British Journal of Developmental Psychology (2001), 19, 219–232 *Printed in Great Britain*

Responses to mother's face in 3-week to 5-month-old infants

Jon Bartrip and **John Morton***
Institute of Cognitive Neuroscience, London, UK

Scania de Schonen
Laboratory of Cognition & Development, Paris, France

Pascalis, de Schonen, Morton, Deruelle, and Fabre-Grenet (1995) showed that while 4-day-old infants looked longer at their mother's face than at a stranger's, they did not do so if both women were wearing headscarves. In the present experiment, we obtained similar results for infants of 19–25 days. In contrast, a group of 35- to 40-day-old infants was able to make the discrimination with mother and stranger wearing headscarves. When both women wore masks, so that only hair and chin lines were visible, the discrimination was not made earlier than 120 days. There was also a developmental trend from interest in the mother for 19- to 25-day-old infants, to interest in the stranger for the 145- to 155-day-old infants. Further investigation showed that the main contribution toward this trend was from the male infants.

Several studies have established that 4-day-old infants look longer at their mother's face than at a stranger's face despite the fact that they are only provided with visual information on identity. In the Bushnell, Sai, and Mullin (1989) study, the mother was instructed not to talk and spraying a strong air-freshener between the mother and her infant before each trial controlled olfactory information. Walton, Bower, and Bower (1992) found that neonates would suck more strongly to see their mother's face than a stranger's face even when the stimuli used were digital still images. Pascalis, de Schonen, Morton, Deruelle, and Fabre-Grenet (1995) have more recently confirmed these findings. Their study instituted some procedural modifications in order to guarantee that the recognition of mother was as context free as possible, in order to guarantee that any selective response to mother was the product of a purely visual discrimination. In Bushnell *et al.*'s (1989) study, the infant was held by an experimenter so providing tactile stimulation and warmth. This could be part of the context in which the mother's face most often becomes available to the infant. On the other hand, in the Pascalis *et al.* (1995) study, the neonate was placed in a special chair and there was no contact with an adult during testing.

The second question addressed by Pascalis *et al.* (1995) was whether the infants use

* Requests for reprints should be addressed to John Morton, Institute of Cognitive Neuroscience, 17 Queen Square, London, WC1N 3AR, UK.

the external characteristics of the face or whether the internal structure of the face was encoded. As adults get familiar with a particular face, they mainly use the internal structure in recognition, but the external features do carry enough information for identification, and Davidoff, Matthews, and Newcombe (1986) report the case of a prosapagnosic patient who used the hairline of faces in order to recognize people. In addition, logically, the colour and contour of the hair could form cues for recognition of individuals. However, with 4-day-old infants, there are severe limitations in capacity imposed by the contrast sensitivity characteristics of the infant's visual system. Even by 4 weeks of age, infants are not capable of discriminating much better than 0.5 cycles per degree (Banks & Salapatek, 1978) which means that many facial details would not be visible. Nevertheless, a certain amount of information about the internal structure of the face is found in the lower spatial frequency spectrum. The relationship between the separation of the eyes and the distance between the eyes and the mouth, for example, and the positioning of that triangle within the outline of the face could be sufficient cues for the infant. On the other hand, the shape and contour of most women's hair would fall well within the sensitivity of a 4-day-old. Pascalis *et al.* (1995) probed these issues by running a condition where mother and stranger both wore headscarves, thus removing the external information concerning identity. In this condition, infants totally failed to discriminate between mother and stranger under conditions where the infants were deprived of olfactory cues and the faces remained immobile.

We can thus conclude that neonates have learnt something about their mother's head or head and face during the first few days of life. It is not clear exactly what has been learned but it is clear that a representation of their mother's face is not one in which the inner configuration of the features is independent of the hairline and outer contour. On the other hand, de Schonen, Gil de Diaz, and Mathivet (1986) showed that 4- to 10-month-old infants recognize their mother's face, in a frontal full view, with their right hemisphere but not with their left. This was also true when a scarf masked the mother's hairline and the outer contour of her head. Moreover, at 3 months, even with a headscarf present, infants are able to recognize a stranger's face which had been learned from a different visual point of view (Pascalis, de Haan, Nelson, & de Schonen, 1998).

There are two main questions that arise. The first is at what age are infants able to discriminate mother's face from that of a stranger on the basis of internal features alone. The second question is whether or not the preference for mother over stranger is due entirely to the external features or whether it is a function of both external and internal features. In the experiment to be described, we probed these issues by testing infants from 19 to 155 days old to see whether they could discriminate between mother and a stranger in the three different circumstances. The primary test was with mother's and stranger's faces fully visible. In the second condition, both women wore a headscarf. In the third condition the women wore masks so that the internal features were not visible and all that the child had available with which to discriminate the two faces was the hair style and face outline.

Of course, with older infants, it cannot be assumed that the ease with which the infant can discriminate between mother and a stranger is going to be directly reflected in looking times. There are many components that determine looking time and it could be expected that as the child gets older and mother becomes more familiar, the amount of time spent in looking at mother could actually reduce.

This would correspond to work indicating novelty preference following extensive exposure (e.g. Hunter & Ames, 1988; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982; Weizmann, Cohen, & Pratt, 1971). All that we can say for certain is that if either mother or stranger is consistently looked at more, then we can conclude that in that condition the child can discriminate the two. On the other hand, it would be possible for the child to be able to make the discrimination without this being reflected in looking behaviour. For example, if mother was not recognized in spite of being discriminated from the stranger, the infant might show no preference. However, we assume that the child's behaviour will be consistent, an assumption central to developmental studies, and that very young infants, placed in a novel situation, exhibit familiarity preference whenever they can. Thus, since the 4-day-old infants in the Pascalis *et al.* (1995) experiment discriminated between mother and stranger with full face we would expect them to do so with internal features alone if they were able to. As the age of the infants tested is increased, there will be a point at which they can discriminate between their mother and a stranger using internal features alone. We would thus feel justified in assuming that this was the earliest age at which they were able to do so given that they are still driven by familiarity preference.

In the Pascalis *et al.* (1995) study, the infants made a choice between mother and a stranger who was chosen 'so as to be broadly similar in terms of complexion, hair colour, and general hair style' (p. 81). The criteria in the present study were the same.

Method

Participants

The participants were 102 infants of mixed SES who were recruited from the London area. Parents were approached either while attending the pre-natal clinic at University College Hospital, London, or from other sources. Infants were included if there had been no serious problems at birth and if birth was no more than 14 days prior to estimated full-term. Infants delivered by Caesarean section were accepted. A paid return taxi fare to the laboratory was the only inducement offered to volunteering parents. Of the 102 recruited participants, nine were subsequently rejected due to drowsiness, 15 due to fussing and one due to experimenter error. The remaining 77 participants were allocated to one of the six, predetermined age groups: Age Group (AG) 1: 19–25 days, 9 males (M); 6 females (F); AG 2: 35–40 days, 8 (M), 7 (F); AG 3: 55–65 days, 6 (M), 5 (F); AG 4: 85–95 days, 5 (M), 7 (F); AG 5: 115–125 days, 6 (M), 6 (F); and AG 6: 145–155 days, 7 (M), 5 (F). Age groups were not equal in numbers for the following reasons. Age Groups 1 and 2 included more infants for the purpose of increased reliability at these young ages. Also an infant was dropped from Age Group 3 when, on subsequent inspection, it was considered the quality of the video recording was not sufficient for reliable coding (experimenter error).

Materials

The apparatus used for the infant looking procedure consisted of a table 75 cm high by 100 cm wide by 150 cm long. On the central longitudinal axis was placed an infant car seat facing one end of the table and mounted by fixings, which allowed its distance from the end of the table to vary from 50 cm to 100 cm. At the end of the table to which the infant seat faced was a vertical black cloth screen 100 cm square. Located centrally and symmetrically about the vertical axis of the screen were two apertures 30 cm high and 20 cm wide and separated by 15 cm. A horizontal axis through the apertures measured 45 cm from the tabletop. Running parallel to and fixed immediately in front of the cloth screen were two curtains meeting centrally along the vertical axis, running on a curtain track and operated by a cord from behind the screen relative to the position of the infant chair. This allowed that when the curtains were closed, the screen with the apertures was occluded, whilst when open, the apertures were exposed, relative to the infant chair. Behind the screen two chairs were provided for the mother and stranger to be seated. Behind the chairs was yet another black screen to prevent anything from behind the screens being visible from the infant chair. On each side of the table was a mobile, mid-grey screen, enclosing the infant during experimental trials. This is illustrated in Fig. 1.

Figure 1. The experimental set-up.

A pair of plain white novelty masks, with the shaped contours of a human face and holes for the eyes were used to obscure the internal features. These were cut down so as to expose the jawline and hairline of the target faces. Two pieces of black cloth, each used in the manner of a scarf, were used to obscure external features whilst leaving the internal features exposed. A monochrome video camera was placed centrally, 15 cm above the apertures and protruding discreetly through the cloth screen and angled so as to enable viewing and recording of an occupant of the infant chair. A second monochrome video camera was placed at the opposite end of the table, high enough and angled down to record the apertures in the black cloth screen.

The outputs from the two video cameras plus that from a timer were mixed and fed into a VCR and a monitor. The video mixer was set to horizontal split screen in a way that, during an experimental session, the monitor image comprised a large view of the infant's face and a smaller view of the faces of the mother and the stranger (10% of the total image). This image was recorded on videotape.

Design and procedure

On arrival at the laboratory, mother and infant waited in reception to allow time for the infant to settle. Infant and mother were then taken to the test room by the experimenter. A brief description of the procedure was then given to the mother and the stranger. The mother placed her infant in the baby seat that had been set to either 75 cm or 50 cm from the plane of the black screen depending on the age of the infant. Age Groups 1, 2 and 3 were set to 50 cm and Age Groups 4, 5 and 6 set to 75 cm. According to the standard contrast sensitivity function for infants, these were appropriate distances for optimal visual resolution. The two side screens were then positioned to enclose the infant entirely within the apparatus.

A female member of staff, of about the same age as the mother, was assigned to act as the stranger. If mother had an unusual hairstyle, such as pigtails, the stranger was chosen to match this. Beyond this, no attempt was made to match mother and stranger, partly because of the administrative difficulties in attempting to do this and partly because we could not find a clear rationale for the matching. The best match for a particular mother would be her identical twin, but we would not be likely to learn a great deal about the infant's visual system from its failure to make such a discrimination. As the criteria for matching becomes less stringent, the discrimination task would become easier. If we knew exactly which cues were important and in what combination one could carry out the matching in a reasoned way. With the procedure we used, the estimates of the earliest age at which mother can be recognized will be at the optimistic end of the scale. A total of six different women served as strangers.

Mother and stranger sat in the chairs provided behind the screen and positioned their heads through the screen aperture in front of them to a point just past their ears. For the full face and external features conditions, hair was arranged in the individuals' normal styles. At this point the curtains in front of the screen were still closed. The experimenter, viewing the infant from the video monitor and judging the infant ready and looking forward towards the screen, opened the curtains between the infant and the screen apertures exposing the two faces. The noise and motion of the curtains was generally sufficient to attract the infant's attention to one of the two faces. If this was not sufficient the experimenter shook a rattle midway between the two faces until attention was attained. At a point when the experimenter judged that the infant was looking at either one of the faces, the video recording and the video timer were begun. This was the beginning of a trial of 20 seconds' duration.

Mother and stranger had been instructed to look into the infant's eyes with a neutral expression for the full duration of each trial. Any change in facial expression or other enticement to the infant could be observed on the monitor by the experimenter. In fact, no such changes of expression occurred.

At the end of the 20-second trial the experimenter closed the curtains in front of the screen and paused recording. To control for any side preference to the looking behaviour of the infant, mother and stranger then swapped seating positions and a second trial was run repeating the above procedure.

This two-trial procedure was followed for each of the three conditions in randomized order; full face (subsequently referred to as 'full'), with external features obscured by the scarf ('internal') and with internal features obscured by the mask ('external'). External features were defined as the hair, ears, jawline and chin. Internal features were defined as that approximately triangular area of the face containing the eyebrows, eyes, nose and mouth.

Looking data for the 77 participants were coded from the videotapes by JB using a computer program which recorded the amount of time the infant looked left or right of centre using two keys pressed and held down by the coder. Using the same scoring program, two random selections of 20 infants' data were coded by two other experienced infant visual data coders and used to acquire a measure of reliability. Pearson correlation coefficients for the time of individual looks taken for the three possible pairing of the three scores were $r = .89$, $r = .92$ and $r = .90$.

Looking scores. The coding program output the data, summed for each 20-second trial, in a format readable by the SPSS statistical package. These data were transformed by first combining the scores for the mother and stranger looks made by the infant from the two trials for each of the three conditions. The looking scores consisted of six data per infant, one each for mother and stranger and for each of the three experimental conditions.

Preference scores. We could not directly test the difference between looking at mother and stranger using analysis of variance due to a small negative association between these two measures resulting from the use of time-limited trials. The proportion of the look time to the mother alone, with look time to mother plus stranger as the denominator, was used to eliminate this problem. Thus, values above 0.5 indicate a preference for mother and values below, a preference for the stranger. Analyses revert to the use of the raw looking data where the paired mother/stranger comparison is not part of the analysis. The preference data thus consisted of three data points per infant, one each for the full, internal and external conditions.

Results

Number of looks

The number of looks to the target faces increased significantly and linearly with increasing age. A mean of 3.5 looks at Age Group 1 (19–25 days) to a mean of 8.0 at Age Group 6 (145–155 days) was found when pooled across conditions. A mixed model ANOVA, using face occlusion condition (three levels) and target face (two levels), both repeated measures, by age group and sex of infant, with number of looks as the dependent measure, revealed only an age group effect: $F(5,65) = 11.34, p < .001$ with a linear component parameter significantly different from zero at $t = 7.03, p < .001$.

Preference scores

For the three conditions, we tested the mean proportion of time spent looking at mother for the six age groups. Our initial analysis of this data transformation was aimed at determining whether there were any effects of the order of presentation of the conditions. For example, it is possible that if an infant was in the mask condition initially, that might affect the subsequent pattern of choice between the faces. For this analysis, we pooled the age groups and did three independent one-way ANOVAs (full face, internal, external) with independent groups determined by the position in which the particular condition was presented (first, second, third). The results were: full face $F = 0.99, p = .38$, n.s.; internal $F = 0.02, p = .99$, n.s.; external $F = 1.65, p = .20$, n.s. For further analyses, we ignored the order of presentation as a factor.

The primary purpose of the experiment was to estimate the earliest age at which infants could discriminate mother's face from that of an unfamiliar female of similar age using the reduced cues created by the scarf and mask conditions. This discrimination is revealed indirectly by the preference score – the proportional look data. A summary of this data is shown in Fig. 2. Since Pascalis *et al.* (1995), using the same technique, showed that 4-day-old infants looked at mother significantly more, we expect to find similar effects with our younger groups of infants. What we need to test for in addition is the earliest age at which we can find evidence that the faces are discriminated in the internal and external conditions. In the figure we show with asterisks those points that are significantly different from a proportion of 0.5 at the 5% level using single sample paired t tests. We feel justified in using this level of significance since we are not looking for whether there is a difference but when this difference appears. The full face condition just failed to display a significant difference from zero preference at Age Group 1 (19–25 days), $t(14) = 2.09, p = .055$, with a preference for the mother. Full face reached significance at Age Group 6 (145–155 days), $t(11) = -2.53, p = .028$, with a preference for the stranger. At Age Group 2 (35–40 days) the internal condition displayed a significant preference for mother with $t(14) = 2.38, p = .032$. This result contrasts dramatically with the findings in the external condition where it was not until Age Group 5 (115–125 days) that there was a significant preference for mother: $t(11) = 2.59, p = .025$. These data indicate that the internal features characterizing mother are learned before the external features.

The results of a one-way ANOVA for the full face condition showed a significant effect for age, $F(5,71) = 2.49, p = .039$, and a linear trend component parameter significantly different from zero at $t = -3.11$, $p = .003$. The equivalent analysis on internal features revealed $F(5,71) = 1.38$, n.s. with a non-significant linear component parameter: $t = -.93$ and the analysis on external features revealed $F(5,71) = 1.30$, n.s. also with a non-significant linear component parameter: $t = -.476$.

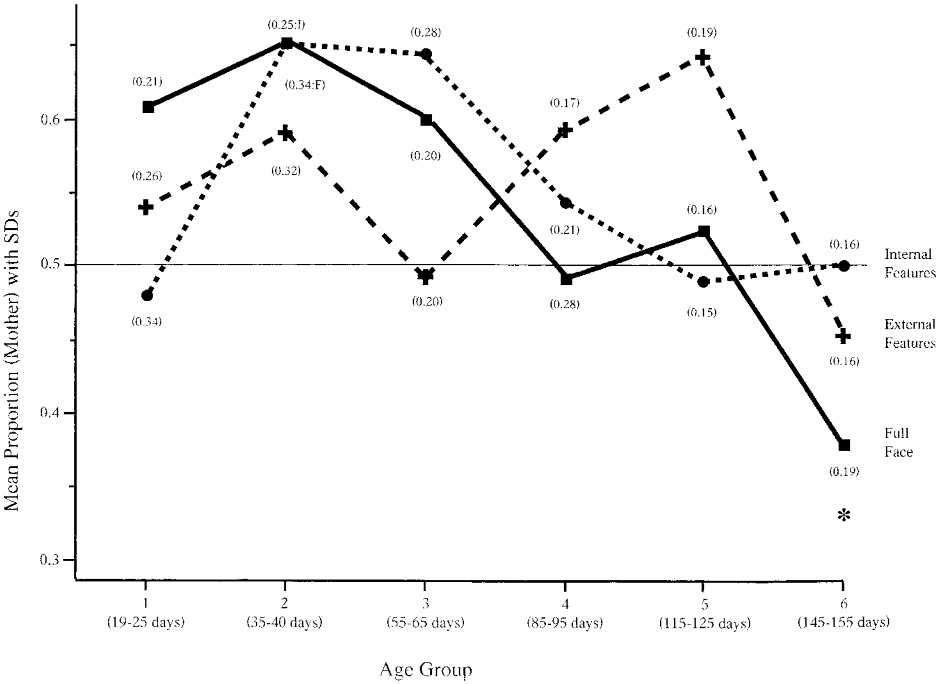

Figure 2. Graph of the proportion data with asterisks indicating group means that significantly differ from zero preference (0.5).

The full face condition also displayed a significant sex difference in the developmental preference for mother. This manifested as a constant separation of preference between the sexes from 35–40 to 115–125 days old so that males have a greater preference for mother than females. This can be seen in Fig. 3. On this figure there is a dip for Age Group 4 (85–95 days) for the male participants. We suspect that this is a random variation since the median scores give a smoother function with age. An ANOVA performed on the full face preference scores, with age group and sex of participant as between participants factors revealed a significant age group main effect ($F(5,65) = 2.50$, $p = .04$) and a significant sex main effect ($F(1,65) = 8.51$, $p = .005$). As can be seen from Fig. 3 the interaction was non-significant.

As a measure of confirmation for these sex differences, a 2×2 χ^2, performed on all 77 participants in the full face condition, divided into those participants who preferred mother and those who preferred the stranger and by sex of participant. This revealed a Pearson's χ^2 of 5.51 (1), $p < .02$, (male: preference for mother 28, for stranger 13; female: preference for mother 15, for stranger 21) indicating a difference in patterns of preference between the sexes. A binomial test showed that males do have a tendency to

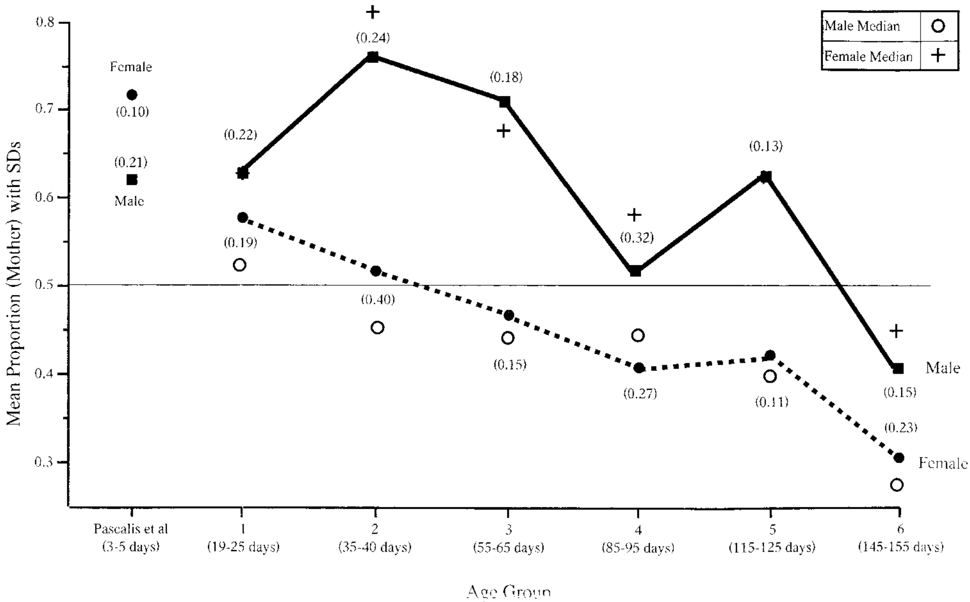

Figure 3. Graph of full face proportion data by sex including the equivalent data for 3–5 days old infants from Pascalis *et al.* (1995).

favour looking at the mother's face ($z = 2.19$, $p = .028$, with continuity correction). The female infants did not show a significant preference.

Also in Fig. 3 are the equivalent data points for the 4-day-old infants, taken from Pascalis *et al.* (1995). These preference scores were taken from 32 seconds actual looking at the two faces, roughly equivalent to our youngest group who average 30 seconds total looking time at the two faces. In their study, both male and female infants looked longer at mother but there was no significant difference between the sexes.

Looking times

To examine the full face effect further we analysed the looking data underlying the preference data transformation. Figure 4 shows the mean look time, in the full face condition, to the mother and to the stranger by age group. A mixed model ANOVA, using the mean look time scores to mother and stranger as the two levels of the repeated measures factor, by age group, revealed no significant effect for age group or mother/stranger but a significant interaction: $F(5,71) = 2.58, p < .05$. A one-way ANOVA on mean look time to the mother produced $F(5,71) = 1.08$, n.s. while the one-way ANOVA on the mean look time for the stranger produced $F(5,71) = 4.45, p < .001$ with a significant linear component parameter $t = 3.954, p < .001$.

To maintain consistency with the preference analysis on the full face data we further examined the full face looking data for evidence of sex differences. Figures 5 and 6 show graphs of the mean look time data as presented by males and females respectively. Two mixed model ANOVAs, using the total look time scores to mother and stranger as the

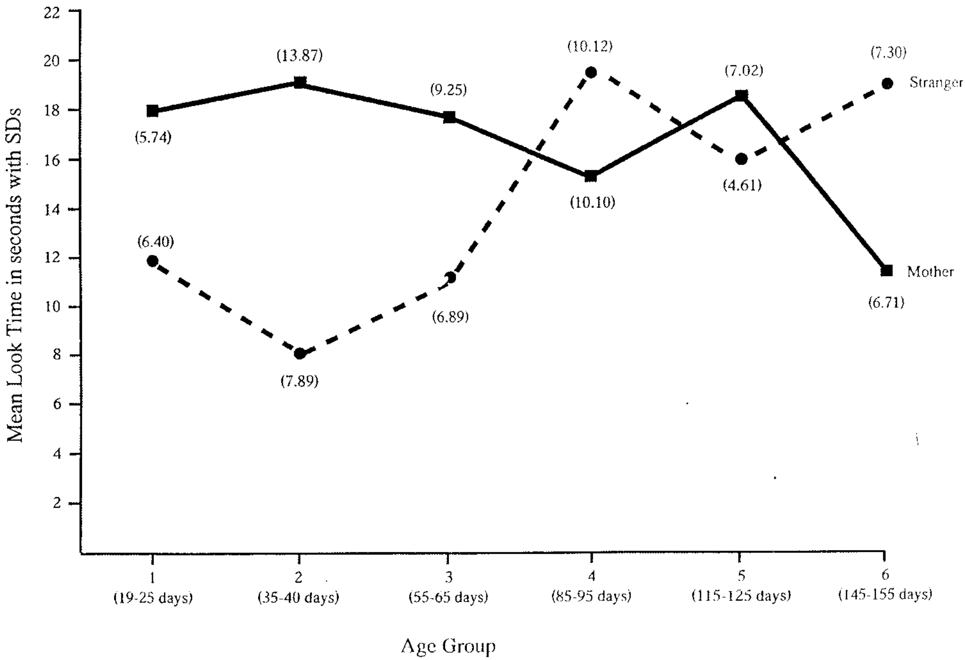

Figure 4. Graph of the raw data, or absolute look times, for the full face condition.

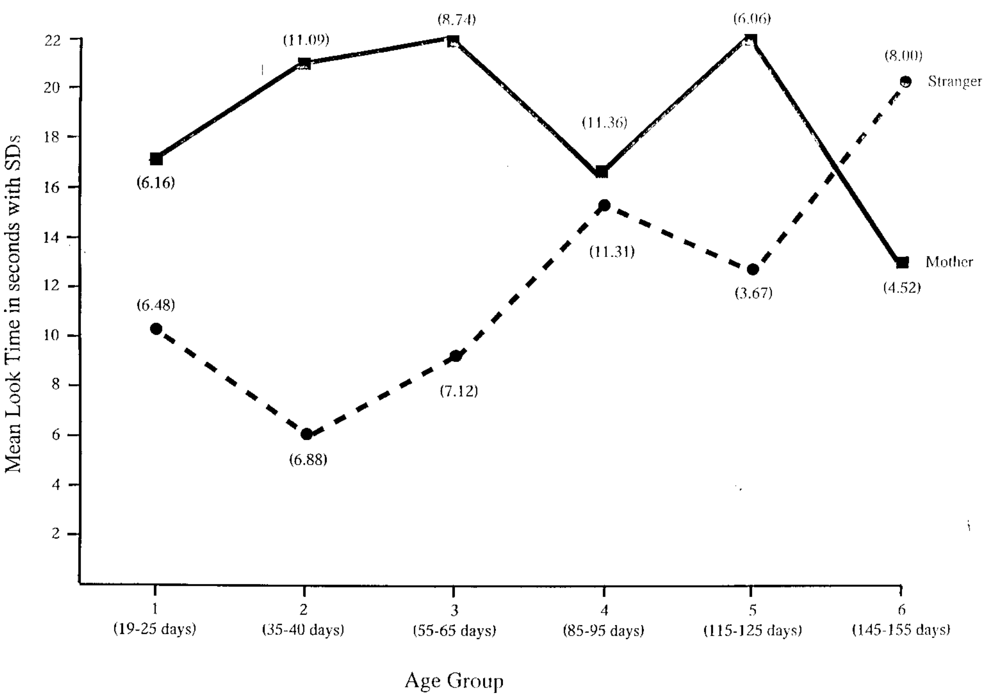

Figure 5. Graph of the raw data, or absolute look times, for male infants in the full face condition.

two levels of the repeated measures factor, by age group, were performed on male and female data separately. The males' data produced no significant age group effect, a significant mother/stranger effect, $F(1,35) = 8.73$, $p < .01$ and an interaction just failing to reach significance with $F(5,35) = 2.47$, $p = .051$. The females' data failed to reach significance in any one of the three partitions of variance. A one-way ANOVA on the total look time to the stranger presented by males produced $F(5,35) = 3.51$, $p < .001$ with a significant linear component parameter $t = 3.497$, $p < .001$, while a similar analysis on the males' total look time to the mother failed to reach significance: $F(5,35) = 1.38$, n.s. One-way ANOVA analyses on the female total look time data failed to produce significant F ratios: mother total look time, $F(5,30) = 1.44$, n.s. and stranger total look time of $F(5,30) = 0.54$, n.s.

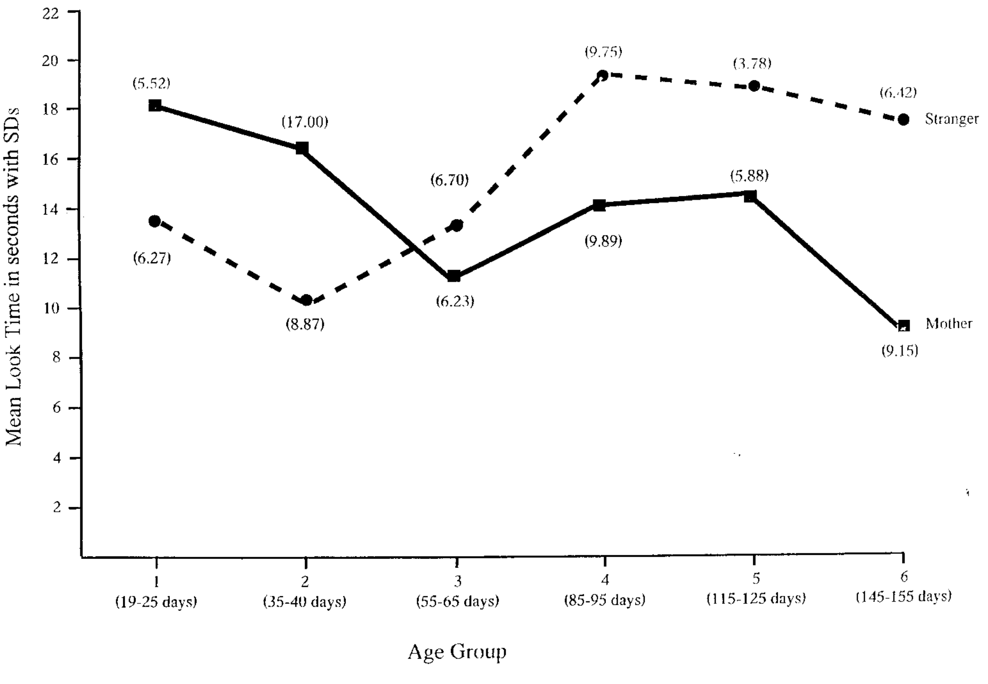

Figure 6. Graph of the raw data, or absolute look times, for female infants in the full face condition.

Discussion

We will first discuss aspects of the data, concentrating on sex differences and familiarity/novelty. We will then relate the data to existing theories of the development of face recognition.

The overall analysis of the preference data indicates a developmental trend from interest in mother in the first 2 months of life shifting with a simple linear function to a preference for the stranger by 5 months of age. This manifests itself statistically only in the 'ecological', full face treatment. However it does appear from viewing the preference data in Fig. 2 that the profile of the data for internal features most closely resembles that of the full face condition. That of external features follows a quite different profile, especially in the first 3 months of life, since it appears that mother is not recognized in the external condition until the infants are 120 days old.

Along with the arithmetic effects of using the subtraction transform to produce the preference measure, a second factor contributing to the presence of extreme variance in the overall analyses of the preference data is the existence of sex differences within the data. The full face preference data indicate a parallel developmental trend for male and female infants. To mitigate against the effects upon the mean data of the extreme variance where outliers would have the effect of pulling the mean across the distribution disproportionately, the data represented in the form of medians indicate an even clearer parallel developmental division between the sexes.

If the medians are a more reliable representation of the data here, it appears that females do not prefer mother to any extent over the ages studied. The bulk of the variance *between* age groups contained in the preference data is from the contribution provided by the declining interest in mother displayed by the male infants. We note again that Pascalis *et al.* (1995) found that female 4-day-olds showed a much greater preference for mother than did male 4-day-olds.

It is noteworthy that the sex difference only appears in the full face condition. It is also noteworthy in that it presents itself as a parallel separation at multiple and contiguous ages and not in isolated age groups. The frequency analysis confirms that indeed more females than males preferred looking at the stranger while more males than females preferred looking at their mother.

The preference data, although necessary for overall analyses, cannot show the absolute values of the total look times of the infants, only the relative difference between looks to the mother and look to the stranger. Also the original looking scores include less noise as a result of the extra variance caused by the subtraction transformation used to create the preference scores. Comparing the total look time to mother and to the stranger in the full face condition, the interest in mother represented by this measure remains constant across the six age groups. Interest in the stranger presents as a highly significant developmental trend towards increased amounts of time spent looking at the stranger as age increases. This, combined with the fact that there is a large increase in the number of looks to both mother and stranger over these age groups, possibly indicates an increase in visual attraction to novelty. Certainly the main differences occur prior to 3 months of age at which point the total look times to mother and stranger becomes a matter of random choice between the two for at least a further 2 months.

When analysed again by sex of the infant it is clear that the profile presented by the overall mean look times in the full face condition is solely the result of the contribution from the male infants. We therefore come to the conclusion that the most parsimonious explanation for the looking behaviour data is that provided by the male participants. By the age of 60 days, females appear to look equally at mother and stranger, if with a slight bias towards the stranger, while the male participants take a further 3 to 4 months development before presenting a similar profile. When considered in terms of absolute look times this represents the male infants' delay in acquiring an interest in the stranger's face. Note that the absence of any decline in looking at mother with age argues against any interpretation of the data in terms of the still-face effect. It is certainly the case that the mothers were instructed to keep their faces free from expression, and this might have been expected to have had an effect on the infants' behaviour. However, such an effect would have led to a reduction in looking at mother with increasing age.

Interpretation of the sex differences in the preference and the basic looking data can only be speculative. Two explanations may be forwarded with a third a combination of these. First, it is possible that the male data represent a straightforward delay in the development of interest in novel faces compared to females who are precocious in this respect. A referee suggested that the difference might be due to holistic rather than sequential processing in males. Secondly, while the first possibility implies it is the same mechanism that is involved in this developmental differentiation, it is conceivable that males use either a different mechanism or different strategies than females. Whatever the account, it must be consistent with the complete absence of sex effects for either the internal or the external features data.

There were no significant overall effects found for the internal and external features conditions when using the ANOVA paradigm. When the age groups were tested separately, mother preference was significant at 35–40 days, but external features was not significant until 115–125 days. The simplest account of the data, is that the infants gradually build up some representation of their mother so that accurate discriminations can be made at the ages indicated.

The external features condition produced the most distress in infants. It was the condition which caused the most fussing, the least smiling and on several occasions required a break in the trials to calm the infant. We assume that this is due to this condition representing the most extreme form of the 'still-face effect' with the mask precluding any expression, even the most passive.

Johnson and Morton (1991) and Morton and Johnson (1991) hypothesized an inborn face preference mechanism they called CONSPEC, which attracts an infant's attention to faces. This mechanism, supposed to be subcortical, accounts for the newborn preference for face stimuli over non-face stimuli which was reported by Goren, Sarty, and Wu (1975; also Johnson, Dziurawiec, Ellis, & Morton 1991). However, it was not supposed by Johnson and Morton that CONSPEC processed the features that characterize the internal configuration of an individual face. The contrasting mechanism is termed CONLERN, which is responsible for maintaining foveal fixation on faces. The present data indicate that this mechanism is not capable of controlling attention until 35–40 days old. This estimate fits reasonably well with the proposal by de Schonen and Mathivet (1989) that 'physiognomy processing', meaning the processing of individual faces, starts between 2 and 4 months, an estimate based on a variety of experimental arguments.

In addition, de Schonen, Deruelle, Mancini, and Pascalis (1993), describing a positron emission tomography (PET) scan study using seven, 2-month-old infants, found superior temporal (posterior parts of T1 and T2) cortical involvement in face processing. Similarly, ERP (Event Related Potential) data show that 1 month later, at the age of 3 months, there is a clear cortical response (return to baseline) corresponding to long-term recognition of a familiarized face (Pascalis *et al.*, 1998). Moreover, this face recognition is intriguing because the familiarization was achieved by presenting several views of the same face. In the recognition test, a new point of view or a new expression of the familiarized face is presented, paired with a new face under the same view and the same expression.

What can we say about the specificity of the mechanisms involved in the earliest recognition of mother? Pascalis *et al.* (1995) concluded that learning about mother over the first 3 days could have been accomplished by a general pattern recognition process rather than by a specific system like CONSPEC. At the age of 3–4 days we know a face is recognized in part through its external features since, if mother wears a headscarf, she is not recognized. Furthermore, it would be consistent with the Pascalis *et al.* (1995) data to regard mother's face simply as the most commonly experienced visual stimulus. However, the present data appear inconsistent with this position. We have shown that 5-week-old infants can recognize mother from internal features alone. Pascalis *et al.* (1995) showed that this was not possible at 4 days old. On the one hand, 5 weeks seems too early for the cortical mechanisms described by de Schonen and her colleagues, or the CONLERN mechanism postulated by Johnson and Morton (1991). On the other hand, the information necessary to distinguish mother from stranger on the basis of internal features seems too complicated to be dealt with by subcortical mechanisms such as CONSPEC. This puzzle remains to be resolved, but it remains possible that cortical face processing might be operating earlier than sometimes assumed.

References

Banks, M. S., & Salapatek, P. (1978). Acuity and contrast sensitivity in 1-, 2- and 3-month-old human infants. *Investigative Ophthalmology and Visual Science, 17*, 361–365.

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.

Davidoff, J., Matthews, W. B., & Newcombe, F. (1986). Observations on a case of prosopagnosia. In H. D. Ellis, M. A. Jeeves, F. Newcombe, & A. Young (Eds.), *Aspects of face processing* (pp. 279–290). Dordrecht: Martinus Nijhoff.

de Schonen, S., Deruelle, C., Mancini, J., & Pascalis, O. (1993). Hemispheric differences in face processing and brain maturation. In B. de Boysson-Bardies, S. de Schonen, P. W. Jusczyk, P. McNeilage, & J. Morton (Eds.), *Developmental neurocognition: Speech and face processing in the first year of life* (NATO ASI series D: Behavioural and social sciences, Vol. 69, pp. 149–164). Dordrecht: Kluwer.

de Schonen, S., Gil de Diaz, M., & Mathivet, E. (1986). Hemispheric asymmetry in face processing in infancy. In H. D. Ellis, M. A. Jeeves, F. Newcombe, & A. Young (Eds.), *Aspects of face processing* (pp. 199–208). Dordrecht: Martinus Nijhoff.

de Schonen, S., & Mathivet, E. (1989). First come first served: A scenario about development of hemispheric specialization in face recognition during infancy. *European Bulletin of Cognitive Psychology (CPC), 9*, 3–44.

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.

Hunter, M. A., & Ames, E. W. (1988). A multifactor model of infant preferences for novel and familiar stimuli. *Advances in Infancy Research, 5*, 69–95.

Johnson, M. H., Dziurawiec, S., Ellis, H. D., & Morton, J. (1991). Newborns preferential tracking of faces and its subsequent decline. *Cognition, 40*, 1–20.

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

Morton, J., & Johnson, M. (1991). CONSPEC and CONLERN: A two process theory of infant face recognition. *Psychological Review, 98*, 164–181.

Pascalis, O., de Haan, M. Nelson, C., & de Schonen, S. (1998). Long term recognition memory for faces assessed by visual paired comparison in 3- and 6-month-old infants. *Journal of Experimental Psychology: Learning, Memory and Cognition, 24*, 249–260.

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.

Rose, S. A., Gottfried, A. W., Melloy-Carminar, P., & Bridger, W. H. (1982). Familiarity and novelty preferences in infant recognition memory: Implications for information processing. *Developmental Psychology, 18*, 704–713.

Walton, G. E., Bower N. J. A. and Bower T. G. R. (1992). Recognition of familiar faces by newborns. *Infant Behavior and Development, 15*, 265–269.

Weizmann, F., Cohen, L. B., & Pratt, R. J. (1971). Novelty, familiarity, and the development of infant attention. *Developmental Psychology, 4*, 149–154.

Received 4 November 1999; revised version received 17 July 2000