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MAIN THEMES IN EUROPEAN RESEARCH ON INFANT PERCEPTION AND COGNITION

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Introduction

My aim in this paper will be to provide a general overview and background to research on infant perception and cognition in Western Europe. I will not attempt to catalogue all the research projects underway, not least because I do not know them! Instead, I will briefly list the main European centres where research is being carried out and leave it to you to follow up these sources personally for detailed information about the variety of work being carried out.

The main part of my talk will be concerned with three themes in infant development research which are exciting great interest in Europe today and which constitute 'new directions'. The three themes concern:

(1) the prenatal origins of behaviour.
(2) event perception and its implications for early experience.
(3) social cognition in infancy.

Main Western European centres for infancy research.

First I will give you some background information on traditions of infancy research and a brief acquaintance with the geographical location of the major infancy research centres in Western Europe. There has been a long and distinguished tradition of research into infant development in Europe, dating back at least as far as Charles Darwin's studies of his baby son at the beginning of the 19th century. Darwin's studies were carried out as a means of investigating the origins of emotional expression and this theme continues until today. Preyer and Bühler in the 19th and early 20th century developed methods of naturalistic observation which were also developed in 20th century ethology by Konrad Lorenz also have their place in infant developmental work. A major European pioneer of research on infant perception and cognition in the 20th century was, of course, the Swiss psychologist Jean Piaget. His brilliant observations on his own three infants carried out in the 1930's continue to inspire many studies on cognitive development, based on a critical appraisal of his sensori-motor theory. Although research on each of the themes is carried out in many centres in the world, they seem particularly European in their theoretical

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motivation and empirical foundations and have been chosen for that reason, even if some of the evidence is decidedly " Mid-Atlantic ".

The major European centres for infancy research with which I am familiar are as follow. As I mentioned earlier, the foundations of a theory of infant cognitive development were laid at Geneva, Switzerland by Jean Piaget. Today, his colleagues Andre Bullinger, Pierre Mounoud and Annie Vynter are continuing to study babies there.

One of the most exciting recent areas of research concerns the naturalstic observation of foetal movements using real time ultra-sonic scanning techniques. A major centre for this work is Heinz Prechtl's laboratories at Groningen and there are other centres, notably in Milan. This work has mainly been carried out by developmental neurologists and has major implications for psychology.

In France there is a very strong group of infancy researchers at various CNRS laboratories. The population of France is approximately 40 million and the French perceive themselves as under populated. Perhaps this explains why infancy research is flourishing and well funded. In Paris, Henriette Bloch has succeeded Eliane Vurpillot in directing research in sensori-motor development, Janine Beaudichon specialises in social development and Jacques Mehler specialises in the origins of language. In addition, Scania de Schonen in Marseilles has also contributed much information on the neuro-psychology of early infant development.

The foundations of a theory of event perception were laid as long ago as the 1930's by Michotte in Belgium. This tradition was developed by Johannson at Uppsala in Sweden and empricial work in this tradition continues in Sweden by Von Hofsten. It is also taken up at many other centres, notably by Tom Bower and colleagues in Edinburgh, and at other centres in Scotland.

Research on infant social cognition has been carried out extensively in Edinburgh by Colwyn Trevarthen and by the Papoušek's in Munich. A major contribution has also been made by Rudolf Schaffer at Strathclyde, Glasgow, and by Bruner when he was at Oxford. Research on attachment theory has also been carried out in Europe, Bowlby's seminal work has perhaps been pursued most actively in recent years by Klaus and Karin Grossmann at Regensburg. I would say that this tradition is not as strong in Europe as in the United States, however. Although I will not be discussing medical applications it is also my impression that there is less involvement by psychologists in medical aspects of infant development, such as in management of premature baby units than in the USA.

Other smaller centres are scattered throughout Europe, for example there is a strong group of researchers in Rome working on the early origins of language including Virginia Volterra and Luigia Camioni. Work on the development of tactual perception has been carried on for many years at Grenoble, France by Yvette Hatwell. It is not possible to list all the individuals involved but there is no doubt that Western Europe represents a strong interest in many aspects of infant development and in particular a strong tradition in infant perception and cognition.

The prenatal origins of behaviour

Let me turn now to my first theme. As I mentioned earlier, the ethological tradition has given rise in recent years to naturalistic observation of foetal behaviour using the new technology of real-time ultra-sonic scanning. The main centre is at Groningen where Heinz Prechtl directs research. Prechtl was a doctoral student of Konrad Lorenz and so you will understand why I have placed his work in the ethological tradition. I believe that his observations of foetal movements are among the most important recent discoveries because they lead to radically different views on the origins of development and to a quite different perspective on the status of the newborn.

Prechtl's description of foetal movement patterns

Information about the extent and importance of movement in the intrauterine environment is becoming available from real-time studies using ultra-sonic scanning. De Vries, Visser and Prechtl (1984) have evidence for 15 distinctly different movement patterns in the foetus by the 15th gestational week. Their descriptions of complex, well coordinated foetal movement patterns illustrate the point that sensori-motor activity observed at its origins, may lead to a better understanding of the nature of subsequent development.

Among the movements observed are isolated arm movements or leg movements which can be seen as early as the 9th gestational week, hand to face contact by the tenth week, head retroflexion by the tenth week and antiflexion by the twelfth week, and an integrated yawn and stretch pattern of the arms by the tenth week. The stretch pattern is described as follows:

A complex motor pattern, always at a slow speed, consists of forceful extension of the back, retroflexion of the head, external rotation and elevation of the arms.

The yawn pattern is described as follows:

Similar to yawn observed after birth; prolonged wide opening of the jaws followed by quick closure, often with retroflexion of the head and sometimes elevation of the arms. Non-repetitive.

The rotation of the foetus at ten weeks from one position to another is described as follows:

Rotation occurs around sagittal or transverse axis, complete change of position around transverse axis is achieved by complex general movement, including alternating leg movements which resemble neonatal stepping. Rotation around longitudinal axis can result from leg movemests with hip rotations, or from rotations of head followed by trunk. Total change in position can be achieved in as little as two seconds but may take longer.

Conjugate lateral eye-movements and downward eye movements are observed at around 18 weeks of age. These are a separate category from those observed in REM sleep, where the eyelids are closed.

The new technology of ultra-sonic scanning makes visible the spontaneous movements of the foetus in the natural environment for the first time. The character of these movements is surprisingly different from what we have been led to expect by the classical description of a limited number of reflexive movements elicited in the exteriorised foetus. Even the principle of cephalo-caudal development is breached by observing the foetus in the natural environment. Spontaneous activity is observed in the whole foetus with no privileged direction of development from head to tail! Futhermore, movement is differentiated from an early age into a variety of postures, movement synergies and programmed sequences which may enter into the subsequent regulation of behaviour.

One implication is that the lack of obvious skill in most newborn behaviour may actually give a misleading picture of the origins of sensori-motor competence since the neonatal period is itself a time of transition from the intra-uterine environment. The characteristically unskilled movements of the newborn may at least in part reflect the need to adapt to a new environment. The developmental transition brought about by birth creates new possibilities for action in which the extent of movement, the additional weight of one's own body and the use of vision to control activity are all factors that did not exist before. Hence it is not surprising that we may characterise the activity of the neonate as limited since behaviour is in transition to a new form of independent movement in the world.

Starting from this perspective, the first few weeks after birth may be considered a period that bridges two states of adaptation, an earlier one which encompasses behaviours most suited to the intra-uterine environment and a later one involving adaptation to the extra-uterine environment with the possibility that there exist continuities between at least some of the organised action systems (e.g. stepping) which may be observed in utero and later action systems.

Event perception

This brings me to my second theme : event perception. Many theorists agree on the indissociability of action and perception. Hence, if recent evidence on complex behavioural organisation in utero is accepted, this can be considered to pave the way for a reconsideration of the perceptual competence of the neonate. The tradition of research known as " event perception " offers a framework within which to relate perception and action and a great deal of challenging research is emerging on this theme.

Until the early 1970's much research on infant visual perception was carried out using static stimuli such as checkerboards, schematic faces, or geometric designs. A lot was learned from these studies about infants' visual acuity, preference for patterned over plain stimuli, colour vision and other psychophysical parameters. Nevertheless, these studies imposed a particular theory of perception on the baby and ignored the fact that in the real world we must obtain information about the environment from an ever changing, dynamic flux of stimulation that impinges on all the senses. There has been a strong tradition of " dynamic " perception in adult psychology, especally in psychology of Michotte in Belgium, of James J. Gibson (1979) of Cornell University in the USA and Gunnar Johannson of Uppnala in Sweden. This approach is known as " event perception " (Johansson, Von Hofsten and Jansson 1980). Information can be generated by the moving objects in the environment, by the movements of the perceiver, or by the interaction of movements of object and observer. On the dynamic theory visual perception occurs by means of information available in the flux of stimulation.

Within this flux certain transitions reliably specify events in the environment and others specify the actions of the perceiving organism. For example, one object may occlude another through its own motion as it passes across a particular point of observation but the observer's own activities need not be involved in generating this sensory transformation in the visual array. Other forms of dynamic information actively involve the observer, they are events that contain information derived from or implicated in the control of action.

The dynamic approach to infant perception has been pioneered by James Gibson's wife, Eleanor and her students at Cornell, by Claus von Hofsten in Sweden and by Tom Bower at the University of Edinburgh in Scotland. A rapidly growing number of studies has shown that even the youngest infant reveals remarkable abilities once the investigator takes a dynamic approach to perception.

When we observe one object occludes another we experience the event as a temporary disappearance of the hidden object, rather than an annihilation of it. The " permanence " of the object is one of the fundamental outcomes of event perception ; the perception of permanence ensures continuity and coherence of experience through the many vanishings and reappearances of things in the field of view.

Bower (1967) was the first to suggest that babies perceive permanence. Infants aged 7 weeks were conditioned to suck on a nipple in the presence of a large red ball. The ball was then made to disappear by slowly moving a screen in front of it. Babies continued to suck, evidence that they perceived the conditioned stimulus to be " present " but invisible.

Further evidence that infants extract information for permanence from the dynamic transitions in visual information obtained through movement has been obtained quite recently. Kellman and Spelke (1983) used the habituation method to investigate infants' perception of occlusion. Four month old babies were repeatedly shown a display that looked like a swinging pedulum with its centre covered but which actually comprised two separate elements in common motion behind a screen. The decline in their attention (habituation) over repeated trials was measured. Then the occluding screen was removed and babies were shown one of two displays, either the two separate objects in common motion or a complete pendulum. The results demonstrated that four month old babies perceived the partially hidden display as a whole object moving behind the screen. When the occluding object at the centre was removed babies showed renewed interest in the display, as if they were not expecting to see two disconnected objects. In the control condition, where a single moving pendulum was revealed behind the screen, babies showed no recovery of attention. Their low level of attention to the unoccluded display showed that they had all along perceived the rod as complete and this was simply one further instance of the same event. The fact that dynamic information was responsible for perception of completion of the rod was demonstrated when the experiment was repeated with the same stimuli presented as stationary displays. Under these static conditions the babies showed no evidence of discriminating between the complete and incomplete rod. It appears that the rigid motion of the two parts leads the infant to perceive them as a single connected rod that is partially hidden. Permanence is also perceived after other types of perceptual transition, such as loss of illumination (Bower, 1982, Hood and Willatts, 1986). These studies suggest that infant perception is much more sophisticated than Piaget had supposed.

A recent study by Granrud et al. (1984) with babies aged 5 months shows the importance of dynamic information for depth perception in the young baby. This study capitalised on the tendency of babies, when given a choice, to reach and touch the nearest of several objects or surfaces presented simultaneously. A randomly moving display of dots was generated by computer and shown on a television screen. By clever computer programming it was possible to create the appearance of depth at an edge by continuous deletion of one part of the visual texture by the remaining texture on the screen. That is, the picture on the TV screen gave the appearance of one moving surface sliding behind another and the position of the " uppermost " surface could be varied from the left to right or centre of the screen. Infants would reach to touch the part of the TV screen where the moving surface appeared nearer to them, as specified by the occlusion of one textured surface by another. A similar study was carried out by Kaufmann-Hayoz and Kaufmann in Berne, Switzerland (1984) with babies aged three months. Displays were produced in which the figure and the background had a similar texture made up of randomly placed dots. When the figure is stationary it is invisible against the background. However, movement deletes texture in the background and immediately reveals the form of the figure. Babies easily discriminated a butterfly shape from a cross when both were in motion against the textured background. Furthermore, they were able to recognise the static form if it was placed on a white background when they had previously seen it in movement, as if the information about shape had been encoded in memory. Slater, Morrison, Town and Rose (1985) have provided evidence that even newborn babies may perceive and encode shape from moving stimuli. It would appear that information derived from relative movement is fundamental in infant visual perception. These data suggest that babies use dynamic information obtained from the relative movements of objects in the perception of a world of spatially connected, separately moveable, whole, permanent objects in the first five months of life.

Biological motion

A line of research originating in Johannson's laboratory in Uppsala concerns the perception of biological motion. Biological motions are mechanically complex, animate movements such as walking or the movements involved in emotional expression. Johannson developed a method of studying the dynamic visual information implicated in biological motion perception known as " point light walkers ". Point light walkers are created by placing lights or luminous tape on the head, torso and limb joints of a person dressed in black who is then filmed in the dark while traversing a path normal to the observer's line of sight. Adults viewing the filmed dots in motion report a compelling experience of seeing a human figure walking. In fact, adults can recognize the characteristic patterns of movement of their friends, and they can often tell the gender of the walking person, just from the moving points of light, (Cutting and Proffitt, 1982). The same luminous points seen when stationary do not reveal anything to the perceiver (nor does a single frame of the film of the point light walker) which shows that the information is carried in the dynamic transitions of the moving display.

Recent evidence obtained in Europe and the USA shows that babies of 4 to 6 months are sensitive to biomechanical motions specified by point light displays (Fox and McDaniel, 1982; Bertenthal, Proffitt, Spetner and Thomas, 1985). Additional detailed studies of infants' perception of computer generated point of light displays have been carried out, (Bertenthal and Proffitt, 1984). In these studies computer generated " coherent " displays are produced in which the points of light mimick a person walking and are placed at the position of the major joints. In an " incoherent " condition the lights are positioned off the joints and move randomly. The authors demonstrated that babies of three months more rapidly encode " coherent " displays than " incoherent " displays. In another control experiment Bertenthal and Proffitt (1986) showed that infants do not discriminate an upside-down point light walker from random movement. Thus, it would appear that infants may be able to extract information about human movement from moving points of light, so long as the essential information for an upright, walking figure is retained in the computer generated display.

Bower (1982, p. 273) discusses an intriguing extension of this line of research. In a study of toddler's perception of point light walkers it was discovered that babies prefer to look at a point light walker display of a baby of their own gender than at a display of an infant of the opposite sex. The films were made in the standard way and showed a boy or girl toddler walking, bending and picking up an object. Bower suggests that gender typical differences in skeletal articulation may underlie this preference for the same sex display. There does seem to be a tendency for little boys to bend and pick up objects from the waist, while little girls bend at the knees. Perhaps this sex difference in babies' selective attention to biomechanical movement is based on gender typical movement patterns. Taking this line of research even further, Kaufmann-Hayoz and Jager (1983) present evidence that infants may obtain sufficient information from point displays to perceive faces. In this study, white dots were placed on the face of a woman wearing black make up. The adult was filmed while behaving as if interacting with a baby. The resulting film showed the dots in dynamic movement with no part of the face visible. Infants' habituation to this filmed display was compared with habituation to a film of random movements of a rubber mask that had been similarly prepared. The experimental data on habituation and emotional expressions during habituation, suggested that infants discriminated the movements of the face from the elastic movements of the mask.

Taken as a whole these results are consistent with the argument put forward by Bower (1974, 1982) and by Walker-Andrews and Gibson (1986) that what young infants first perceive are the superordinate aspects of perception. Faces, voices, emotional expression and properties of skeletal articulation are perceived in the world to arise at a unified, embodied source. People behave in a coordinated fashion, in ways that yield information that has superordinate, common properties revealed by spatio-temporal patterning. Infants appear to be able to detect these commonalities, even in minimal form (as in point light displays). Early perception captures the essential, abstract, spatio-temporal transitions that yield a unified, coherent experience of persons and matter in motion.

Intersensory events

As the previous examples show, not only do babies perceive events specified within a single modality, there is also evidence that they are sensitive to intersensory information. One of the earliest studies to show intersensory coordination was by Wertheimer (1961) who showed that an infant only 8 minutes old would turn her eyes toward a sound played softly in one ear or the other. This early demonstration of an innate link between vision and audition has since been supported by a wide variety of research (see Butterworth, 1981 for a review) and again, a striking ability to extract information from the dynamic properties of sensory stimulation is revealed.

Kuhl and Meltzoff (1982) carried out a study in which 4 month old babies were simultaneously presented with two video-recorded faces to left and right. One face was shown repeating the vowel " i " and the other repeated the vowel " a ". However, the baby heard only one sound track, to correspond with one of the visually presented vowels, in a randomly counterbalanced experiment. It was found that babies preferred to look at the face that matched the sound track, suggesting that they detect an intersensory correspondence between the auditory and visual information for the vowel sound. In a related series of studies, Meltzoff and Moore (1977), Meltzoff (1981) and Vynter (1984) have carried out extremely interesting research on imitation in newborn babies that may also be implicated in mechanisms of speech perception and production. These authors have shown that neonates will selectively imitate mouth opening, tongue protrusion and lip pursing movements. Imitation of " invisible " movements such as these may involve the same abilities as lip reading and this could be important in the acquisition of language. The dynamic approach shows that babies' speech perception may profitably be investigated as an inter-modal event.

Many further examples of infant event perception are reviewed by Gibson and Spelke (1983) which I have not had time to mention. The evidence suggests that event perception is not a modality specific process, rather it occurs by gathering of information from many sensory channels each attesting to the same external reality.

Perception and action

The dynamic approach to visual perception also enables us better to comprehend control of action. When the whole visual field is in motion movement of the observer in a stable visual space is specified. A number of studies have been carried out using the "moving room " technique, in which the whole visual environment is made to move in relation to the baby. Infants are tested inside a small room comprising three walls and a ceiling which can be moved above a rigid floor. Babies stand, sit or are seated with support in the room which is then moved relative to the infant so that the end wall comes toward or away from the baby. This movement of the room produces a flow pattern of visual information which corresponds to that which would ordinarily occur if the baby sways backwards or forwards. Several studies have demonstrated that babies maintain a stable standing or sitting posture through sensitivity to the visual flow pattern. They lose balance when standing or sitting in the moving room and their loss of balance is always appropriate to the direction of instability specified by the misleading visual flow (Lee and Aronson, 1974, Butterworth and Cicchetti, 1978). In fact, this information may even be important in gaining head control, one of the earliest postures to be mastered by the infant. Pope (1984) showed that babies gain control of their heads with respect to the stable visual surroundings at least as early as the second month of life. Thus, dynamic transitions giving rise to a total flow of the visual array serve to specify the movement of self and babies use this dynamic information to gain control of the succession of postures and the motor milestones they achieve in the first eighteen months of life.

Another example of the importance of dynamic information in the control of action comes from studies of the catching skills of very young babies. Von Hofsten (1982) reviews a series of studies in which he has shown that infants will manually intercept an object moving within reach on an elliptical trajectory. Babies will adapt the speed of their reach to the speed of the moving object. Even the nowborn baby will attempt an interception, although obviously the very young infant is not as spectacularly successful in catching the moving target as the 9 month old. This example of eye-hand coordination in the baby again shows that event perception is not modality specific. Visual information for object movement specifies the possibility of encountering the object on a conjoint kinaesthetically specified trajectory of the arm.

These examples show that visual perception is very important in the development and control of reaching and locomotion in the sighted baby. But what about the baby who cannot make use of this information through blindness? It is worth noting that theoretical advances stemming from the dynamic approach to perception offer the possibility of constructing prosthetic devices in which information that is unavailable through vision may nevertheless be substituted in another modality. Bower (1977) reported one such case in which a congenitally anopthalmic baby was equipped with a sonar device. The sonar was worn on the head and it projected a continuous stream of ultrasound onto the environment. Reflections of the sound were converted electronically to audible sounds which convey information about the properties of objects. For example, the texture of an object is reliably specified by the clarity of the echoed signal (a hard object produces a clear sound, a soft one a fuzzy sound), the amplitude of the signal specifies the size of the object (loud big, soft small), the direction of the object is given by differences in time of arrival of the stereo signal at the ears. After some practice in using this device the baby was able to reach and grasp objects, to place the arms as if to break a fall when lowered toward a surface and would even play peek a boo with his mother with great pleasure as his head movements brought her in and out of the field of the sonic guide. The dynamic approach to infant perception not only helps us to understand better the abilities of the normal infant, it also offers the possibility of developing new methods of helping those with sensory handicaps.

The study of infant perception has entered a new era. The move from static to dynamic theories of perception has revealed so much about the perceptual world of the very young baby that there is no going back to the old theory of limited perceptual abilities. Johansson (1985) said that his own studies of event perception led him to the conclusion that sensory systems are most efficient under conditions that are exceedingly complex to describe mathematically. By the same token, we may conclude that early infant perception is most efficient in the complex dynamic case.

Social cognition

In the few minutes that remain I should like briefly to describe some of my own recent research on social cognition. As I mentioned at the beginning many European researchers have been interested in the origins of social sensitivity, especially in relation to language acquisition. My own current programme of research is on joint visual attention or put very simply " How a baby knows where someone else is looking ". The aim is to establish the very early precursors of referential cognition both in the comprehension of referential activity by the infant and in the production of referential gestures for others. A major contribution to the field from R. Schaffer is summarised in his book published in 1984.

Scaife and Bruner (1974) showed that infants as young as two months would readjust their gaze contingent on a change in the focus of attention of an adult. The phenomenon of joint visual attention draws attention to a social, inter-mental dimension of early experience.

Butterworth and Cochran (1980) and Butterworth and Jarrett (1980) made an extensive series of studies in an attempt to establish the mechanisms serving joint visual attention. The studies were carried out under strictly controlled conditions in an undistracting environment, with identical targets placed at various positions relative to the mother and infant. These conditions allow relatively unambiguous conclusions to be drawn concerning how the baby is able to single out the referent of the mother's gaze since distractions and other possible artifacts are eliminated. In these experiments the mother was instructed to interact naturally with the infant and then on a signal, to turn, in silence and without pointing manually, to inspect a designated member of a set of targets placed at various positions relative to the mother and baby around the room. Babies between the ages of 6 and 18 months were studied.

We found evidence for three successive mechanisms of joint visual attention in the age range between 6 and 18 months. At six months, babies look to the correct side of the room, as if to see what the mother is looking at, but they cannot tell *on the basis of the mother's action alone* which of the two identical targets on the same side of the room the mother is attending to, even with angular separations as large as 60 degrees between the target. Although the babies are accurate in locating the referent of the mother's gaze when the correct target is first along their scan path, they are at chance level when the correct target is second along the scan path. Furthermore, infants only localise the targets within their own visual field and hardly even locate targets which the mother looks at in the region behind the baby, out of view.

If the mother looks at a target behind the baby, the infant either fixates a target in front and within the visual field or does not respond. On the other hand, so long as all the possible locations are within the infants' field of view, they are capable of correctly locating targets presented one at a time at visual angles which introduce separations between mother and the referent of her gaze of up to 135 degrees.

At 6 months, therefore, joint visual attention is restricted to targets within the infant's view (i.e. to targets that are not occluded by the baby's own body). Within the field of view, accurate localisation of the referent seems to depend not only on the adult's signal but also on the intrinsic differentiating properties of the object being attended by the mother. The addition of movement to one of the otherwise identical targets, is sufficient to lead the infant to fixate it. This earliest mechanism of joint visual attention we have called " ecological ", since we believe that it is the differentiated structure of the natural environment that completes for the infant the communicative function of the adult's signal. What initially attracts the mother's attention and leads her to turn, is also likely, in the natural environment, to capture the attention of the infant. The ecological mechanism enables a " meeting of minds " in the self same object.

By twelve months of age the infant is beginning to localise the targets correctly, whether first or second along the scan path, so long as the target is in the visual field. The only information allowing this is the angular displacement of the mother's head and eye movement. It is interesting to note that the infant fixates intently on the mother while she is turning, then when the mother is still, the infant makes a rapid eye and head movement in the direction of the target. The mean latency of response after the end of the mother's head movement is about one second (Butterworth and Cochran, 1980, p. 268). This brief interval may be sufficient for the baby to register information about the angular orientation of the mother's head. We call this new ability the " geometric " mechanism since it seems to involve extrapolation of an invisible line between the mother and the referent of her gaze, as plotted from the infants' position.

Despite this newfound geometric ability however, babies at 12 months still fail to search for targets located behind them. Again, we have carried out control studies in which the visual field is emptied completely of targets yet babies of one year do not turn behind them at the mother's signal. Instead, they turn to scan to about 40 degrees of visual angle and give up the search when they fail to encounter a target. It seems that if the geometric mechanism is available, it must still be restricted to the infant's perceived space.

By eighteen months babies are as accurate when the correct target is first along their scan path from the mother, as when it is the second target they encounter.

Furthermore, although the babies still do not search behind them when there are targets in the field of view, they will do so if the visual field is empty of targets. We found that head and eye movements to targets behind the baby would elicit turning to the correct target, so long as there was nothing in front of the 18 month infant, in the field of view.

In summary, we have evidence in the first eighteen months of life that three successive mechanisms are involved in " looking where someone elseis looking ". The earliest, " the ecological mechanism", depends on completion of joint attention by the intrinsic, attention-capturing properties of objects in the environment, as well as on the change in mother's direction of gaze. At around 12 months, we have evidence for the beginning of a new machanism, a " geometric" process, whereby the infant from her own position extrapolates the intersection of the line of the mother's gaze with its intersection with a precise location in visual space. Finally, at sometime between 12 and 18 months, there is an extension of joint reference to a " represented " space which contains the infant.

In our more recent studies we have attempted to establish how the infant's comprehension of gaze may be related to comprehensitn of manual pointing. Manual pointing, the use of an outstretched arm and index finger to denote an object in visual space, is species-specific to humans and it is thought to be intimately linked to language acquisition. It is the specialised referential function that is of interest here since it is a particularly human type of social cognition. Could the comprehension of pointing be related to comprehension of looking?

There is a fairly sparse literature on manual pointing and it has been reviewed by Schaffer (1984). It is generally agreed that comprehension of manual pointing occurs toward the end of the first year, somewhat in advance of production of the gesture.

Looking where others point is observed in most babies by about twelve months (Guillaume, 1926/1962; Leung and Rheingold, 1981, Schaffer, 1984) whereas pointing for others is observed in most babies at about 14 months (Schaffer, 1984). Piaget (1952) considered comprehension of manual pointing to arise simultaneously with comprehension of other complex signs, between 10 and 12 months (e. g. p. 249).

Our own research on mechanisms underlying the production of pointing has only just begun and there is little to say so far, except that it clearly involves coordination of viewpoints, with the index finger " holding " the position of the interesting object while the baby checks to see whether the mother has located the referent. We do have quite extensive data on the infant's comprehension of pointing however which can be readily summarised. Infants at 12 months fail to locate targets behind them, whether the mother looks or looks and points. They can correctly locate the mother's referent target within their own visual field whether the target is first or second on their scan path. The main effect of adding the manual point however is significantly to increase the probability that the infant will respond. Adding manual pointing to simple change of gaze has a compelling offect on the infants' attention. The proportion of trials to which the infant responds when looking is accompanied by pointing increased to 96% (from 59% of trials when the mother only looks at the target).

In a later study Grover (1982) examined the development of comprehension of pointing at 6 months, 9 months and 12 months. The experimental laboratory and cameras were arranged so that the direction of the infants gaze, whether toward the mother's hand or to the referent target, could be precisely measured.

The results demonstrate that infants at 6 months and 9 months do not comprehend the manual pointing gesture. They are equally likely to fixate the mother's hand as the target to which she is pointing. By 12 months, 96% of responses are to the target and hand fixations are very few indeed. The 12 month infants have little difficulty in comprehending the manual point and they swiftly and smoothly look to the target being designated. They understand that they must look on from the hand toward the location in the visual field. By contrast, 6 and 9 month old infants, if they locate the target, do so relatively slowly, in a two-step movement in which they first gaze at the mother's hand for a second or two before moving onto the target.

These experiments are important because they demonstrate that quite extensive experience in responding to mother's direction of gaze in the first 10 months of life does not help the infant with comprehension of her manual pointing. An apprenticeship in " looking where someone else is looking " does not qualify the infant to " look where someone else is pointing ". On the contrary, the evidence is much more consistent with the hypothesis that comprehension of looking changes from an " ecological " to a " geometric " mechanism and this aspect of *cognitive development* allows comprehension of manual pointing.

Taking the series of experiments as a whole, babies begin to comprehend manual pointing at about 12 months, the age at which the new " geometric " mechanism first becomes available.

This review of our research programme on comprehension of deictic gaze and manual pointing has provided a framework to examine the origins of social cognition in development. Our observations are relevant to at least four issues (i) the status of perception in early development as a means of comprehending reality (ii) the relation between precocious abilities such as comprehension of gaze and later appearing abilities such as comprehension of pointing which are thought to be related to language acquisition (iii) the inter-mental aspect (in Vygotsky's terms) of cognitive development and (iv) the origins and status of childhood egocentrism which has usually been considered a limiting factor on cognition.

Our results make it clear that even the very young infant may enter into a communicative network with others through comprehension of an adult's direction of gaze; communication is not solely dependent on the greater cognitive sophistication of the adult. At 6 months, the signal value of the mother's head movement will indicate the general direction (left or right) in which to look. Communication occurs because the easily distractible baby will attend to the same attention compelling features of the objects in the environment as the mother. When seen in social context, the earliest " ecological " mechanism of joint attention allows communication in relation to publically shared objects through their common offects on intrinsic attention mechanisms of mother and baby.

A more general theoretical implication concerns the infant's comprehension of object permanence. The infant clearly takes the mother's action to signal the existence of a potentially interesting object somewhere in its own visual field. That is, although the infant will not search for hidden objects before 8 or 9 months, the mother's behaviour nevertheless signals the " permanent possibility of an object " potentially *within the field of view.*

During the first year joint visual attention remains limited to locations within the infant's own visual space. The baby behaves as if its own field of vision in shared with the adult and this gives us an insight into infantile egocentrism. On the one hand, the fact that the infant responds at all might suggest that babies are not egocentric, since a change in the other person's point of view has led them to respond. On the other hand, since under circumstances when the mother looks behind the baby, the infant assimilates her line of gaze into his or her own visual field, this might be taken as evidence for egocentrism. To resolve this paradox we need to move away form a solipistic theory of infant perception and toward a realist account. A theory of direct perception, such as that of J. J. Gibson (1979) enables us to understand that perception must originate at a particular viewpoint. This need not mean that the infant cannot perceive that others also have a perspective on a space that is common to several points of view. The phenomenon of joint visual attention is ultimately possible because perception, even in the infant, presupposes a world of objects that exist in a space that is held in common with others.

Superimposed on this basic mechanism, with cognitive development, comes precise " geometric " localisation of the referent of the mother's gaze, a development that simultaneously allows comprehension of manual pointing. The geometric mechanism lessens the ambiguity of reference, since even targets that are identical in all respects except position can now be singled out by the infant. Once the geometric mechanism is avilable communication does not require differential intrinsic properties of the objects being singled out, the infant will choose the correct object in relation to the angular displacement of the mother's head and arm. In seems likely that this ability arises from a cognitive developmental process of the Piagetian type, which allows invisible displacements to be monitored. Furthermore, this change also enables the comprehension of manual pointing, itself an important social means for re-directing attention.

Conclusion

In conclusion, our three themes from recent European research emphasise the degree of pre-adaptation of motor and perceptual systems. The unexpectedly complex activities of the foetus raise severe doubts about reflex models of early infant behaviour. Evidence from event perception in infancy suggests action and perception are intimately linked and that the infant may be pre-attuned to the dynamic proprties of sensory perception. Research on joint visual attention again suggests that the perceptual sophistication of the young infant enables proto-communicative interaction. Cognitive development in Piaget's sense is also implicated in the acquisition of geometric mechanisms that enable comprehension of pointing. The overall conclusion of the last twenty years must be that we are only now coming to realise the full extent of infant perceptual, motor and social competence and the ways in which these competencies enter into the process of cognitive growth.

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