WHERE KNOWLEDGE BEGINS : PHYSICAL CONCEPTS IN INFANCY

ELIZABETH S. SPELKE

Cornell University

Introduction

Welcome to the invited lecture of Elizabeth Spelke. As you may know, in the past 10 years Professor Spelke has conducted very influential research on infant intermodal perception and early object concept. In this relatively short period of time Liz has produced an imposing amount of work demonstrating unsuspected competence in young infants to perceive and understand the world that's around them. By combining great experimental skills and ingenuity with a sharp theoretical approach which integrates views as apparently as far apart as Gibson and Chomsky she has shaken all conceptions on infant perception and cognition. Professor Spelke got her doctoral degree from Cornell University in 1977 where she returned last year as a full professor after 8 years at the University of Pennsylvania. As proof of Professor Spelke's sky-rocketing career and productivity, when I introduced Liz the other night to a Japanese friend and colleague, he reacted with great surprise telling Liz that he though she was an old lady. It causes me to receive a bad look from Liz, suspecting me to have told nasty things about her to my friend. As you can see, Liz is modest on top of that. I will give now the microphone to Professor Spelke so she can tell us about where knoledge begins and about physical concept in infancy.

Begin

Thank you Phillipe for that very exaggerated introduction, almost as exaggerated as the title of my talk, for which I apologise. What I will talk about today is something more modest thal "where knowledge begins". I want to talk about the capacity to organise the world that we perceive into the units that we generally consider physical bodies ; units like cups and chairs, glasses and tables—the things that we call physical objects.

For a number of years I've been fascinated by this ability. We as adults perceive objects effectively, immediately, and effortlessly, but the information on which our apprehension of objects is based is extremely indirect and partial. This is true in all sensory modalities, but let me illustrate some of the problems with the case of vision. I can do this if we have the first slide please. [Slide 1]

This print is by Hokae, and it illustrates some of the problems of object perception. First the objects that appear in visual scenes never appear to us in their totality. At any given time and from any given point of view, the back of every object in a scene is, and in the case of a great majority of objects, most of the front surfaces of objects are hidden as well by objects that stand in front of them. We experience objects as complete, however, despite these patterns of occlusion. For example, if you were asked to describe this scene in a common sense way, you would surely mention the boat, despite the fact that its underside is completely hidden and its topside is largely hidden by the people who are occupying it. Even when objects are not hidden by nearer occluding objects, they stand upon and beside other objects and this creates a second problem, the problem of perceiving their boundaries. We as adults are able to perceive, for example, that the green box in the foreground of this is picture distinct from the woman in blue sitting next to it and from the crossbar underneath it. We perceive the boundaries of objects, determining when two adjacent surfaces lie on a single object and when they lie on distinct objects. If you look around this scene, however, you'll see that in many cases these boundaries are obvious. The third aspect of object perception that interests me can't be illustrated with a slide, although it is the most striking one The objects that present themselves to the field of view do so sporadically : Images of objects are constantly coming into and going out of view, as we move our eyes around a scene, or as we move ourselves or objects themselves through the scene. Nevertheless we experience objects as persisting continuously through time, even when they are out of sight. When an object goes out of sight and then comes back into sight, moreover, we are usually able to determine that the object that we see now is the same as the object we saw before.

My question, then, is this : How are we able to perceive the unity, the complete shape, the boundaries, and the persisting identity of objects through time? I've been trying to address this question by studying the early development of the ability to apprehend objects in infancy. To give you a very brief overview of the conclusions and suggestions I will present today, our studies provide evidence that infants have quite considerable abilities to perceive objects in the scenes they see or touch. For example, an infant can sometimes perceive the complete shape of an object that's partly hidden, he can sometimes perceive the boundaries of distinct objects that touch or send overlapping images to the eye, he can sometimes perceive the persistence of an object that goes fully out of view, and he can sometimes perceive the identity of objects that are seen at different times, in different places. But our studies also provide evidence that infants' capacities to apprehend objects are much more limited than the capacities of adults. Infants are able to perceive the unity, the boundaries, and the persistence of objects under some of the conditions that are effective for adults, but not under all the conditions effective for adults. This finding is, I think, of special interest, because a consideration of infants' patterns of successes and failures can shed light on the mechanisms of object perception. The work I'm going to present today suggests that those mechanisms are surprisingly central—so central that I now think it misleading to talk of objects as being perceived. Objects are apprehended, I believe, by a mechanism of thought, a mechanism that makes sense of the physical world and of its behaviour in terms of an early developing object concept.

In this talk today, I will discuss some of the research that leads me to these suggestions. Then I will say something about the initial object concept, what I think it is and how I think it functions in infancy. Finally, I will speculate about how conceptions of physical objects change over the course of growth and development. So, on to the research.

I first began working on the problem of object perception with philip Kellman, who is now at Swarthmore College, and we were joined soon after by Hilary Schmidt, who is now at Monell Chemical Senses Centre. When our work began some ten yeass ago, we were convinced that objects were perceived, and our work was guided by 2 general theories about the development of object perception that came from a larger theoretical debate within perception. One theory, from the Gestalt psychologists, proposed that objects are apprehended by virtue of a general tendency to confer the simplest, most regular organisation on a perceptual scene. This tendency, in turn, was thought to reflect an intrinsic tendency of the nervous system to assume a state of maximal simplicity and balance. Thus, the capacity to perceive objects by organising arrays into simple units was expected to be present as early in development as anything could be perceived at all. On a Gestalt view, therefore, you would expect a young infant to organize surface arrays into objects when ever Gestalt configurational properties favoured that organisation. The other theory, from a tradition of empiricism in philosophy and then psychology, proposed that object perception is the outcome of an inferential process. In the visual mode, for example, a perceiver an array of visible surfaces and then fills in the unseen parts of objects by making inferences about the most likely source of the visual configuration that's presented. This inferential process has been thought to depend on processes of learning that occur as an infant or child reaches out for the things that he sees, manipulates them, moves around them, and discovers the consequences of these various activities.

Kelman, Schmidt and I sought to distinguish these views by investigating infants' perception of partly hidden objects. In particular, we focussed on displays like the one in the next slide 'Slide 2] All of the studies that I'll be talking about were conducted with real, 3-dimensional objects, althongh you will only see sketches of them here. All were conducted with four-month-old infants, who can see quite well but cannot yet reach for visible object or crawl around.

In the first study I'll be describing, a rod was presented a few centimeters behind a wooden blook. It was presented in motion, back and forth from this left-most position on the slide, to a comparable position to the right, although never moving far enough to bring the centre into view. Adults shown this display (and all our studies have been conducted with adults as well as infants report a powerful impression of a unitary rod, connected behind the block. In order to see what infants perceived, we used a habituation of looking time method — a very familiar method in infant research. We presented this display to infants with the rod in motion and allowed them to look at it for as long as long as they wanted. When they looked away, we took it away and then presented it again, beginning the next trial.

These trials continued until infants became bored with this display, as reflected by a decline in looking time to half its original level. At that point we took the block away and presented infants in alternation with a complete rod [Slide 3] the display that adults report seeing, and [Slide 4], a rod with a gap in the centre a display that corresponds to the visible areas of the partly occluded rod. Our reasoning was as follows. Once infants had become bored with the partly hidden rod, if they (as Gestalt psychologists would claim) perceive the rod as a connected unit, they should continue to be bored with the complete rod, and they should be relatively more interested in this broken rod. On the other hand, prereaching, prelocomtor (as Empiricists would claim) see visual displays as a mosaic of visible surfaces, then after becoming bored with the occlusion display, they should continue to be bored by the broken rod and should look relatively longer at the complete rod.

The results are on the next slide. On the top figure, you can see that looking time did decline over the habituation sequence, and then infarts tended to look longer at the broken rod, particularly on the first trial. This difference did not reflect a general preference for the broken rod: Baseline preferences between the 2 rods down here in an given in the lower figure which depicts a condition in which infants were presented with the same test trials after being habituated to something completely different. It looked, from this first study, as if we have evidence against the Empiricist view—prereaching infants did not seem to perceive this display as a mosaic of visible surfaces—and some evidence for the Gestalt view—infants appear to perceive this display as a connected rod. As we continued our research in this area, however, our studies began to cast doubt on the Gestalt view of object perception as well.

In our next studies, we switched from moving objects to stationary objects. For example, we tested infants' perception of a stationary rod otherwise like the one used in this first study. We also tested infants' perception of a stationary displays with better Gestalt forms. Such as this display patterned on a display studied by Michotte: three rods forming an equilateral triangle [Slide 5]. We also conducted studies using displays like that on the next slide—solid objects of the best forms, in this case a sphere [Slide 6]. All of these studies supported the same conclusions: four-month-old infants did not seem to perceive any of these objects either as a set of visible fragments or as unitary, continuous objects. Let me give you just one pattern of results, which you see on the next slide [Slide 7]. This slide gives me resurts for the study with the triangle, and it illustrates a second control procedure that we've used. At the top is the experimental group, infants who were habituated to a triangle partly hidden behind a block. In addition, other infants were habituated to a fully visible triangle in front of the same block, or a triangle with a gap in the centre in front of the block. After habituation, the block was taken away in all three cases, and infants saw the complete and the broken triangles in alternation. In both control groups, habituation to a fully visible figure was followed by very low looking at that figure, and higher looking at the novel figure. In the experimental condition, we got quite different results from either control group. Infants looked equally at the 2 test displays, and when you compare their looking time to that of the infants in the control groups, it looked as if they were treating both displays as novel that is infarts did not appear to perceive the original partly hidden triangle either as a single connected object or as 2 separate object visible fragments ending where the occluder began. Why do infarts fail to perceive the unity of partty hidden, statiorary objects? Perhaps, we thought, they do not see such objects at all. Maybe babies don't pay attention to partly hidden objects unless they move. We've been able to show in a number of studies, however that infants are sensitive to the visible areas of a partly hidden stationary object, and that they respond to changes in those visible areas. Then we thought that infants might see partly the visible areas of partly hidden objects but not be sensitive to their configurational properties : Maybe infarts can't tell that the edge of the top and bottom of an object are aligned, for example. Research from a number of laboratories including our own, however, has shown that infants are sensitive to the configurational properties of stationary objects: They know when they are seeing a good form that's partly hidden, but they seem not to perceive whether that form continues in a definite way behind its occluder if it's stationary.

Our conclusion, so for, was that, Gestalt configurational properties such alignment, surface similarity, and figural goodness do not, by themselves, evoke perception of a unitary object. Must an object both move as a whole as have "good" Gestalt properties to be perceived as unitary? We tested this idea using the display or the next slide [Slide 8]: an object where top and bottom differed in color and texture, whose edges were not aligned, but that moved as a whole, just as the rod had moved in the first experiment. The results are on the next slide [Slide 9]. In this study, as in the first study with the moving rod, infants seemed to perceive a single object connected behind that occuder. Having habituated to that display, they looked longer at a display with a gap than at a connected display. This again is not a baseline preference for such a display, for the baseline preference was in the opposite direction. A comparison of the findings of this study with the findings of the original study with the moving rod suggested that there was no effect of Gestalt configurational properties on infants' perception of partly hidden objects—all that seemed to matter was motion. We conclude, from all this research, that motion influences young infants' perception of the unity of a pastly hidden object, but that static configurational properties do not.

Shortly after beganning research on partly occluded objects, we began to study infants' perception of the boundaries of objects whose images are adjacent or overlapping in the visual field—that second aspect of object perception that I described at the beginning. For example, we have investigated displays like the one on the next slide [Slide 10]: 2 rectangular solid objects that differed in color, texture, and shape one standing in front of the other. We've presented babies with a variety of displays like these, asking in every case whether infants see such a display as consisting of 2 simple and regular objects or as consisting of a single object of two different colors and texture and a complicated shape.

We've investigated percepion of object boundaries using 4 different methods. First research with Roberta Kestenbaum has used a habituation method similar to the method of Kellman and Schmidt. Second, research with Claes von Hofsten has used a reaching method in which we've looked to see whether infants reach for an array of 2 objects as a single unit, or whether they reach separately for one of the objects as a distinct unit. Third research with Wendy Born has used a surprise method, in which we moved different parts of a two objects display and looked to see whether babies were surprised by any such motions. Finally, research with Penny Prathes has used a number detection method. As some of you may know, young infants have been shown to be sensitive to the number of items in a display, provided that number is small. Therefore, we have used number detection methods to ask young infarts, in effect, whether an array of two objects like the one in this slide consists of 1 unit or 2 units.

All of these studies were conducted with infants of 3 to 5 months, and all of them support the same conclusions. First we've found that infants perceive the boundaries of 2 adjacent objects by detecting the relative motions of those objects. For example, if one object is stationary while the object moves behind it, or if 2 objects move in different directions, infants will perceive those objects as distinct. Motion specifies the boundaries of overlapping objects, just as it specifies the unity of a partly occluded object. Second, infants perceive the boundaries of objects if those objects are separated by gap in 3-dimensional space. For example, if two objects are arranged in depth with a gap between them, and infarts are allowed to move their heads and therefore discover the thinness of these objects and their separation in depth, infants will perceive the 2 objects as distinct. However, if 2 objects undergo no distinctive motion, and if they are not separated in space (i.e., they touch one another), infants perceive them as a single unit, even when the 2 objects differ in shape, size, color, texture and they are presented such that no surfaces of one object are aligned with the surfaces of the other. In the case of perceiving object boundaries, as in the case of perceiving the unity of objects, it appears 3—65 month-old infants do not organize surfaces into objects by detecting Gestalt configurational properties of a scene. On the positive side, such infants do organize surfaces into objects by detecting spatial and kinetic relationships between surfaces. We found, moreover, that spatial and kinetic information interact in an interesting way: Surfaces must both be touching each other and move together in order to be perceived as a single object. If 2 surfaces touch but move relative to each other, or if 2 surfaces are spatially separated and move together they are seen belonging to distinct objects. Infants evidently group surfaces into objects so as to form units that are cohesive and bounded: units that are spatially connected, remaining connected as they move and spatially distinct from each other, moving independently.

What kind of mechanism would organize surfaces into cohesive bodies? Certainly not a mechanism such as those proposed by the Gestalt or Empiricist theories of perception. As I said at the outset, I now think that the mechanism for apprehending objects is a relatively central one, I will present evididnce that this mechanism is central in 3 respects. First if takes as input the spatial layout as it is perceived. Humans don't apprehend objects by operating directly on patterns of optical, acoustical or haptic stimulation, but by operating on representations of the surface layout that perceptual systems deliver. Object perception begins where perception of the layout ends. Second, the mechanism for apperehending objects is amodal. Humans don't have separate visual, auditory and haptic mechanisms for apprehending objects, but rather a single mechanism that accept as input the surface representations delivered by any perceptual system. Third, the mechanism for apprehending objects carries infants beyond the domain of immediate perception in space and in time. It allows infants to represent objects and make sense of their behaviour under situations in which an object has gone out of view for long enough intervals that we as adults would not be tempted to say that we "perceive" it, although we might know, under certain conditions, where the object is and what it is doing.

These 3 conclusions structure the rest of my talk. Let me go through them one at a time, outlining the research that supports them. First, does object perception depend on an analysis of representations of the perceived layout, or does it depend directly on an analysis of incoming sensory information? We've asked the question in the case of vision, through research conducted with Philip Kelman on perception of partly hidden objects. Kellman and I asked, what it is about the motion of a pastly hidden object that leads infants to perceive the object as unitary and connected behind its occludes? In particular, we sought to distinguish two possibilities. First as an object moves in the world, its motion causes certain changes in the array of light at the eye. In the case of a lateral translation, there is a 2-dimensional retinal displacement of the images of the objects visible surfaces. Thus, infants might have perceived the unity of a moving object by detecting such 2-dimensional displacements. On the other hand, it is possible that infants perceived the actual three-dimentional motion of an object, and that this motion was the objects unity.

These possibilities can be distinguished because of the many : many relationship that exist between distal motions of things in the word and the proximal changes that accompany those distal motions. Two sets of studies have exploited this relationship. You can see both the displays and the results of the first set of studies on the next slide (Slide 11). Kellman, Kennethshort and I asked what would happen if instead of moving a rod laterally, thereby causing a horizontal displacement of its images at the eye, we moved the rod in some other direction. For example, if a rod moves vertically, all that happens at the eye is that one image of the rod lengthens synchronously with the shortening of the other image as the rod travels up and down : there is no horizontal retinal displacement. We also wondered what would happen if a rod moved in depth. In this case there is no displacement in any direction, horizontal or vertical ; rather, the 2 images of the visible parts of the rod undergo a simultaneous shrinkage or expansion, respectively, as the rod moves away or lateral noting vertical, and motion in depth have the same effect on 4-month-old infants' responses in a habitation study : In all 3 cases habituation leads to greater lookinsg at a broken object than at a complete object. Thus, infants perceive a rod as a continous unit, not only when it moves horizontally but also if it moves vertically in depth.

This finding suggested that what matters for apprehending the unity of a partly hidden object is perceived motion in 3-dimensional space, not some particular pattern of proximal change at the eye. However, the study was not fully decisive. It remained possible that object perception depends on the detection of proximal changes in the array of light at the eye, but that these are several mechanisms for detecting such changes, one of which detects lateral displacement, one vertical displacement, one simultaneous shrinkage and expansion.

Our next study addressed this possibility : it is diagramed on the next slide (Slide 12). In this study we attempted to pit proximal changes against distal changes by presenting a baby with a partly hidden object while the baby herself was in motion. The figure presents an overhead view of the 2 conditions of this experiment. In both conditions, the baby was moved in a chair on a semi-circular track in front of an occuder behind which stood a rod just like the rods from previous research. In one condition, the rod was stationary. As the baby moved, however, the image of the rod was displaced in the visual field, producing the same pattern of horizontal, retinal notion as was produced in our first study when the baby was stationary and the object moved. Thus there was displaccement of the image of the object with no real motion of the object, the displacement of the image being caused by the motion of the baby. The second condition was the same as the first except that the rod was now presented in motion, and it moved exactly so as to cancel the pattern of image displacement that occurred in the first condition. The rod remained always directly in front of the baby, centred in the field of view and undergoing no image displacement as it moved. Neverthless the rod actually was in motion, and an adult would perceive both its motion and his own.

What do 4-month-old infants perceive in each of these 2 cases? The results are on the next slide [Slide 13]. You can see that all that mattered in this study was the real motion of the object, not the displacement of its images. When the object was really stationary but is images were in motion, the results were the same as in studies with stationary objects and stationary infants: low levels visual attention and no differential dishabituation to complete and broken objects. When the object really moved, in contrast, even though there was no notion-caused displacement of its image in the visual field, the results were the same as in studies with moving objects and stationary infants: habituation, there was longer looking at the broken rod. Putting this study together with the last one, what appears to matter for the perception of the unity of a partly hidden object is the real, perceived motions of its visible surfaces, not any particular pattern of proximal change that accompanies those motions. This suggests, in turn, that apprehending objects is at least a 2 step process, in which one first perceives a layout of surfaces in 3-dimensional space and the 3-dimensional motions of those surfaces, and then groups those surfaces into objects, filling in areas that are hidden, by analysing those perceived arrangements and motions. This, then, is the first piece of evidence for the relative centrality of the mechanism for apprehending objects.

Let me turn to evidence that the mechanism of object perception is amodal. This evidence comes from research that was conducted collaboratively with Arlette Streri at the University of Paris. (She is here to answer your questions, or to correct me when I say something wrong.) I should add that this research is at a relatively early stage and the conclusions that I'll be offering we still quite tentative. We have been studying object perception in the haptic mode: infants' ability to perceive the unity and the boundaries of objects when they explore those objects by touching them and munipulating them.

The logic of these studies may best be understood if you consider an analogy to them, which can befound in studies of sign language. People have studied sign language to address many questions, but one prominent question is this: Are the mechanisms underlying language competence part of the auditory system, or are they located more centrally? If language mechanisms are relatvely central, then language should obey the same principles, if it's acquired naturally and spontaneously whether the modality of its expression is auditory or gestural. Similarly, we think, if object perception depednds on a single mechanism that's relatively central, rather than on modality specific mechanisms, then object perception should obey the same principles when infants explore objects haptically as when they explore them visually. You should see the same patterns of success and failure to perceive the unity and boundaries of objects in each of the 2 modalities. This is the prediction that Streri and I are engaged in testing.

The situation on which we have focussed is one in which an infant explores with 2 hands surfaces that are outside the field of view. In our studies, infants were given 2 ring-like objects to explore, one in each hand. The rings were presented underneath a bib that completely blocked the infant's view of the objects or her own body: She could feel the rings but not see them [Slide 14]. We asked whether and under what conditions, such an infant can determine whether the 2 rings that she feels are 2 distinct objects separate from one another, or two ends of a single object that continues between her 2 hand? These studies were conducted with 4 months old infants, the same age as in the visual studies and a convenient age to study because at that age, unlike somewhat older infants, infants are content to hold and explore objects without attempting to bring them into the field of view, and they tend to explore them by clutching them and moving them around. What happens, then, when infants grasp 2 ends of an object without feeling or seeing the area between them: Are they ever able to make inferences about whether the ends are connected or not?

The first studies explored the role of motion in haptic perception of objects. Infants were run in 2 conditions (Slide 15). In 1 condition, the 2 rings that they felt were connected by a bar that they could't feel but that constrained the 2 rings' possible motions. The rings could only be moved rigidly together as the infant actively moved them. In the other condition, the 2 rings felt the same but were connected by an elastic band which impeded their motions much less: The rings could be moved with relative independence. In order to see whether infants perceived these 2 rings as connected or as separated from each other under each of these conditions, we conducted a haptic habituation and visual transfer experiment, using a method developed by Streri and Marie-Germaine Pêcheux. We presented infants repeatedly with a ring display until their holding time (i.e., the time until they spontaneously dropped one or both rings) declined to half its original level (just as in our visual perception experiments). Then we took the rings and the bib away, and we presented the infants with 2 visual displays. One display consisted of the two rings connected by a sar: A single, connected object. The other display consisted of the 2 rings with a gap between them: two distinct objects. The two visual displays underwent no distinctive motion; thus, the only thing that distinguished them was the presence or absence of a connection between the rings. We hoped to see from the looking time patterns what infants had perceived during the original haptic exploration.

The results are on the next slide (Slide 16). After habituation to the rigidly movable rings infants looked longer at the separated rings. After hasituation to the independently movable rings, infants showed the reverse preference, looking longer at the connected rings. Both of these preferences differed reliably from the baseline preference between the 2 objects, which was roughly equal. We conclude that when 2 rings can be felt to move independently, infants perceive them as distinct objects, where as two rings can be felt to move rigidly together infants perceive them as a single object. Motion appears to influence object perception in the haptic modality, just as it does in the visual modality, at 4 months of age.

We next went on to test whether Gestalt properties would influence haptic perception of the unity and boundaries of objects. The displays for this study were also rings (Slide 17). In one condition, the 2 rings differed in shaped and substance: One of them was (rounded) light, rough, and flexible, and the other was square, heavy, smooth and rigid. In the other condition, the 2 rings were of the same shape and sabstance: either both were round, light, and flexible or both were square, heavy, and rigid. The rings always moved together rigidly. We asked whether their Gestalt properties would affect infants' perception of their unity or boundaries.

The next slide shows the results of the good Gestalt condition (Slide 18), and you see a replication of the finding I showed you before. After habituating to rigidly movable rings that are the same in shape, texture and so forth, infants perceived those as connected and looked longer at separated objects. In the next slide though, you see the results of the bad Gestalt condition (Slide 19), and those results are the same: reliably different from baseline, not reliably different from the first condition. In the haptic modality, as in the visual modality, object perception appears to be influenced by the motions of surfaces but not by the configurational properties of surfaces such as their sameness or difference in texture, shape, weight, and rigidily.

These studies provide evidence for a single mechanism of object perception taking as input the resceived motions of surfaces, whether those motions are perceive by looking by touching. This evdidence, as I said, is not fully conclusive: It is possible that 2 separate mechanisms just happen to succeed and fail under the same conditions at 4 months of age. We hope to obtain more conclusive evidence in the future on this point by studying the development of object perception. One thing we would like to ask is, at what point do infants begin to use Gestalt properties in the visual and in the haptic modes: Do these tendencies appear at the same point in time? The evidence already suggests, however, that the mechanisms for apprehending objects are amodal.

Let me turn to the last general source of evidence for the centrality of the mechanism for apprehending objects, evidence that this mechanism carries infants beyond the domain of immediate perception and allows them to make sense of events in which objects move fully out of view. As you all know, the ability to apprehend objects as persisting when they move fully out of sight is one of the most studied abilities in infancy : It has been studied intensively for the last 60 years, ever since the pioneering work of Piaget on the development of object permanence. Virtually all of the evidence that's been collected has suggested that the ability to represent the continued existence of a hidden object develops very slowly over the course of infancy not until children are about 18 months of age do they first represent hidden objects and make inferences about their behaviour.

I have been led to question these conclusions, because of the nature of the methods that had been used to assess infants' developing klowledge of the existence and the behaviour of objects that are out of view. Virtually all of the studies that have been conducted since Piaget's original work have assessed infants' apprehension of hidden objects by focussing on their abilities to act on objects in co-ordinated ways, by searching either maually or visually for objects that are hidden. Because these studies depend on patterns of co-ordinated activity, they raise a question : Do the developmental changes that are observed over the course of infancy reflect developmental changes in infants' conceptions of objects, or do they rather reflect changes in infants' ability to act on their conceptions in a co-ordinated manner ? I think, ironically, the best reason for favouring the latter possibility comes from Piaget's own work, his studies of sensory motor development as described in "The Origins of Intelligence". Piaget provides, compelling evidence for genaral developmental changes in the child's ability to act in a co-ordinated manner : for example, putting separate actions together into means ends sequences. To the extent that those chasges occur, it is inappropriate to study young infants' conceptions of objects by requiring them to act with a degree of co-ordination that's beyond their general motoric capacity. Most studies of object permanence simply cannot tell us, therefore, whether young infants apprehend objects as persisting or not.

For this reason, we have gone back to some of the original questions of Piaget and others, using methods that do not require co-ordinated search behaviotr from young infants. In particular, the studies I'll be talking about today use the same habitution method that I've been describing to you all along, but now in situations where we present objects that move fully out of view and ask whether infants are able to represent them and make sense of their behaviour.

The first study was conducted with Renée Baillargéon. (Baillargéon has gone on to extend this research in many interesting directions, first at the University of Texas and now at the Univercity of Illinois. Today, I will focus only on her first study in this area.) In this study there were 2 critical events involving a stationary 3-dimensional cube and a flat screen which initially lay on a table in front of it [Slide 20]. The screen was presented in motion : In one event, it rotated upward about its stationary back edge until it completely covered the cube and then it continued moving until it got to the place that the cube had occupied. That was after about 120 degrees of rotation, and about 8 seconds after the cube had first disappreared. At that point the screen stopped moving, reversed direction, came back to the table, revealling the cube again. In the other event, the screen rotated so as to hide the cube and then continued to rotate a full 180 degrees, passing through the place that the cube had occupied. Adults consider the first event to be expected and the second event to be impossible since we represent the cube as existing behind the screen and as constraining the screen's motions.

In order to see how infants apprehended these events, infants were first habituated to a rotating screen with no cube present : The screen rotated back and forth 180 degrees between two flat positions on a table. Infants saw that event until they were bored with it, and then the cube was introduced and the 2 critical areas were presented in alternation. Our reasoning was as follows : if young infants (these were 5 month olds in this study) have no notion that an object continues to exist when it is hidden, then after being habituated to the 180 degree rotation, they should find the new 180 degree rotation relatively boring, since it is physically the same motion that they had been seeing before, and they should be relatively more interested when they see the 120 degree rotation, which is a novel motion. On the other hand, if infants represent the continued existence of a hidden object then they should be more interested when the screen rotates 180 degrees than when it rotates 120 degrees, because although the formers motion is superficially more familiar, it is deeply different from what they have been seeing. Infants have been seeing the unimpeded motion of a screen, but now they see an impossible event: a screen moving through a place that another object occupies.

The results are on the next slide (Slide 21), and they provide evidence that 5 month-old infants apprehend these events as adults do. After habituation to the rotating screen, infants look longer at the physically identical but impossible motion than at the physically different but expected motion. The experiment provides evidence that, young infants perceive an object as continuing to exist when it is out of view for a fairly appreciable period of time 8 seconds. Baillargeon has gone on to demonstrate the same ability at 4 and even 3 months. She's shown, moreover, that infants represent not only the continued existence of an object that's out of sight, but also a considerable number of the object's properties. Infants are sensitive to the size of that object, its orientation, even its substance, and all of these properties influence the predictions they make about how far that screen can move befere it ought to stop moving. These are quite impressive abilities to represent that objects continue to exist when they are out of view.

At Cornell, we have been attempting to extend this work in a number of directions. First we are asking what happens when a moving object leave the infant's view: Are infants able to make predictions about how an object will move and when it will stop moving when it is hidden? As adults we are usually able to make good predictions about where objects will move and where they'll stop moving after they've moved behind occluders of various sorts. For example, if I take a cup and lower it behind a screen and then remove my hand, you may not know exactly where that cup is, but you will know certain things about where it can that the cup and cannot be. You know, for example, that the cup has to have come to rest somewhere on or above the surface of this table, not below it. This follows from the notion that objects are substantial and cannot pass through other objects or surfaces. You also expect that the cup will come to rest on the table: It will not stand suspended without support in mid-air. That prediction follows from the notion that objects are subject to gravity and require external support of some kind if they are to stand stably. Janet Macomber, Frank Keil, and I have asked whether infants are also able to make these predictions.

We have been conducting studies with 4-month-old infants, looking at a situation, very much like the one I just demonstrated to you. In one situation, infants are first allowed to see an open display area, sort of like a puppet stage, and they can see that there's nothing in this area except a single blue surface at the bottom. Then a screen is put down covering most of the puppet stage. An object is displayed above the screen until the infant looks at it, and then we drop the object. A second later, we raise the screen and allow the infant to see that the object has come to rest on the surface of the table, exactly where an adult would predict it to be. Infants are allowed to look at the display as long as they want. When they look away, we present the event again and run this repeatedly in a habituation procedure. Once infants are habituated to this event, we introduce a second surface half-way up the display, in the path of the object's former (unseen) motion. Then once again we lower the screen, drop the object, and raise the screen, revealing the object in 1 of 2 positions: On one kind of test trial, the object appers on top of the new surface: a superficially novel position but the position adults would expect it to occupy. On the other kind of test trial, appears in the object the same position that it was in before, a position it could only have reached by passing through the screen, an event we take to be impossible. Those are the events for the substance experiment and now that I've described them to you, you may be able to make sense of the next slide, which depicts then schematically (Slide 22). We've used very similar events to test infants' knowledge of gravity, which you can see depicted on the same slide. We habituate infants to the display with 2 surfaces and an object that falls behind a screen and lands on top of the upper surface, where adults would expect it to be. Then we remove the upper surface and present a superficially new but possible event, in which the object now moves down to the lower surface, and also a superficially familiar but impossible event, in which the object moves to the same position it did before and stands there suspended in mid-air.

How do infants react to these events? The results are on the next slide (Slide 23). Looking first at the substance experiment on top, you can see results very much like Baillasgéon's. After habituation to the object moving to the floor, infants look more at the superficially familiar but impossible event, in which the object appears to have moved through a solid surface. This pattern provides evidence that 4-month-old infants conceive of objects as substantial and do not expect them to pass through other objects or surfaces. In the gravity experiment, however, results are quite different. After habituating to the object landing on the surface, when the surface is taken away, infants look longer when the object subsequently lands on the table than they do when the object is suspended in mid-air, in the same position it was in before.

These findings suggest that, 4 month old infants conceive of objects in some, but not all, of the ways that we do as adults. Young infants appreciate that objects cannot pass through each other, but they do not seem to appreciate that objects cannot stand suspended in mid-air: they are not surprised when they encounter an object there. This pattern appears to change gravity between 4 and 6 months: 6 month old infants run in the same gravity experient look longer at the superficially familiar but impossible event than at the superficially novel but possible event. Knowledge of gravity and its effects on objects may begin to conerge whether 4 and 6 months.

Finally, we have conducted studies infants' ability to apprehend the identity of objects that are seen at different places and times as they move in and out of view. As in the case of perception of the persistence of an object that moves out of view, this is something that has been intensively studied over the last 60 years, and virtually all of the evidence has suggested that there are considerable developmental changes in the means by which infants identify objects through time. Some investigations suggest, in effect, that young infants have no ability to identify objects through time. Other studies, by Bower, Moore, and others, suggest that infants identify objects through time in ways radically different from the ways we identify objects as adults. For adults, objects are movable can occupy different places at different times, but they have to move from one place to another on paths that are spatiotemporally continuous. Based on a variety of studies, Bower and Moore have proposed that infants have just the opposite notion: they identify an object with a particular place or a particular trajectory of motion and are perfectly happy for an object to exist in a discontinuous fashion in space and time. Once again, I was led to question these conclusions, because all of them depend on patterns of co-ordinated activity: The studies by Bower and Moore focus on patterns af visual tracking and visual search for objects. These studies raise the possibility that what's developing over the course of infancy is not a conception of object identity but rather an ability to act on that conception by looking for objects more and more effectively. We have started, therefore, to investigate infants' notions of object identity using a method that requires no visual search: our familiar habituation methods.

Our first study, conducted with Roberta Kestenbaum, used diplays develped by Moore, Borton and Darby for an ingeneous study. Here are our versions of their desplays (Slide 24). displays involve 2 narrow screens and a single object that move behind them. In one condition, the object moves continuously: It moves behind the first screen, appears between the 2 screens, moves behind the second screen, and then reappears. In the other condition, the object moves discontinously: It moves behind the first screen, then there's a pause, and at the time that the first object would have emerged in the first condition, the object emerges from behind the second screen. These 2 events are superficially quite similar: In both of them, only 1 object is visible at a time, the events are equal in duration, and so forth. But adults, of course, understand the events very differently. We describe the first event as involvinsg a single object, and we describe the second event as involving 2 objects identical in their features but numerically distinct. That description follows from the notion that objects have to move on spatiotemporally connected paths: An object can't jump from one place to another without traversing some path between the 2 places. To see how infants apprehend these events, we took 2 separate groups of 4 month-old infants and habituated one of them to the continuous motion event and the other to the discontinuous motion event. Then we took the screens away and presented the infants on alternating trials with a single cylinder and with 2 cylinders undergoing no distinctive motion, hoping to see from their patterns of interst on those test trials whether the infants had understood these events as involving 1 or 2 objects.

We conducted 3 such studies, all of which gave the same results. You'll see the results of one study on the next slide (Slide 25). Infants habituated to the continuous event showed relatively low interest in the single object test display and looked longer at the display of 2 objects, suggesting that they saw the continuous motion event as involvinsg 1 object. In contrast infants habituated to the discontinuous event showed the opposite pattern more lookinsg at the single object suggesting that they saw this event as involving 2 objects. We conclude that infants apprehend these events in much the way that adults do, in accord with a notion of spatiotemporal continuity : Objects must move on continuous paths.

That is our positive finding, but I will end again with a negative finding that comes from a study with Roberta Kestenbaum and Debka Wein that's depicted on the next slide. Having found that 4-month-old infants perceive object identity by analysing the spatiotemporal continuity of object motion, we went on to ask whether such infants would apprehend the identity of objects by analyzing the velocity of object motion. This was something that research by Bower, Moore, and others had suggested young snfants might be able to do. If an object moves at a constant speed behind an occluder and then re-emerges after an appropriate interval of time, infants had to track the object smoothly—a search patters that suggested that infants, like adults, perceive a single object moving continuously behind the screen. In contrast if the occlusion time is inappropriate to the visible speed of motion then young infants' tracking tends to be interrupted as if infants use the inappropriate velocity relationship, as adults do, as information for 2 distinct objects. Since are this evidence are from studies of visual handicap, however, we have looked again at the effects of velocity relationships on perceived identity, using a habituation method.

In our research, objects moved under 3 velocity conditions. In one condition the object's occlusion time was appropriate to its visible velocity. In a second condition an object was occluded for only a third the amount of time that it should been occluded. In the third condition, (which adults see as surprising), the object emerges immediately after it is occluded. We found no difference between infants' reactions in these 3 events (Slide 26). Unlike adults, 4-month-old infants not seem to be affected by the velocity relationships of moving objects, when they perceive object identity or distinctness. They are affected only by the spaciotemporal continuity of an object's path of motion.

In conclusion, I've suggested that infants have a relatively central mechanism for apprehending objects : a mechanism that takes as input the perceived 3-dimensional surface layout and that groups that layout into bodies with 4 properties. First, physical objects are cohesive : They are spatially connected, and they remain connected as they move, moving as wholes. Second, physical objects are bounded : They are spatially distinct from one another and move independently of each other. Third, physical objects are substantial : They occupy space uniquely, and such that 2 things cannot be in the same placce at the same time. One thing cannot pass through another. Fourth, physical objects are spatiotemporally continuous : They exist and move on connected paths in space and time.

I suggest that infants can find objects in the layout that they perceive, because the 4 properties they attribute to objects constrain how surfaces can be arranged and how they can move with respect to one another. The surfaces of cohesve bodies have to move together ; the surfaces of bounded objects move independently, the surfaces of substantial bodies cannot pass through space occupied by other substantial bodies ; And the surfaces of spatiotemporally continuous bodies have to move on connected paths. That is why, I think, infants apprehend objects by analyzing the spatial arrangements and motions of surfaces.

I suggest that infants fail to apprehend objects by analyzing other properteis of surfaces such as their Gestalt configurational properties, the speed of their motion, and their relation to supporting surfaces because their notions of physical bodies place no constaints on those properties. The properties of cohesion, boundedness, substance and spatiotemporal continuity say nothing about whether objects move at regular or irregular speeds, whether they are uniformly or non-uniformly shaped or colored, and the like. Infants appear to detect all of these properties of the layout, but they apprehend objects only by analyzing surface arrangment and motions, because the units for which they are looking only constrain those arrangements and motions.

I suggest that the properties of cohesion, boundedness, substance and spatiotemporal continuity constitute an initial conception of the physical world, an initial object cencept. This conception appears to function, for the infant, much as our physical conceptions function for us as adults. It enables the infant to organize her experience into units, in a way that may be akin to the ways scientific theories divide the world of a scientist into units like molecules or porticles. It enables the infants to predict how objects are going to behave, and to make inferences about the behaviour of those units when they are out of sight and beyond reach.

Based on these suggestions, let me speculate about how physical conceptions might develop after infancy, from this initial notion of the physical world and the bodies of which it's composed. I think hints of an account of the development of physical conceptions can be gleaned from a consideration of the nature of our conception of physical objects and of the physical world as adults, in relation to the infants' conception. There has been a lot of work within philosophy, and some work recently within psychology, on intuitive conceptions of physical objects and the physical world. One thing that's been revealed very clearly by this work is that a good deal of confusion surrounds our physical conceptions. Different people disagree about how objects should move. People disagree about what we should even call an object, and what the conditions are under which objects persist through time. We heard a bit of that disagreement at the end of Jocn Flavell's talk : It tends to arise very quickly when one talks about conceptions of the physical world and of objects and identity. But amid this the disagreement and confusion, there seems to be an islaand of clarity in adults' conceptions ; that island of clarity seems to consist of just the conceptions that infants appers to adhere to.

For example, consider what entilies you will and will not consider to be physical objects. As adults, we believe that most objects are relatively reqular in their Gestalt properties, but are tolerant of objects that are totally irregular in its color, texture and form. We believe that objects are subject to gravity and that most objects require stable support, but we accept objects that do not, such as helium balloons, airplanes in flight, and so forth. In contrast, we are unlikely to consider something an object if it lacks any of the properties that infants adhere to : If is's not cohesive (like a mound of ashes), not bounded (like drop of water released into the ocean), not substantial (like a shadow), or spatiotemporally continuous (like a row of lights). These notions seen to be central to our conception of physical bodies, so much so that something doesn't count as a body if it doesn't have them.

Similarly, consider the ways in which we reason about the behaviour of objects. As I've said, there has been a lot of work on this suggesthing that adults are prone to many errors in their physical reasoning. For example, if an object follows people are given a simple task, such as to draw the path that dropped from a moving airplane most people get the path wrong : They'll say the object will fall straight down, that it will move backward, or ever that it will move along with the airplane for a short distance and then abruptly fall. People disagree with each other in these judgements and they are not accurate about the paths that objects will follow, or the speeds at which they will move. But there are certain predictions about which adults are in total agreement and totally correct. Everbody expects an object to move through the air as a whole, to move separately from the objects around it, to move only through empty space (not to pass through the earth, for example, and come out the other side), and to move on a spatiotemporally continuous path. I think these intuitions suggest that the notions we find in infants are at the very centre of our conceptions of the physical world.

It makes sense, I believe, that our initial notion of the physical world should remain central to our thinking, if that notion serves as a basis for the development of physical knowledge. Such development proceed as follows : The infant starts with an initial cencetion of physical objects which allows him to pick out cohesive, bounded, substantial, continuous bodies under certain conditions by analyzing the motions and spatial arrangements of surfaces. Having picked out these bodies, the infant is in a position to learn more about them. She can learn, for example, that when things fall they are going to keep falling until they hit a surface. She can also learn that most of these things around her tend not only to be cohesive and bounded and but also relatively regular in their shapes and relatively uniform in their substances. This conception, therefore could come to be enriched by further notions. Note, however, that what the infant is learning about in these cases, is just the cohesive, bounded, substantial, continuous bodies that his initial conception picked out. Thus, initial conceptions of the world will tend to perpetuate themselves over the course of development. They will remain central to our thinking because they tell us what there is in the world for us to learn about in the first place.

I suspect that the developmental picture that I am sketching of an initial core of conceptions, that is enriched but not fundamentally re-organized by a growing periphery of conceptions whose acquisition if supports, is true of a number of domains of human knowledge, not just knowledge of physical objects. Knowledge of number may develop in this way, and also klowledge of space and geometry. Kloowledge of other persons, their intentions and their mental states (the kinds of things that John Flavell talked about on Monday and that I know many people here are working on) may also undergo this kind of development. In all these cases, there may be initial notions that single out a domain of things to learn about, and cognitive development may be a process of enriching those notions, not fundamentally overturning them. When it is suggested that development is a process of enrichment rather than a process of revolutionary reconstruction, I have noticed, many developmental psychologists get unhappy—as if development would be more interesting and more important to study if it consisted of revolutions, re-formulations, and re-constructions of experience than if it were orgasized around a common, unchanging core of competence. On the contrary, however, I think that the possibility that development in certain domains of knowledge takes place around an unchanging core of conceptions, gives one a special reason for studying early development. In such cases, developmental studies can shed special light on the deepest aspect of our own cognitive natures as adults. As adults, we know many things. Our abilities are so various and our knowledge is so rich, that it is often expremely difficult, even with systematic studies, to sift through all that we know and isolate our foundamental conceptions and fundamental ways of knowing the world. Here, I think, infants and young children may teach us something. They know much less about the world than we do, and they can do much less with their knowledge. Thus, infants both to reflect and to highlight some of our own most fundamental ways of thought. Thank you.

—Are there any questions?

Question (Paul Harris): Liz, you did mention one change between about 4 months and 6 months, I think it was, with respect to the findings on gravity, so you do get fairly sharp changes in a couple of months. What makes you think that if you tested 2 month olds, or 1 month olds, you might not get equally dramatic changes with respect to the 4 principles that you've mentioned?

Answer: I think that possibility is very much alive and one of myimmediate goals is to do research to investigate it. However, I see the change that's come in from 4 to 6 months as perhaps less dramatic than you're suggesting. The 4 month old infant I'd say has a conception of objects (to oversimplify it) as having 4 properties. The 6 month old infant seems to have added another property to that list, objects have weight, they are subject to gravity, they require certain conditions of support. That's not a reformulation and it's not a reorganization, it's a growth of knowlede, made possible, I pressume, by the initial conception that allowed infants to see things and so forth. But you're right in calling attention to the possibility that infants begin with less knowledge than we find at 4 months. I don't think they begin with something fundamentally different, but they may begin with less.

Question (Pierre Mounoad): You seem very convinced about the fact there can't be any re-construction so I'm ready that's no reconstruction Liz. But the first question that it is the physical world, something different to the social world. There is, for example, the face. An object that can be considered a physical object as well as a social object. If the face will be apprehended by the baby following the description you have given. If it can be considered partly similar, how you will integrate in your provocative statement all of the results of them in early retention, and how would you restitute the change in the behaviour of the baby from birth to 12 months. It has been described that a child needs to reach 1 year or more to be able to make this kind of correspondence between a different part of his face and the face of a partner, it was a description given by Piaget. So it has been discovered that the new-born is able to establish a certain correspondence between the part of his face and the part of the partners face. Everyone is agree this 2 levels are not similar, this 2 diffent level of control of an area, so how would you react to this?

Answer: If I understand you question, you could ask the same question about some of the studies that I described vis-a-vis the literature on searching for objects. That we find early competences when we use very simple methods, but that when you ask babies to do something more elaborate, they make patterns of errors that really look quite bizarre, and you see a very slow and regular developmental sequence. I think it's probably the same phenomenon. My answer must be tentative because I don't know very much about imitation and what infants know about other people or about relation between other people and themselves. But I think one live possibility, at this point, is that knowledge of the general correspondence between one's own face and another person's face could precede the ability to engage in specific motions that match rather precisely what another person is doing, and that even involve doing things that are new. The latter abilities could depend on the development of motor co-ordination as in the case of object search.

To your more general question, do I say no re-organizations occur? I don't want to be quite that radical. Even in the domain of physical knowledge, some adults get to the point where they can think of the world as being composed of particles and all sorts of things that exist discontinuously and so forth. What I want to say is the following: that in certain domains (physics being one) knowledge seems to develop rapidly and spontaneously over the course of infancy and early childhood. It develops in advance of language. It develops well in advance of specific instruction. Children do not have to be taught by other people about gravity, it now seems, and about lots of other things having to do with number and these other domains I mentioned: Children can learn them spontaneously. My bet is that in cases where development is like that, where it's rapid and it's sponpaneous and not guided from outside, development will turn out to be guided by initial structures that single out what there is to be learned about, and that come (in the adult state) to constitute the core of conceptions in that domain. That doesn't mean that we cannot come to override our conceptions as we go to school, as we think about things explicitly, as we import structures from one domain to work on another (for example mathematising physics), re-organizations of all kinds are still possible. My bet, however, is that they are going to be rare, and perhaps non-existent, in cases where development occurs rapidly, and spontaneously, early in life.

Question (Peter Bryant): Before I ask my question could I just check one detail in part of you talk which went quite quickly. When you had that upside-down slide (the one with all the stars on it) I think you said, but I may have got it wrong, that babies could realize they were 2 surfaces if they were, in fact, separate-if there was a spatial gap between the 2 and if they could move their heads around, I think you said that. Well then my question is about movement parallax, because it seems to me that therefore is use of different parallax to distinguish between two separate surfaces. And yet in a later experiment where you actually moved a child in a semi-circle, that has (if one is thinking in movement parallax) precisely the same cues, except that in one case the child's head is being moved, the child is moving its own head, whereas in the second case the child is being moved around. Otherwise, logically, it's exactly the same problem, so why do they succeed in one and not in the other?

Answer: I'm really glad you brought that up because this is a place where, I am rarely clear and it's easy to get confused. Motion parallax provides information to the visual system about the layout of surfaces in 3-dimensional space and there's some reason to think that it's effective fairly early in life. There is also good reason to think that other kinds of information that you get as you move your head, for example progressive occlusion and disocclusion of surfaces, is effective very early in life and serves to evoke, for an infant, perception of a 3-dimensional arrangement of surfaces in the layout. That's necessary, but not sufficient, for percetion of objects. In the case of perceiving the unity of a partly hidden object, you need to know more than that the top and bottom of that object are behind the occluder. Simply knowing that the top and bottom are behind the occluder doesn't tell the child, and wouldn't tell an adult, whether those 2 things are connected or not. For them to be perceived as connected, they have to actually move, and there what matters is not motion parallax, but real motion of those surfaces through the perceived layout however that motion was specified in the optic array. Is that clear now? (Questiones still looks puzzled)

The role that I think motion parallax is playing is this. The baby can be thought to have too rules for perceiving objects unity: First if 2 surfaces are nowhere spatially adjacent (you can't get from one to the other without jumping through 3-dimensional space), then those surfaces lie on separate objects. And second, if 2 surfaces are moving in parallel and there's a possible connection between them, infer a connection. Those rules are specified with respect to the 3-dimensional properties of things: where surfaces really are in 3-dimensional space, how things are really moving. But somehow the baby has to find out what the actual 3-dimensional situation is. His visual system performs that task by uses a variety of cues, including motion parallax. So in the situation where you have one object that's spatially in front of another, lacking E.S.P., the baby has got to get some information that tells him it's in front. Once he knows it's in front by any means (and motion can provide that information, other things can provide that information as well), then he can infer that they lie on separate objects. Motion parallax, therefore, affects the perceptuual system that brings information about surfaces. Real motion, in contrast, affects the cognitive system that organizes those surfaces into objects. That's the idea.

—Do you have something to add?

You don't look happy.

Bryant: —Well I suppose really all I can say is that I didn't understand the answer.

It seems to me that it's possible to explain the difference between 2 experiments in terms of the kind of motion involved. In one case the child actively moving its head, in the other the child being moved around. And one of my problems with that second experiment was that it could all be explained, I think (that negative result when the child is moved around), by the child actually being sort of bemused by moving around because I didn't see any control for that.

Spelke : —No for 2 reasons. First, active movements of the head are not sufficient for perceiving the unity of a partly hidden object. We know that because in our earlier studies with stationary objects, babies are in the same set—up with the same possibilities of active movement as in the case of the adjacent objects—and those active movements do nothing. Perception is ambiguous in those cases, they don't see that as a connected object. So, that kind of motion information is not sufficient for object perception from the beginning. As for the possibility that the baby is distracted by his own motion, that's why we had 2 conditions. The baby is moving in the same way in both conditions ; in one case the object is moving and in the other case it's not, and in one case he sees it as a unit and in the other case he doesn't. So, we were worried, actually, that the motion could be distracting but I think the results of the case where the object moves as well shows that it's not.

An other question? Yeah Pierre.

Question (Pierre Mounoud) : i don't know if we are all too much tired, but think it is very exciting, all the time I listen to Ms. Spelke I'm very stimulated. Thank you for your talk, but one more thing. You tell us that we didn't, well nobody discovered the real truth of the concept of objects as long as research has been based on co—ordinative structures. But what you have called co—ordinated structure that you can call on the action of the baby reaching. So during the last 20 years it is has been discovered of the things related to the co—ordinative structure, or to the motor capacity of the baby, also we have heard from Phillipe that at 3 months or 4 months old the baby have co—ordinated structure relating the hand to the mouth, and how it was important for the integration of apprehension of the objects. So is it not too radical to consider that it cannot be studied, the conception of the object cannot be studied using the co—ordinative structure as well as the kind of situation you have used?

Answer : Absolutely, when the structures on which you're focussing are within the competence of the infant, certainly. In fact we've done that in the studies with von Hofsten where we look at reaching as an index of object perception. The only point I wanted to make is that one must be sure that those structres are, in fact, within the competence of the infant ; because otherwise the lack of competence that you may find may stem not from deficiencies in the conception of the world, but the deficiences on the ability to act upon that conception, that's all.

Rochat : Well if there are no more questions, I want to thank very much Liz for her compelling and stimulating, as Pierre said, talk. Thank you very much.

Thank you all.

——END——

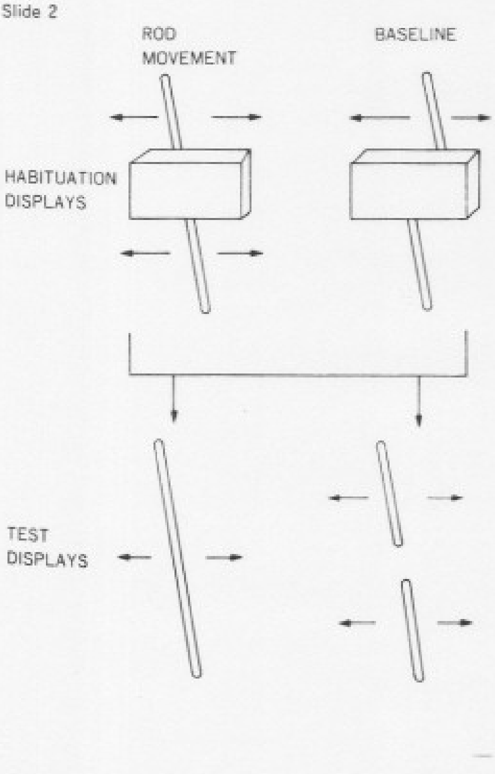
Figure Captions

To save space, only a few figures are included. Most of the remaining figures depict stimulus displays and data that are published in kellman & spelke, 1983(slides 3-9) ; Kellman, Gleitman, & Spelke, 1987(slides 12-13) ;Streri & Spelke, 1988(slides 14-15); and Baillargeon, Spelke, & Wasserman, 1985(slides 20-21).

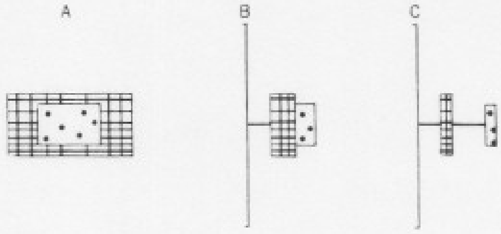
Slide 1 : Wood block print by Hokkei.
Slide 2 : Displays from Kellman & Spelke, 1983.
Slide 10 : Display from Kestenbaum, Termine, & Spelke, 1987.
Slide 11 : Displays and data from Kellman, Spelke, & Short, 1986.
Slide 16 : Data from Streri & Spelke, 1988.
Slide 22 : Displays from Maycomber, Speike, & Keil, 1988.
Slide 23 : Data from Maycomber, Speike, & Keil, 1988.
Slide 25 : Displays and data from Spelke, Kestenbaum, & Wein, 1988.

Slide 1

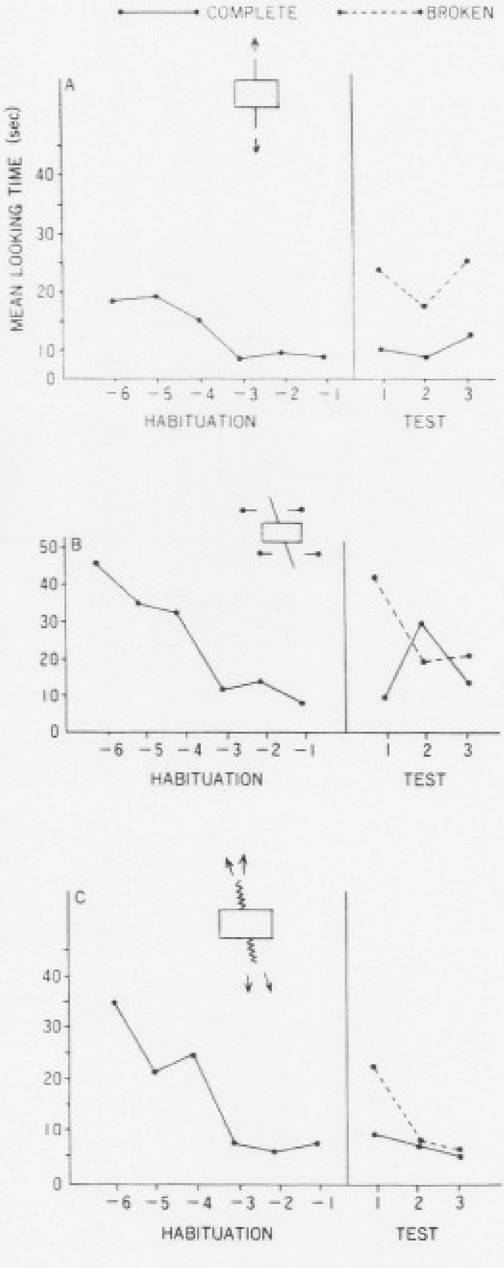
Slide 2



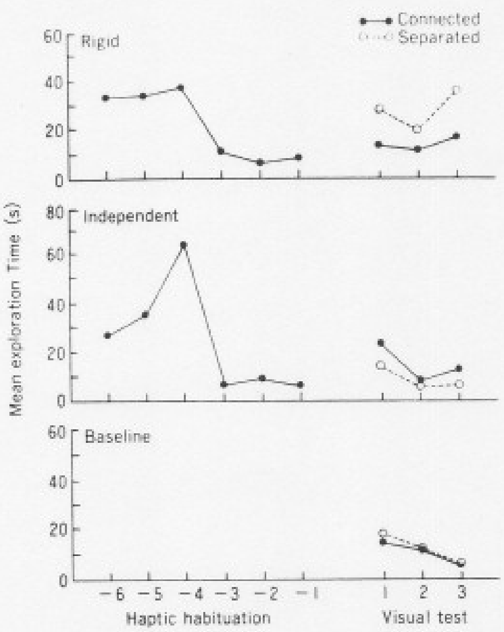
Slide 10



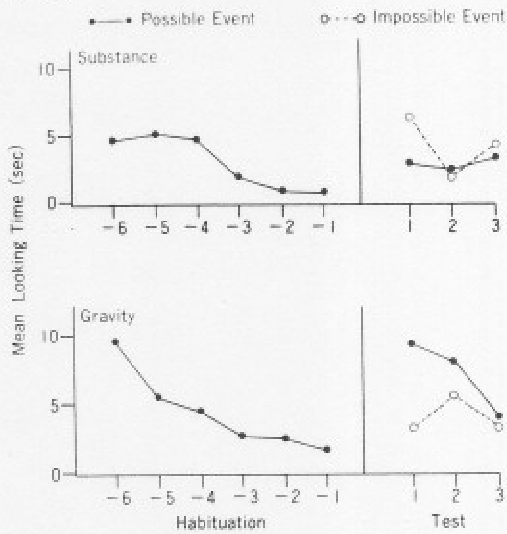
Slide 11



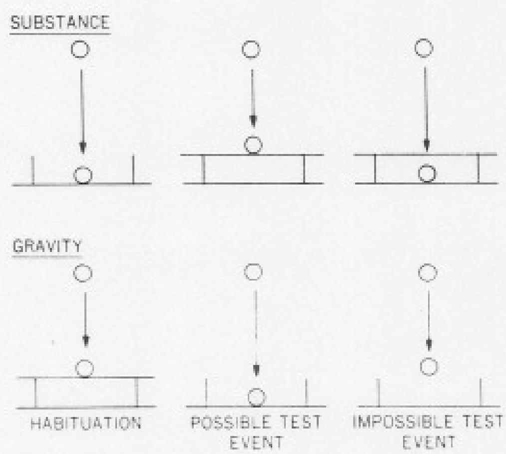
Slide 16



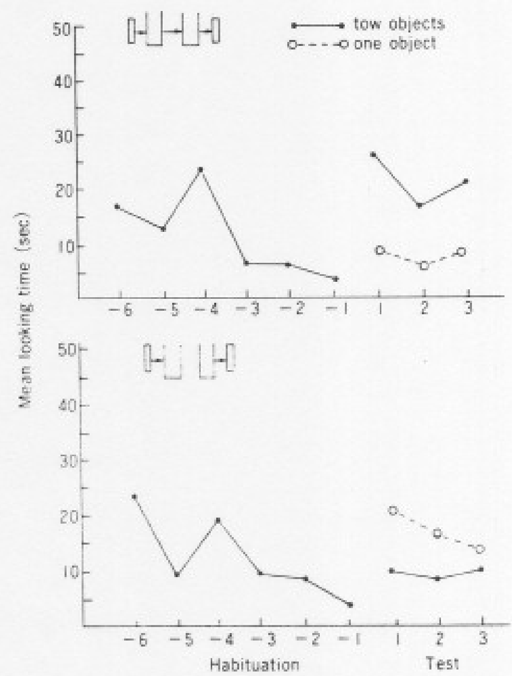
Slide 23



Slide 22



Slide 25



BIBLIOGRAPHY

Baillargeon, R., Spelke, E.S., & Wasserman, S. (1985). Object permanence in five-month-old infants. Cognition, 20, 191-208.

Hofsten, C. von, & Spelke, I.S. (1985). Object perception and object directed reaching in infancy. Journal of Experimental Psychology: General, 114, 198-212.

Kellman, P.J., & Spelke, E.S. (1983). Perception of partly occluded objects in infancy. Cognitive Psychology, 15, 483-524.

Kellman, P.J., Spelke, J.S., & Short, K. (1986). Infant perception of object unity from translatory motion in depth and vertical translation. Child Development, 57,72-86.

Kellman, P.J., Gleitman, L., & Spelke, E.S. (1987). Object and observer movement in the perception of objects by infants. Journal of Experimental Psychology: Human Perception and Performance, 13, 586-593.

Kestenbaum, R., Termine, N., & Spelke, E.S. (1987). Percepttion of objects and objectboundaries by three-month-old infants. British Journal of Developmental Psychology, 5, 367-383.

Prather, P., & Spelke, E.S. (1982, April). Three-month-old infants' perception of adjacent and partly occluded objects. Paper presented at the International Conference on Infant Studies, Austin, TX.

Schmidt, H. & Spelke, E.S. (1984, April). Gestalt relations and object perception in infancy. Paper presented at the International Conference on Infant Studies, New York.

Schmidt, H. & Spelke, E.S. (1985, April). Gestalt perception in early childhood. Paper presented at the meeting of the Society for Research in Child Development, Toronto, Canada.

Schmidt, H., Spelke, E.S. & LaMorte, V. (1986, April). The development of Gestalt perception in infancy. Paper presented at the meeting of the International Conference on Infant Studies, Los Angeles, CA.

2

Spelke, E.S. (1982). Perceptual knowledge of objects in infancy. In J. Mehler, M. Garrett & E. Walker (Eds.) Perspectives on mental representation. Hillsdale, NJ: Erlbaum.

Spelke, E.S., & Born, W.S. (1983). Visual perception of objects by three-month-old infants. Unpublished manuscript.

Spelke, E.S., Born, W.S., Mangelsdorf, S., Richter, E., & Termine, N. (1983). Infant perception of adjacent objects. Unpublished manuscript.

Spelke, E.S., (1985). Perception of unity, persistence, and identity: Thoughts on infants' conceptions of objects. In J. Mehler & R. Fox (Eds.) Neonate cognition. Hillsdale, NJ: Erlbaum.

Spelke, E.S., (1985). Preferential looking methods as tools for the study of cognition in infancy. In G. Gottlieb & N. Krasnegor (Eds.) Measurement of audition and vision in the first year of postnatal life. Norwood, NJ: Ablex.

Spelke, E.S., & Hofsten, C. von. (1986). Do infants reach for objects? A reply to Stiles-Davis. Journal of Experimental Psychology: General, 115, 98-100.

Spelke, E.S., & Kestenbaum, R. (1986). Les origines du concept d'objet. Psychologie Francaise, 31, 67-72.

Spelke, E.S., Hofsten, C. von, & Kestenbaum, R. Object perception and object-directed reaching in infancy: Interacoion of spatial and kinetic information for object boundaries. Submitted for publication, 1986.

Spelke, E.S. (1987). Where perceiving ends and thinking begins: The apprehension of objects in infancy. In A. Yonas (Ed1) Perceptual development in infancy. Minnesota Symposium on Child Psychology (Vol. 20). Hillsdale, NJ : Lawrence Erlbaum, Assoc.

Termine, N., Hrynick, T., Kestenbaum, R., Gleitman, H., & Spelke, E.S. (1987). Perceptual completion of surfaces in infancy. Journal of Experimental Psychology : Human Perception and Performance, 13, 524-532.

Spelke, E.S. The origins of physical knowledge. To appear in L. Weiskrants (Ed.) Thought without language. Cambridge University Press.

3

Spelke, E.S. Origins of visual knowledge. To appear in D. Osherson et al (Eds.) An invitation to cognitive science. Cambridge, MA : MIT Press.

Streri, A., & Spelke, E.S. (in press). Haptic perception of objects in infancy. Cognitive Psychology.