Origins of Mind
Lecture 02

Stephen A. Butterfill
<s.butterfill@warwick.ac.uk>

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slide-3 The question for this course is … We are going to approach this question by examining the evidence from developmental science, and identifying philosophical problems created by the evidence.

slide-4 A key challenge concerns the nature of mental states and actions in children who developing capacities to know simple facts about of the world. Last week I illustrated this by discussing knowledge of physical objects …

slide-5 When do humans first come to know facts about the locations of objects they are not perceiving?

Suppose we ask, When do humans first come to know facts about the locations of objects they are not perceiving? Some evidence points to an early age, perhaps 2.5 months or earlier. But other evidence points to a much later age, 7 months at the earliest.

You might think, this is just an issue about measuring age. But I want to argue that it points to a deeper problem. The problem is how to characterise the mental states and actions of typically developing infants in their first months of life, when they can perform some actions for the reason that there is an object behind a screen but when this ability is strictly limited.

slide-6 If I'm right, we need to rethink fundamental claims about mental states. These are coded in the Uncomplicated Account of Minds and Actions.

But faced with this, we should try to hold on to the Uncomplicated Account for as long as possible. There are two ways to do this.

slide-7 One possibility is to insist that infants, despite failures to search, really can have beliefs about, and knowlegde of, the locations of unseen objects. For all we have seen so far, it might be that this is right. Perhaps, for example, there is something especially tricky about searching. Or perhaps there are other studies which show, contra Shinskey and Munakata, that four months olds really can search for unperceived objects. This deserves careful investigation.

slide-8 Another possibility is to insist that infants, despite apparently demonstrating intelligent responses to unperceived objects in their looking behaviours, just can't act for the reason that there is an object behind a screen. Their responses are not really intelligent but driven by some more basic process.

I want to consider this possibility first.

slide-9 We're going to consider lots of evidence. As you'll see, different researchers have quite different theories. Why? I could just tell you what I think the balance of scientific evidence allows us to conclude. But I want you to learn to evaluate the scientific evidence for yourself. More importantly, there is uncertainty about what the balance of scientific evidence allows us to conclude. If you look at the research carefully, I thin you'll find that no one yet has a fully adequate answer to the question, When do humans first come to know facts about the locations of objects they are not perceiving? So this question presents a significant challenge for us.

unit_161

Objects vs Features

slide-11 The question for this lecture concerns knowledge of physical objects. When do humans first come to know simple facts about particular physical objects? To illustrate, consider the fact that this telephone is located here, or the fact that this telephone is square. I take it that no one is born knowing any such facts. So there was a time when you knew no facts about particular physical objects at all, and then, sometime later, you came to know some such facts. How did you make this transition? How do humans first come to know facts about particular objects?

(For the rest of this lecture I'll drop the qualifier 'physical' since this is all about physical objects as opposed to, say, abstract objects like numbers or forms.)

slide-12 [features picture] First, what does knowledge of physical objects involve? One way to approach this question is by contrasting objects with features. Physical objects contrast with features in three ways

1. physical objects have boundaries whereas mere features do not. (This needs qualifying because there is a sense in which we can regard features as having boundaries; but when it comes to features, the boundaries are merely projections. To see the contrast, consider that we could all be permanently mistaken about the boundaries of a physical object but not about the boundaries of a feature—another species could not discover a million years from now that humans are wrong about

the boundaries of this feature, that they thought it was one feature whereas really it is two.)

2. physical objects persist in a way that features do not. You cannot ask, concerning a feature now, whether this is the same feature as some time ago. At least, you cannot ask this in the same sense that you can ask it about a physical objects.
3. physical objects can interact with each other in way that features cannot: they can causally interact.

Imagine not knowing anything at all about particular physical objects and living in a world consisting entirely of features. Nothing interacts, there are only patterns. And things outside your perceptual field do not exist. From your point of view, the world is limited your perceptual field now.

segment_persist_interact Contrasting features with physical objects suggests three requirements on having any knowledge about particular physical objects.

slide-14 Knowledge of objects depends on abilities to (i) segment objects, (ii) represent them as persisting and (iii) track their interactions.

Let's look at each of these in turn.

slide-15 How do infants and adults discern where one object begins and another ends?

slide-16 [ducks picture] The way objects are ordinarily arranged in space, so that one occludes parts of another, prevents us from doing this in any simple way.

slide-17 [features picture] Recall my imaginary world of features. In this world there is no principled way of saying where one object ends and another begins. As I said, features differ from genuine objects in not allowing us to make sense of the question of whether we are carving them at their joints. So an ability to segment physical objects is not necessary for knowing anything about mere features but it is probably necessary for having any knowledge concerning particular physical objects.

segment_persist_interact2 So much for the first requirement (segmentation) ...

slide-19 ... what about the second requirement, representing objects as persisting?

slide-20 When Hannah hides behind the logs and a girl later pops up, we can ask whether it is Hannah again or another girl. That is, we know that objects

can persist despite disappering from view—and despite becoming entirely imperceptible.

slide-21 [features picture] Contrast features again. You might see this red feature moving across the scene. But suppose it disappears and then, later a similar looking feature appears. There is no fact of the matter about whether this is the same feature or a different one. As I mentioned before, in the case of features we can't make sense of them as persisting over time, or as there being interruptions in their presence. I suppose, then, that to have knowledge concerning physical objects rather than merely concerning features, it is necessary to be able to represent objects as persisting even while unperceived.

segment_persist_interact3 That was the second requirement, now there's just one more ...

slide-23 This is the requirement that you can track objects' interactions.

slide-24 Objects causally interact with each other; one pan supports another, two people collide and bounce off each other. Relatedly, objects have counterfactual lives: sometimes you can say, truly, that if that barrier had not been there, the car would be at the bottom of the valley now.

slide-25 [features picture] As I mentioned, this is another respect in which objects are distinct from features. Features do not causally interact with each other and they do not have counterfactual lives either. This point of contrast suggests that knowledge concerning physical objects as opposed to mere features requires at least a limited ability to track causal interactions.

slide-27 So reflection on how physical objects differ from mere features suggests three minimal requirements on having any knowledge at all of facts about particular physical objects. Knowing things about particular physical objects, unlike knowing things about mere features, requires abilities to segment objects, to represent them as persisting, and to track at least some of their cauasl interactions.

slide-28 As mentioned, the question we'd like to answer is how humans first come to know any facts about particular physical objects. Before you know any such facts you live in something like a world of mere features. In this feature world, nothing persists and there are no causal interactions only patterns. And nothing exists except in your perceptual fields.

Now the question of how humans make this transition to knowing some facts about particular physical objects is too hard to face head on. But we can approach it by asking, How do humans come to meet the three requirements on knowledge of objects?

unit_171

Segmentation and the Principles of Object Perception

slide-30 How do humans segment objects?

slide-31 Recall that the way objects are ordinarily arranged in space, so that one occludes parts of another, prevents us from doing this in any simple way.

slide-32 Infants from 4.5 months of age can use featural information to segment objects.

slide-33 In Amy Needham's 1998 study, 4.5 months old infants were shown a display like this. Featural information—the difference in textures of the objects—suggests that these are two separate objects. But can infants use this information to detect that there are two objects?

slide-34 Some infants were then shown the object being moved like this, so that it is clearly two separate objects.

slide-35 Other infants where shown the object being moved like this. If infants think there is one object, they should expect the second kind of movement. But if infants think there are two objects—if, that is, they can use the featural information to segment objects—then they should expect the former kind of movement. What were the results? ...

slide-36 Needham's results are evidence that infants from 4.5 months of age can use featural information to segment objects.

slide-37 [I need to explain the method used in violation-of-expectations, and to compare it with the method of habituation.] A violation-of-expectations experiment involves a pair of events. Infants are divided into two groups; one group sees one event, the other sees the other event. (This is the between-subject version; it might also be done within subjects.) The experimenter measures how long the infants look at each event. Of interest is whether infants reliably look longer at one of the two events. If they do, this is interpreted as evidence that this event—the one infants reliably look longer at—is in some way interesting to them. And, if the events are well chosen, their interest indicates that the event violates an expectation they have. In the experiment we are considering, the expectation violated is the expectation that the two objects should move separately.

slide-38 At this point you might well ask, What is an expectation? This is an important question but let me postpone it for now.

slide-39 To return to Needham's experiment, interestingly, 4.5 month old infants were able to succeed even when the point of contact between the two objects was occluded, as in this diagram.

slide-40 These are the results for 4.5 month old infants.

One further thing: infants can also use shape information in segmenting objects, and shape information appears to trump featural information (Needham 1999).

slide-41 Can we fully explain how infants segment objects just by appeal to features? To see why it couldn't be just features that we use to segment objects, consider some more cases …

slide-42 Here is an occluded object—a stick behind a box.

The movement is enough to convince 4-month-old infants that there is just one stick even though they never see its middle (Kellman and Spelke 1983). We can discover this by measuring how different displayes cause them to dishabituate.

slide-43 After being habituated to this this, 3-month-old infants were shown one of two displays.

slide-44 And here are the results (subjects were 3-month-old infants).

slide-45 The fact that infants can correctly segment partially occluded objects based on their movements already indicates that they can't be thinking about features only.

For more evidence, consider this display. The two parts of the moving object are featurally different. Despite this, infants expect to see a single connected object behind the block (Kellman and Spelke 1983, Experiment 6; Spelke 1990).

slide-46 Here are the test stimuli (each groups is shown one or the other).

slide-47 And here are the results.

Subjects in this experiment were 4-month-old infants.

So we saw that infants can use featural information to segment objects, but the principle of cohension can trump featural indicators of difference.

So infants' abilities to segment objects are not based entirely on recognising features.

slide-48 If infants do not rely only on features to do this, then how do infants segment the objects in the displays we've just been seeing?

slide-49 Spelke (1990) suggests that infants rely on a set of principles to segment objects. But what are the principles?

slide-50 Recall this diplay with on object moving behind a stationary block. What kind of principle could be used to identify that the occluded thing is a single object?

Spelke (1990) suggests the principle of rigidity. This principle says that 'objects are interpreted as moving rigidly if such an interpretation exists' The hypothesis that this principle describes in part how infants segment objects correctly predicts that they will treat the moving occluded stick as a single object.

But rigidity is not the only principle we need to explain how infants segment objects ... What justifies us in supposing that a rigidly moving object needs to be joined up?

What justifies us in supposing that a rigidly moving object needs to be joined up?

slide-51 ... to answer this question, consider the Principle of Cohension

slide-52 Another principle which seems to be involved in segmenting objects is the principle of cohension. According to this principle, 'two surface points lie on the same object only if the points are linked by a path of connected surface points' (Spelke 1990).

slide-53 For example, objects arranged as on your left were percevied by 3-month-olds as two objects, whereas infants treated the displays like that on your right as if they were one object. (This was measured using a habituation paradigm (Kestenbaum et al. 1987). Infants were habituated to the display. Then either one object's position changed, or both objects' positions changed but in such a way as to preserve the overall configuration of the two objects. Infants could show that they perceived the configuration as a single object by looking longer when just one object's position changed.)

slide-54 Here's a second example using moving rather than static stimuli and a different method: reaching rather than looking. Let me explain the stimuli first.

How does the principle of cohension apply to this moving display? As we just formulated it, it doesn't seem to. After all, in both cases all points on the stimuli are lnked by a path of connected surface points. However, the principle should be read as saying more implying that: 'When two surfaces are separated by a spatial gap (as in Figure 4a) or undergo relative motions that alter the adjacency relations among points at their border (as in Figure 4i), the surfaces lie on distinct objects' (Spelke 1990, p. 49).

The question is, Do infants segment these objects in accordance with the Principle of Cohesion? Spelke et al. (1989, Experiment 2) used a reaching experiment with 5-month-old infants. The smaller of the two objects was always closer to the infants. Infants should reach more often for the smaller, nearer object when they represent the simuli as two separate objects than when they represent it as a single object. (This is not obvious, but the researchers do justify this claim carefully (Spelke et al. 1989, p. 186).) So the idea is that by comparing how often 5-month-olds reach for the smaller object, we can see whether they treat it as a separate object in one case but not the other. To make this vivid, let me show you their apparatus …

slide-55 Here you can see the infant sitting in front of the two objects which could be made to move together or separately.

slide-56 And here are the results. You don't need to read the table, I put it here just to mention that this is a within-subject design.

[*explain within- vs between-subject].

Overall, infants reached to the smaller, top object more often when they moved in opposite directions than when they moved together. Given the background assumption, this is evidence that infants segmented the objects differently depending on their motions, and did so in just the way that adults would (Spelke et al. 1989, Experiment 2).

slide-57 Spelke (1990) proposes that our ability to segment objects depends on four principles. We've already seen two of these in action (rigidy and cohesion), and we will shortly see that a further principle is needed, too.

slide-58 We've already seen this principle in action.

slide-59 Boundedness is just the converse of cohesion. Strictly speaking, cohension allows us to infer that we have two distinct objects, but not to infer that we have a single object—for that, we need boundedness. So when I was talking a moment ago about the Principle of Cohesion, strictly speaking I was also appealing to the Principle of Boundedness.

slide-60 We saw an example of the principle of rigidity in action earlier, with the moving stick experiment.

slide-61 The final Principle, no action at a distance, is a converse to rigidity.

slide-62 I don't want to obsess too much about the details of these principles. It isn't important that there are exactly four, nor are their precise formulations. (Surely the principles as stated here are not exactly the principles we need to characterise how infants segment objects.) What I want us to focus on is just the fact that we can use a small number of principles

to characterise how infants segment objects in a way that generates testable predictions, and these principles have been confirmed. This motivates us to ask …

What is the status of these principles?

Spelke's position might be put like this:

1. We (as perceivers) start with a cross-modal representation of three-dimensional perceptual features which includes their locations and trajectories.
2. Our task is to get from these representations of features to representations of objects.
3. *Descriptive component* We do this as if in accordance with certain principles (cohesion, boundedness, rigidity, and no action at a distance).
4. *Explanatory component* We acquire representations of objects because we apply the principles to representations of features and draw appropriate inferences.

The key point for our purposes is the explanatory component. The principles are not supposed to be merely heuristics for describing and predicting infants' performance on preferential looking tasks. Rather, these principles are supposed to explain why infants look longer at some things than at others. This what motivates the hypothesis that infants know these principles and use them in reasoning about objects: unless this hypothesis is true, it's hard to understand how the principles could have explanatory relevance.

slide-63 The conjecture that someone can segment and represent physical objects does not by itself generate readily testable predictions. Everything depends on which model of physical objects characterises her phyiscal cognition.

So we should ask …

slide-64 1. How do four-month-old infants model physical objects?

In asking how infants model physical objects, we are seeking to understand not how physical objects in fact are but how they appear from the point of view of an individual or system.

The model need not be thought of as something used by the system: it is a tool the theorist uses in describing what the system is for and broadly how it works. This therefore leads us to a second question …

slide-65 2. What is the relation between the model and the infants?

slide-66 3. What is the relation between the model and the things modelled (physical objects)?

slide-68 The Simple View is inspired by two famous cognitive scientists, Marr and Chomsky. Marr showed that many visual processes can be described as inferences. And Chomsky pioneered the idea that humans' knowledge of language depends on their knowing of a small number of principles. Similarly, Spelke's suggestion is that human infants (and adults) come to know facts about particular physical objects by virtue of making inferences from a small number of principles which they know or believe.

What unites these three cases, Spelke on object segmentation, Marr on vision and Chomsky on syntax? It's that they are straightforwardly cognitivist in appeal to knowledge and inference. Principles are known, and they are used via a process of inference. (There's a nice quote from Fodor underlining this point.)

slide-69 'Chomsky's nativism is primarily a thesis about knowledge and belief; it aligns problems in the theory of language with those in the theory of knowledge. Indeed, as often as not, the vocabulary in which Chomsky frames linguistic issues is explicitly epistemological. Thus, the grammar of a language specifies what its speaker/hearers have to know qua speakers and hearers; and the goal of the child's language acquisition process is to construct a theory of the language that correctly expresses this grammatical knowledge.' (Fodor 2000, p. 11)

slide-70 So what is the status of Spelke's principles of object perception? Consider what I shall call the Simple View …

The simple view The principles of object perception are things that we know or believe, and we generate expectations from these principles by a process of inference.

The simple view is that the Spelke principles are just known in whatever sense anything is known or believed. (We can't say the principles are known because strictly speaking they are not truths but only heuristics.) The simple view isn't exactly Spelke's, but it's a useful starting point for discussion.

slide-71 The Simple View is worth considering in its own right because it is so, well, simple. But our interest in it may be piqued by the fact that Spelke herself appears to have accepted the Simple View at one point in her thinking:

'objects are conceived: Humans come to know about an object's unity, boundaries, and persistence in ways like those by which we come to know about its material composition or its market value' (Spelke 1988, p. 198).

slide-72 Now you might think that the case for these principles is not yet very strong. In that case, asking hard questions about their status would hardly be necessary. So let's consider further evidence for these principles.

We can do this by turning from segmentation (which was our first requirement on knowledge of objects) to representing objects as permanent.

slide-73 So I'm arguing that infants act for reasons which involve particular physical objects well before they are 7 months old. This is what is pushing us in the direction of ascribing beliefs about those objects to the infants.

unit_181

Permanence

slide-76 [*TODO*] Integrate converging findings on anticipatory (predictive) looking (Rosander and von Hofsten 2004): 'The obtained results are in general agreement with the numerous habituation studies that have investigated infants' emerging ability to represent temporarily occluded moving objects. The individual data show that 9–12-week-old infants begin to predict the reappearance of the object towards the end of the centrally occluded trials.'

[*TODO*] integrate this on reaching: (van Wermeskerken et al. 2011) (Interpretation is a bit out there, but it nicely illustrates how occlusion duration can affect reaching at around 7 months of age.)

[*TODO*] integrate this ERP measure of permanence: (Kaufman et al. 2005)

slide-77 Permanence is a matter of living in a world where things don't go out of existence when unperceived.

You may not be perceiving your keys now, but there is a fact of the matter about where they are and you know this. (If not where they are, then at least you know that there is a fact about where they are.)

slide-79 Although segmentation and permanence are conceptually distinct, they are closely related because movement is a clue to segmentation and movement sometimes invovles occlusion.

This becomes evident if we think about one more principle of object perception, the principle of continuity.

slide-80 We easily understand this principle by considering cases that accord with, and violate, it.

Here is motion in accord with it.

slide-81 Here is one violation of continuity.

slide-82 And here is another violation of continuity.

slide-83 Spelke et al. (1995) tested sensitivity to the principle of continuity in 4-month-old infants.

The infants were habituated to one of two displays.

slide-84 Now in the continuous event we should perceive one object whereas in the discontinous event we should perceive two objects. But is this about segmentation or persistence? Segmentation since it's about distinguishing one object from another; and persistence since it's about representing temporarily unperceived objects.

slide-85 They were then shown one of two test stimuli.

slide-86 The measure was the degree of dishabituation as measured by looking time.

slide-88 What's beautiful about these results is that the two groups show opposite patterns of dishabituation.

slide-89 Recall that the continuity principle could be violated in two ways.

We've just seen a 'continuity violation'. Next I want to show you a solidity violation.

slide-90 Further evidence that infants represent unperceived objects from around four months includes Baillargeon's famous drawbridge study.

These are the test events from Experiment 1 of Baillargeon et al's 1987 study.

'The habituation event was exactly the same as the impossible event, except that the yellow box was absent.' (Baillargeon et al 1985, 200)

slide-93 These are the results from Experiment 1 of Baillargeon et al's 1987 study.

slide-94 I'm presenting this experiment as showing that infants represent objects as persisting, and do so in accordance with the Principle of Continuity. However, the experiment is also about causal interactions between objects. After all, infants are demonstrating sensitivity to the fact that a solid object must stop the drawbridge from rotating all the way back.

slide-95 Some have been critical of the methods used in this experiment.

slide-96 'The lack of interaction between rotation angle and presence of a box in the looking time data is inconsistent with the suggestion of object permanence in our sample.' (Sirois and Jackson 2012, p. 73)

'our use of a factorial design as opposed to collapsing rotation angle and box in a single pair of test events clarifies the picture.' (Sirois and Jackson 2012, p. 74)

slide-97 So Baillargeon's drawbridge study doesn't demonstrate object permanence?

slide-98 Things are rarely so straightforward. Sirois and Jackson used computer generated stimuli whereas Baillargeon had a physical set-up, they studied 10-month-olds rather than 4-month-olds, and they used a different method (' children were ... not habituated by the time testing began'). So what can we conclude from the fact that Sirois and Jackson did not find evidence for an ability to represent objects as persisting? This certainly justifies caution in relying on any single experiment. Taken alone, Baillargeon's (1987) studies are inspiring but not fully convincing. However many further experiments involving different groups of researchers, different scenarios and different methods provide converging evidence for the same conclusion: even four-month-olds can represent objects as persisting (for reviews see Spelke and Hespos 2001 or Baillargeon 2002). The initial, groundbreaking studies are probably methodologically imperfect, but the balance of evidence from subsequent experiments suggests that the discovery they illuminate is probably real.[1]

Whatever your views on this experiment, not everything hangs on it. Fortunately there are at least a hundred further experiments which provide evidence pointing in the same direction. Here we'll look at just one more experiment.

slide-99 Here is another way of demonstrating object permanence.

This experiment will suggest, incidentally, that the principles we have seen—continuity, rigidity and the rest—don't fully explain how infants succeed in representing objects as persisting.

The subjects were 4 month old infants.

They were shown a large object disappearing inside a small conatiner, or behind a narrow screen.

slide-101 The experiment was very simple.

All the experimenters did was measure how long infants looked in at the two events.

Infants looked longer at the narrow-occulder event.

slide-102 There was also a control condition.

In the control condition, infants saw a small rather than a large object.

slide-103 Here's the experimental condition again for comparison.

[1] For an opposing view see Schöner and Thelen (2006); for critical discussion of measures involving looking times generally, see Aslin (2007).

slide-104 And here's the control condition again.

slide-105 As you can see, there was a difference in looking times only in the experimental condition.

By the way, this experiment is interesting partly because it doesn't use habituation, as Baillargeon's earlier drawbridge experiment did. It is also hard to explain the result by appeal only to the Principle of Object Perception that we have so far listed.

slide-106 We're considering abilities to represent objects as persisting even when not perceived. Where are we? We've seen that characteristing these abilities in terms of Principles of Object Perception enables us to make testable predictions, many of which have been confirmed. Importantly, we made the same claim about these Principles for abilities to segment objects. The abilities to segment objects and to represent them as persisting are conceptually distinct. However it may be that beliefs about a single set of principles underlies both abilities. This is one of Spelke's brilliant insights.

Where does this leave us? We still want to know about the status of the principles of object perception. As I said before, it is one thing to say they are descriptively adequate and another thing to understand how the Princples relate to cognitive mechanisms (processes and representations). But now the question about the status of these Principles is more pressing because the claim that these principles of object perception explain infants' (and adults', and other primates') performance is now harder to reject. It's harder to reject because we have converging evidence for the psychological reality of the principles from both segmentation and permanence.

slide-109 On the status of the Principles, consider this claim about the interpretation of the results of a violation-of-expectation experiment:

'evidence that infants look reliably longer at the unexpected than at the expected event is taken to indicate that they (1) possess the expectation under investigation; (2) detect the violation in the unexpected event; and (3) are surprised by this violation. The term surprise is used here simply as a shorthand descriptor, to denote a state of heightened attention or interest caused by an expectation violation.' (Wang et al. 2004, p. 168)

slide-110 What does 'surprise' mean here?

slide-111 So this is not surprise in a sense that requires awareness of a change in one's own beliefs. It is rather that there is a particular way in which the detection of the violation is manifested.

slide-112 Note that we are talking about expectations. This raises two questions: How do we arrive at these expectations? and What is an expectation?

Spelke's claim is that we arrive at these expectations by inference from the Principles of Object Perception, including the principle of contintuity. So what is an expectation? On the simple view we are adopting for now, an expectation is just a belief. The attraction of this simple view is it allows us to take literally the claim that we know the principles of object perception and arrive at expectations by a process of inference.

slide-113 Here is an illustration of the Simple View ...

'To make sense of such results [i.e. the results from violation-of-expectation tasks], we ... must assume that infants, like older learners, formulate ... hypotheses about physical events and revise and elaborate these hypotheses in light of additional input.'

slide-114 So infants formulate hypotheses

slide-115 And infants revise and elaborate these hypotheses in light of additional input. Now you might suggest that these researchers in talking about formulating and revising hypotheses do not mean to suggest that infants are doing this in the sense that you or I might, and so do not mean to imply that they have beliefs or knowledge. But ...

slide-116 ... they explicitly specify that infants do this 'like older learners'.

slide-117 So our current working hypothesis about the Principles is the Simple View. But before we go any further, let me say a little more about the third thing on our list, causal interactions ...

slide-118 We are far from fully understanding how humans are first able to represent objects as persisting. However, the fact that the ability appears so early in development entails that it does not demand language, nor much conceptual sophistication. This view is supported by the fact that the ability to represent objects as persisting is found in a wide variety of nonhuman animal including monkeys (Santos et al. 2006), lemurs (Deppe et al. 2009), dogs (Kundey et al. 2010), wolves (Fiset and Plourde 2013), cats (Triana and Pasnak 1981), crows (Hoffmann et al. 2011), chicks (Chiandetti and Vallortigara 2011), and dolphins (Jaakkola et al. 2010).[2] It is possible that humans' abilities to represent objects as persisting are unrelated to some or all of these animals', of course. Nevertheless, the fact that chicks can represent objects as persisting does show that doing this is not necessary something that requires much cognitive effort or conceptual sophistication.

[2] If you read these studies you will find that some of the authors talk about Piaget's stages of object permanence, and about visible and invisible displacements. For our purposes few of these details matter; the main thing you need to know is just that having *object permanence* is being able to represent objects as persisting even when they are briefly hidden from your view.

1. monkeys (Santos et al. 2006)
2. lemurs (Deppe et al. 2009)
3. crows (Hoffmann et al. 2011)
4. dogs and wolves (Fiset and Plourde 2013)
5. cats (Triana and Pasnak 1981)
6. chicks (Chiandetti and Vallortigara 2011)
7. dolphins (Jaakkola et al. 2010)
8. …

(Wolves matter because their performing similarly to dogs that show dogs' performance probably isn't a consequence of domestication, as Fiset and Plourde (2013) argue.)

Most of these animals have been tested using search as the measure, rather than looking times. (This will be important later.)

Note also that many of these studies contrast visible with invisible displacements, or talk about Piaget's stages of object permanence. For simplicity, that's not something I'm covering.

slide-119 [Aside] Comparative research is hard.

unit_201

Causal Interactions

slide-123 The third requirement on knowledge of objects is an ability to track objects through causal interactions.

Here we're interested in very simple causal interactions, such as the collision of two balls or the interaction of a ball with a barrier.

slide-124 Consider this case where a ball falls and lands on a bench.

Suppose that there was a barrier in front of the bench, like the dotted line.

Because the bench protrudes from the barrier, you could easily see where the ball will land.

But of course you can only see this if you know that barriers stop solid balls.

Spelke used this observation to provide evidence that 4-month-old infants can track objects' causal interactions.

Infants were habituated to a display in which a ball fell behind a screen, the screen came forwards and the ball was revealed to be on the ground, just where you'd expect it to be.

After habituation infants were shown one of two displays.

Infants in the 'consistent group' were shown this.

Whereas infants in the 'inconsistent group' were shown this.

What should we predict?

If infants were only paying attention to the shapes and ignoring properties like solid, they should have dishabituated more to the consistent than to the inconsistent stimlus.

After all, that stimlus is more different from the habituation stimulus in terms of the surfaces.

But if infants were are to track some simple causal interactions, then they might dishabituate to the 'inconsistent' stimulus more than to the 'consistent' stimulus because that one involves an apparent violation of a physical laws.

slide-125 Here are the results.

(Recall that the subjects are 4-month-old infants.)

This is evidence that infants can track causal interactions among objects, even when those causal interactions are occluded.

slide-126 Chimpanzees also understand something of phyiscal interactions insofar as their looking times show sensitivity to support relations (Cacchione and Krist 2004).

slide-127 Here are the results.

Lots of studies like this have been done with infants in their first six months of life.

slide-128 Dogs can do this too.

This experiment used a search measure rather than a looking time measure.

Dogs had to retrieve a treat. The right location to search depended on whether the barrier was present or absent.

slide-129 The results show brilliant performance.

'Dogs correctly searched the near location when the barrier was present and the far location when the barrier was absent. They displayed this behavior from the first trial' (Kundey et al. 2010) (from the abstract).

slide-130 How do infants, adult humans and nonhumans track causal interactions among objects (including causal relations like support)?

Spelke suggests that the principles of object perception can explain this.

slide-131 For example, the position of an object falling onto a bench is predicted by the principle of continuity mentioned earlier.

Principle of continuity An object traces exactly one connected path over space and time (Spelke et al. 1995, p. 113).

(The other principles of object perception are on your handout.)

slide-134 This is Spelke's brilliant insight.

I think there's something here that should be uncontroversial, and something that's more controversial.

But first let me recap …

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Recap and Questions

slide-136 As I said at the start, knowledge of objects depends on abilities to (i) segment objects, (ii) represent them as persisting and (iii) track their interactions.

Question 1 How do humans come to meet the three requirements on knowledge of objects?

Until quite recently it was held, following Piaget and others, that these three abilities appeared relatively late in development.

However, as we saw last week, more recent investigations provide strong evidence that all three abilities are present in humans from around four months of age or earlier.

Infants' looking behaviours indicate that they have expectations concerning segmentation, persistence and causal interactions.

Discovery 1 Infants manfiest all three abilities from around four months of age or earlier.

slide-137 We've seen that infants' abilities to segement objects, represent them as persisting and track their causal interactions can be described by appeal to a single set of principles, the principles of cohension, boundedness, rigidity and no action at a distance.

This suggests that *Discovery 2* Although abilities to segment objects, to represent them as persisting through occlusion and to track their causal interactions are conceptually distinct, they may all be consequences of a single mechanism (in humans and perhaps in other animals).

Spelke suggests, further, that these principles of object perception explain infants' looking behaviours.

This means we must ask *Question 2* What is the relation between the principles of object perception and infants' looking behaviours?

Let me explain this question.

slide-140 formal adequacy:

Let's suppose that Spelke is right that the principles are *formally adequate*. That is, someone who knew the principles and had unlimited cognitive resources could use the principles to infer the track physical objects through simple causal interactions like those we've been considering. (So formal adequacy is a question of what is possible in principle.) I don't think we should question this.

slide-141 descriptive adequacy

I also want to allow that Spelke's principles are *descriptively adeqaute*. That is, they successfully describe how infants, adults and nonhumans deal with various situations. We can think of this in terms of *as if*: it is as if these individuals are using the principles. But we have yet to come to what really matters to Spelke and to us. For accepting formal and descriptive adequacy is consistent with denying that Carey and Spelke's claim that 'A single system of knowledge … appears to [does] underlie object perception and physical reasoning' (Carey and Spelke 1994, p. 175).

That's because formal and descriptive adequacy leave open the question of what mechanisms are involved in tracking physical objects' causal interactions.

slide-142 mechansim: Finally, we might claim that these principles are realised in the cognitive mechansisms invovled in object tracking. It just here that we have to face the second question, What is the relation between the principles of object perception and infants' looking behaviours?. (e.g. the simple view) In answer to Q2, I suggested that we start with the simple view. The *simple view* is the view that the principles of object perception are things that we know or believe, and we generate expectations from these principles by a process of inference. The attraction of the Simple View is that it promises to explain infants' sensitivity to objects' boundaries, their persistence and their causal interactions as manifested in a variety of looking behaviours. But, as we're about to see, the Simple View is completely wrong.

unit_207

A Problem

slide-144 As just mentioned, the Simple View is the view that the principles of object perception are things that we know or believe, and we generate

expectations from these principles by a process of inference..

slide-145 Why must we reject the simple view?

slide-146 Some philosophers have offered intuitive arguments against the Simple View. Bermúdez (2003), for instance, holds that those without the ability to use a language cannot make inferences; and Davidson (1984) holds that those without language cannot think at all. It may be hard to accept that four-month-old infants are in the business of inferring truths about particular objects' locations from abstract principles. (And perhaps it is no less hard to accept that adults typically do this in segmenting objects.) But scientific and mathematical discoveries sometimes require us to reject intuitions, even intuitions about very fundamental things like space and time. For this reason there seems to be slim prospect of effectively challenging the Simple View on the basis of intuitions about the nature of knowledge, belief and inference. Doing so is also unnecessary as there are scientific reasons for rejecting the simple view.

slide-147 I think we shouldn't try to challenge the simple view on the basis of intution.

slide-148 And we don't need to because there are also scientific reasons for rejecting the simple view.

One set of reasons concerns the apparent discrepancy between looking times and manual search …

slide-149 *(The basic idea is to say there's a discrepancy regarding BOTH (a) permanence and (b) causal interactions)

slide-150 Recall this experiment which used habituation to demonstrate infants' abilities to represent objects as persiting while unperceived (in this case, because occluded). Infants can do this sort of task from 2.5 months or earlier (Aguiar and Baillargeon 1999).

But what happens if instead of measuring how infants look, we measure how they reach?

slide-151 Shinskey and Munakata (2001) did just this. Here you can see their appratus. They had a screen that infants could pull forwards to get to an object that was sometimes hidden behind it. They made two comparisons. First, were infants more likely to pull the screen forwards when an object was placed behind it? Second, were how did infants' performance compare when the barrier was not opaque but transparent?

slide-152 Here are their results with 7-month old infants.

slide-153 Now we have the beginnings of a problem. The problem is that, if the Simple View is right, infants should succeed in tracking persisting objects regardless of whether we measure their eye movements or their reaching actions. But there is a gap of around five months between looking and reaching.

The attraction of the simple view is that it explains the looking. The problem for the simple view is that it makes exactly the wrong prediction about the reaching.

Can we explain the discrepancy in terms of the additional difficulty of reaching? A lot of experiments have attempts to pin the discrepancy on this, or on other extraneous factors like task demands. But none of these attempts have succeeded. After all, we know infants are capable of acting because they move the transparent screen.

slide-154 As Jeanne Shinskey, one of the researchers most dedicated to this issue says,

slide-155 If there were just one discrepancy, concerning performance, we might be able to hold on to the Simple View. But there are systematic discrepancies along these lines.

Related discrepancies concerning infants' understanding of physical objects occur in the case of their abilities to track causal interactions, too.

slide-156 Recall this experiment about causal interactions, which used a habituation paradigm. Now imagine a version which involved getting infants to reach for the object rather than simply looking. What would the results be? There is an experiment much like this which has been replicated several times, and which shows a discrepancy between looking and searching. Basically infants will look but not search.

slide-157 *todo

slide-158 *todo

slide-159 *todo

slide-160 Here are the looking time results.

slide-161 You can even do looking time and reaching experiments with the same subjects and apparatus (Hood et al. 2003).

2.5-year-olds look longer when experimenter removes the ball from behind the wrong door, but don't reach to the correct door

slide-162 here are the search results (shocking).

slide-163 *todo: describe

**todo: Mention that (Mash et al. 2006) show infants can also predict the location of the object (not just identify a violation, but look forward to where the object is)

slide-164 Amazingly, 2 year old children still do badly when only the doors are opaque, so that the ball can be seen rolling between the doors, as in this diagram (Butler et al. 2002).

slide-166 Similar discrepancies between looking and reaching are also found in some nonhuman primates,

both apes and monkeys (chimpanzees, cotton-top tamarins and marmosets).

(Some of this is based on the gravity tube task and concerns gravity bias.)

'A similar permanent dissociation in understanding object support relations might exist in chimpanzees. They identify impossible support relations in looking tasks, but fail to do so in active problem solving.' (Gómez 2005)

slide-168 Note that this research is evidence of dissociations between looking and search in adult primates, not infants.

This is important because it indicates that the failures to search are a feature of the core knowledge system rather than a deficit in human infants.

'to date, adult primates' failures on search tasks appear to exactly mirror the cases in which human toddlers perform poorly.' (Santos and Hood 2009, p. 17)

slide-169 What about the chicks and dogs? This isn't straightforward. As I mentioned earlier, (Kundey et al. 2010) show that domestic dogs are good at solidity on a search measure. And as we covered in seminars, (Chiandetti and Vallortigara 2011) demonstrate object permanence with a search measure in chicks that are just a few days old. Indeed, for many of the other animals I mentioned, object permanence is measured in search tasks, not with looking times. To speculate, it may be that the looking/search dissociation is more likely to occur in adult animals the more closely related they are to humans. But let's focus on the fact that you get the looking/search in any adult animals at all. This is evidence that the dissociation is a consequence of something fundamental about cognition rather than just a side-effect of some capacity limit.

slide-173 So far we can draw two conclusions about infants' and adults abilities to track interactions. My **first conclusion** from this section is that infants from around 4 months of age or younger and nonhuman animals are able to track simple causal interactions.

slide-174 I started by identifying three requirements for knowledge of physical objects: abilities to segment objects, to represent them as persisting, and to track their causal interactions. My **second conclusion** is that a single set of principles likely underlies these abilities. The ability to segment objects is bound up with the ability to represent them as persisting and with the ability to track their interactions.

slide-175 My **third conclusion** is that we have a problem. The problem is that we have to reject the simple view. Recall that the simple says that the principles of object perception are things that we know or believe. We must reject this view because it makes systematically incorrect predictions about actions like searching for objects.

But why is this a problem? Because, as we'll see, it is hard to identify an alternative.

unit_211

Like Knowledge and Like Not Knowledge

slide-177 I'm sorry to keep repeating this but I want everyone to understand where we are.

There are principles of object perception that explain abilities to segment objects, to represent them while temporarily unperceived and to track their interactions.

These principles are not known. What is their status?

slide-178 The problem is quite general. It doesn't arise only in the case of knowledge of objects but also in other domains (like knowledge of number and knowledge of mind). And it doesn't arise only from evidence about infants or nonhuman primates; it would also arise if our focus were exclusively on human adults. More on this later. For now, our aim is to better understand the problem as it arises in the case of knowledge of objects.

slide-179 One hopeful alternative is to shift from talk about knowlegde to talk about representation.

Will this help?

Only as a way of describing the problem.

We need to say what we mean by representation. The term is used in a wide variety of ways. As I use it, representation is just a generic term covering knowledge, belief and much else besides.

slide-180 If we are going to substitute representation for knowledge, we need to characterise what kind of representation we have in mind. The term

is tricky. As Haith (1998) says, 'no concept causes more problems in discussions of infant cognition than that of representation.'

slide-181 Take a paradigm case of representation.

slide-183 The subject might not be the agent but some part of it.

That is, we can imagine that some component of an agent, like her perceptual system or motor system, represents things that she herself does not.

(Of course, to make sense of this idea we need to invoke some notion of system.)

slide-185 The content is what distinguishes one belief from all others, or one desire from all others.

The content is also what determines whether a belief is true or false, and whether a desire is satisfied or unsatisfied.

There are two main tasks in constructing a theory of mental states.

The first task is to characterise the different attitudes.

This typically involves specifying their distinctive functional and normative roles.

The second task is to find a scheme for specifying the contents of mental states.

slide-187 The second task is to find a scheme for specifying the contents of mental states.

Usually this is done with propositions.

But what are propositions?

Propositions are abstract objects like numbers.

They have more mystique than numbers, but, like numbers, they are abstract objects that can be constructed using sets plus a few other basic ingredients such as objects, properties and possible worlds.

slide-188 So that was some quick background on representation.

Note that the issue of representation comes up twice for us.

There is a question about whether the principles of object perception are represented.

And there is a question about whether objects, their locations, properties, and interactions are represented.

The problem raised by the discrepancy between looking and acting is a problem for two claims: (i) the simple view (the principles of object perception

are knowledge &c); and also (ii) the claim that the representations of objects which derive from the principles of object perception are knowledge states.

slide-189 So to say that we don't know the principles of object perception but only represent them doesn't tell us much. This is a step in the right direction. But it tells us that we represent them without knowing them.

What we need if we're to have an explanatory answer to Q2a is to know positively how we do represent the principles of object perception — subject, attitude and content. We need to characterise a form of representation that is like knowledge but not like knowledge.

slide-190 Your handbag is bluging, and when you swing it at me something really hard hits me.

It must be full of rocks.

Except it can't be because you are not strong enough to lift such a big bag full of rocks.

In that case, it must be wrocks not rocks.

A wrock is just like a rock except that it lacks mass.

Compare: this representation is just like knowledge except that it doesn't guide action; this process is just like inference except that it lacks the normative aspects of inference.

slide-191 Munakata (2001) suggests that there are 'graded representations', that is knowlegde can be stronger or weaker.

Presupposes we have an account of subject, attitude and content. Let's grant that.

What is strength? Some additional component, over and above subject, attitude and content.

The idea is quite intuitive but difficult to make systematic sense of.

The idea might well make sense if we were talking about neural representations.

But here we aren't. Let's not introduce radically new ideas about representation unless we really have to.

(By the way, Munakata (2001) is a nice review of dissociations, not only developmental dissociations.)

slide-192 Recall what Davidson said: we need a way of describing what is in between thought and mindless nature. This is the challenge presented to us by the failure of the Simple View.

slide-194 To conclude, the question for this lecture concerned knowledge of physical objects.

We examined how three requirements on having knowledge of physical objects are met.

Knowledge of objects depends on abilities to (i) segment objects, (ii) represent them as persisting and (iii) track their interactions.

We looked at each of these in turn and found evidence for two discoveries. First infants meet these requirements in the first months of their lives.

slide-195 Second, a single set of principles is formally adequate to explain how someone could meet these requirements, and to describe infants' abilities with segmentation, representing objects as persisting and tracking objects' interactions.

This left us with the a question about mechanism: What is the relation between these principles and infants' competence?

slide-196 A natuaral answer is the Simple View: the principles of object perception are things that we know or believe, and we generate expectations from these principles by a process of inference.

However, as we saw, the Simple View must be wrong because it generates incorrect predictions. This was the lesson of the discrepancy bewteen looking and search measures for both infants' abilities to represent objects as persisting and their abilities to track causal interactions.

As I've just been arguing, the failure of the Simple View presents us with a problem. The problem is to understand the nature of infants' apprehension of the principles given that it doesn't involve knowledge. This is a problem that will permeate our discussion of the origins of mind because it problems of this form come up again and again in different domains. It isn't the only problem we'll encounter, but none of the problems are more important or more general than this one.

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