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COGNITIVE DEVELOPMENT

Recognition of individual faces and average face prototypes by 1- and 3-month-old infants

Michelle de Haan[a,*], Mark H. Johnson[a], Daphne Maurer[b], David I. Perrett[c]

[a]*Centre for Brain and Cognitive Development, Birkbeck College, University of London, 32 Torrington Square, London WCIE 7JL, UK*
[b]*Department of Psychology, McMaster University, Hamilton, ON, Canada*
[c]*School of Psychology, University of St. Andrews, Fife, Scotland, UK*

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Abstract

We tested the ability of 1- and 3-month-old infants to form prototypic representations of faces. Following familiarization to four individual faces, both 1- and 3-month-olds showed evidence of recognizing the individual faces but only 3-month-olds showed evidence of recognizing, and thus having mentally computed, the average of the four face stimuli. Additional experiments showed that (a) 1-month-olds failed to show evidence of recognizing the average face even when the test was made easier, and (b) the results could not be attributed to preexisting visual preferences among the faces. These results are discussed in relation to a two-process theory of the development of face recognition and the hypothesis that babies' abilities to form prototypes of faces underlies their visual responsiveness to attractive faces.

Keywords: Face recognition; Categorization; Infancy; Cortical development

1. Introduction

From birth, infants appear to find faces very interesting to look at and, from a very young age, they display impressive competency at detecting information in

* Corresponding author. Tel.: +44-20-7905-2929; fax: +44-20-7833-9469.
E-mail address: m.de-haan@ich.ucl.ac.uk (M. de Haan).

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the face such as identity (Pascalis & de Schonen, 1994), emotional expression (Field, Woodson, Greenberg, & Cohen, 1982), and direction of eye gaze (Farroni, Johnson, Brockbank, & Simion, 2000; Vecera & Johnson, 1995). However, face-processing abilities continue to undergo changes for many years before they become adult-like (e.g., Carey & Diamond, 1994). The purpose of this study was to examine one developmental change in face processing, the emergence of the ability to recognize the central tendency of a group of faces.

Johnson and Morton (1991) have argued that at birth face processing is mediated primarily by subcortical systems and only some weeks later do cortical areas begin to exert an influence (see de Schonen & Mathivet, 1989, for a similar argument). In the theory's original form, the cortical system mediating the recognition of individual identity was thought not to emerge until after 6–8 weeks of age. However, studies demonstrating that within hours or days of birth infants can recognize the mother's face (Bushnell, Sai, & Mullin, 1989; Field, Cohen, Garcia, & Greenberg, 1984; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995) and a face to which they have been familiarized experimentally (Pascalis & de Schonen, 1994) indicated that this aspect of the theory required revision. One proposal (Johnson & de Haan, 2001) is that in the first few weeks of life recognition of faces, and likely other stimuli, is mediated by an early hippocampal-based pre-explicit memory described by Nelson (1995). While this hippocampal system is able to able to form an accurate representation in memory of an individual visual stimulus, its limitation is that without higher cortical input it does not relate information from one memorized stimulus with another. Thus, this type of processing differs from that in adults, for whom one important aspect of encoding for facial identity is information about an individual face relative to a prototypic or average face representation (Benson & Perrett, 1991; Mauro & Kubovy, 1992; Rhodes, 1993; Rhodes, Brake, & Atkinson, 1993; but see Rhodes, Carey, Byatt, & Proffitt, 1998).[1] By this view, adults have formed a prototypic representation of facial features and their relative positions and one way they can encode new faces is in terms of how they deviate from this prototype. This ability to relate information from one face to another and thereby form a prototypic representation of the face may develop only with the emergence of functional occipito-temporal cortical involvement in face processing, after 6–8 weeks. Thus, the revised theory would predict that infants can recognize individual faces both before and after the cortical system becomes influential, but that after this time the way that faces are represented changes because the baby can form a prototypic representation of faces.

[1] The cognitive representation of faces by adults can be described in terms of this prototype-based model or in terms of an exemplar-based model in which each individual face is defined as a point in multidimensional "face space." The relative merits of these different models are discussed in Rhodes et al. (1998) and Valentine (1991). The purpose of our study is to evaluate developmental changes in infants' responsiveness to the average of a category of faces and not to distinguish between exemplar-based and prototype models.

Previous research provides evidence in support of the idea that infants older than 6–8 weeks are able to form perceptual categories based on stimuli experienced in the visual environment. In one study, newborns and 3- to 5-month-olds were familiarized with six different exemplars of the same shape, and then tested with a new exemplar of the same shape and a different shape (Slater & Morison, 1987, cited in Slater, 1989). The older infants looked longer at the different shape, while the newborns did not. This suggests that infants a few months old, but not newborns, can form categories based on perceptual similarity. Infants also are able to form perceptual categories of complex visual stimuli by 2–4 months of age. For example, in one study (Quinn, Eimas, & Rosencrantz, 1993) infants were familiarized to the category ''cats'' or ''dogs'' for six 15-s trials during each of which two exemplars of the same category were shown. During a subsequent test infants looked longer at an exemplar from a novel category, bird, than at the familiar category. Importantly, control experiments showed that infants' recognition of the familiar category was not due simply to a failure to discriminate between different exemplars of dogs or cats. These results show that infants can form categorical representations based on seeing pictures of perceptually complex natural kinds.

Evidence from other studies converges to suggest that infants who are at least 3 months old form prototypic representations of perceptual categories (Bomba & Siqueland, 1983; Quinn, 1987; Rubenstein, Kalakanis, & Langlois, 1999; Strauss, 1979; Younger, 1985). For example, following familiarization to 12 exemplars from a form category (e.g., triangular arrangements of dots distorted by displacing dots in random directions), 3- to 4-month-olds look longer at a previously seen exemplar than at the prototype (perfect triangular arrangements of dots; Bomba & Siqueland, 1983). The fact that infants treated the previously unseen prototype as familiar suggests that they were averaging the familiarization patterns together, rather than only storing individual exemplars. A similar pattern of results has been observed for older infants tested with faces: After familiarization to eight individual photographs of faces each presented for two 5-s trials, 6-month-olds look longer at a novel face or at one of the familiar individual faces than at a prototype created by averaging the familiarization faces (Rubenstein et al., 1999; see also Strauss, 1979). Whether infants younger than 3 months can form prototypic representations of perceptual categories is unclear. In the only study to test for it, newborns looked longer at a composite of four familiar faces (prototype) than a composite of four unfamiliar faces (Walton & Bower, 1993). One interpretation of this result is that even newborns are able to form a prototype. However, because newborns' abilities to discriminate among the faces were not tested, an equally likely explanation is that apparent ''recognition'' of the prototype was simply a failure to discriminate it from the exemplars.

Thus, infants appear able to form perceptual categories of faces by 3 months of age and, at least by 6 months of age, the nature of this representation may be prototypic (Rubenstein et al., 1999; Sherman, 1985; Strauss, 1979). Whether younger babies differ from older ones in the ability to form prototypes of faces is unknown, because no study has tested this ability using the same method before

and after 6–8 weeks of age. This was the purpose of the present study. In the first experiment, we familiarized babies to four individual faces, and then tested whether they recognized (a) a computer-generated face comprised of the average of the four, and (b) one of the exact individual faces. Recognition of the average face was tested by showing the baby a pair of faces consisting of the average and one of the four faces seen during familiarization. The logic of this test pair is that, if the babies are storing the faces only as individual exemplars, the familiar exemplar should be perceived as familiar and the average as novel; in contrast, if the infants are forming an average representation during the familiarization, then they should perceive the average face as most familiar, more so even than an individual face actually seen during familiarization. Thus, we predicted that 3-, but not 1-month-olds, would look longer at the familiar than the average face. Recognition of an individual face was tested by showing the baby a pair of faces consisting of a novel face and one of the four faces seen during familiarization. We expected from previous studies (e.g., Pascalis, de Haan, Nelson, & de Schonen, 1998; Pascalis & de Schonen, 1994) that babies of both ages would recognize the familiar individual faces, and thus would look longer at the novel face. In two further experiments, we investigated what 1-month-olds would do when given an easier test for recognition of the average (Experiment 2) and whether a spontaneous preference for the average face could account for the pattern of results (Experiment 3).

2. General method

2.1. Participants

One- and 3-month-old infants were recruited from the London area through an existing list of parents who had expressed an interest in participating in research by responding to advertisements. All of the infants were born full term and were of normal birthweight. Parents were compensated for their travel expenses.

2.2. Stimuli

The stimuli were high-quality color dye sublimation print-outs of eight different female faces plus one "average" face made from four of the eight (see Fig. 1). All faces were shown against a grey background, and hair was cropped. The size of the faces was 12 cm in height by 10 cm in width (14 by 17 visual degrees when viewed from the testing distance of 40 cm).

The method for creating the average face is described in Rowland and Perrett (1995). Briefly, for each of four images the x and y coordinates of 224 feature points were defined manually. The average position of each feature point was calculated for the four faces and the points were joined to produce a line-drawn representation of the "average" face shape. Each of the four original images was then morphed into the average shape. The four faces with the same remapped

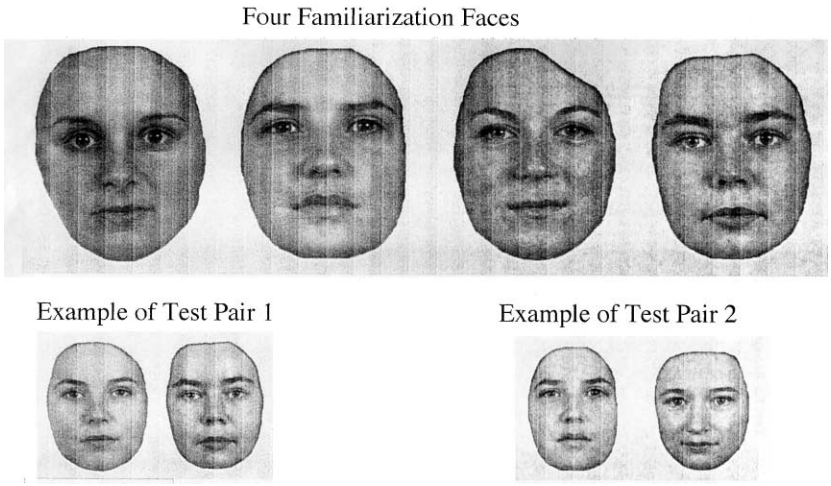

Fig. 1. The stimuli used in Experiments 1–3. Faces 1–4 are the faces used during familiarization in Experiments 1 and 2. The example of test pair 1 shows the average face (left) with one of the familiarization faces (right) and the example of test pair 2 shows a novel face (right) with one of the familiarization faces (left). The stimuli were presented in colour.

shape were then blended together to form the average composite by averaging the colors and intensities of corresponding pixels in constituent images.

2.3. Apparatus

Infants were tested in a version of the portable visual preference apparatus used by Fagan (1970) modified to allow the presentation of visual stimuli to infants seated in the caregiver's lap without the caregiver being able to view the stimuli. It consists of a wooden testing chamber mounted on wooden legs with wheels. When wheeled over the caregiver's lap, the baby resting in the lap sees gray wooden walls to the sides and a gray wooden "door" with two slots for stimuli to the front. When the door is open the stimulus slots are not in the baby's view and the stimuli can be removed or inserted. When the door is closed, the stimuli can be viewed by the baby and there is a peephole positioned between the two stimulus slots that allows the trained observer to measure the looking times to each stimulus using stopwatches. The times are recorded by a second experimenter, who also removes and inserts the appropriate stimuli in position between trials so that the observer is not aware of the exact stimuli being presented on a given trial. For all experiments, each trial began when the infant first looked at either stimulus and ended when a prespecified period of time had elapsed. A trial was repeated if the baby looked for a total of less than 1 s; however, this rarely occurred. Babies were excluded if they showed a side bias by looking to one side for greater than 85% of the time.

3. Experiment 1

The purpose of Experiment 1 was to determine whether 1- and 3-month-olds can form an average representation of a group of faces. We predicted that, following familiarization with a number of individual faces, infants at both ages would be able to recognize an individual face from the group, but only the 3-month-olds would recognize the average of the group.

3.1. Method

3.1.1. Participants

The participants were twelve 1-month-olds ($M = 33.19$ days, range 28–36) and twelve 3-month-olds ($M = 83.5$ days, range 77–91). Half the babies in each group were male. An additional 1-month-old was tested but was excluded because he fell asleep during testing.

3.1.2. Procedure

The procedure consisted of a familiarization period during which the baby was familiarized to four faces, and then two types of test trials: (a) one to determine whether the baby recognized the average of the four faces and (b) one to verify that the baby could remember an individual face.

3.1.2.1. Pilot study. One issue to be considered in designing the study was the length of the familiarization period. We wanted to be certain that infants of both ages received sufficient exposure to each individual face to be able to encode it into memory, so that differences between ages in the ability to recognize an average representation could not be attributed to insufficient exposure to the faces. One approach would be to use habituation-to-criterion with infant-controlled trials to ensure that infants in both age groups reached an objectively equivalent level of familiarization. However, in this procedure, because the first trials are by definition longer than the last trials, infants do not receive equal exposure to all familiarization stimuli. This would be of concern for the present study because longer exposure to a particular face might bias prototype formation to that face and away from the test average in which all four stimuli were represented equally. Thus, we chose instead to use a familiarization procedure and to conduct a pilot study to determine what length of exposure to a face was sufficient for subsequent recognition by 1- and 3-month-olds.

In the pilot study, we tested thirteen 1-month-olds ($M = 29.19$ days) and fourteen 3-month-olds ($M = 84.9$ days). The experiment consisted of twelve 10-s trials. The first trial and alternating trials thereafter (i.e., Trials 1, 3, 5, 7, 9, 11) were the familiarization trials, during each of which the same face was presented on both sides of the screen across all of the trials. After each familiarization trial (i.e., Trials 2, 4, 6, 8, 10, 12), the familiar face was presented paired with a trial-unique novel face. The left–right position of the novel face alternated across

trials. Ten of fourteen 3-month-olds looked longer at the novel face by the second test (Trial 4; *M* group = 65% looking to novel). By this time, the babies had looked at the familiar face for 22 s. One-month-olds did not consistently show a preference for the novel face until the fifth test (Trial 10). On this test, all (13/13) babies looked longer at the novel than the familiar face (group average equals 96% looking to novel). By this time, the babies had looked at the familiar face for 52 s. These data, together with the observation that babies looked at the faces for about 75% of the available time, allowed us to determine the optimal familiarization times for Experiment 1.

3.1.2.2. Familiarization. Based on the results of the pilot study, the exposure times during familiarization were set at 30 s per face for 3-month-olds and 80 s per face for 1-month-olds. The order of the four faces during familiarization was counterbalanced across infants.

3.1.2.3. Test trials. Following familiarization we presented infants with four 10-s test trials. The test trials were the same duration for both ages as the pilot study showed that 10-s exposure was sufficient for infants at both ages to show novelty preferences. The first two trials consisted of a test of the average face paired with one of the four familiarization faces with left–right reversal. Half the infants saw the average on the left side during the first presentation and half saw it on the right. The last two trials consisted of a test of a novel face paired with one of the four familiarization faces different from the one that had been presented during the first two test trials (i.e., not the same one that was paired with the average). Half the infants saw the novel face on the left side during the first presentation and half saw it on the right, in each case followed by a left–right reversal. Across babies, each familiar face was used equally often to make the test pair with the average face and to make the test pair with the novel face. Each of the four novel faces was used equally often and was randomly paired with a particular familiar face. The use of four different novel faces and random pairings of these faces with the four different familiar faces ensured that any preference for the novel face would be due to its novelty and not to any other systematic difference among the faces.

The test pairing the familiar and novel individual faces was always presented second so that the novel face would not influence the average representation the baby had formed from the four faces shown during familiarization.

3.2. Results

3.2.1. Familiarization

To determine whether infants showed habituation of looking across the four familiarization trials, mixed ANOVAs were performed separately for the two age groups with Sex (male, female) as the between-subjects factor and Trial (1, 2, 3, 4) as the within-subjects factor. There were no significant effects at either age,

indicating that looking time did not decrease across familiarization. This pattern is not unusual for procedures where a different stimulus is shown during each trial of familiarization (see Quinn, 1998, for review). For the purposes of this study it is preferable to have approximately equal looking across trials because this means that the babies had equal exposure to the four individual faces contributing to the average and their representations are thus not biased to a particular face that was inspected longer.

3.2.2. Test of familiar versus average

The looking time to each face on each of the two test trials was first converted to a proportion by dividing the looking time to each face by the total looking time for the trial, and then the proportion of looking to each face was averaged across its two presentations. To test whether babies had formed an average representation during familiarization, we computed a three-way mixed ANOVA with Sex (male, female) and Age (1 month, 3 months) as the between-subjects factors and Face (average, familiar) as the within-subjects factor. There was a main effect of Face, F (1,20) = 7.16, $P < .05$, that was qualified by an Age × Face interaction, $F(1,20) = 4.89$, $P < .05$). This occurred because the 3-month-olds looked longer at the familiar ($M = 0.76$, S.D. = 0.23) than the average face ($M = 0.24$, S.D. = 0.23), $F(1,11) = 23.85$, $P < .01$, while the 1-month-olds did not, $F(1,11) = 0.08$, $P > .1$ (Average Face $M = 0.47$, S.D. = 0.25; Familiar Face $M = 0.53$, S.D. = 0.25; see Fig. 2). Inspection of the individual infants' data showed that ten of the twelve 3-month-olds looked longer at the familiar than the average face, while only four of the twelve 1-month-olds did so.

3.2.3. Test of novel versus familiar

Proportion of looking to the Novel and Familiar Faces was computed as described above for the Average and Familiar Faces. To test whether infants recognized the Familiar Face, we computed a three-way mixed ANOVA with Sex (male, female) and Age (1 month, 3 months) as the between-subjects factors and Face (novel, familiar) as the within-subjects factor. There was a main effect of Face, F (1,20) = 20.85, $P < .01$, which occurred because infants at both ages looked longer at the Novel than at the Familiar Face (3-month-olds: Novel Face $M = 0.62$, S.D. = 0.21 and Familiar Face $M = 0.38$, S.D. = 0.21; 1-month-olds: Novel Face $M = 0.77$, S.D. = 0.22 and Familiar Face $M = 0.23$, S.D. = 0.22; see Fig. 2). The three way interaction of Age, Sex and Face was also significant, $F(1,20) = 5.39$, $P < .05$. Separate ANOVAs at each age showed that this was due to a marginally significant Sex × Face interaction for 3-month-olds, but not 1-month-olds, $F(1,10) = 4.89$, $P = .05$, due to the stronger novelty preference displayed by 3-month-old boys compared to girls.

Inspection of the individual infants' data showed that 7 of the 12 three-month-olds looked longer at the Novel than at the Familiar Face, and 9 of the 12 one-month-olds did so.

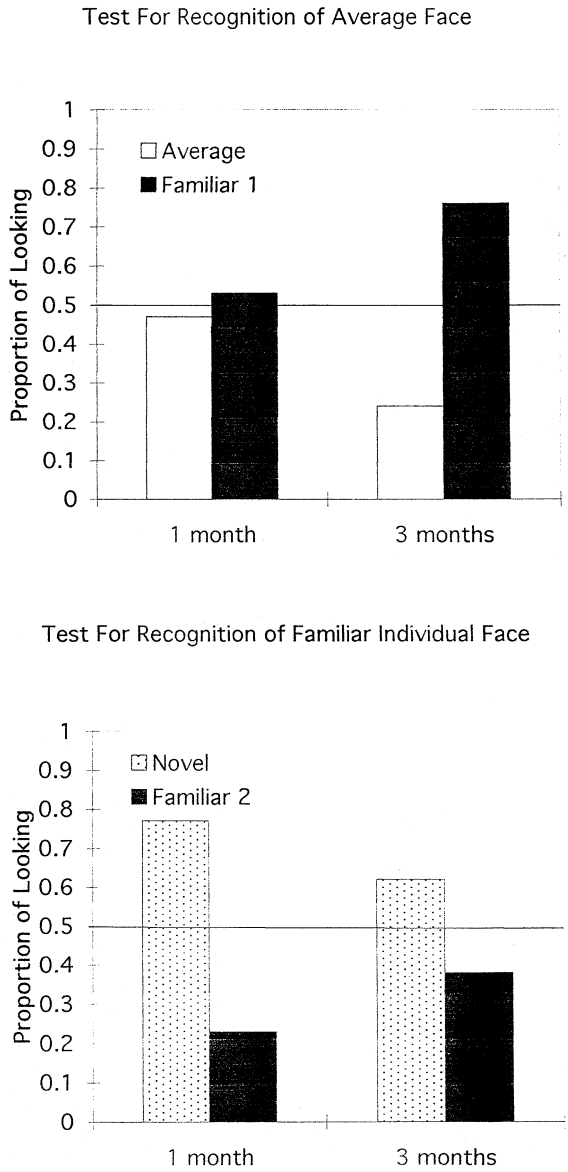

Fig. 2. One-month-olds' ($n = 12$; left bars) and 3-month-olds' ($n = 12$; right bars) mean proportion of looking to each face in the Average versus Familiar Individual Face test trial (top) and in the Novel versus Familiar Individual Face test trial (bottom) in Experiment 1. The horizontal line at 0.5 shows the level of looking to each face expected by chance.

3.3. Discussion of experiment 1

The goal of this study was to determine whether 1- and 3-month-olds could form an average prototype representation of a group of faces. As predicted, only 3-month-olds showed evidence of recognizing the average of the four faces seen during familiarization. They showed this by looking longer at the familiar face than at the average of the four familiarization faces during the first test, presumably because the average looked even more familiar than the individual face they had seen before. Infants at both ages demonstrated that they recognized individual faces by looking longer at the novel face than the familiar face during the second test. This shows that the stimuli were visible and discriminable to babies of both ages.

While the results are consistent with the hypothesis, one must be cautious in concluding that the null results of the 1-month-olds really indicate a failure to recognize the average face. One explanation is that too few examples were shown during familiarization. In models of concept formation, the prototype is a memory-saving alternative to storage of individual examples when there are a large number of examples to be remembered (Medin, 1989). Thus, 1-month-olds might have stored only the four individual faces and not formed a representation of the prototype because the memory demands were too low. However, the finding that 3-month-olds tested under the same conditions did recognize the average face argues against this view. Moreover, norm-based or prototype models of face recognition differ from models of concept representation in that, unlike the latter, the former assume that both the different individual faces and the prototype are stored (Valentine, 1991).

One alternate explanation is that the pairing of the average face with an individual face seen during familiarization was too difficult a test for the 1-month-olds because both the average face and the familiar exemplar looked familiar to them, and the relative greater novelty of the individual familiar face compared to the average face was not compelling enough to elicit longer looking. If this is the case, then 1-month-olds should look longer at a novel individual face than at the average face following familiarization. This possibility was tested in Experiment 2. Another alternative explanation for 1-month-olds' failure to provide evidence of recognizing the average face in Experiment 1 is that they have a preexisting bias to look at the average face. If so, the 1-month-olds' approximately 50% looking to the familiar individual face following familiarization is actually an increase over a baseline value. This possibility was tested in Experiment 3 by investigating whether there are preferences for looking at the average face without prior familiarization.

4. Experiment 2

The purpose of Experiment 2 was to determine whether 1-month-old infants would show evidence of recognizing the average face following

familiarization if the test was made easier by pairing the average face with a novel individual face.

4.1. Method

4.1.1. Participants

The participants were twelve 1-month-olds ($M = 33$ days, range = 21–35). Half the participants were male. An additional four babies were tested but were excluded because they fell asleep.

4.1.2. Stimuli

The stimuli were the same as those used in Experiment 1.

4.1.3. Procedure

The procedure was identical to that used in Experiment 1 except that during the first two trials of the test phase the average face was paired with a novel face rather than one of the four familiarization faces.

4.2. Results

4.2.1. Familiarization

To determine whether infants showed habituation of looking across the four familiarization trials, a mixed ANOVA was performed with Sex (male, female) as the between-subjects factor and Trial (1, 2, 3, 4) as the within-subjects factor. There were no significant effects.

4.2.2. Test of average versus novel

To test whether 1-month-olds would show evidence of recognizing the Average Face when it was paired with a Novel Face, we computed a mixed two-way ANOVA with Sex (male, female) as the between-subjects factor and Face (average, novel) as the within-subjects factor. None of the effects were significant. Infants did not look significantly longer at the Novel Face ($M = 0.52$, S.D. = 0.26) than the Average Face ($M = 0.48$, S.D. = 0.26) and thus did not provide evidence of recognizing the Average Face (see Fig. 3).

4.2.3. Test of novel versus familiar

To test whether infants recognized the familiar face we computed a mixed two-way ANOVA with Sex (male, female) as the between-subjects factor and Face (familiar, novel) as the within-subjects factor. There was a main effect of Face, $F(1,10) = 39.40$, $P < .01$, which occurred because the infants looked longer at the Novel ($M = 0.80$, S.D. = 0.16) than at the Familiar Face ($M = 0.20$, S.D. = 0.16; see Fig. 3).

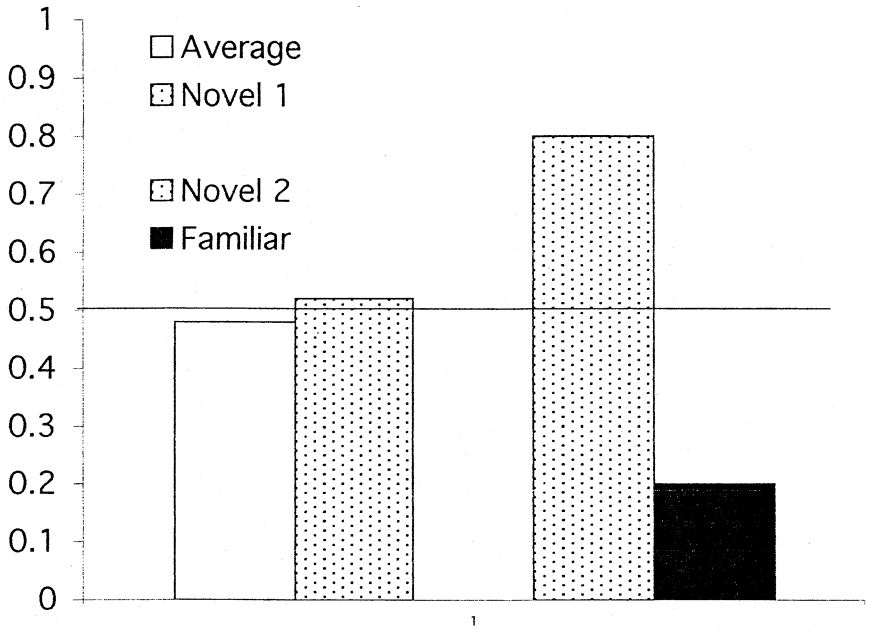

Fig. 3. One-month-olds' ($n = 12$) mean proportion of looking to each face in the Average versus Novel Individual Face test trial (left) and in the Familiar versus Novel Individual Face test trial (right) in Experiment 2. The horizontal line at 0.5 shows the level of looking to each face expected by chance.

4.3. Discussion of Experiment 2

One-month-old infants showed no evidence of recognizing the average of four faces they had seen during habituation, even when the average was paired with an entirely novel face. The failure to recognize the average is consistent with the results of Experiment 1 and suggest that the null result of Experiment 1 was not due to the difficulty of the test used to assess recognition of the average face. In contrast, 1-month-olds did show evidence of recognizing a familiar individual face by looking longer at a novel than a familiar individual face. These results replicate the results of Experiment 1 and show that the failure to recognize the average face was not due to a general failure to attend or encode the familiarization faces.

While 1-month-olds showed no evidence of recognizing the average face (they did not look longer at a novel face than the average face in Experiment 2), they also did not treat it as an entirely novel face (they did not look longer at the average face than a familiar individual face in Experiment 1). One-month-olds' pattern of looking times might reflect the "ambiguous" state of the average face for infants who can only store individual faces in memory. On the

one hand, the average face is novel because the exact face has never been experienced before (and for this reason one might predict no difference in looking when it is paired with a novel individual face as was the case in Experiment 2). On the other hand, even to infants who cannot compute the average, it may seem more familiar than a truly novel face because it is more similar to the four familiar faces of which it is composed (and for this reason one might predict no difference in looking when it is paired with a familiar individual face as was the case in Experiment 1).

The results of Experiments 1 and 2 together support the hypothesis that at 1 month of age infants are able to encode individual faces but do not recognize an average of a set of individual faces. However, one rival hypothesis that still remains is that 1-month-olds failed to provide evidence of recognizing the average face in Experiment 1 because they have a preexisting bias to look at the average face. This possibility was tested in Experiment 3.

5. Experiment 3

The purpose of Experiment 3 was to determine whether there is a spontaneous preference to look longer at the average face than at one of the individual faces that contributed to the average. Infants were presented with the first two test trials of Experiment 1, but *without* the preceding familiarization phase. We tested both 1- and 3-month-old infants so that we could assess the impact of spontaneous preferences on the previous results at both ages.

5.1. Method

5.1.1. Participants

The participants were twelve 1-month-olds ($M = 30.25$ days, range 21–35) and twelve 3-month-olds ($M = 82.58$, range = 80–89). Half the participants at each age were male. An additional four 1-month-olds were tested but were excluded because they fell asleep during testing ($n = 1$) or showed a side bias ($\geq 85\%$ of total looking to one side; $n = 3$) and an additional six 3-month-olds were tested but were excluded because they showed side bias.

5.1.2. Stimuli

The stimuli were the four individual faces shown during familiarization in Experiments 1 and 2, and the average of the four.

5.1.3. Procedure

The test consisted of two trials during which the average face and one of the four faces that made the average were presented in the same way as in Experiment 1.

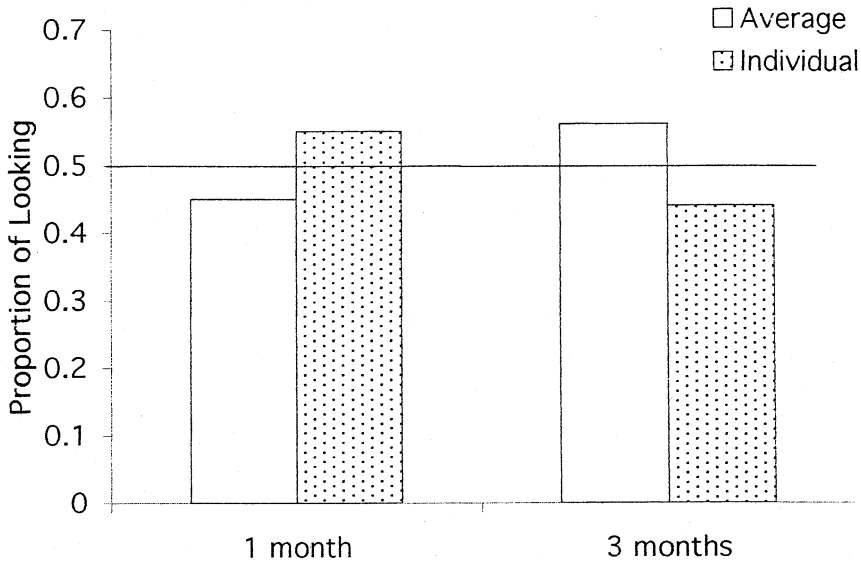

Fig. 4. One-month-olds' ($n = 12$; left bars) and 3-month-olds' ($n = 12$; right bars) mean proportion of looking to the average face and an individual face in Experiment 3. The horizontal line at 0.5 shows the level of looking to each face expected by chance.

5.2. Results

The data were analyzed in a mixed three-way ANOVA with Sex and Age as the between-subjects factors and Face (average, individual) as the within-subjects factor. The means are displayed in Fig. 4. The only significant effect was an Age × Sex × Face interaction, $F(1,20) = 13.55$, $P < .01$. Follow-up F tests at each age showed that this was due to a significant Sex × Face interaction for 3-month-olds only, $F(1,10) = 26.86$, $P < .01$. This occurred because 3-month-old girls looked longer at the Average ($M = 0.74$, S.D. = 0.21) than at the Individual Face ($M = 0.26$, S.D. = 0.21), but 3-month-olds boys did not.

5.3. Discussion of Experiment 3

The results of Experiment 3 show that 1-month-olds do *not* show a bias for looking towards or away from the average face. Thus, their failure to look longer at a novel or familiar individual face than at the average face in Experiments 1 and 2 cannot be due to a spontaneous preference to look at the average face. Rather, it seems likely that the 1-month-olds did not form an average representation of the four faces shown during familiarization.

In contrast to the 1-month-olds and the 3-month-old boys, 3-month-old girls showed a preference for looking at the average face compared to an individual

face. The basis of this preference is not clear. It is known that adults consider average faces more attractive than individual faces, and that 3-month-olds look longer at attractive than unattractive faces (Langlois, Ritter, Roggman, & Vaughn, 1991). Thus, it may be that 3-month-old girls prefer the average face because it is more attractive (see General Discussion). However, this conclusion must be tentative because the average was made of only four faces and even adults require averages across greater numbers before they consider the average more attractive than an individual face (Langlois et al., 1991).

Whatever the reasons for 3-month-old girls' preference for the average face, the result strengthen the findings of Experiment 1. It shows that the familiarization procedure actually shifted the girls' looking not just from chance looking to a preference for the familiar individual face, but from a preference for the average face to a preference for the familiar individual face.

6. General discussion

The aim of this study was to determine whether there are changes between 1 and 3 months of age in the ability to form a prototype representation of faces experienced in the visual environment. Based on Johnson and Morton's (1991) two-process theory of face recognition, we predicted that only 3-month-olds would be able to do so because this ability relies on cortical systems that do not become functional until 6–8 weeks of age. However, based on the results of previous studies (e.g., Pascalis et al., 1998; Pascalis & de Schonen, 1994), we expected infants at both ages would be able to recognize individual faces following familiarization. Overall, the pattern of results supports these predictions.

Following familiarization to four individual faces, both 1- and 3-month-olds showed evidence of recognizing the individual faces but only 3-month-olds showed evidence of recognizing, and thus having mentally computed, the average of the four face stimuli. These results are consistent with previous results showing that by 3 months of age infants can form categories of complex, natural stimuli (e.g., Eimas & Quinn, 1994; Quinn et al., 1993) and with previous reports showing that 6-month-olds and older infants can form average prototypic representations of faces (Rubenstein et al., 1999; Strauss, 1979). We demonstrate for the first time that, when tested with the same procedure as older infants, 1-month-olds do not show evidence of forming average prototypic representations of faces. This suggests that, while infants can memorize individual faces from birth (e.g., Pascalis & de Schonen, 1994), only by sometime between 1 and 3 months of age are they beginning to be able to relate these isolated bits of information. In other words, only at this time will their previous experience with faces affect how they encode a new face. As discussed in the Introduction, one way adults are thought to encode new faces is relative to a prototype representation (Benson & Perrett, 1991; Mauro & Kubovy, 1992; Rhodes, 1993; Rhodes et al., 1993). Evidence that adults find distinctive, unusual faces easier to remember

than typical faces (Light, Kayra-Stuart, & Hollander, 1979; Valentine & Bruce, 1986) and sometimes find caricatures easier to recognize than veridical portraits (Mauro & Kubovy, 1992; Rhodes, Brennan, & Carey, 1987; but see Benson & Perrett, 1991; Tversky & Baratz, 1985) supports this view. That the prototype is likely based on the individual's experience with faces in the visual environment is supported by studies showing other-race and other-species effects: Adults are worse at recognizing novel members of other races or other species than at recognizing novel members of their own race and species, presumably because the latter can be more easily related to the prototype formed from faces seen most frequently in their daily experience (Rhodes, Tan, Brake, & Taylor, 1989). The two process theory of face processing during infancy (Johnson & de Haan, 2001) would predict that these effects would emerge only after the cortical system has become functional.

The hypothesis that before 2 months infants only process faces at the individual level might seem inconsistent with evidence showing that newborns orient preferentially to faces, which suggest that even at this early age they have formed a category of "face" (e.g., Johnson et al., 1991; Mondloch et al., 1999). However, this early preference for faces is believed to be due to a subcortical congenital bias rather than infants' experience with particular individual faces in the environment. Thus, the change between 1 and 3 months can be described as the emergence of cortical processing systems that allow formation of a category of face *based on baby's visual experience with individual faces*. The purpose of newborns' preference may in fact be to orient babies to faces in the visual environment to provide input to developing cortical circuits.

One finding that could be taken as evidence against the view that infants' ability to form a prototypic representation of faces emerges only by about 3 months of age is that newborns are able to recognize the mother's face (e.g., Pascalis et al., 1995). Given that every time the infant views the mother s/he must see her from at least slightly different perspectives it could be argued that the newborn could not recognize her without having formed a prototype. We disagree with this view for two reasons. First, some apparent "generalization" early in life may in fact be due to lack of discrimination—infants may respond similarly to two views of the mother not because they categorize them as the same but because they cannot perceive the difference between the two. Second, the available evidence suggests that young infants do not have a generalized representation of the mother. For example, newborns appear to recognize the mother's face on the basis of external features, such as her hair (Pascalis et al., 1995) and they do not recognize her face in profile (Sai & Bushnell, 1988). In contrast, 3-month-olds can recognize a face across different views on the basis of only the internal facial features (Pascalis et al., 1998). This evidence supports the view that there is a fundamental change around 3 months of age in the way faces are processed, even though recognition of individual faces is possible earlier using different mechanisms.

Some investigators have argued that infants' ability to form average prototype representations underlies their reactions to attractive versus unattractive faces (Rubenstein et al., 1999). Research demonstrates that (a) adults judge average faces as more attractive than individual faces, (b) 3-month-old infants look longer at attractive than unattractive faces, (c) 6-month-old infants are able to form average representations of faces, and (d) 6-month-old infants look longer at an average face than an individual face that contributed to the average (Langlois et al., 1991; Langlois & Roggman, 1990; Langlois, Roggman, & Musselman, 1994; Rubenstein et al., 1999). Our finding that 3-month-olds are able to recognize an average prototype composed of individual familiar faces supports these findings. However, recently it has been reported that even newborns look longer at attractive than unattractive faces (Slater et al., 1998), despite having had little experience from which to form a prototype and, based on our findings with 1-month-olds, lacking the cognitive capacity to do so. Thus, something in addition to averageness may draw infants to look at attractive faces. Indeed, research with adults indicates that averageness is only one of a set of characteristics that contribute to judgements of attractiveness (Perrett, May, & Yoshikawa, 1994: Vokey & Read, 1995). In other words, newborns' and older infants' reactions to attractive faces are not necessarily based *only* on the averageness of the face and may also or instead be based on some other characteristic (Geldart, Maurer, & Carney, 1999; Geldart, Maurer, & Henderson, 1999). Moreover, there are likely to be developmental changes in the characteristics that draw infants' attention to attractive faces as, with increasing age, they scan the internal features more thoroughly (Maurer & Salapatek, 1976) and learn to decode facial expression (reviewed in de Haan & Nelson, 1998).

The results of Experiment 3 provide direct evidence that averageness does not attract the looking of young infants, at least when the average is formed from four faces. In that experiment we tested directly whether infants would treat the average face like an attractive face and look longer at it than at an individual's face. We found no evidence of preference for the average before 3 months of age, and at 3 months only girls preferred looking at the average face. These results should be interpreted with caution because the average was made of only four faces, and even adults require averages across greater numbers before they consider the average more attractive than an individual (Langlois et al., 1991). However, overall our findings do suggest that it may only be around 3 months of age that averageness begins to contribute to babies' responsiveness to attractive faces.

The overall pattern of results is consistent with Johnson and Morton's (1991) two-process theory, which postulates that there is a change in the nature of face processing over the first 6–8 weeks of life due to functional emergence of cortical systems. In adults there is evidence to suggest that face processing is mediated by specialized cortical systems different from those used to process most other types of object (reviewed in Farah, 2000 and Tovee, 1998). Does the emergence of infants ability to form prototypic representations of faces reflect the emergence of a face-specific cortical system? The finding that at 3 months babies can also form

prototypes of patterns of dots (Bomba & Siqueland, 1983) suggests that the ability to form prototypic representations is not specific to faces, but may be a general mechanism whereby the infant perceives structure in the visual world. Specialization of the cortical systems mediating face processing might emerge due to a combination of factors including (a) subcortical mechanisms that function to guide infants' visual attention to faces during the first weeks of life, biasing the input to the developing cortical system such that when it emerges it is particularly useful or efficient for processing faces and (b) increasing experience with faces and increasing demands to remember more and more individual faces as infants develop. Further experiments in which memory for faces and other objects are compared can help to address this question.

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