Object permanence in infancy: challenges to the Piagetian account.

The impact of Jean Piaget's account of cognitive development (e.g. Piaget, 1954; Piaget & Inhelder, 2000) on developmental psychology is practically incalculable (Flavell, 1996; Miller, 1993; Slater, Hocking & Loose, 2003) but the latter part of the 20th Century saw his theories under attack from several quarters. What follows is a discussion of challenges to his account of the development of the object concept.

Usually characterised as cognitive constructivist, Piaget's theories are fully neither nativist nor empiricist (Lamb, Bornstein & Teti, 2002; Overton, 2003) but closer to the latter than the former (Carey & Markman, 1999). Although Piaget's commitment to invariant stages might seem to imply an innate developmental programme he was clear that they were the necessary outcome of interactions between maturational processes and the experiences children have. The stages are universal because the world is as it is and because all children bring the same set of tools to bear upon it. Piaget conceived of children as systems with an equilibriating tendency. Disequilibrium results when experience contradicts internal representational structures (Sugarman, 1990) and drives the reorganisation and extension of representations to accommodate the disequilibriating experiences (Feldman, 1994). Development, then, is a process by which the child comes to represent the world and its logic with increasing accuracy (Thelen & Smith, 1994). The interdependence of mental structures causes internal representations to organise themselves into structured wholes whose unity underlies the distinctness of each developmental stage (Boden, 1994).

The acquisition of object permanence typifies Piaget's account of the development of mental structures. Infants do not conceive of discrete physical objects. Their universe consists "only of shifting and insubstantial 'tableaux' which appear and are totally reabsorbed" (Piaget & Inhelder, 2000; p.14). Through their transactions with the physical world children develop a concept of independent physical objects that occupy space and persist in time (Beard, 1969). This advance underpins a conception of the spatial, temporal and causal organisation of the world. The onset of object permanence occurs at sub-stage 4 of the sensorimotor period when the child starts to search for an object that is hidden whilst it watches. A mature object concept is not immediately established since search will continue in an accustomed hiding place even if the object has been hidden in a different location in the infant's sight (the 'A not B error'; Piaget, 1954; Piaget & Inhelder, 2000). Object permanence as assessed using search tasks starts to appear at around eight or nine months and develops fully only towards the end of the first year (Light & Oates, 1991; Bremner, 2003).

The reliability of Piaget's search findings is impressive (Bremner, 1985; Harris, 1987). However, their status as evidence for a lack of object permanence rests on how failure to search is interpreted. Many 'standard' Piagetian tasks for assessing cognitive development conflate competence and performance (Gelman, 1972; Donaldson, 1978). Failure to search might indicate inability to co-ordinate the necessary movements rather than the absence of an object concept (Mehler & Dupoux, 1994). If so, tasks without complex motor demands should detect object permanence in children younger than eight months. Bower (1966; 1967) investigated this using a violation of expectation (VOE) paradigm. Infants were exposed to object occlusion and reveal events, some of which were possible (e.g. an object gradually hidden by another) and some impossible (e.g. an object gradually

dissolving). Bower claimed that differences in how the infants responded to the possible and impossible events (revealed through changes in heart rate) indicate a degree of object permanence in children just eight weeks old. Interpretation of these results, however, is complicated by the use of static displays and by the confounding effects of novelty: the infants will previously have encountered occlusion but not dissolution.

Bower, Broughton and Moore (1971) continued this line of enquiry using tracking tasks. Twenty week-old infants' tracking of a moving object was recorded as it approached and passed behind a screen. They found that the infants' gaze moved to where the object would be expected to emerge and that switching the original object for a different one disrupted tracking performance. These findings imply, *contra* Piaget, a belief in the object's continued existence whilst occluded and a persistent internal representation of its appearance, both present well before search tasks would indicate. Bower and Wishart (1972) used twenty week-old infants in an adapted Piagetian task in which the object was occluded by darkening the room. The infants continued to reach for the object suggesting, once again, a belief in its continued existence. Although these findings challenge the Piagetian account of object permanence the discovery that infants' tracking movements continue when the object they are following is stopped whilst fully visible (Bower & Patterson, 1973) suggests they may demonstrate only that infants have difficulty inhibiting motor programs once they have been instantiated.

These problems were addressed in a line of research established by Baillargeon, Spelke and Wasserman (1985), based on earlier work by Kellman and Spelke (1983) on infants' perception of object unity. They used VOE within a habituation framework which exploits infants' ability to differentiate behaviourally between novel objects or events and those previously encountered (Siqueland & Delucia, 1969). In the tests developed by Baillargeon *et al* infants are repeatedly exposed to a moving, three-dimensional stimulus (the *habituation event*). Habituation is assumed to have occurred once the infants start looking away. They are then shown two equivalent test events based on the first, one of which is consistent with object properties (the *possible event*), and one of which is not (the *impossible event*). Differences in looking time between the test events indicate different degrees of dishabituation and form the basis of inferences about infants' object knowledge.

In Baillargeon *et al* (1985) the habituation event was a 'drawbridge' rotating through 180°. Following habituation, a coloured block was introduced. Five-month-old infants were shown test events in which the block was placed behind the drawbridge, such that the rise of the drawbridge to vertical occluded the block. In the possible event, the drawbridge stopped at the point where the block would prevent further progress. In the impossible event, the drawbridge continued on its accustomed path, passing through the space previously occupied by the block. In both events, the drawbridge reversed at the end of its path, revealing the block in its original position. Baillargeon *et al* (1985) and Baillargeon (1987) found that infants as young as 14 weeks looked longer at impossible events. This has been confirmed by subsequent studies using a variety of stimuli (e.g. Baillargeon 1986; Baillargeon & Graber, 1987; Baillargeon & DeVos, 1991; Spelke, Breinlinger, Macomber & Jacobson, 1992). Baillargeon (1985; 1987; 2000; 2002) interprets dishabituation to the impossible event as surprise on the infants' part implying that their expectations about the behaviour of objects have been violated. According to Baillargeon these expectations derive from an object concept which exists substantially earlier than Piaget would allow.

Most attempts to explain these findings have invoked *core knowledge* (e.g. Spelke, 1988; 1994; Spelke et al, 1992). These accounts suggest that infants are innately endowed with an understanding of the physical world that includes continuity of movement and solidity of objects. Initial interpretations suggested that infants' object concepts are similar to those of adults but subsequent research has revealed substantial limitations. A young infant's understanding of events like occlusion is based on basic, all-or-nothing rules which are narrow in scope. Experiences with different types of event result in the elaboration of these rules to include an increasing number of relevant variables and increasing integration between rules (Baillargeon, 2002). Advances in infants' object knowledge are slow, incremental over the first two years and are triggered by challenges to their more primitive conceptions (Aguiar & Baillargeon, 1999; Hespos & Baillargeon, 2001), observations that are consistent with Piaget's account of developmental processes. However, Spelke's and Baillargeon's nativist interpretation of VOE findings disagrees fundamentally with Piaget, for whom spatial and causal relations amongst objects are later discoveries contingent upon the prior realisation, at about eight months, that there *are* such things as objects.

Since Baillargeon's original publications a substantial corpus of supportive findings has accumulated (see Baillargeon [2002; 2004] for reviews). Increasingly, however, their interpretation is disputed. The issue centres on what can be inferred from infants' ability to differentiate two stimuli in the VOE paradigm.

The principal objection is that VOE findings can be explained by known attentional and perceptual processes, without the need for the innate 'high level' concepts demanded by Spelke and others[1]. Bogartz, Shinskey and Speaker (1997) and Rivera, Wakeley and Langer (1999) argue that VOE findings reflect only transient perceptual preferences. Bogartz *et al* reanalyse the results of Baillargeon & Graber (1987) and Baillargeon and DeVos (1991), showing how the trajectory of an infant's gaze during habituation could miss stimulus features that subsequently attract attention in the impossible test event, confounding the outcome. Rivera *et al* attribute the differences in looking time in the 'drawbridge' studies to the greater similarity of the impossible test event to the habituation event (both involved a 180° drawbridge rotation) and a preference amongst infants for more movement (the impossible event involved a 180° rotation, the possible event only 112°). Whilst Rivera *et al* and Bogartz *et al* usefully draw attention to the incompleteness of some VOE experimental designs the argument that habituating events create transient preferences is unsustainable in the face of Wang, Baillargeon and Brueckner's (2004) replication of VOE findings without habituation trials. Baillargeon (2000) and Bremner (2001) concede that plausible 'low level' interpretations of VOE findings are possible, but argue that each different VOE task requires a different interpretation and that innate/early object knowledge, which can accommodate all findings, should therefore be preferred on grounds of parsimony.

The most serious challenge to Baillargeon's interpretation of VOE findings comes from Schöner and Thelen (2006). They present a dynamic field model of habituation and VOE task performance grounded in dynamic systems theory (Thelen & Smith, 1994) and derived from Thompson and Spencer's (1966) Two Process Theory in which a repeatedly presented stimulus produces general

[1] Since Baillargeon and Spelke believe preferential looking denotes an emotional response whereas perceptual/attentional accounts involve no such commitment this issue might be resolved if a suitable metric of infant surprise could be identified. Curiously, this line of enquiry has not been pursued until very recently. Pupillary dilation may be a candidate (Jackson & Sirois, 2009).

excitatory *activation* and stimulus specific *inhibition*. Habituation occurs once the inhibitory response is sufficiently strong to overcome the excitatory one. Dishabituation to a novel stimulus depends on two variables: its strength of activation and its degree of similarity to the habituated stimulus.

Schöner and Thelen (2006) mathematically model infant looking/not looking as the output of two coupled and interacting fields representing activation and inhibition. Their model allows the system to evolve dynamically to produce behaviour that is influenced by its own history and which, under certain circumstances, is non-linear in character. It accurately simulates infant looking in a variety of habituation and VOE paradigms, including the 'drawbridge' studies (Baillargeon *et al*, 1985; Baillargeon, 1987) and accommodates some features of VOE data that embarrass other interpretations, including an order effect (VOE effects are stronger when the impossible stimulus is presented second; Baillargeon, 1987; Rivera *et al*, 1999) and response differences between fast- and slow-habituating infants (Baillargeon, 1987; Cashon & Cohen, 2000). Critically, all this is accomplished by treating VOE tasks as "a series of perceptual events subject to basic habituation dynamics" (Schöner & Thelen, 2006; p.289) and without invoking any kind of symbolic mental representation, innate or otherwise. By Baillargeon's (2000) parsimony criterion the model is therefore preferable to her own explanation of the VOE findings.

Schöner and Thelen show that the assumptions underlying the VOE paradigm oversimplify the dynamics of habituation in significant and misleading ways and that it is therefore unwarranted to draw inferences about infants' object knowledge from studies that use it. More fundamentally, they demonstrate how accounts in which behaviours like preferential looking emerge from the interaction of many variables in a dynamic system are more powerful that those based on a "sense-think-act" distinction (Smith, 2006; p. 88) that grants privileged explanatory status to static symbolic representations. This has profound implications for theory, and also for research, since the methods employed in developmental psychology do not typically generate the finely-grained, time sensitive data on which the development of dynamic models depends (Thelen & Smith, 1994).

The isomorphism between the behaviour of Schöner and Thelen's model and the results of VOE studies is compelling, but some caveats should be noted. First, a model is not the thing it purports to represent (Korzybsky, 1994). Schöner and Thelen's model is a mathematical abstraction (albeit a highly principled one) and it will eventually become necessary for dynamic field theorists to specify how such models are realised as biological systems[2]. Second, in their modelling of Baillargeon's 'drawbridge' studies, Schöner and Thelen assume that the impossible event more closely resembles the habituation event than the possible event does. This does not resolve the question about stimulus equivalence in VOE tasks; it begs it. The obvious issue is that a sufficiently sophisticated model can produce any behaviour the modeller wishes, provided appropriate parameter values are chosen.

[2] Thelen and Smith (1994) do present a speculative account based on Edelman's (1987) Theory of Neuronal Group Selection and this point, of course, applies equally to the core knowledge explanations. Spelke *et al* (1992) claim that resolving the underlying mechanisms of innate representation is not a task for psychologists. It could be argued that this represents a pessimistic, even vacuous response to a question clearly of fundamental concern to developmental psychology.

In Piaget's theory children assemble, through their own activity, an understanding of the world whose stability they work to maintain. The shift in the past thirty years has been towards a view in which children's understanding of the world in some sense pre-exists them. Dynamic systems theory represents a shift back in the Piagetian direction, although not back to Piaget. It abolishes the central theoretical role of symbolic internal representations like 'object concept'. It remains to be seen, however, whether the fields and attractors it proposes as a replacement are anything more than elaborate mathematical metaphors.

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