Review Article

The Shaping of the Face Space in Early Infancy: Becoming a Native Face Processor.

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Abstract

Because of its importance face perception remains one of the most intensively researched areas in psychology and allied disciplines and there has been much recent debate regarding whether face processing is an acquired or innate faculty. This article reviews studies, the majority of which have appeared in the last decade, which clarify the broad nature of race representation at birth, and documents the prominent role of experience in shaping infants' face processing abilities. In the first months of life infants develop a preference for female and own-race faces and become better able to recognise and categorize own-race and own-species faces. This perceptual narrowing of the 'face space' forms a foundation for later face expertise in childhood and adulthood and testifies to the remarkable plasticity of the developing visual system.

KEYWORDS –infancy; face perception; neural plasticity; own-race effect; own-species effect; gender preferences; perceptual narrowing

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INTRODUCTION

Faces are perhaps the most prominent and important visual stimuli in infants' lives, and from birth onwards they will encounter thousands of faces. Because of their importance face perception remains one of the most intensively researched areas in psychology and allied disciplines. Faces are multi-dimensional stimuli and they provide rich sources of visual information with social significance. This information can be transient, Face states such as emotions and expression, or more permanent and durable, Face traits which include gender, attractiveness, species and race. Recent research has documented some of the ways in which infants' "face space" becomes narrowed and attuned over the course of the first year and we review this work which has important implications for the nature/nurture issue, the adaptive significance of our face processing ability, and for our understanding of the role of experience in developing species- and race-specific face expertise.

NATURE VERSUS NURTURE: FACE PERCEPTION AT BIRTH

One of the longest-standing debates that continues to motivate research on the development of face processing concerns the origin of our face expertise. Are we born with an intrinsic predisposition to attend to faces, and an innate representation of faces? Or does our considerable expertise with faces stem from our abundance of experiences with faces relative to other visual stimuli?

We have known for some time that newborn infants have a preference for faces, especially when shown in their canonical upright orientation. Just a few minutes from birth newborn infants will track with their eyes a face-like schematic visual stimulus more than they will track a stimulus with the features scrambled (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991). These and other findings have led to the view that newborn infants come into the world with some representation of faces. There have been differing accounts of the nature of this representational bias. One is that there is nothing "special" about faces, and newborns' responses to and preferences for face-like stimuli result from general structural characteristics of the immature visual system, such as a preference for more elements in the upper part of a stimulus (up-down asymmetry) (Cassia, Turati, & Simion, 2004; Turati, Simion, & Milani, 2002). Johnson and Morton (1991) have argued for the existence of an innate face-detecting device they call "CONSPEC" (short for conspecifics), which comprises just three dark patches in a triangle, corresponding to eyes and mouth, and which serves to direct the newborn infant's visual attention to faces. This view is complemented by the finding that newborns also prefer the relationship between this triangular formation of three "blobs" when embedded in a triangular orientation of the external frame to a display where the external frame (but not the "blobs") is inverted (the congruent and incongruent patterns shown in Figure 1 (Cassia, Valenza, Simion, & Leo, 2008).

FIGURE 1 ABOUT HERE

These views suggest that the "face template" at the initial stage of development is rather crude. Other authors (e.g., Quinn & Slater, 2003) have argued that this representational bias is likely to be something more elaborate and face-specific than simply a tendency to attend to stimuli that possess nonspecific perceptual properties, such as three blobs in the location of eyes and mouth, “top-heaviness” or congruency, i.e., properties that are not necessarily face-specific. This possibility is suggested by two sets of findings, imitation of facial gestures and preferences for attractive faces, both of which are displayed by newborn babies, just minutes or hours from birth.

Newborn (and older) infants will imitate a variety of facial gestures they see an adult model performing (Meltzoff & Moore, 1977, 1983) and will even imitate facial gestures produced by the first face they have seen, within minutes from birth (Reissland, 1988), and it seems probable that “mirror neurons” serve to mediate imitation (Jackson, Meltzoff & Decety, 2006). 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. Clearly, they will have to do this by a process of “active intermodal matching”, that is, matching the facial gesture(s) they see exhibited by adults to those they feel themselves make, the latter mediated by proprioceptive feedback (Meltzoff & Moore, 1997).

For thousands of years humans have been attracted to and beguiled by beautiful and attractive faces, and facial attractiveness is detected and responded to at an early stage of processing, even before facial identity is detected (McDonald, Slater, & Longmore, 2008). A commonly held view has been that this attraction reflects arbitrary standards of beauty that emerge as a result of experience and reflect cultural norms, i.e., “beauty is in the eye of the beholder.” This view has been challenged by two sets of findings: 1) there is cross-cultural agreement on facial attractiveness, such that individuals from different cultures and ethnic groups agree on ratings of attractiveness of faces from their own and other ethnic groups (Rhodes, 2006).There is also evidence, which is reviewed next, suggesting that preferences for attractive faces are present in very early infancy and persist throughout life.

Several experimenters have found that infants prefer to look at attractive faces when these are shown paired with faces judged by adults to be less attractive (Langlois, Ritter, Roggman, & Vaughn, 1991; Langlois, Roggman, Casey, Ritter, Rieser-Danner, & Jenkins, 1987; Samuels & Ewy, 1985; van Duuren, Kendell-Scott, & Stark, 2003). This “attractiveness effect” seems to be robust in that it is found for stimulus faces that are infant, adult, male, female, and of different races (African-American and Caucasian), and babies also preferred attractive to symmetrical faces when attractiveness and symmetry were varied independently (Samuels, Butterworth, Roberts, Graupner, & Hole, 1994). The effect has also been found with newborn infants, who averaged less than 3 days from birth at the time of testing (Slater et al., 1998). In newborns the effect is orientation-specific in that it is found with upright, but not inverted, faces, and it is driven by attention to the internal features (Slater, Bremner, Johnson, Sherwood, Hayes, & Brown, 2000; Slater, Quinn, Hayes, & Brown, 2000). Nevertheless, however detailed infants’ facial representations may be, from birth on, it appears not to be specific to human faces, at least in early infancy, since 3- 4-month-old human infants prefer attractive over unattractive domestic cat and wild cat (tiger) faces, as judged by adult humans! (Quinn, Kelly, Lee, Pascalis, & Slater, 2008). We know that attractive traits signal important aspects of mate quality and reproductive quality, and this latter finding argues against a prevalent theoretical view, which is that preferences for attractive faces may be a by-product of adaptations for mate choice.

There have been two interpretations of the attractiveness effect, in terms of either prototype formation or innate representations. When several faces of the same gender, ethnicity and age are averaged or morphed, usually by computer, the resulting average or prototype is always perceived as attractive, and typically more attractive than the individual faces that make up the prototype. This effect was first noted in the early 20th Century and has since been verified on many occasions (Langlois & Roggman, 1990; Young & Bruce, 1998). The interpretation of the attractiveness effect that results from this finding is that attractive faces are seen as more "face-like" because they match more closely the prototype that infants have formed from their experience of seeing faces: thus, infants prefer to look at faces and they may prefer attractive or prototypical faces because they are easier to classify as a face (Langlois & Roggman, 1990).

This interpretation is compromised by the finding that newborn babies, who will have seen very few faces, also show the attractiveness effect, together with the finding that infants younger than 3 months do not form face prototypes, at least in a laboratory setting (de Haan, Pascalis, & Johnson, 2002). Thus, it is possible that newborn infants' preference for attractive faces results from an innate representation of faces that infants bring into the world with them (Langlois & Roggman, 1990; Quinn & Slater, 2003) and an evolutionary account of attractiveness preferences is offered by Etcoff (2000).

The evidence supports the view that newborn infants enter the world with a specific representation of faces that is more elaborate than simply a tendency to attend to stimuli that possess three blobs in the location of eyes and mouth ("CONSPEC"). This view is supported by evidence that newborns imitate the facial gestures produced by the first face they have ever seen, by their preferences for attractive faces, and by their preference to look at faces that engage them in mutual gaze (Farroni, Csibra, Simion, & Johnson, 2002; Grossmann et al., 2008). It is possible that experiences in utero (for example, proprioceptive feedback from facial movements) contribute to the newborn infant's representation of faces, which might therefore result from innate evolutionary biases, in interaction with prenatal experiences.

Neurological and behavioural evidence converge to suggest that this face-space is initially broad and is not specifically attuned to human faces, and it becomes more specific or narrowed with development and is particularly attuned to the types of faces that are most often encountered (Nelson, 2003; Simion, Leo, Turati, Valenza, & Barba, 2007). This perceptual tuning is evident in very early infancy, as we discuss next.

BECOMING A NATIVE FACE PROCESSOR

It is well documented that infants' speech perception becomes exquisitely attuned to their native language in the second half of their first year of life, and just before they produce their first meaningful word. Until the age of around 6 months infants can discriminate subtle phonetic differences that distinguish speech sounds in both their native and unfamiliar languages, whereas by 12 months of age infants have lost this capacity for unfamiliar languages and have become particularly attuned to the phonetic variations in their native language, and are even sensitive to the particular variant (i.e., dialect) that they hear: they have become "native language specialists" or "native listeners" (Hollich & Houston, 2007; Kuhl, Stevens, Hayashi, Deguchi, Kiritani, & Iverson, 2006; Nazzi, Jusczyk, & Johnson, 2000; Werker, 1989).

In recent years evidence has emerged that the face processing system, or "face space" undergoes a similar process of perceptual narrowing and tuning over the first year of life, as infants become attuned to the faces that they encounter the most frequently, and that this perceptual narrowing is accompanied by considerable neural plasticity. Experience has an impact within hours from birth: within the newborn period infants come to prefer their mother's face (Bushnell, Sai, & Mullin, 1989; Pascalis, de Schonen, Morton, Deruelle, & Fabregrenet, 1995), and as early as 3 months from birth there is evidence for some degree of perceptual and cortical specialization in infants' processing of faces (de Haan, Pascalis, & Johnson, 2002; Halit, Csibra, Volein, & Johnson, 2004; Humphreys & Johnson, 2007). Recent investigations that have focused on how infants respond to gender, species and race information in faces have produced evidence that illustrates this perceptual narrowing over the first three months.

By 3 months of age infants who have a female as their primary caregiver (the vast majority of them!) prefer to look at female faces when these are shown paired with male faces. Three-month-olds reared by a female caregiver and shown a series of female faces will subsequently prefer a novel female face when paired with one of those shown previously; however, when shown a series of male faces they will not show a novelty preference for a new male face, and they are also better able to discriminate between individual female faces than between male faces – they have become, in some small way, "female experts" (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002; Ramsey, Langlois, & Marti, 2005). The role of experience in inducing this effect is confirmed by the complementary finding that infants reared with a male as their primary caregiver look more at male than female faces! (Quinn et al., 2002). Although we do not know for sure, presumably as infants have additional exposure to other-gender faces (usually male) this perceptual bias will diminish and perhaps disappear. Interestingly, this early female preference interacts with the other-race effect (see below) since it is found with own-race but not other-race faces (Quinn et al., 2008).

A similar finding, of attunement to the category of faces that is most often encountered, is seen with the other-race effect (ORE), which is the well-established finding that individuals find it easier to discriminate between faces of their own race than between faces of other races ("why do they all look the same?") The ORE has its origins in early infancy. When shown own-race faces paired with other-race faces newborn infants demonstrated no spontaneous preference for faces from their own ethnic group, a further confirmation that the initial face space is broadly based. However, at three months, infants showed a significant looking preference for own-race faces, a finding that applies to Caucasian, African and Chinese infants (Bar-Haim, Ziv, Lamy, & Hodes, 2006; Kelly et al., 2005, Kelly, Liu et al., 2007; Sangrigoli & de Schonen, 2004). The ORE is readily modified at this age, and short-term familiarization with just a few exemplars of another race group is sufficient to reduce the other-race effect (Sangrigoli & de Schonen, 2004). In similar vein, infants who are raised in a cross-race environment do not show the effect: specifically, African-Israeli 3-month-old infants, who have experienced intensive cross-race exposure, look equally at Caucasian and African faces (Bar-Haim et al., 2006).

These nascent origins of the ORE become more finely tuned as infancy progresses: despite showing a preference for looking at own-race faces, 3-month-old Caucasian infants were able to discriminate between individual faces within their own facial group and within three other-race groups (African, Middle Eastern and Chinese). However, after extensive continued experience with own-race faces and limited experience with other-race faces, by 9 months their discrimination was restricted to own-race faces. This effect has been found both with Caucasian infants who have had little exposure to Asian faces, and with Chinese infants who have had little exposure to Caucasian faces (Kelly et al., in press; Kelly, Quinn, Slater, Lee, Ge, & Pascalis, 2007). While 9-month-old Caucasian infants discriminated better between own-race faces, they nevertheless retained the ability to form discrete categories of Caucasian and Asian faces, each of which excluded instances of the other, suggesting that categorization and individuation are subserved by different, but interrelated, neural structures (Anzures, Quinn, Pascalis, Slater, Lee, in press; Ge et al., in press).

A parallel phenomenon to the ORE is the other-species effect (OSE). Six- and 9-month-olds and adults have no problem in discriminating between individual human faces of their own race, and 6-month-olds are equally adept at discriminating between the faces of a monkey species (Macaca fascicularis), see figure 2. However, by 9 months human infants only showed evidence of discrimination between individuals of their own species, as did adults (Pascalis, de Haan, & Nelson, 2002). But like the ORE the OSE effect is readily modified: 6- to 9-month-olds who were exposed to different individual same-species monkey faces no longer showed the other-species effect at 9 months (Pascalis et al., 2005).

FIGURE 2 ABOUT HERE

CONCLUSIONS

Collectively, these findings are a clear indication that facial input from the infant's environment shapes the face-processing system early in infancy, resulting in visual preferences for gender and for own-race faces in early infancy, and better recognition accuracy with own-race, and own-species faces. This perceptual narrowing effect in face perception, which is paralleled by an equivalent native language effect, suggests a more general change in neural networks involved in early perception and cognition. (Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005; Scott, Pascalis, & Nelson, 2007). This review has focussed on changes in face processing in the first year of life, but of course there is considerable flexibility subsequently. In the case of gender preferences same-sex preferences and recognition advantages emerge in childhood, and these advantages are maintained in adulthood, although there may be an opposite-sex face preference. With respect to the ORE and OSE, both effects are reversible in childhood and adulthood: for race, Korean adults who were adopted by French families when aged between 3 and 9 years were better able to identify Caucasian faces than Asiatic ones (Sangrioli et al., 2005); and for species adults who specialise in a particular species (e.g., birds, zoo animals, etc.) or breed (e.g., dog show judges) become face experts with their chosen species (Diamond & Carey, 1986). The fact that the "face-space" is malleable in infancy, yet remains plastic in childhood and probably throughout life, testifies to the remarkable plasticity both of the developing and mature visual system.

REFERENCES

Anzures, G., Quinn, P. C., Pascalis, O., Slater, A., & Lee, K. (in press). Racial categorization of faces in infancy: A new other-race effect. Developmental Science.

Bar-Haim, Y., Ziv, T., Lamy, D., & Hodes, R. M. (2006). Nature and nurture in own-race face processing. Psychological Science, 17, 159-163.

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.

Cassia, V. M., Turati, C., & Simion, F. (2004). Can a nonspecific bias toward top-heavy patterns explain newborns' face preference? Psychological Science, 15, 379-383.

Cassia, V. M., Valenza, E., Simion, F., & Leo, I. (2008). Congruency as a nonspecific perceptual property contributing to newborns' face preference," Child Development, 79, 807-820.

de Haan, M., Pascalis, O., & Johnson, M. H. (2002). Specialization of neural mechanisms underlying face recognition in human infants. Journal of Cognitive Neuroscience, 14, 199-209.

Diamond, R., & Carey, S. (1986). Why faces are and are not special: an effect of expertise. Journal of Experimental Psychology – General, 115, 107-117.

Etcoff, N. (2000). Survival of the prettiest: The science of beauty. New York: Doubleday.

Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. Proceedings of the National Academy of Sciences of the United States of America, 99, 9602-9605.

Ge, L., Zhang, H., Wang, Z., Pascalis, O., Quinn, P. C., Kelly, D. J., et al. (in press). Two faces of the other-race effect: Recognition and categorization of Caucasian and Chinese faces. Perception.

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.

Grossmann, T., Johnson, M. H., Lloyd-Fox, S., Blasi, A., Deligianni, F., Elwell, C., et al. (2008). Early cortical specialization for face-to-face communication in human infants. Proceedings of the Royal Society B-Biological Sciences, 275, 2803-2811.

Halit, H., Csibra, G., Volein, A., & Johnson, M. H. (2004). Face-sensitive cortical processing in early infancy. Journal of Child Psychology and Psychiatry, 45, 1228-1234.

Hollich, G. J., & Houston, D.M. (2007). Language development: From speech perception to first words. In A. Slater & M. Lewis (Eds.), Introduction to infant development (pp. 170-188). Oxford: Oxford University Press.

Humphreys, K., & Johnson, M. H. (2007). The development of “face-space” in infancy. Visual Cognition, 15, 578-598.

Jackson, P. L., Meltzoff, A. N., & Decety, J. (2006). Neural circuits involved in imitation and perspective-taking. Neuroimage, 31, 429-439.

Johnson, M. H., & Morton, J. (1991). Conspec and Conlern – a 2-process theory of infant face recognition. Psychological Review, 98, 164-181.

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

Kelly, D. J., Liu, S., Ge, L., Quinn, P. C., Slater, A. M., Lee, K., et al. (2007). Cross-race preferences for same-race faces extend beyond the African versus Caucasian contrast in 3-month-old infants. Infancy, 11, 87-95.

Kelly, D. J., Liu, S., Lee, K., Quinn, P. C., Pascalis, O., Slater, A. M., et al. (in press). Development of the other-race effect in infancy: Evidence towards universality? Journal of Experimental Child Psychology.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L., & Pascalis, O. (2007). The other-race effect develops during infancy: Evidence of perceptual narrowing. Psychological Science, 18. 1084-1089.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Gibson, A., Smith, M., et al. (2005). Three-month-olds, but not newborns, prefer own-race faces. Developmental Science, 8, F31-F36.

Kuhl, P. K., Stevens, E., Hayashi, A., Deguchi, T., Kiritani, S., & Iverson, P. (2006). Infants show a facilitative effect for native language phonetic perception between 6 and 12 months. Developmental Science, 9, F13-F21.

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., & 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 stereoptype? Developmental Psychology, 23, 363-369.

McDonald, P. R., Slater, A. M., & Longmore, C. A. (2008). Covert detection of attractiveness among the neurologically intact: Evidence from skin-conductance responses. Perception, 37, 1054-1060.

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. (1983). Newborn infants imitate adult facial gestures. Child Development, 54, 702-709..

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

Nazzi, T., Jusczyk, P. & Johnson, E. K. (2000). Language discrimination by English-learning 5-month-olds: Effects of rhythm and familiarity. Journal of Memory and Language, 43, 1-19.

Nelson, C. A. (2003). The development of face recognition reflects an experience-expectant and activity-dependent process. In O. Pascalis and A. Slater (Eds.), The development of face processing in infancy and early childhood (pp. 79-97). New York: Nova Science Publishers, Inc., 2003.

Pascalis, O., de Haan, M., & Nelson, C. A. (2002). Is face processing species-specific during the first year of life? Science, 292, 1321-1323.

Pascalis, O., de Schonen, S., Morton, J., Deruelle, C., & Fabregrenet, M. (1995). Mother's face recognition by neonates – A replication and extension. Infant Behavior and Development, 18, 79-85.

Pascalis, O., Scott, L. S., Kelly, D. J., Shannon, R. W., Nicholson, E., Coleman, M., et al. (2005). Plasticity of face processing in infancy. Proceedings of the National Academy of Sciences of the United States of America, 102, 5297-5300.

Quinn, P. C., & Slater, A. (2003). Face perception at birth and beyond. In O. Pascalis & A. Slater (Eds.), The development of face processing in infancy and early childhood (pp. 3-11). New York: Nova Science Publishers, Inc.

Quinn, P. C., Kelly, D. J., Lee, K., Pascalis, O., & Slater, A. M. (2008). Preference for attractive faces in human infants extends beyond conspecifics. Developmental Science, 11, 76-83.

Quinn, P. C., Uttley, L., Lee, K., Gibson, A., Smith, M., Slater, A. M., et al. (2008). Infant preference for female faces occurs for same- but not other-race faces. Journal of Neuropsychology, 2, 15-26.

Quinn, P. C., Yahr, J., Kuhn, A., Slater, A. M., & Pascalis, O. (2002). Representation of the gender of human faces by infants: A preference for female. Perception, 31, 1109-1121.

Ramsey, J. L., Langlois, J. H., & Marti, N. C. (2005). Infant categorization of faces: Ladies first. Developmental Review, 25, 212-246.

Reissland, N. (1988). Neonatal imitation in the 1st hour of life – observations in Rural Nepal. Developmental Psychology, 24, 464-469.

Rhodes, G. (2006). The evolutionary psychology of facial beauty. Annual Review of Psychology, 57, 199-226.

Samuels, C. A., & Ewy, R. (1985). Aesthetic perception of faces during infancy. British Journal of Developmental Psychology, 3, 221-228.

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

Sangrigoli, S., & de Schonen, S. (2004). Recognition of own-race and other-race faces by three-month-olds. Journal of Child Psychology and Psychiatry, 45, 1219-1227.

Sangrigoli, S., Pallier, C., Argenti, A. M., Ventureyra, V. A. G., & de Schonen, S. (2005). Reversibility of the other-race effect in face recognition during childhood. Psychological Science, 16, 440-444.

Scott, L. S., Pascalis, O., & Nelson, C. A. (2007). A domain general theory of the development of perceptual discrimination. Current Directions in Psychological Science, 16, 197-201.

Simion, F., Leo, I., Turati, C., Valenza, E., & Barba, B. D. (2007). How face specialization emerges in the first months of life. Progress in Brain Research, 164**,** 169-185.

Slater, A., P.C. Quinn, P. C., R.A. 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., Bremner, J. G., Johnson, S. P., Sherwood, P., Hayes, R. A., & Brown, E. (2000). Newborn infants' preference for attractive faces: the role of internal and external facial features. Infancy, 1, 265-274.

Slater, A., von der Schulenberg, C., Brown, E., Badenoch, M., Butterworth, G., Parsons, S., et al. (1998). Newborn infants prefer attractive faces," Infant Behavior and Development, 21, 345-354.

Turati, C., Simion, F., & Milani, I. (2002). Newborn preference for faces: What is crucial? Developmental Psychology, 38, 875-882.

van Duuren, M., Kendell-Scott, L., & Stark, N. (2003). Early aesthetic choices: Infant preferences for attractive premature infant faces. International Journal of Behavioral Development, 27, 212-219.

Werker, J. F. (1989). Becoming a native listener. American Scientist, 77, 54-59.

Young, A., & Bruce, V. (1998). Pictures at an exhibition – The science of the face. Psychologist, 11, 120-125.

Figure captions

Figure 1: Two of the patterns presented to newborns by Cassia et al. [10]: Facelike congruent (left) and Facelike non-congruent (right).

Figure 14. By 9 months human infants only showed evidence of discrimination between individuals of their own species, as did adults, Pascalis et al., [51].

Figure 1

Figure 2