How do we develop knowledge of physical objects?

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1. The Question

Contemporary philosophy of mind tends to focus on thought experiments, intuitions and very abstract arguments. But it was not always like this.

As Locke saw it, questions about the nature of minds are bound up with questions about their developmental origins:

> '... 'tis past doubt, that Men have in their Minds several Ideas ...:
> It is in the first place to be enquired, How he comes by them?'
> (Locke 1975 1689, p. 104)

Where Locke asked a question about Ideas, I want to consider a perhaps simpler question about knowledge. How do humans make the transition from not knowing any simple facts about particular things in a given domain to possessing some such knowledge?

As this is a very broad question, I will narrow it down by considering only knowledge of physical objects, their movements and causal interactions.

2. Four- and Five-month-olds Can Track Briefly Occluded Objects

Evidence that four- and five-month-olds can track momentarily occluded objects comes from studies using habituation, violation-of-expectations, anticipatory looking and the completion of an action directed to a fully occluded object that was prepared in advance of the object being fully occluded.

A wide range of evidence suggests that four- and five-month-olds can track briefly occluded objects.

Such evidence comes from infants' reactions to a range of different scenarios. Some scenrios involve a comparision between the number of objects (e.g. Spelke et al. 1995), others involve infants' abilities to track the causal effects of unperceived objects (e.g. Baillargeon 1987), while others require infants to track properties such as the shape and size of unperceived objects (e.g. Wang et al. 2004), or to remember the location of a hidden object (e.g. Wilcox et al. 1996).

The evidence also comes from studies using a variety of different methods. These include habituation (e.g. Spelke et al. 1995), violation-of-expectation (e.g. Wang et al. 2004), and anticipatory looking (e.g. Rosander & von Hofsten 2004; Bertenthal et al. 2013).

How do infants track briefly occluded objects? An early idea was that infants' earliest abilities involved knowledge of physical objects:

> 'objects are conceived: Humans come to know about an object's ... boundaries ... in ways like those by which we come to know about its material composition or its market value.' (Spelke 1998, p. 198)

One prediction of this idea is that infants should be able to search for briefly occluded objects. Because that prediction has been falsified (e.g. Shinskey & Munakata 2001), the idea should probably be rejected.

We therefore need alternative ideas about how infants track briefly occluded objects ...

3. Object Indexes

If infants' lack knowledge of physical objects, how do they track them even when they cannot see them?

In adult humans, there is a system of object indexes which enables them to track potentially moving objects in ongoing actions such as visually tracking or reaching for objects, and which influences how their attention is allocated (Flombaum et al. 2008).

But what is an object index? Formally, an object index is 'a mental token that functions as a pointer to an object' (Leslie et al. 1998, p. 11). If you imagine using your fingers to track moving objects, an object index is the mental counterpart of a finger (Pylyshyn 1989, p. 68).

Leslie et al say an object index is 'a mental token that functions as a pointer to an object' (Leslie et al. 1998, p. 11)[1]

Object indexes have several features. They:

- guide ongoing action (e.g.~visual tracking, reaching);
- can influence how attention is allocated (Flombaum et al. 2008);
- can be assigned in ways incompatible with beliefs and knowledge (e.g. Mitroff et al. 2005; Mitroff & Alvarez 2007);
- have behavioural and neural markers, in adults and infants (Richardson & Kirkham 2004; Kaufman et al. 2005);
- are subject to signature limits (Carey 2009, pp. 83–87); and
- sometimes survive occlusion (Flombaum & Scholl 2006)

[1] see also Scholl & Leslie (1999): 'Pylyshyn's FINST model: you have four or five indexes which can be attached to objects; it's a bit like having your fingers on an object: you might not know anything about the object, but you can say where it is relative to the other objects you're fingering.'

For our purposes, the interesting thing about object indexes is that a system of object indexes (at least one, maybe more) appears to underpin cognitive processes which are not strictly perceptual but also do not involve beliefs or knowledge states. This makes it possible to entertain a conjecture about infants' abilities:

> *The CLSTX conjecture:* Five-month-olds' abilities to track briefly unperceived objects are not grounded on belief or knowledge: instead they are consequences of the operations of a system of object indexes.

This is a wonderful conjecture due to several scientists (Leslie et al. 1998; Scholl & Leslie 1999; Carey & Xu 2001; Scholl 2007).

There is just one problem.[2] We saw earlier that infants' abilities to track briefly occluded physical objects can be tested using experiments. And in these experiments infants will look at an incongruous scene for perhaps 20 seconds. This is not something we could explain by invoking object indexes. Apart from anything else, 20 seconds is much longer than an object index assigned to a vanished object could survive.

What could connect object indexes with looking times in experiments?

4. Metacognitive Feelings Connect Object Indexes to Looking Behaviours

What links the operations of object indexes to facts about what is novel or strange to an infant? Not beliefs but metacognitive feelings.

What links the operations of object indexes to patterns in looking duration in experiments?

My conjecture: it is metacognitive feelings. Errors in the assignment of object indexes give rise to metacognitive feelings of suprise, and these are what cause infants to look longer.

But what is a metacognitive feeling? Best to start with some examples. Hopefully some of these are familiar to you:

- familiarity (Whittlesea & Williams 1998; Scott & Dienes 2008)
- the feeling of knowing (Koriat 2000)

[2] This isn't quite true: there is a second problem involving infants' success in searching for objects hidden in milk or which have disappeared after the lights went down. There are some details about this and a proposed solution in (Butterfill 2020).

- feeling that a name is on the tip of your tongue (Brown 1991)[3]
- the feeling you have when someone's eyes are boring into your back
- Déjà vu (Brown & Marsh 2010)
- ? surprise (Reisenzein 2000)
- the feeling of being the agent of an event ('sense of agency') (Haggard & Chambon 2012)[4]

As an example, take the feeling of familiarity. What causes feelings of familiarity? Not familiarity as such, it turns out. Instead they are caused by the ease with which you can process the features of a face relative to difficulty of identifying the person. Roughly, the greater the discrepancy between fluency of processing and difficulty of identification, the stronger the feeling of familiarity (Whittlesea & Williams 1998).

So what is this feeling of familiarity if it is not caused by familiarity?

First, it is phenomenal. It is an aspect of the phenomenal character of some experience associated with acting. So we can call it a feeling.

Second, it is metacognitive in the sense that it's normal causes include processes which monitor fluency of processing. This is why the feeling of familiarity counts as a metacognitive feeling.[5]

Third, it does not necessarily give rise to beliefs. The feeling does not lessen even if you believe (or know) that the thing which causes your feeling of familiarity is not one you have ever encountered before.

Fourth, you are not forced to treat feelings of familiarity as being about actual familiarity: instead you can use feeling of familiarity in deciding whether a stimulus is from that grammar (Wan et al. 2008). In this respect, metacognitive feelings are unlike perceptual experiences and unlike emotions. As Dokic observes:

> 'It is difficult to imagine fear that does not have the function of detecting danger. In contrast, many [metacognitive] feelings

[3] Widner et al. (2005) provides evidence that the feeling of knowing is distinct from the feeling that something is on the tip of your tongue.

[4] This is not supposed to be an exhaustive list. Dokic (2012) lists several more, and others have postulated novel metacognitive feelings (for example, Velasco & Casati (2020) argue that there is a metacognitive feeling of disorientation). It is also possible that some items on the list do not qualify as metacognitive feelings.

[5] Compare Dokic (2012, p. 310): 'the causal antecedents of [certain] feelings can be said to be metacognitive insofar as they involve implicit monitoring mechanisms that are sensitive to non-intentional properties of first-order cognitive processes.'

> seem to be recruited by the organism through some form of learning' (Dokic 2012, p. 308).

What, then, are metacognitive feelings? They are aspects of the overall phenomenal character of experiences which their subjects take to be informative about things that are only distantly related (if at all) to the things that those experiences intentionally relate the subject to.[6]

To illustrate, having a feeling of familiarity is not a matter of standing in any intentional relation to the property of familiarity, but it is something that we can interpret as informative about familiarity.[7]

5. Conclusion

It is time to return to the question we started with. How do humans make the transition from not knowing any simple facts about particular things in a given domain to possessing some such knowledge?

Part of the answer is this. At four- to five-months of age they already have in place a system of object indexes which enables them to track briefly occluded physical objects. Although the system of object indexes operates in accordance with some basic physical principles, assigning indexes to objects is not the same as knowing facts. Indeed infants at this age appear incapable of knowing even the simplest facts about an object's location. Object indexes are therefore a potential bridge between lacking any abilities to track objects and having full-blown knowledge of them.

To be a bridge, object indexes must somehow influence thoughts and actions. This they can do indirectly, via metacognitive feelings.

If this partial answer is roughly right, development is a process of rediscovery. Many facts about physical objects' movements and interactions are already implicit in systems that appear early in development. But these systems are inferentially isolated from knowledge states and so the facts implicit in them have to be discovered again.

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[6] This is consistent with, but weaker than, Koriat's theory: 'metacognitive feelings are mediated by the implicit application of nonanalytic heuristics … [which] operate below full consciousness, relying on a variety of cues … [and] affect metacognitive judgments by influencing subjective experience itself' (Koriat 2000, p. 158; see also Koriat 2007, pp. 313–5).

[7] Why accept this? You cannot perceive familiarity or agency any more than you can perceive electricity. Perceptual processes do not reach far back into your past, nor are they concerned with questions about whether you are the agent of an action. So to think that metacognitive feelings intentionally relate you to facts about familiarity or agency requires postulating a novel kind of sensory process, some kind of inner or bodily sense.

Glossary

habituation Habituation is used to test hypotheses about which events are interestingly different to an infant. In a habituation experiment, infants are shown an event repeatedly until it no longer holds their interest, as measured by how long they look at it. The infants are then divided into two (or more) groups and each group is shown a new event. How much longer do they look at the new event than at the most recent presentation of the old event? This difference in looking times indicates *dishabituation*, or the reawakening of interest. Given the assumption that greater dishabituation indicates that the old and new events are more interestingly different to the infant, evidence from patterns of dishabituation can sometimes support conclusions about patterns in how similar and different events are to infants. 2

track For a process to *track* an attribute or thing is for the presence or absence of the attribute or thing to make a difference to how the process unfolds, where this is not an accident. (And for a system or device to track an attribute is for some process in that system or device to track it.)

Tracking an attribute or thing is contrasted with *computing* it. Unlike tracking, computing typically requires that the attribute be represented. 2

violation-of-expectation Violation-of-expectation experiments test hypotheses about what infants expect by comparing their responses to two events. The responses compared are usually looking durations. Looking durations are linked to infants' expectations by the assumption that, all things being equal, infants will typically look longer at something which violates an expectation of theirs than something which does not. Accordingly, with careful controls, it is sometimes possible to draw conclusions about infants' expectations from evidence that they generally look longer at one event than another. 2

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