step, however, that seems to go too far.

I am convinced by Mandler's work, and by other work on infants and adults, that some sort of visual-spatial mode of thought is often invoked in a wide range of cognitive tasks, including ones that on the surface do not involve visual-spatial components, such as thoughts about time. I am further convinced that some aspects of causal thought also invoke visual-spatial relations, even when the causal relations involved do not seem overtly visual or spatial, such as how repeated nagging at another might 'push' that person 'over the edge'. There seems to be little doubt that we invoke visual-spatial relations in many reasoning tasks that are not direct about visual or spatial relations. None of this, however, commits one to the view that propositional thought emerges only when language is overlaid on image-schemas. Nor does it oblige one to conclude that image-schemas are the only basis for infant cognition and categorization that goes beyond use of perceptual features.

Infants often seem to categorize and reason in ways that suggest concepts that are not based on image-schemas. They think about malevolence, order, and before long ownership, among others. Moreover, they do so in ways that do not seem to fit with the basic forms of image-schemas and their combinations. Even metaphorical extensions of those notions do not seem adequate without lots of additional ancillary representational and computational support. Image-schemas simply are not the full story of infant cognition. They also pose a dilemma for explaining the origins of propositional thought. Either infants do not have it and somehow magically get it when language and image-schemas come together—a process that seems completely underspecified and mysterious—or they do have propositional thought prior to language (the view I favor), but then must have it in a way that cannot be captured by image-schemas.

I do not see any easy way out. One could try to expand the reach of image-schemas by adding new ones and ever more elaborate rules of combination, supplemented by rich analogical and metaphorical skills, but without carefully worked out details, there is the serious risk of image-schemas losing predictive and explanatory value. Image-schemas are certainly important parts of thought. They appear early and pervade many areas that are not directly visual or spatial. They are not, however the basis for all early concepts. Space may be the final frontier for human exploration, but it is not the first frontier for human cognition.

Acknowledgments

Preparation of this article and some of the research described therein was supported by NIH grant R37HD023922 to Frank C. Keil.

References

Baillargeon, R. (1994). How do infants learn about the physical world? *Current Directions in Psychological Science*, *3*, 133–139.

Baillargeon, R., Kotovsky, L., & Needham, A. (1995). The acquisition of physical knowledge in infancy. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal cognition.' A multidisciplinary debate. Symposia of the Fyssen Foundation* (pp. 79–116). New York: Oxford University Press.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, *59*, 617–645.

Carruthers, P. (2002). The cognitive functions of language. *Behavioral and Brain Sciences*, *25*, 657–674.

Chen, M. K., Lakshminaryanan, V., & Santos, L. R. (2006). The evolution of ourpreferences: Evidence from capuchin monkey trading behavior. *Journal of Political Economy*, *114*(3), 517–537.

Choi, H., & Scholl, B. J. (2006). Perceiving causality after the fact: Postdiction in the temporal dynamics of causal perception. *Perception*, *35*(3), 385–399.

Fasig, L. G. (2000). Toddlers' understanding of ownership: Implications for self-concept development. *Social Development*, *9*, 370–382.

Fodor, J. A. (1975). *The language of thought*. Cambridge, MA: Harvard University Press.

Fodor, J. A. (1998). *Concepts: Where cognitive science went wrong*. Oxford: Oxford University Press.

Gelman, S. (2003). *The essential child: Origins of essentialism in everyday thought*. Oxford: Oxford University Press.

Hamlin, J. K., Wynn, K., & Bloom, P. (2007). Social evaluation by preverbal infants. *Nature*, *450*, 557–559.

Inagaki, K., & Hatano, G. (2002). *Young children's naïve thinking about the biological world*. New York: Psychology Press.

Inagaki, K., & Hatano, G. (2004). Vitalistic causality in young children's naive biology. *Trends in Cognitive Science*, *8*, 356–362.

Kay, D. A., & Anglin, J. M. (1982). Overextension and underextension in the child's expressive and receptive speech. *Journal of Child Language*, *9*, 83–98.

Keil, F. C. (2003). Folkscience: Coarse interpretations of a complex reality. *Trends in Cognitive Science*, *7*, 368–373.

Keil, F. C. (2006). Cognitive science and cognitive development. In W. Damon & R. Lerner (Series Eds.) & D. Kuhn & R. S. Siegler (Vol. Eds.), *Handbook of child psychology*: *Vol* 2: *Cognition, perception, and language* (6th ed.) (pp. 609–635). New York: Wiley.

Keil, F. C., Smith, W. C., Simons, D. J., & Levin, D. T. (1998). Two dogmas of conceptual empiricism: Implications for hybrid models of the structure of knowledge. *Cognition*, *65*, 103–135.

Kemp, C., Perfors, A., & Tenenbaum, J. B. (2007). Learning overhypotheses with hierarchical Bayesian models. *Developmental Science*, *10*(3), 307–321.

Kuhlmeier, V., Wynn, K., & Bloom, P. (2003). Attribution of dispositional states by 12-month-olds. *Psychological Science*, *14*, 402–408.

Landau, B., & Gleitman, L. (1985). *Language and experience. Evidence from the blind child*. Cambridge, MA: Harvard University Press.

Mandler, J. M. (1998). Babies think before they speak. *Human Development*, *41*, 116–126.

Mandler, J. M. (2006). Actions organize the infant's world. In K. Hirsh-Pasek & R. M. Golinkoff (Eds.), *Action meets word: How children learn verbs* (pp. 111–133). New York: Oxford University Press.

Mandler, J. M. (2008). On the birth and growth of concepts. *Philosophical Psychology*, *21*(2), 207–203.

Marcus, G. F. (2001). *The algebraic mind: Integrating connectionism and cognitive science*. Cambridge, MA: MIT Press.

Newman, G., Herrmann, P., Wynn, K., & Keil, F. C. (in press). Biases towards intrinsic features in infants' reasoning about objects, *Cognition*.

Newman, G. E., & Keil, F. C. (in press). 'Where's the essence?': Developmental shifts in children's beliefs about the nature of essential features. *Child Development*.

Newman, G., Kuhlmeier, V., Keil, F. C., & Wynn, K. (2005) 12-*month-olds know that agents defy entropy: Exploring the relationship between order and intentionality*. Poster presented at the Biennial meeting of the Society for Research on Child Development, Atlanta, GA.

Rodgon, M. M., & Rashman, S. E. (1976). Expression of owner-owned relationships among holophrastic 14- and 32-month-old children. *Child Development*, *47*, 1219–1222.

Rogers, T. T., & McClelland, J. L. (2004). *Semantic cognition: A parallel distributed processing approach*. Cambridge, MA: MIT Press.

Scholl, B. J., & Tremoulet, P. (2000). Perceptual causality and animacy. *Trends in Cognitive Sciences*, *4*(8), 299–309.

Simons, D. J., & Keil, F. C. (1995). An abstract to concrete shift in the development of biological thought—the inside story. *Cognition*, *56*(2), 129–163.

White, P. A., & Milne, A. (1999). Impressions of enforced disintegration and bursting in the visual perception of collision events. *Journal of Experimental Psychology: General*, *128*, 499–516.

Wolff, P. (2007). Representing causation. *Journal of Experimental Psychology: General*, *136*, 82–111.

Zlatev, J. (2005). What's in a schema? Bodily mimesis and the grounding of language. In B. Hampe (Ed.), *From perception to meaning: Image schemas in cognitive linguistics* (pp. 313–342). Berlin: Mouton.