Development as Rediscovery: core knowledge and speech perception

s.butterfill@warwick.ac.uk; revision 1

Infants can tackle physics, number, agents and minds thanks to a set of innate or early-developing abilities, often labelled "core knowledge". Several features distinguish core knowledge from adult-like understanding: its content is unknowable by introspection and judgement-independent;[1] it is specific to quite narrow categories of event and does not grow by means of generalization;[2, 3] it is best understood as a collection of rules rather than a coherent theory;[2] and it has limited application being usually manifest in the control of attention (as measured by dishabituation, gaze, and looking times) and rarely or never manifest in purposive actions such as reaching.[4-9]

How does infants' "core knowledge" relate to adult-like understanding?

Development-as-Rediscovery Conjecture The role of some early-developing abilities in explaining the later acquisition of conceptual understanding does not involve direct representational connections; rather the early developing abilities influence attention and inform behaviour, and these influences facilitate development.

This conjecture is an alternative to (i) Spelke's notion that mature understanding of objects, number, and mind derives from core knowledge by virtue of core knowledge representations being assembled[1]; (ii) claims by Alan Leslie and others that modules provide conceptual identifications of their inputs[10]; and representational re-description[11]. The development-as-rediscovery conjecture implies that in some *but not all* cases these models, (i)-(iii), are incorrect.

Analogy Knowledge of speech

Infants acquire a rich body of expectations about phonotactic constraints plus phonological and prosodic structure in their first year[12]. These expectations have the signature features of core knowledge, being unknowable by introspection, judgement-independent, and so on. Few adults have explicit knowledge of these structures, and such knowledge can only be gained by reflection on speech. Since explicit knowledge does not interfere with speech production (having false beliefs about phonological structures does not inevitably affect speech behaviours), we can be sure that early-acquired core knowledge of phonology is independent of later explicit knowledge.

The development-as-rediscovery conjecture is that the relation core knowledge bears to later-developing understanding is analogous to the relation expectations about phonology acquired in infancy bear to explicit knowledge of the same acquired by some adults. In both cases early-developing abilities are task-specific and facilitate later understanding not by providing representations directly but by guiding behaviour; reflection on this behaviour in turn facilitates the later understanding.

Case study Phoneme perception and phonological awareness

1. A decalage: infants from four months or earlier enjoy categorical perception of phonemes,[13] but it takes them until around four *years* before they can think or reason about phonemes. For example, infants and younger children who hear 'bud' or 'bat' can distinguish the words by virtue of perceiving distinct intended phonic gestures but they but cannot act on or think about this difference. As I. Liberman put it, "it does not follow from the fact that a child can easily distinguish *bud* from *bat* that he can therefore respond analytically to the phonemic structure that underlies the distinction."[14]

2. Phoneme perception and phonological awareness also differ with respect to the way they develop and the factors that influence their development. Unlike phoneme perception, children's acquisition of phonological awareness develops gradually over several years, varies systematically depending on their language (e.g. Turkish vs. French), and is facilitated by learning a writing system where some types of writing system help more than others (e.g. syllabaries vs. alphabets). Furthermore, children find certain types of phoneme harder to distinguish in thought than others (e.g. those that differ only with respect to voicing are harder to distinguish than those that differ only with respect to articulation), whereas they have no corresponding difficulties perceiving distinctions between phonemes.

3. In principle there might be several ways of explaining these developmental findings. But a natural explanation is generally taken for granted by researchers in this area: in becoming aware of phonemes we have to rediscover them, lacking access to them as objects of perception. Innate or early-developing perceptual knowledge of phonemes guides linguistic behaviours; later reflection on these linguistic behaviours leads to rediscovery of phonological notions. This view is plausible given that phonemes as we think and reason about them sometimes differ with respect to their identities and properties from the intended phonic gestures we perceive.

4. Writing systems, although probably not necessary for phonological awareness, clearly facilitate and shape the development of phonological awareness where present. Written words provide the child with a

model for understanding phonemes and their relation to utterances. The role of phoneme perception in later understanding is not to acquaint us with the nature of phonemes but to guide behaviours through reflection on which we can later rediscover them.

Inefficiency The development-as-rediscovery conjecture is not a priori and needs to be tested case-by-case. However, it is sometimes rejected outright on the presumption that evolving or developing multiple independent systems would be inefficient.

This presumption is incorrect, as can be seen by the case of face perception. It is widely held that from birth there is a mechanism, CONSPEC, present in humans and chickens that uses crude heuristics to identify faces and generates orienting reflexes. Developmentally the role of this mechanism is to provide experience of faces for CONLEARN, a later-appearing mechanism that uses more sophisticated principles geared to features of one's particular conspecifics and enables smooth tracking of moving faces. Crucially the two mechanisms do not share any representational resources; they are linked only indirectly, by means of behaviour: the first orients the gaze to faces, thereby providing the second with data.[15-17] Presumably the cost of maintaining two distinct mechanisms is outweighed by the optimal balance between reliability and sophistication. The need to reliably identify faces from birth calls for fixed heuristics that work in the commonest cases, whereas the need to identify the widest range of conspecifics' faces from different viewpoints calls for sophisticated but error-prone learning. Having multiple independent mechanisms avoids a trade-off: the more sophisticated mechanism benefits from the reliability of the less flexible mechanism without being constrained by the fixed heuristics it employs.

Application Core knowledge of objects

1. Infants' looking behaviours reveal expectations about object trajectories based on interactions with other solid objects from four months.[18-20] Yet at 2.5 years their reaching behaviours systematically indicate a failure to understand interactions.[5, 7]

2. Reaching for interacting objects when unseen improves gradually between 2- and 3-years-old and appears to involve developments in both perceptual and reasoning abilities.[21] Children's difficulties appear to be specific to interacting objects: they can reach for objects in quite complex tasks providing objects do not interact.[22, 23]

3. What explains this discrepancy in knowledge as revealed by gaze and action? A range of methodological and performance factors have been suggested.[6] Another possibility is that infants' core knowledge of objects is encapsulated, just as is their knowledge of phonological structure. On this view, core knowledge of objects is used by perceptual mechanisms in identifying and tracking objects but is unavailable for other tasks; the later-developing understanding of physical interactions revealed by reaching behaviours is a rediscovery.

4. Tool use may play a role analogous to writing in explaining this rediscovery. Basic forms of tool use may not require understanding how objects interact,[24, 25] and may depend on core knowledge of contact-mechanics.[26, 27] Experience of tool use may in turn assist children in understanding notions of manipulation, a core causal notion.[28, 29] If so, it may be that core knowledge of objects leads to later understanding not via representations but via enabling tool use.

Conclusion In at least some cases (objects, speech) core knowledge, like knowledge of phonological structure in infancy, surfaces in consciousness only in distinctive phenomenological effects—effects that may guide behaviours but do not reveal the content of this knowledge. Explicit understanding of objects and speech is not a matter of assembling representations already provided by core knowledge, it is a matter of rediscovering them. Rediscovery is facilitated by behaviours such as writing and tool use which core knowledge makes possible.

References

1. Spelke, E. (2000) Core Knowledge. *American Psychologist* 55, 1233-1243

2. Baillargeon, R. (2002) The Acquisition of Physical Knowledge In Infancy: A Summary in Eight Lessons. In *Blackwell Handbook of Childhood Cognitive Development* (Goswami, U., ed), 47-83, Blackwell

3. Baillargeon, R. (2001) Infants' Physical Knowledge: Of Acquired Expectations and Core Principles. In *Language, Brain, and Cognitive Development: Essays in Honor of Jacques Mehler* (Dupoux, E., ed), 341-361, MIT Press

4. Spelke, E. (1994) Initial Knowledge: Six Suggestions. *Cognition* 50, 431-445

5. Berthier, N.E., *et al.* (2000) Where's the Ball? Two- and Three-Year-Olds Reason about Unseen Events. *Developmental Psychology* 36, 394-401

6. Keen, R. (2003) Representation of Objects and Events: Why Do Infants Look So Smart and Toddlers Look So Dumb? *Current Directions in Psychological Science* 12, 79-83

7. Hood, B., *et al.* (2003) Looking and Search Measures of Object Knowledge in Preschool Children. *Developmental Science* 29, 61-70

8. Clements, W., and Perner, J. (1994) Implicit understanding of belief. *Cognitive Development* 9, 377-395

9. Southgate, V., *et al.* (2006 forthcoming) Action Anticipation through Attribution of False Belief By Two-Year-Olds. *Psychological Science* in press

10. Leslie, A. (1988) The Necessity of Illusion: Perception and Thought in Infancy. In *Thought Without Language* (Weiskrantz, L., ed), 185-210, Clarendon

11. Karmiloff-Smith, A. (1992) *Beyond Modularity: A Developmental Perspective on Cognitive Science*. MIT Press

12. Jusczyk, P. (1995) Language Acquisition: Speech Sounds and the Beginning of Phonology. In *Speech, Language and Communication* (Miller, J., L., and Eimas, P.D., eds), Academic Press

13. Eimas, P.D., *et al.* (1971) Speech Perception in Infants. *Science* 171, 303-306

14. Liberman, I.Y., *et al.* (1974) Explicit Syllable and Phoneme Segmentation in the Young Child. *Journal of Experimental Child Psychology* 18, 201-212

15. Johnson, M.H. (2001) The Development and Neural Basis of Face Recognition: Comment and Speculation. *Infant and Child Development* 10, 31-33

16. Johnson, M.H., and Morton, J. (1991) *Biology and Cognitive Development: the Case of Face Recognition*. Blackwell

17. de Haan, M. (2002) The Neuropsychology of Face Processing during Infancy and Childhood. In *Handbook of Developmental Cognitive Neuroscience* (Nelson, C.A., and Luciana, M., eds), 381-398, MIT Press

18. Spelke, E., and Van de Walle, G. (1993) Perceiving and reasoning about objects. In *Spatial representation: problems in philosophy and psychology* (Eilan, N., *et al.*, eds), Oxford University Press

19. Wang, S.-h., *et al.* (2003) Should All Stationary Objects Move When Hit? Developments in infants' causal and statistical expectations about collision events. *Infant Behavior and Development* 26, 529-567

20. Baillargeon, R., *et al.* (1995) The Acquisition of Physical Knowledge In Infancy. In *Causal cognition. A multidisciplinary debate* (Sperber, D., and Premack, D., eds), 79-115, Clarendon

21. Haddad, J.M., *et al.* (2008) Conflicting cues in a dynamic search task are reflected in children's eye movements and search errors *Developmental Science* 11, 504-515

22. Santos, L.R. (2004) 'Core knowledges': A dissociation between spatiotemporal knowledge and contact-mechanics in a non-human primate? *Developmental Science* 7, 167-174

23. Hespos, S., and Baillargeon, R. (2006) Decalage in infants' knowledge about occlusion and containment events: Converging evidence from action tasks. *Cognition* 99, B31-B41

24. Lockman, J.J. (2000) A Perception-Action Perspective on Tool Use Development. *Child Development* 71, 137-144

25. Barrett, T.M., *et al.* Learning about Tools in Infacy. *Developmental Psychology* 43, 352-368

26. Goldenberg, G., and Hagmann, S. (1998) Tool use and mechanical problem solving in apraxia. *Neuropsychologia* 36, 581-589

27. Johnson-Frey, S.H. (2004) The neural bases of complex tool use in humans. *Trends in Cognitive Sciences* 8, 71-78

28. Menzies, P., and Price, H. (1993) Causation as a Secondary Quality. *British Journal for the Philosophy of Science* 44, 187-203

29. Woodward, J. (2003) *Making Things Happen: A Theory of Causal Explanation*. Oxford University Press