Intellectica, 2002/1, 34, pp. 57-76

Visual perception in the newborn infant: issues and debates

Alan Slater*

The newborn infant enters the world visually naïve but possessed of a number of means with which to make sense of the world. This article focuses on two currently topical and debated interrelated issues: early face perception and the extent to which newborn vision is subcortically mediated. With respect to face perception it is suggested that the newborn infant enters the world with a representation of the human face that is considerably more detailed than simply three dots in the locations of eyes and mouth. This view is supported by findings that newborn infants will track face-like patterns soon after birth, they will prefer to look at attractive faces, they have been found to imitate facial gestures such as mouth opening and tongue protrusion, and they learn to recognise individual faces within hours from birth. It is argued that the newborn infant's representation of the human face is provided by evolution and perhaps also by prenatal learning, and constitutes some sort of prototype from which future learning will develop.

For many years there have been claims that visual perception at birth is primarily subcortically mediated. However, it is now clear that "At birth visual processing begins with a vengeance" (Karmiloff-Smith, 1996, p. 3). The newborn infant learns rapidly about visually experienced stimuli and events, and this learning is both flexible and influenced by inherent (unlearned) constraints and biases. These findings are a clear demonstration that the visual cortex is actively involved in the processing of visual information.

Keywords : Newborn; Face perception; Early learning; Visual Cortex

La perception visuelle chez le nouveau-né : enjeux et débats. Le nouveau-né arrive au monde visuellement naïf, mais possède un certain nombre de moyens lui permettant de donner sens au monde. Cet article est centré sur deux thématiques reliées, et actuellement objet de débat : la perception précoce des visages et la mesure dans laquelle la vision du nouveau-né est sous-corticale. Concernant la perception des visages, l'article suggère que le nouveau-né arrive au monde avec une

---

* **Acknowledgements** : The author's research described here was supported by research grants R000235288 and R000237709 from the Economic and Social Research Council, UK.
Address for correspondence: Alan Slater, School of Psychology, Washington Singer Laboratories, University of Exeter, Exeter, EX4 4QG, U.K. email: a.m.slater@exeter.ac.uk

représentation des visages humains qui est bien plus détaillée que simplement trois points à l'emplacement des yeux et de la bouche. Ce point de vue est étayé par des données montrant que les nouveau-nés poursuivent visuellement des patterns ressemblant à des visages peu après la naissance, qu'ils préfèrent des visages attractifs, qu'ils imitent des gestes faciaux comme l'ouverture de la bouche et la protrusion de la langue, et ils apprennent à reconnaître des visages particuliers dans les heures qui suivent la naissance. L'article défend l'idée qu'une représentation des visages humains est fournie par l 'évolution et peut-être aussi par des apprentissages prénataux et constitue une sorte de prototype à partir duquel les apprentissages futurs vont s'effectuer.

Pendant très longtemps, on a affirmé que la perception visuelle était sous-corticale à la naissance. Cependant il est maintenant clair que « à la naissance le traitement visuel commence par une revanche » (Karmiloff-Smith, 1996 p. 3). Le nouveau-né apprend rapidement à propos des stimuli et des événements visuels et cet apprentissage est à la fois flexible et influencé par des contraintes inhérentes au système (et non acquises). Ces résultats constituent une démonstration claire du fait que l'activité du cortex visuel est impliquée dans le traitement de l'information visuelle.

Mots-clés : nouveau-né, perception des visages, apprentissages précoces, cortex visuel.

The major characteristic of perception, which applies to all the sensory modalities, is that it is organised. With respect to visual perception, the world that we experience is immensely complex, consisting of many entities whose surfaces are a potentially bewildering array of overlapping textures, colours, contrasts and contours, undergoing constant change as their position relative to the observer changes. Given the complexity of visual perception it is not surprising to find that many researchers and theoreticians have emphasised the visual limitations of the young infant.

Here are just two observers and theoreticians commenting on the limited visual capabilities of the young infant: "With respect to vision, – his eyes were fixed on a candle as early as the 9th day, and up to the 45th day nothing else seemed thus to fix them …" (Darwin, 1877, in Slater & Muir, 1999, p 19); "Perception of light exists from birth (but) All the rest (perception of forms, sizes, positions, distances, prominence, etc.) is acquired through the combination of reflex activity with higher activities" (Piaget, 1953, p. 62). From these accounts (and others not given here) one might expect to find that vision is exceptionally impoverished at birth and that a lengthy period of development through infancy and childhood is necessary before anything approaching mature functioning is reached.

Darwin and Piaget were presenting their views when there was little experimentation into perceptual development in infancy, and as Zuckerman and Rock (1957) pointed out, "One can hardly take a dogmatic position in an area where, as yet, there exists so little decisive experimentation" (p. 293). As soon as sensitive methods to test infants' visual abilities were developed, in the 1960s and beyond, research into infant perceptual abilities began in earnest and it soon became apparent that extreme empiricist views were untenable. As early as 1966 Bower concluded that "infants can in fact register most of the information an adult can register but can handle less of (it)" (p. 92). Research over the last 40 years has given rise to conceptions of the 'competent infant', who enters the world with an intrinsically organised visual world that is adapted to the need to impose structure and meaning on the people, objects and events that are encountered.

The purpose of this paper is to describe some of this research, with an emphasis on the visual and learning abilities of the newborn infant (0-7 days from birth). Following a brief review of *Basic Visual Functions* and *Visual Organisation at and Near Birth* the paper will focus on two interrelated topics that are currently controversial, which are whether vision at birth is subcortically or cortically mediated (or both), and whether the infant enters the world with a representation of the human face. These themes are discussed under the headings of *Subcortical or Cortical: The Origins of a Controversy, Face Perception at Birth*, and *Visual Learning at Birth.*

BASIC VISUAL FUNCTIONS

Figure 1 shows schematic horizontal sections through the (left) eyes of the adult and newborn to illustrate differences in overall size, in the shape of the lens, and in the depth of the anterior chamber. The eye at birth, like the brain, is relatively large: both increase in volume about 3 or 4 times compared with the rest of the body which increases in volume about 21 times to reach adult size. At the time of normal birth the peripheral retina of the eye is relatively well developed, but the central retina (the macular region and the fovea) which allows for the detection of fine detail is poorly developed. The fovea is quite well developed by 6 months from birth, by which time visual acuity (see below) has developed to near-adult levels.

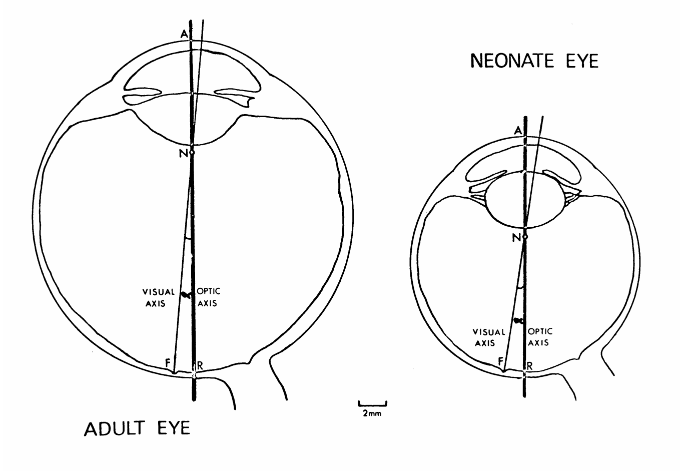

Figure 1. Schematic horizontal sections through the (left) eyes of the adult and neonate (to scale), to illustrate differences in gross size, in the shape of the lens, and in the depth of the anterior chamber. F = fovea; R = retina.

It is not surprising to find that the visual information detected by the newborn is very impoverished compared with that detected by the adult. Visual acuity, the ability to detect fine detail, is measured by showing to infants pairs of stimuli, each one being a black and white stripes pattern paired side-by-side with a grey patch. This is known as the 'visual preference method' or 'preferential looking' (PL), and the rationale underlying its use in measuring acuity is that if the infant can discriminate, or resolve the stripes (i.e., detect them) it will spend more time looking at them in preference to the grey patch. The stripe width is systematically varied and the smallest stripe width that is reliably looked at in preference to the grey gives an estimate of acuity.

An alternative way of measuring acuity is to record electrical activity from the visual areas of the brain while the infant is shown stripes and grey stimuli – the measure of acuity is then the smallest stripe width that gives a visual evoked potential (VEP) that is different from that to the grey. These two methods (for reasons that are not fully understood) give different estimates of acuity, with the VEP measures suggesting the better acuity. Combining these two measures gives an estimate of acuity in the newborn that is between 10-30 times poorer than that in the adult. Figure 2 shows how a face might look to the newborn infant, and to us: while vision might be poor at birth it is far from being non-existent! The newborn's level of acuity, curiously, is about the same as that of the adult domestic cat, whose acuity is some ten times poorer than the average human adult's.

Figure 2. A face as it might appear to a newborn (left) and to us.

As we have seen, the visual information detected by newborn infants is poor compared with that of the adult and many important visual functions, including scanning abilities, contrast sensitivity, depth perception and stereopsis, and colour discrimination, are limited at birth. However, visual development is rapid, and many visual functions approach adult standards 3 or 4 months from birth. Even the poor vision of very young infants does not hamper their development: there is "little indication that young infants are handicapped by their purported primitive visual abilities" (Hainline, 1998, p. 5). Young infants do not need to scrutinise the fine print in a contract, or to see things clearly at a distance. The most important visual stimuli are to be found in close proximity and better acuity, which would allow infants to focus on distant objects that are of no relevance to their development, might well hinder, rather than promote, their development. Hainline (1998, p. 9) summarises it rather nicely: "visually normal infants have the level of visual functioning that is required for the things that infants need to do".

It is clear that the visual system is functioning at birth, and that even newborn infants see well enough to begin making sense of their visually perceived world. The next section considers several types of visual organization that are found in early infancy.

VISUAL ORGANISATION AT AND NEAR BIRTH

There are many types of visual organisation that develop throughout infancy, for example an understanding of the physical properties of objects, of causality, and of pictures. However, thirty years of research has demonstrated that the visual world of the newborn infant is highly organised, in the sense of allowing perception of coherent objects and shapes rather than a jumbled mass of stimulation. A few of these experimental findings will be presented here, under the subheadings of *size and shape constancy*, and *Gestalt organisational principles.*

Size and shape constancy

As objects move they change in orientation, or slant, and perhaps also their distance, relative to an observer, causing constant changes to the image of the objects on the retina. However, we do not experience a world of fleeting unconnected retinal images, but a world of objects that move and change in a coherent manner. Such stability, across the constant retinal changes, is called perceptual constancy. Perception of an object's real shape regardless of changes to its orientation is called shape constancy, and size constancy refers to the fact that we see an object as the same size regardless of its distance from us. If these constancies were not present in infant perception the visual world would be extremely confusing, and they are a necessary prerequisite for many other types of perceptual organisation.

Over 30 years ago E.J. Gibson (1969) suggested that shape and size constancy are present early in life:

> *I think, as is the case with perceived shape, that an object tends to be perceived in its true size very early in development, not because the organism has learned to correct for distance, but because he sees the object as such, not its projected size or its distance abstracted from it. (p. 366).*

Recent experiments have given clear evidence that Gibson was correct. Slater and Morison (1985), and Slater, Mattock and Brown (1990) gave clear evidence that these constancies are present at birth. In their size constancy experiment Slater et al. (1990) familiarised newborn infants to a single object (either a large or a small cube) which, over trials, was presented at different distances from the eyes. On subsequent test trials the infants looked more (i.e., gave a novelty preference) at a *different-sized* cube than to the same-sized one, despite the fact that the paired stimuli were at different distances in order to make their retinal size the same. An infant being tested is shown in Figure 3, and the sizes of the two cubes from the infant's viewing point is shown in Figure 4.

Slater and Morison (1985) report similar findings on shape constancy at birth, and it is clear that newborns can base their responding on objects' real shapes and sizes, even when their viewing distance and orientation varies, and that shape and size constancy are organising features of perception that are present at birth.

Figure 3. A newborn infant being tested in a size constancy experiment.

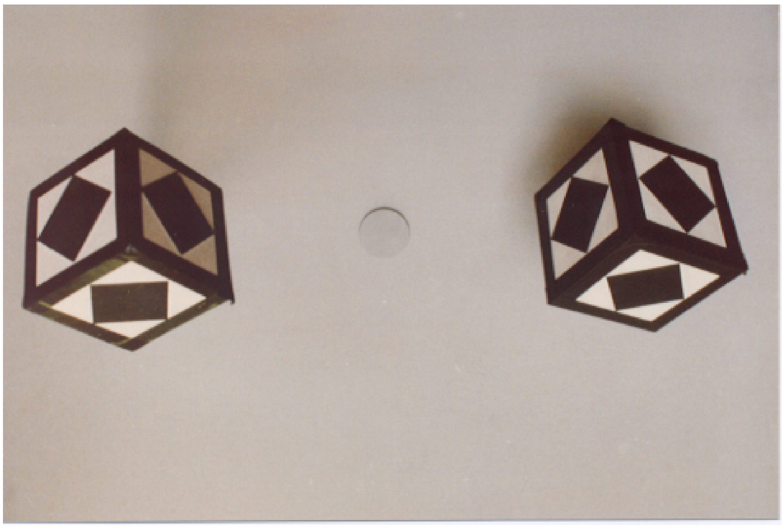

Figure 4. The stimuli shown to the infants on the post-familiarisation test trials. This photograph, taken from the babies' viewing position, shows the small cube on the left at a distance of 30.5 cm, and the large cube on the right at a distance of 61 cm.

Gestalt organisational principles

Many organisational principles contribute to the perceived coherence and stability of the visual world. In addition to size and shape constancy several other types of visual organisation have been found in young infants, and by way of illustration one of these is discussed here, Gestalt organisational principles. One of the main contributions of the Gestalt psychologists, who were active in the early part of the last century, was to list rules of perceptual organisation that describe how groups of stimuli spontaneously organise themselves into meaningful patterns. They argued that visual organisation is a natural characteristic of the human species that is innately provided.

Quinn, Burke and Rush (1993) report evidence that 3-month-old infants group patterns according to the principle of lightness similarity. Two of the stimuli they used are shown in Figure 5. Adults reliably group the elements of such stimuli on the basis of lightness similarity and represent the figure on the left as a set of rows, and the other as a set of columns. Three-month-olds do the same, in that those habituated to the columns pattern generalise to vertical lines and prefer (perceive as novel) horizontal lines, while those habituated to the rows prefer novel vertical lines. In recent experiments, using similar stimuli, Farroni, Valenza, Simion and Umilta (2000) found that newborn infants also group by similarity. More recently, Quinn, Bhatt, Brush, Grimes and Sharpnack (2002) have found that 3-4-month-old infants have difficulty in grouping stimuli into rows and columns when the stimuli differ only in shape (i.e., form similarity), and not in lightness. In their experiments 6-7-month-olds were able to do this grouping by form similarity and they suggest that different Gestalt principles may become functional over different time courses of development.

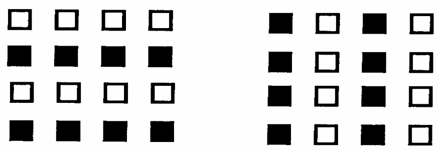

Figure 5. Stimuli used by Quinn et al. (1993) with 3-month-olds and by Farroni et al. (2000) with newborns. Infants, like adults, group by similarity and perceive the pattern on the left as rows, and that on the right as columns.

Quinn, Brown and Streppa (1997) describe experiments using an habituation-novelty testing procedure, to determine if 3- and 4-month-old infants can organise visual patterns according to the Gestalt principles of good continuation and closure. The stimuli they used are shown in Figure 6. Following familiarisation to pattern (a) in Figure 6, tests revealed that the infants parsed the pattern into a square and circle (b) rather than into the 'less-good' patterns shown in (c): that is, they had parsed the familiarised figure into the two separate shapes of a square and a circle in the same way that adults do.

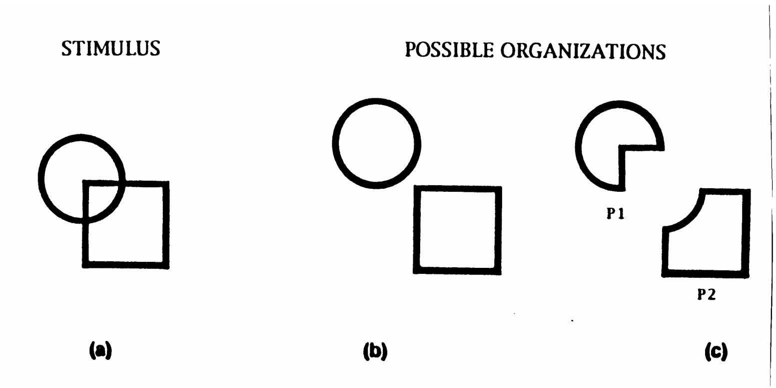

Figure 6. Patterns used by Quinn, Brown and Streppa (1997).

Overview

The above is just a sample of the many studies which demonstrate that young infants organise the visually perceived world in a similar manner to that of adult perceivers. These examples have been chosen to make the point that at least some organisational features of visual perception are present at birth and seem to remain largely unchanged from birth to maturity. However, this apparent perceptual maturity goes hand in hand with claims of considerable perceptual *immaturity*, and the purpose of the remaining sections of this paper is to describe these claims and to point to issues that are the subject of current debate and controversy.

SUBCORTICAL OR CORTICAL? THE ORIGINS OF A CONTROVERSY

Nearly 30 years ago an influential article by Gordon Bronson was published (1974) in which he argued that the visual perceptual abilities that are available to the newborn infant are controlled totally by subcortical brain structures, such as the superior colliculus and the lateral geniculate nucleus, and that cortical parts of the brain become active from about 6 weeks from birth, from which point vision becomes controlled or mediated by both subcortical and cortical networks. A detailed account and model of the developing visual brain is given by Atkinson (2000). At the simplest level the subcortical visual system is responsible for reflex-like shifts of visual attention, via the initiation of eye movements, in order to orient the eyes (and visual attention) to new areas of interest within the visual field. The cortical system allows detailed scanning of a visual stimulus and also the formation of visual memories – i.e., the ability to remember what is seen.

With respect to the formation of visual memories there were several reports in the early 1970s by Friedman and his colleagues (e.g., Friedman, 1972) which appeared to demonstrate habituation of visual attention to one stimulus and subsequent recovery of attention to a novel stimulus. Habituation is one of the simplest forms of learning and is a decline of attention to a repeatedly presented (visual) stimulus, and it is dependent on the infant being able to remember what they see. Thus, Friedman's findings seemed to contradict any claim that the visual cortex is not functional at birth.

Bronson considered these findings and suggested that the apparently successful reports of habituation and dishabituation (novelty preferences) might be attributable to retinal adaptation rather than the formation of visual memories. This interpretation suggests that when the newborn looks at a visual stimulus its fixations are 'locked on' to a salient portion of the picture, and the population of retinal cells that detect the stimulus undergoes adaptation during the course of the 'familiarisation' or habituation trials. The recovery of visual attention that follows when a new stimulus is shown results from the activation of a new population of retinal cells, which makes the new stimulus more detectable.

Many effects are caused by retinal adaptation. For example, if an observer stares at a green circle and then looks at a gray surface a negative afterimage of the complementary colour red is seen. The two eyes work independently, so that if one eye is adapted, the other does not see the afterimage. This independence means that the experiment to test Bronson's model was quite simple: Newborns were habituated with one eye as the 'seeing eye', and the other eye was covered by a gauze patch. When visual attention had declined the viewing eye was changed by reversing the patching. Under these experimental conditions the newborns gave clear novelty preferences, thereby demonstrating that a retinal adaptation model can be ruled out (Slater, Morison & Rose, 1983.

An additional test of cortical functioning is discrimination of orientation: Orientation-selective neurons are found in cells of the visual cortex but not in subcortical parts of the visual system, and orientation selectivity is therefore an indicator of cortical functioning. Two studies were reported in 1988 (Atkinson, Hood, Wattam-Bell, Anker & Tricklebank; Slater, Morison & Somers) which demonstrated orientation discrimination in newborn infants. In both studies newborns were habituated to a diagonal grating (tilted either clockwise or anticlockwise from the vertical), and subsequently gave novelty preferences when presented with a mirror-image grating.

From these studies it is clear that the visual cortex is functioning at birth, and it is therefore reasonable to suppose that the visual cortex is implicated in visual processing from birth. Nevertheless, the demonstration that some degree of cortical functioning is available to the newborn infant is not a demonstration that the visual cortex is *fully* functioning, and there remain theoreticians who claim that visual perception during the first few weeks from birth is primarily under the control of subcortical structures. This claim formed the basis of the Conspec/Conlern model of face perception in early infancy, and this is discussed in the next section.

FACE PERCEPTION AT BIRTH

The human face is one of the most complex stimuli encountered by the human infant, and faces possess several stimulus characteristics, such as movement, contrast, three-dimensionality (and they talk!), which ensure that they will be attention-getting and attention-holding for the infant. Despite this complexity, as adults we are able to recognise thousands of faces and it has been argued that "our ability to process information about faces is greater than that for any other class of visual stimuli" (Johnson & Morton, 1991, p. 23).

How does this ability develop? One view is that it is a product of learning and that face perception only becomes special after several postnatal months of viewing faces (e.g., Nelson, 2001). An alternative view is that faces are special even at birth, and that evolution has provided newborn infants with a 'headstart' in their recognition and learning about faces (e.g., Farah, Rabinowitz, Quinn & Liu, 2000; Slater & Quinn, 2001). Evidence will be presented from three sets of studies which support the latter interpretation, in each of which newborn infants have been the subjects: (1) tracking of face-like patterns soon after birth; (2) preferences for attractive faces; (3) imitation of facial gestures.

Tracking of face-like patterns soon after birth

In an early study Goren, Sarty and Wu (1975) presented laterally moving stimuli to newborn infants similar to those shown in Figure 7. They reported that their infants, who averaged only 9 *minutes* from birth at the time of testing, turned their heads and eyes significantly more to follow (i.e., track) the two-dimensional schematic face-like stimulus than the scrambled face, which in turn was tracked more than the blank pattern. Johnson, Dziurawiec, Ellis and Morton (1991) replicated this finding, and Johnson and Morton (1991) used this and other findings to offer an influential theory of early face perception based on hypothetical mechanisms called

Conspec (short for conspecifics) and Conlern (learning about conspecifics).

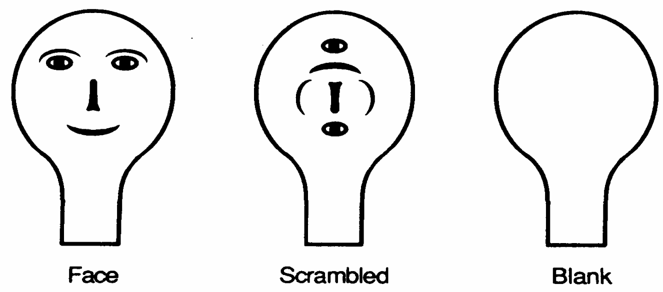

Figure 7. Schematic face-like, scrambled, and blank stimuli used in studies of newborn visual tracking.

In their model Conspec is available at birth. It is a subcortical mechanism which responds to three dots in the positions of eyes and mouth, and its sole purpose is to orient the newborn infant to faces. The other mechanism, Conlern, detects both similarities and differences between faces. It is cortically driven, and is not supposed to make its appearance until the baby is about 2 months old. The Conspec/Conlern model continues to inspire research (e.g., Simion, Cassia, Turati & Valenza, 2001), and it has recently been updated (Johnson & de Haan, 2001), but there appear to be several problems with it which are discussed next.

In the studies by Goren et al. (1975) and Johnson et al. (1991) the stimuli used were highly schematic stimuli, and we have no idea whether infants perceive them as bearing any resemblance to real faces. An additional problem with the hypothesized Conspec is that the finding that newborn infants will track (with eye and head movements) face-like patterns in preference to non-face-like patterns has proven difficult to replicate (e.g., Easterbrook, Kisilevsky, Hains & Muir, 1999). However, there are many studies with newborns that have used more realistic stimuli: from these studies a rather different picture emerges.

Preferences for attractive faces

Several experimenters have found that infants prefer to look at attractive faces when these are shown paired with faces judged to be less attractive (for example, Langlois, Ritter, Roggman & Vaughn, 1991, Samuels Butterworth, Roberts & Graupner, 1994). The usual interpretation of the attractiveness effect is in terms of prototype formation and a cognitive averaging process (e.g., Langlois & Roggman, 1990; Langlois, Roggman, Casey, Ritter, Rieser-Danner & Jenkins, 1987). According to this interpretation attractive faces are seen as more 'face-like' because they match more closely the facial representation or prototype that infants either form from their experience of seeing faces, or with which they enter the world. An alternative to the prototype view is offered by de Haan, Johnson, Maurer and Perrett (2001), who were unable to find evidence of prototype formation in 1-month-old infants. They suggest that "something in addition to averageness may draw infants to look at attractive faces" (p. 675).

Recently, the attractiveness effect has been found in three sets of studies with newborn infants who averaged less than 3 days from birth at the time of testing (Slater, von der Schulenburg, Brown, Badenoch, Butterworth, Parsons & Samuels, 1998; Slater, Bremner, Johnson, Sherwood, Hayes & Brown, 2000; Slater, Quinn, Hayes & Brown, 2000). In these studies newborns were found to use information about internal facial features in making preferences based on attractiveness, and the attractiveness effect is orientation-specific: when the pairs of attractive-unattractive faces were inverted the attractiveness preference disappeared. These findings suggest that the newborn infant has a facial representation that is quite detailed, and that months of experience viewing faces are not necessary for its emergence.

Imitation of facial gestures

One of the first published reports of imitation by newborn and older infants was by Meltzoff and Moore (1977), and there are now many such reports of young infants imitating a variety of facial gestures they see an adult modeling. Despite the large number of reports of imitation in young infants, however, there are still researchers who would question the replicability and generality of the effect (e.g., Anisfeld, Turkewitz, Rose, Rosenberg, Sheiber, Couturier-Fagan, Ger & Sommer, 2001; Heimann, 2002). Among the various successful reports of newborn imitation is a demonstration of infants imitating mouth opening and tongue protrusion produced by the first face they have ever seen (Reissland, 1988). Infants can see the adult's face, but of course they cannot see their own. This means that in some way they have to match their own, unseen but felt, facial movements with the seen, but unfelt, facial movements of the adult. Meltzoff and Moore (e.g., 2000) propose that they do this by a process of "active intermodal matching".

Overview: early facial representation

The evidence presented here suggests that the infant enters the world with some sort of representation of the human face, and this seems to be more detailed than the minimal response to three blobs in the location of eyes and mouth (i.e., Conspec). This representation appears to be sensitive to facial orientation and enables the infant to imitate facial gestures. The data support Meltzoff's (1995) claim that "newborns begin life with some grasp of people" (p. 43) and that they have "some representation of their own bodies" (p. 53). It is possible that this early representation is innately provided by evolutionary pressures, and it is also possible that experiences *in utero* (for example, proprioceptive feedback from facial movements) contribute to the newborn's representation of faces.

In the next section we will comment on the extent to which cortical functioning might assist newborn infants in experiencing their newly perceived visual world.

VISUAL CORTICAL FUNCTIONING AT BIRTH? LEARNING AND MEMORY

Several lines of evidence converge to support the claim that the visual cortex is functional at birth, in addition to the demonstrations of post-retinal processing of visual information and orientation-selectivity mentioned earlier. This section of the paper will be organized under the following headings: Visual memory at birth; Early learning about faces; Flexibility of newborn visual learning.

Visual memory at birth

As was mentioned earlier, until some 20 years ago there was general acceptance of the view that newborn infants could not remember what they saw: "No relatively more complex processes – such as … a dependence on memory – are posited for the newborn infant" (Bronson, 1982, p. 60); "For the newborn with little memory, the physical characteristics of the external stimulus pretty much account for the direction of looking" (Salapatek, 1982, p. X1). This claim had previously been called into question by the work of Friedman, mentioned earlier, and has been shown to be incorrect on innumerable occasions subsequently. The most consistently reported demonstration of visual memory at birth is from the many studies that have successfully reported habituation and dishabituation (novelty preferences) with newborns: a review of many of these studies is given in Slater (1995).

Habituation procedures are critically dependent upon the infant remembering what is seen. However, for each infant a typical habituation-dishabituation experiment lasts only for a few minutes: the infant sees the to-be-familiarised stimulus for perhaps two minutes until it reaches a criterion of habituation, and then the critical test trials follow immediately and typically last for less than one minute. If the visual learning that takes place were to fade and disappear within another minute or so then we would have evidence only for a very brief activation of the visual cortex. That the memories formed from repeated encounters with a visual stimulus can be relatively enduring was recently demonstrated by Ian Bushnell (2001), who reported that newborn infants, with a mean age of 2 days 16 hours, remembered their mother's face after a delay of 15 minutes. He argues that "memory for the mother's face is very stable and established in a long-term store within a few days of birth".

Early learning about faces

It is clear that learning about faces can be very rapid, even in the newborn period. Several experimenters have reported that newborn infants, just a few hours from birth, are able to discriminate between individual faces and will show a preference for the mother's face when this is shown paired with a female stranger's face. There are now at least six reports of this 'mother preference', using both real faces (e.g., Bushnell, 2001; Bushnell, Sai & Mullin, 1989; Pascalis de Schonen, Morton, Deruelle & Fabre-Grenet, 1995) and video presentations of the faces (Walton, Bower & Bower, 1992). These findings are clear evidence of face recognition and learning in the newborn period. Such remarkable early learning might result from a face-specific learning mechanism, or it might be a product of a more general pattern processing system. These possibilities are discussed after the next section.

Flexibility of newborn visual learning

In addition to being able to learn about their visual world, findings that are also emerging are that such learning is flexible in that it is not rigidly linked to external visual input, it can occur very rapidly, and it is guided by certain constraints. These themes are illustrated here with reference to face perception and intermodal learning.

The flexibility of visual learning has been illustrated by Meltzoff and Moore (1994, 1997) in an experiment on imitation. In this experiment (with 6-week-olds) the infants saw an adult modeling tongue protrusion, and the adult's tongue finished at the side of the mouth. The infants' initial attempts to imitate the 'tongue-to-the-side' gesture produced a small tongue movement but with no lateral component. However, over time the imitative response became a closer and closer match to the adult gesture and there were several ordered steps in achieving the matching: "The (learning) process is not trial and error or even a simple progression from small to large, but rather an ordered constructive process … (and it) results in a novel behaviour that was not initially present" (1997, pp. 186-187).

The evidence from habituation studies and from learning about the mother's face are a clear indication that newborn humans are capable of very rapid learning, and it was recently claimed that newborns can learn to identify a face after seeing it for as little as eight-tenths of a second (Walton, Armstrong & Bower, 1998). It is also apparent that newborn infants don't learn about every visual (or other) event that they see or experience, and that learning is intrinsically guided by certain constraints, which makes for very efficient learning. This specificity of learning is illustrated by research on newborn learning of arbitrary auditory-visual associations.

Most objects and events provide information to more than one sensory modality and many of the intermodal relationships that we perceive appear to be quite arbitrary, and vary across different objects and across contexts. For example, the relation between the colour of an object and its shape or smell, or a person's face and the sound of his/her voice are arbitrary (in the sense of not being predictable in advance) and must be learned through experience. Recent experimental findings have shown that newborn infants are able to learn arbitrary intermodal associations, but only when there is information specifying that the stimuli belong together.

Morrongiello, Fenwick & Chance (1998) found that newborn infants learned toy-sound pairs when the paired stimuli were spatially co-located, but not when the sound and the toy were presented in different locations. Slater, Quinn, Brown & Hayes (1999) tested newborn infants in two conditions. In their *auditory-contingent* condition 2-day-old infants were familiarized to two alternating visual stimuli (differing in colour and orientation), each accompanied by its 'own' sound. The spatially co-located sound was presented only when the infant looked at the visual stimulus – when the infant looked away the sound stopped. Thus, presentation of the sound was contingent upon the infant looking. In their *auditory-noncontingent* condition the sound was continuously presented when its associated visual stimulus was available, independently of whether the infant looked at the visual stimulus. They found that their newborn infants learned the arbitrary auditory-visual associations when the *contingent* information was present, but not when it was absent.

These findings are a clear demonstration that newborn infants can detect arbitrary auditory-visual relations in the presence of information that indicates that the auditory and visual events come from the same source (for Morrongiello *et al*. this was spatial co-location, and for Slater *et al*. it was synchronised onset and offset of sound). The absence of learning when this information is not present prevents the infant from associating other co-occurring events that do not belong together.

OVERVIEW AND CONCLUSIONS

The newborn infant enters the world visually naïve but possessed of a number of means with which to make sense of the world. Many basic visual functions, such as visual acuity, are poor at birth but are nevertheless adequate for allowing infants to perceive those objects that are of most relevance to them, i.e., objects that are close to the infant and which interact with him/her. Size and shape constancy are present at birth, as are other innately provided organizational principles. From these findings it is reasonable to conclude that the newborn infant does not have to learn to see, but of course the newborn does have to learn to make sense of what is seen.

In this article we have focused on two currently topical and debated interrelated issues – early face perception and the extent to which newborn vision is subcortically mediated. With respect to face perception we suggest that the newborn infant enters the world with a representation of the human face that is considerably more detailed than simply three dots in the locations of eyes and mouth. This representation of the human face is provided by evolution and perhaps also by prenatal learning, and constitutes some sort of prototype from which future learning will develop.

There is an emerging consensus that face recognition is 'special', and it is subserved by discrete neural systems. There is, however, no consensus on when these neural systems develop: for example, Nelson (2001) rejects the view that "face recognition represents an innate ability (or at least an experience-independent ability)" and concludes that "Overall, the bulk of the evidence suggests that the ability to recognize faces is one that is learned". The alternative view is offered by Farah and her colleagues. They argue that "the distinction between faces and other objects, and the localization of faces relative to other objects, is fully determined prior to any postnatal experience" (2000, p. 117). Given the evidence described above, of a detailed facial representation at birth, imitation of facial gestures, and early learning about faces, the mounting evidence would support the view put forward by Farah and her colleagues.

For many years there have been claims that visual perception at birth is primarily subcortically mediated. However, it is now clear that "At birth visual processing begins with a vengeance" (Karmiloff-Smith, 1996, p. 3). The newborn infant learns rapidly about visually experienced stimuli and events, and this learning is both flexible and influenced by inherent (unlearned) constraints and biases. These findings are a clear demonstration that the visual cortex is actively involved in the processing of visual information.

References

Anisfeld, M., Turkewitz, G., Rose, S.A., Rosenberg, F.R., Sheiber, F.J., Couturier-Fagan, D.A., Ger, J.S. & Sommer, I. (2001). No compelling evidence that newborns imitate oral gestures. *Infancy, 2*(1), 111-122.

Atkinson, J. (2000). *The developing visual brain.* Oxford University Press: Oxford, UK and New York.

Atkinson, J., Hood, B., Wattam-Bell, J., Anker, S. & Tricklebank, J. (1988). Development of orientation discrimination in infancy. *Perception*, 17, 587-595.

Bower, T. G. R. (1966). The visual world of infants. *Scientific American,* 215(6), 80-92.

Bronson, G. (1974). The postnatal growth of visual capacity. *Child Development*, 45, 873-890.

Bronson, G. (1982). *The scanning patterns of human infants: Implications for visual learning*. Norwood, NJ: Ablex.

Bushnell, I. W. R. (2001). Mother's face recognition in newborn infants: learning and memory. *Infant and Child Development*, 10, 67-74.

Bushnell, I. W. R. Sai, F., & Mullin, J. T. (1989). Neonatal recognition of the mother's face. *British Journal of Developmental Psychology,* 7, 3-15.

Darwin, C. (1877). A biographical sketch of an infant. In A. Slater & D. Muir (Eds., 1999). *The Blackwell reader in developmental psychology*, pp. 17-26. Oxford, UK, and Massachusetts: Blackwell.

de Haan, M., Johnson, M.K., Maurer, D. & Perrett, D.I. (2001). Recognition of individual faces and average face prototypes by 1- and 3-month-old infants. *Cognitive Development*, 16, 659-678.

Easterbrook, M. A., Kisilevsky, B. S., Hains, S. M. J. & Muir, D. W. (1999). Faceness or complexity: Evidence from newborn studies. *Infant Behavior and Development,* 22, 17-35.

Farah, M. J., Rabinowitz, C., Quinn, G. E & Liu, G. T. (2000). Early commitment of neural substrates for face recognition. *Cognitive Neuropsychology*, 17, 117-123.

Farroni, T., Valenza, E., Simion, F. & Umilta, C. (2000). Configural processing at birth: Evidence for perceptual organisation. *Perception*, 29, 355-372.

Friedman, S. (1972). Habituation and recovery of visual response in the alert human newborn. *Journal of Experimental Child Psychology,* 13, 339-349.

Gibson, E.J. (1969). *Principles of perceptual learning and development.* New York: Appleton-Century-Crofts.

Goren, C. C., Sarty, M., & Wu, P. Y. K. (1975). Visual following and pattern discrimination of face-like stimuli by newborn infants. *Pediatrics,* 56, 544-549.

Hainline, L. (1998). The development of basic visual abilities. In A. Slater (Ed.), *Perceptual development: visual, auditory and speech perception in infancy*, pp. 5-50. Hove: Psychology Press.

Heimann, M. (2002). Neonatal imitation – a fuzzy phenomenon? In F. Lacerda, C. V. Hofsten & M. Heimann (Eds.), *Emerging cognitive abilities in early infancy,* (pp. 231-246). Hillsdale, NJ: Earlbaum.

Johnson, M.H. & de Haan, M. (2001). Developing cortical specialization for visual-cognitive function: the case of face recognition. In J.L. McClelland & R. S. Seigler (Eds.), *Mechanisms of cognitive development: behavioral and neural perspectives* (pp. 253-270). Mahwah, NJ: Lawrence Erlbaum Associates.

Johnson, M.H., Dziurawiec, S., Ellis, H. D. & Morton, J. (1991). Newborns' preferential tracking of face-like stimuli and its subsequent decline. *Cognition*, 40, 1-19.

Johnson, M.H. & Morton, J. (1991). *Biology and cognitive development: the case for face recognition*. Oxford: Blackwell Publishers.

Karmiloff-Smith, A. (1996). The connectionist infant: would Piaget turn in his grave? *Society for Research in Child Development, Newsletter, Fall*, 1-3 and 10.

Langlois, J.H., Ritter, J.M., Roggman, L.A., & Vaughn, L.S. (1991). Facial diversity and infant preferences for attractive faces. *Developmental Psychology*, 27, 79-84.

Langlois, J. H., & Roggman, L. A. (1990). Attractive faces are only average. *Psychological Science,* 1, 115-121.

Langlois, J. H., Roggman, L. A., Casey, R. J., Ritter, J. M., Rieser-Danner, L. A., & Jenkins, V. Y. (1987). Infant preferences for attractive faces: rudiments of a stereotype? *Developmental Psychology,* 23, 363-369.

Meltzoff, A. N. (1995). Infants' understanding of people and things: from body imitation to folk psychology. In J. L. Bermudez, A. Marcel & N. Eilan (Eds.), *The body and the self* (pp. 43-69). Cambridge, MA, and London: MIT Press.

Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science,* 198, 75-78.

Meltzoff, A. N., & Moore, M. K. (1994). Imitation, memory, and the representation of persons. *Infant Behavior and Development*, 17, 83-99.

Meltzoff, A. N., & Moore, M. K. (1997). Explaining facial imitation: A theoretical model. *Early Development and Parenting*, 6, 179-192.

Meltzoff, A. N., & Moore, M. K. (2000). Resolving the debate about early imitation. In D. Muir & A. Slater (Eds.) *Infant development: The essential readings,* pp. 176-181. Oxford and Massachussetts: Blackwell Publishers

Morrongiello, B.A., Fenwick, K.D. and Chance, G. (1998). Crossmodal learning in newborn infants: Inferences about properties of auditory-visual events. *Infant Behavior and Development*, 21, 543-554.

Nelson, C. A. (2001). The Development and Neural Bases of Face Recognition. *Infant and Child Development*, 10, 3-18.

Pascalis, O., de Schonen, S., Morton, J., Deruelle, C., & Fabre-Grenet, M. (1995). Mother's face recognition by neonates: a replication and an extension. *Infant Behavior and Development,* 18, 79-85.

Piaget, J. (1953). *The origins of intelligence in the child*. London: Routledge and Kegan Paul.

Quinn, P. C., Bhatt, R. S., Brush, D., Grimes, A., & Sharpnack, H. (2002). Development of form similarity as a Gestalt grouping principle in infancy. *Psychological Science*, 13, 320-328.

Quinn, P. C., Brown, C. R., & Streppa, M. L. (1997). Perceptual organization of complex visual configurations by young infants. *Infant Behavior and Development,* 20, 35-46.

Quinn, P. C., Burke, S., & Rush, A. (1993). Part-whole perception in early infancy: Evidence for perceptual grouping produced by lightness similarity. *Infant Behavior and Development,* 16, 19-42.

Reissland, N. (1988). Neonatal imitation in the first hour of life: Observations in rural Nepal. *Developmental Psychology*, 24, 464-469.

Salapatek, P. (1982). Foreward to G. Bronson, *The scanning patterns of human infants*. Norwood, NJ: Ablex.

Samuels, C. A., Butterworth, G., Roberts, T., & Graupner, L. (1994). Babies prefer attractiveness to symmetry. *Perception,* 23, 823-831.

Simion, F., Cassia, V. M., Turati, C. & Valenza, E. (2001). The origins of face perception: Specific vs non-specific mechanisms. *Infant and Child Development*, 10, 59-65.

Slater, A. (1995). Visual perception and memory at birth. *Advances in Infancy Research*, 9, 107-162.
Slater, A., Bremner, G., Johnson, S.P., Sherwood, P., Hayes, R. & Brown, E. (2000). Newborn infants' preference for attractive faces: the role of internal and external facial features. *Infancy*, 1, 265-274.
Slater, A., Mattock, A., & Brown, E. (1990). Size constancy at birth: Newborn infants' responses to retinal and real size. *Journal of Experimental Child Psychology*, 49, 314-322.
Slater, A., & Morison, V. (1985). Shape constancy and slant perception at birth. *Perception*, 14, 337-344.
Slater, A., Morison, V. & Rose, D. (1983). Locus of habituation in the human newborn. *Perception*, 12, 593-598.
Slater, A., Morison, V. & Somers, M. (1988). Orientation discrimination and cortical function in the human newborn. *Perception*, 17, 597-602.
Slater, A. & Muir, D. (1999) (Eds.), *The Blackwell reader in developmental psychology.* Oxford, UK, and Massachusetts: Blackwell.
Slater, A. & Quinn, P.C. (2001). Face recognition in the newborn infant. *Infant and Child Development*, 10, 21-24.
Slater, A., Quinn, P.C., Brown, E. and Hayes, R. (1999). Intermodal perception at birth: Intersensory redundancy guides newborn infants' learning of arbitrary auditory-visual pairings. *Developmental Science*, 2, 333-338.
Slater, A., Quinn, P.C., Hayes, R.A. & Brown, E. (2000). The role of facial orientation in newborn infants' preference for attractive faces. *Developmental Science*, 3, 181-185.
Slater, A., von der Schulenburg, C., Brown, E., Badenoch, M., Butterworth, G., Parsons, S. & Samuels, C. (1998). Newborn infants prefer attractive faces. *Infant Behavior and Development*, 21, 345-354.
Walton, G.E., Armstrong, E. & Bower, T.G.R. (1998). Newborns learn to identify a face in eight-tenths of a second. *Developmental Science, 1*, 79-84.
Walton, G. E., Bower, N. J. A., & Bower, T. G. R. (1992). Recognition of familiar faces by newborns. *Infant Behavior and Development,* 15, 265-269.
Zuckerman, C.B. & Rock, I. (1957). A reappraisal of the roles of past experience and innate organizing processes in visual perception. *Psychological Bulletin*, 54, 269-296.