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Contribution of Motion Information to Maternal Face Discrimination in Infancy

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The contribution of motion and feature invariant information in infants' discrimination of maternal versus female stranger faces was assessed. Using an infant controlled habituation–dishabituation procedure, 4- and 8-month-old infants (N = 62) were tested for their ability to discriminate between their mother and a female stranger in 4 different conditions varying whether motion or feature information about the faces was available. The faces were presented in a still or dynamic video image with either a positive or a negative contrast. In each condition, infants habituated to a stranger's face and then viewed, in 3 pairs of alternating novelty test trials, either a new stranger or their mother's face. Results show that motion information contributes to the 8-month-old infants', but not the 4-month-old infants' discrimination of maternal faces. These results are interpreted in relation to recent findings and models in the adult literature suggesting that there is an enhanced contribution of dynamic information in face recognition when the face is familiar. Our data confirm that from the outset, there is a complex interplay of feature and motion information in the discrimination of the mother's face when the viewing condition is not optimal.

Recent adult literature on face identification and recognition documents the combined role of information specifying invariant facial *feature* structure and *motion* structure of idiosyncratic facial movements and gestures (O'Toole, Roark, & Abdi, 2002). In their review of the adult literature, O'Toole et al. (2002) showed that in general, motion information is an important contributor of face recognition under nonoptimal viewing conditions. These conditions typically affected the facial feature structure via blurring, inversion, depixelation, or the use of photographic negatives (Knight & Johnson, 1997; Lander, 2001; Lander & Bruce, 2000).

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Research consistently demonstrates that motion information available in the moving display of faces either supplements or enhances invariant facial feature information when viewing conditions are impoverished. However, this phenomenon is particularly evident when familiar faces are involved. This suggests that the use of motion as either supplementing or enhancing structure information of a face necessitates learning. In an analogous way, it is only via learning that one can detect the motor signature or idiosyncratic "vitality contours" that specifies a familiar face in motion (see Stern, 1999).

In this research, we investigate whether the interplay between feature and motion detection in face recognition reported in adults is deeply rooted in development. The question is, can such interplay be observed from the outset, when infants begin to show discrimination of familiar and unfamiliar faces? Our goals were (a) to tentatively replicate findings with infants on the recognition of moving faces that are now well documented and modeled in the adult literature; (b) to consider the extent to which infants, as they learn to discriminate faces, show analogous interplay between feature and motion information; and (c) ultimately to document the importance of motion information in early social cognition.

As a general rationale, and in relation to the ultimate goal of the study, we considered the fact that infants first learn to discriminate faces in nonoptimal viewing conditions, due mainly to the slow development of contrast sensitivity and focal vision that normally takes place over the first 6 to 8 postnatal months (Banks & Dannemiller, 1987; Rochat, 2001). In reference to the adult literature, we thus hypothesized that motion, as opposed to feature information, might play a particularly important role in the developing ability of young infants (less than 1 year old) to discriminate the faces of familiar people to whom they eventually attach to survive.

Infants are reported from birth to discriminate among moving facelike displays (two-dimensional sketch of eyes, nose, and mouth) that are either in a canonical (right side up) or noncanonical organization (scrambled or inverted). Newborns tend to track more canonical than noncanonical facial displays that are rigidly moving in their field of view (Morton & Johnson, 1991). Some research also suggests that infants less than 1 month old differentiate familiar and unfamiliar faces (Slater & Butterworth, 1997), and even prefer to look at faces that are typically considered by adults as more "attractive," showing greater regularity and symmetry of features (Slater et al., 1998). These facts would suggest that as a species we evolved sophisticated face detection systems that are expressed from birth on (Morton & Johnson, 1991). Although such systems might form an innate basis for the development of social cognition, other research shows that much development in face discrimination occurs in the first 8 months of life.

Between birth and 5 months, infants' sensitivity to internal facial features (nose, eyes, or mouth) as opposed to external features (hairline or ear position) increases (e.g., Bushnell, 1982; Ellis, Shepard, & Davis, 1979; Haith, Bergman, & Moore, 1977; Morton, 1993). Infants younger than 2 months rely on areas of high contrast (e.g., face to hair) and external cues (face shape or placement of the ears) to discriminate between faces (Bushnell, Sia, & Mullin, 1989; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995). By 2 to 3 months, infants discriminate between their mother and a stranger even when external features (i.e., hairline and ears) are masked (Morton, 1993).

By at least 4 to 5 months, infants appear to pick up invariant facial feature structure in their discrimination of faces, namely the complex individual characteristics and spatial relations between eyes, nose, and mouth as prominent features of the face (Ellis et al., 1979). Already by 3 months, in an optimal viewing condition, infants are shown to discriminate among individual static faces, even recognizing a computer-generated face that is an average of the features of faces experienced prior (de Haan, Johnson, Maurer, & Perrett, 1999). This research indicates that from at least 3 months, infants are able to form fast prototypic representations of faces. By 3 to 5 months, in optimal viewing conditions, the discrimination among unfamiliar faces is enhanced when faces are moving as opposed to static (e.g., Otsuka, Kanazawa, Yamaguchi, O'Toole, & Abdi, 2005). By this age, infants seem already capable of picking up dynamic feature information to discriminate among faces and other dynamic displays (see Bertenthal, Proffitt, & Cutting, 1984; Bertenthal, Proffitt, Spenter, & Thomas, 1985).

From an information-processing perspective, face discrimination seems to develop from discrete toward more integrated processing of features, a general pattern found in other perceptual and cognitive domains (Cashon & Cohen, 2001). For example, by 3 months infants discriminate upright faces by processing discrete internal features. By 7 months, they integrate internal and external features of the face in their processing when faces are presented upright, but not when presented in an inverted orientation (Cohen & Cashon, 2001).

Aside from mere information-processing capacity development, from the outset, face discrimination depends on social experience, namely familiarity and relative exposure to particular persons. By 4 days of age, newborns tend already to look longer at their mother's static face than at a stranger's face. However, this evidence of maternal face discrimination by newborns disappears when the mother or the stranger is wearing a headscarf, suggesting that hairline features, rather than internal facial features, are the basis of this early discrimination (Pascalis et al., 1995). By 2 months, infants start to discriminate their mother's face from a stranger's face with or without a headscarf (Bartrip, Morton, & De Schonen, 2001). As discussed prior, infants begin to process discrete internal features of their mother. Between 3 and 7 months infants develop the ability to process faces as a second-order, integrated structure of external and internal features (Cashon & Cohen, 2004; Cohen & Cashon, 2001; de Haan et al., 1999). This ability enables infants to differentiate between familiar and unfamiliar faces (e.g., their mother's from a stranger's), presumably with more accuracy because they detect invariant structures that are less dependent on particular viewing conditions. These conclusions, however, are based mainly on the presentation of static faces in optimal viewing conditions.

The question raised here is whether the processing of dynamic information contributes to the detection of invariant facial features in nonoptimal viewing conditions. More precisely, we ask whether infants, by 8 months, rely more on motion information to enhance or supplement invariant structures of facial features when viewing conditions are not optimal, a phenomenon that is reported in the adult literature (O'Toole et al., 2002).

We investigated this question by using an infant-controlled habituation/dishabituation paradigm (Cohen & Cashon, 2001). In four independent conditions infants were first habituated to the image of a female adult stranger face, then tested while viewing either the face of a new female stranger or the face of their own mother. We measured the relative recovery of looking to the two new posthabituation test trials.

In each condition, the faces were either static (still photo) or dynamic (video recording of the talking face). Furthermore, in both static and dynamic conditions, the still photo or the dynamic video was either in a normal positive contrast presentation (optimal viewing) or in a negative contrast presentation (nonoptimal viewing). Negative presentation of face affects the clarity of the distinct facial features, a major impediment of face recognition in adults (Knight & Johnson, 1997; Lander, 2001; Lander & Bruce, 2000). Finally, considering the development of face processing in the first 7 months (Cohen & Cashon, 2001), we tested infants older and younger than 6 months, respectively, clustered in groups of 4- and 8-month-olds.

The goal was to capture possible developmental changes in the role of motion in maternal face discrimination when the context was of optimal (positive) and nonoptimal (negative) viewing conditions.

As a working hypothesis, we expected that, at least for the 8-month-olds, we would replicate what is now well documented in the adult literature, namely that motion information enhances or supplements familiar face discrimination when viewing conditions are nonoptimal (i.e., negative images).

METHOD

Participants

A total of 65 infants, age 6.39 months on average (47% boys, 53% girls), were tested to form two final age groups of 32 four-month-olds ($M = 4.50$, $SD = 0.22$) and 32 eight-month-olds ($M = 8.29$, $SD = 0.226$), with clear-cut age difference and no overlap. Gender was counterbalanced across age and conditions. A 2 (age) × 4 (condition) analysis of variance (ANOVA) testing the difference in months between the two groups yielded a highly significant age main effect, $F(1, 3) = 20.608$, $p < .0001$, and no significant Age × Condition interaction, $F(1, 3) = 1.65$. One 4-month-old was not included in the final sample due to fussiness. All participants were healthy, full-term infants with no known history of visual impairments. Infants were born of predominantly (90%) middle-class White families and recruited from a large maternity hospital in suburban Atlanta, Georgia.

Procedure and Design

As shown in Figure 1, the testing session consisted of an orientation pretest, a habituation phase, a posthabituation test, and a repeated posttest to assess overall fatigue. The pre- and posttest consisted of a simple display involving two balls moving across the screen. Each trial started with an attention getter consisting of a looming and zooming colorful circle. Once the experimenter determined that the infant was attending to the TV monitor, the successive trials of the habituation phase began. Each habituation trial ended if 20 sec of looking time accumulated or if a total of 1 sec of look-away time (time spent looking at anything other than the television) occurred. A habituation trial was repeated if the infant did not reach a minimum of 2 sec of looking time over the first 10 sec of a trial. The habituation phase ended when infants reached the criterion of looking at 50% or less of the preceding 4 trials or being presented with the maximum of 16 habituation trials (minimum of 5, maximum of 16). These parameters were implemented based on the Cohen and Cashon (2001) procedure, which used similar parameters in their investigation of infants' perception of internal and external facial features.

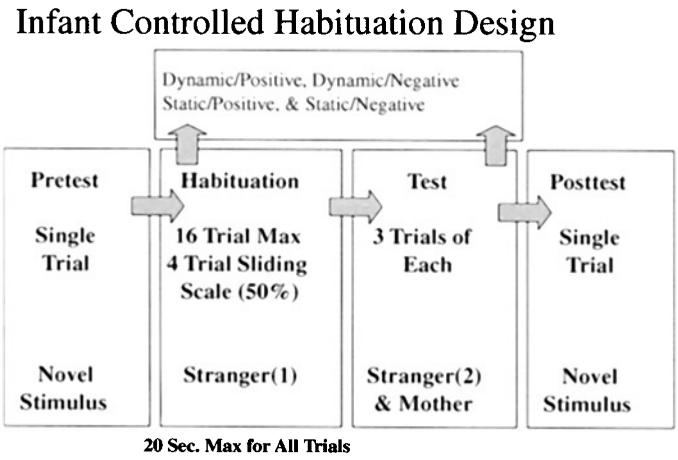

FIGURE 1 Diagram of the design.

During habituation and in all conditions, infants were presented with the same unfamiliar person (female stranger) on each trial. This stranger was unknown to the infant. Once the habituation criterion was reached, the posthabituation test phase began with the TV presentation of three pairs of successive trials with either the image of a new stranger (unknown to the infant) or the face of the child's mother. The order of presentation of new stranger and mother was counterbalanced across infants in all conditions.

Each infant was habituated and tested in one of four conditions (between-subject design; see Figure 1; $n = 16$ per age in each condition). The four conditions (dynamic/positive, dynamic/negative, static/positive, static/negative) were randomly assigned.

1. Dynamic/positive condition: Regular silent video clip of the moving and talking but silent face in full color, providing both feature and dynamic cues.
2. Dynamic/negative condition: Silent video clip of the moving and talking but silent face in negative, providing nonoptimal viewing with impoverished feature cues (Knight & Johnson, 1997).
3. Static/positive condition: Still of the face providing clear static feature cues but no dynamic cues.
4. Static/negative condition: Still of the face providing nonoptimal viewing with impoverished feature cues and no dynamic cues.

Measure

The dependent measure consisted of infant looking time at the television monitor during habituation and test trials. Because infants' attentiveness, habituation, and overall looking time at the image vary greatly, data were reduced to a comparable ratio for later statistical comparisons (see also Rochat, Striano, & Morgan, 2004). T ratios were calculated for all infants by dividing the looking duration during each posthabituation test trial by the average looking duration of the last four habituation trials. For all infants, a T ratio of 1 or less indicated no dishabituation with either equal or more looking during the last four habituation trials, than during test trials of either the mother or a new stranger. A T ratio greater than 1 indicated dishabituation, with infants looking longer at the display during test trials compared to the average of the last four habituation trials.

Stimuli

All face stimuli were recorded from a Canon Optura 20 Digital Mini DV camcorder and captured on an Apple PowerBook G4 using iMovie. All recorded participants wore the same blue scrub top and hat, revealing only the internal features of the face while sitting in front of a white background. From the approximately 3-min recording during which mothers were asked to tell an experimenter how they chose the name of their child, a 20-sec clip, a still frame, or both were exported and edited using Macintosh iMovie software. The 20-sec clips were chosen using three basic guidelines: Clips should not contain any unintentional cues for discrimination such as sneezing or scratching of the face. All clips needed to include both rigid facial movements such as turning from side to side, and nonrigid facial movements, such as smiling and talking. In all, the criteria were for the movements to appear natural and not forced. The stills were chosen to capture a "neutral" expression, a straight-ahead gaze at the camera with no smile or other marked emotional expression. This editing was performed at the beginning of the session prior to testing. It took approximately 15 min, during which the mother was asked to play with her child in an adjacent room.

Once the clip, still, or both were exported, Adobe After Effects 6.0 for Macintosh software was used to apply the negative effect (see conditions later) and to adjust the head's central location on the monitor and its size corresponding to 1/1, "real" scale (see Figure 2). The negative effect applied consisted of a color inversion of the face. This software was also used to create the clips used for the attention getter, pretest and posttest.

Apparatus

Infants sat on their mother's lap in front of a 90-cm Panasonic Color View Monitor located approximately 150 cm from the infant. To control for inadvertent cuing, mothers wore opaque glasses preventing them from seeing what was shown to their infant. They were also instructed not to talk to their child. Above the monitor was a small closed circuit television camera (Panasonic, black and white) providing a view of the infant's face as he or she watched the monitor. This view was used to record visual attention. In an adjacent area separated by a curtain, the experimenter was able to view the images from this camera on a 40-cm Panasonic color monitor. The experimenter recorded the infants' looking using an Apple PowerBook G4 running HabitX software (Cohen, Atkinson, & Chaput, 2004). HabitX was also used to control the presentation of stimuli while looking times were recorded online with set habituation criteria computed by Cohen's HabitX software, which was graciously made available for this experiment. Looking times for all participants were recorded online during testing on the computer running Habit X software by pressing assigned keys while monitoring the child. In replay sessions of the video, recordings were reanalyzed by another coder for reliability calculation (20% of the total number of tested infants, randomly picked across ages and conditions as well as for all phases of the procedure). The mean Pearson correlation coefficient between the two independent coders for all sessions was 97.29 (*SD* = 2.52) with a maximum of 99.7 and minimum of 89.3.

FIGURE 2 Illustration of the same face presented in an optimal (positive) and nonoptimal (negative) condition.

RESULTS

The looking duration at the two balls moving across the TV screen during pre- and posttest trials was comparable for both age groups. There was no significant decrease, and hence no evidence of overall fatigue.

On average, infants reached habituation criterion in 11.27 trials (*SD* = 3.37). A 2 (4- vs. 8-month-olds) × 2 (static vs. dynamic) × 2 (positive vs. negative) mixed factorial ANOVA yielded only a main effect of static versus dynamic, $F(1, 63) = 6.343, p < .015$. Infants presented with static displays habituated in 12.31 trials (*SD* = 3.33), whereas infants shown dynamic displays reached habituation criterion in only 10.22 trials (*SD* = 3.37). No significant difference between the two age groups, no effect of gender, and no significant interaction between these factors were found.

During habituation, in the optimal (positive picture) viewing conditions, infants looked at the face display on average a total of 99.26 sec (*SD* = 42.35 sec) against 68.20 sec (*SD* = 29.88) in the nonoptimal (negative picture) conditions. This difference was significant, $F(1, 63) = 12.58, p < .001$. During habituation, regardless of conditions, 4-month-olds accumulated significantly more looking time compared to the 8-month-olds, $F(1, 63) = 10.21, p < .002$. This developmental pattern is consistent with what is reported in the literature using the same procedure with comparable age groups (Rochat et al., 2004).

Regarding the actual posthabituation recovery test of discrimination between new stranger's and mother's faces, T ratios were calculated for all infants, dividing the looking duration during posthabituation test trials by the average looking duration of the last four habituation trials (see measure in "Method" section earlier for more details). Table 1 presents the aggregated mean looking time according to age and condition during the last four habituation trials and during the novelty posthabituation test trials that involved either a new stranger or the mother.

Using the T ratio measure, we performed an overall 2 (age: 4- vs. 8-month-olds) × 2 (movement: static vs. dynamic) × 2 (viewing condition: positive vs. negative

TABLE 1
Mean Looking Time in Seconds and Standard Deviation During the Last Four Habituation Trials (Habituation) and the Posthabituation Tests Involving the New Stranger (Stranger) or the Mother (Mother) as a Function of Age and Condition

	C1		*C2*		*C3*		*C4*	
	4 Months	*8 Months*	*4 Months*	*8 Months*	*4 Months*	*8 Months*	*4 Months*	*8 Months*
Habituation								
M	6.94	5.04	5.50	3.39	4.46	3.83	4.98	2.66
SD	1.68	1.02	2.33	0.82	0.98	1.90	1.92	1.55
Stranger								
M	13.45	9.88	11.02	7.09	5.01	3.20	4.77	2.49
SD	3.91	2.85	4.60	1.82	1.97	1.28	2.13	0.83
Mother								
M	14.94	12.67	9.70	10.44	4.96	8.03	4.56	2.45
SD	2.08	4.19	2.90	3.90	2.17	2.96	1.81	0.32

Note. C1 = dynamic/positive; C2 = static/positive; C3 = dynamic/negative; C4 = static/negative.

image) × 2 (familiarity: new stranger vs. mother's face) mixed design ANOVA with familiarity as a repeated measure. The ANOVA yielded a significant four-way interaction, $F(1, 56) = 12.73, p < .001, \omega^2 = 0.939$; one significant three-way interaction (Movement × Viewing Condition × Familiarity), $F(1, 56) = 4.129, p < .047, \omega^2 = 0.515$; and one highly significant two-way interaction (Age × Familiarity), $F(1, 56) = 20.89, p < .0001, \omega^2 = 0.994$. For sake of clarity and considering the complex patterns of significant interactions, we tested for simple effects within each age group treated separately. Figures 3 and 4 present the average T ratio data for 4- and 8-month-olds, respectively, in all four conditions and relative to the measures of familiarity (average of the three repeated posthabituation test trials with either new stranger or mother's face). Note that the horizontal line on the graphs indicates the level of zero recovery, hence zero discrimination (T ratio of 1).

As shown in Figure 3, in the positive (optimal) compared to the negative (nonoptimal) viewing condition, the group of 4-month-olds demonstrated a marked increase in the value of the T ratio for both the new stranger's and the mother's face, independent of movement. For this age group, the ANOVA yielded only a significant main effect of viewing condition, $F(1, 28) = 35.71, p < .001$.

This result indicates that in the positive viewing condition, 4-month-olds discriminate both the new stranger's and their mother's face in the posthabituation tests. They fail to do so in the negative viewing condition, regardless of motion or familiarity. One-sample t tests of the observed T ratios against a ratio value of 1, which would indicate no change of visual attention, confirm these findings by

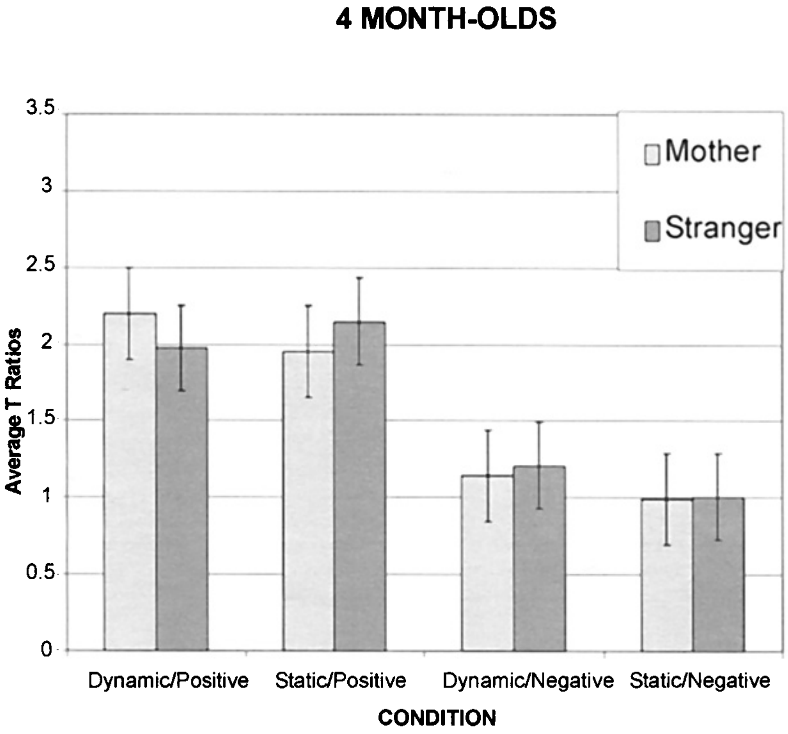

FIGURE 3 Results as average T ratios for the group of 4-month-olds. A T ratio of 1 (horizontal line) or less than 1 indicates no dishabituation (i.e., no recovery in looking times).

yielding significant results in the positive (optimal) viewing conditions only ($p < .01$) and none in the negative (nonoptimal) viewing conditions (see Figure 3).

As shown in Figure 4, the pattern of results regarding the T ratios of 8-month-olds across conditions and familiarity is more complex. An ANOVA for this group yielded a significant three-way interaction of movement (static vs. dynamic), viewing (positive vs. negative), and the repeated measure of familiarity (mother vs. new stranger), $F(1, 28) = 11.384, p < .002, \omega^2 = 0.903$.

The patterns of results are contrasted between the positive (optimal) and the negative (nonoptimal) conditions (see left and right halves of Figure 4). For the positive (optimal) viewing conditions, analysis of the simple effects yielded only a significant main effect of familiarity, $F(1, 14) = 15.354, p < .002$, and no significant interaction (see left half of Figure 4). In these optimal viewing conditions, T ratios for the mother were significantly greater than for the new stranger. Both faces were discriminated as novel by the infants, but significantly more so for the mother. One-sample *t* tests against the T ratio value of 1 yielded significant

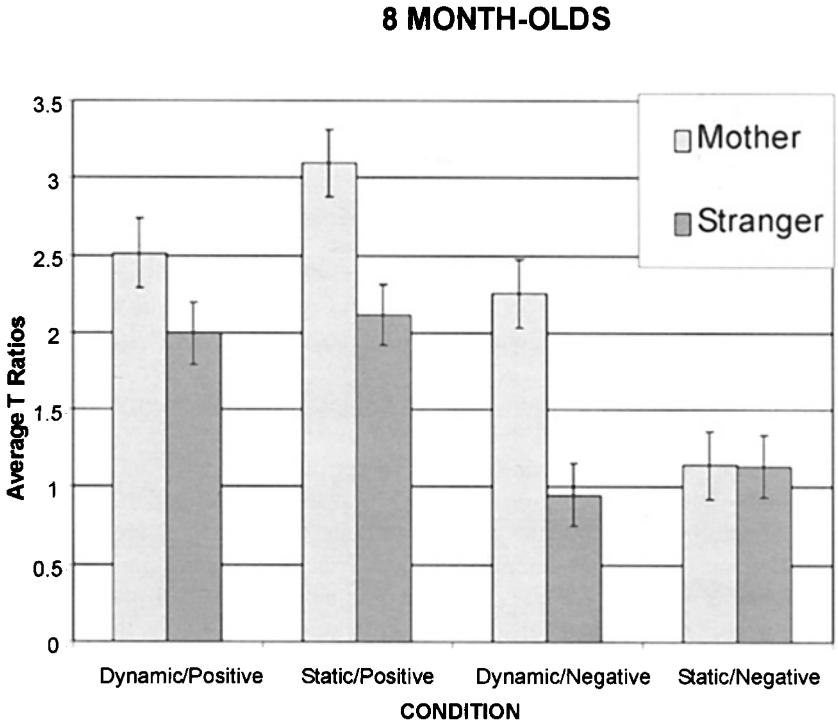

FIGURE 4 Results as average T ratios for the group of 8-month-olds. A T ratio of 1 (horizontal line) or less indicates no dishabituation (i.e., no recovery in looking times).

dishabituation (novelty effect) for both the mother and the new stranger, respectively, $t(15) = 9.346$, and $t(15) = 7.901$, $p < .001$.

For the negative (nonoptimal) viewing conditions, analysis of the simple effects yielded a significant Movement × Familiarity interaction, $F(1, 14) = 13.88$, $p < .002$ (see right half of Figure 4). This interaction rests on the fact that in the nonoptimal viewing condition, and when there is no motion, 8-month-olds do not demonstrate any posthabituation (novelty) discrimination for either their mother or a new stranger. In these conditions, T ratios averaged around 1 (see far right static-negative conditions of Figure 4).

In contrast, when there is motion, 8-month-olds show significant dishabituation (novelty effect), hence discrimination of their mother but not of the new stranger. This finding is critical in relation to our research question. It demonstrates that for 8-month-olds, motion information in negative (nonoptimal) viewing conditions does indeed contribute to the discrimination of familiar faces only. One-sample *t* test of observed T ratios against a T ratio of 1 (no discrimination) yielded a significant result for the mother's face only, $t(7) = 4.111$, $p < .005$, not for the new stranger's face, $t(7) = 0.270$, $p = 0.795$. This result is evident in Figure 4 (see the dynamic-negative conditions in the right half of the figure).

DISCUSSION

The question guiding this research pertains to the contribution of motion information to face recognition in early development. Based on phenomena reported in the adult literature (see O'Toole et al., 2002, for a review), we investigated whether young infants as they develop an ability to process and discriminate faces would demonstrate that, like adults, motion information contributes to the discrimination of faces in nonoptimal viewing conditions, particularly when the faces are familiar. Using an infant-controlled habituation procedure, our results corroborate such phenomena with 8-month-olds, but not with 4-month-olds.

In general, when the viewing is optimal (positive images), both 4- and 8-month-olds show face discrimination between a new stranger and the mother in posthabituation tests, recovering attention to both. This finding confirms that, in optimal viewing conditions, infants from an early age process invariant facial feature structures whether faces are presented in static or dynamic displays. We can assume that, at both ages, the discrimination reported here rests on the ability to process internal facial features because both mother and strangers wore a scrub hat. The scrub hat hid the particular hairline and other external features specifying the person's face. However, the process underlying the discrimination of internal facial features is probably not identical at either age. Past research shows that facial features tend to be treated as discrete entities around 3 to 4 months, and more as an integrated structure by 7 to 8 months (see Cashon & Cohen, 2004; Cohen & Cashon, 2001; de Haan et al., 1999). Although our data do not permit such distinction, presumably both ways of processing internal features allow infants to discriminate new familiar and unfamiliar faces in optimal viewing conditions.

The novelty detection measured by looking time increase during posthabituation trials referred to both a new unfamiliar face (new stranger) and a familiar face (the mother). Evidence for such detection could thus reflect both the detection of a perceptual novelty per se and the recognition of a familiar face (the mother). The procedure we used did not allow for a direct comparison of the two processes. However, our results in both optimal (positive images) conditions reveal an interesting developmental pattern suggesting that the recognition of the familiar face accounting for novelty discrimination begins to play a role only by 8 months, and not prior. Younger infants showed equal novelty discrimination for the new stranger and the mother in posthabituation trials. In contrast, 8-month-olds showed significantly greater novelty discrimination when their mother was the novel face during posthabituation trials. They discriminated the new stranger but showed relatively less marked discrimination compared to the mother's face (see Figure 4, left panel). This result suggests that by 8 months, infants are both discriminating and recognizing the novel face when familiar. By 4 months, infants behave as if they might just be discriminating face novelty independently of any recognition. More research should confirm and explore further the possibility of an increasing role of familiarity in face discrimination between 4 and 8 months, the age at which children become wary of strangers (see Spitz, 1965, regarding the 8-month-olds' anxiety).

Of interest is the fact that when the viewing conditions of faces are nonoptimal (negative images), rendering the extraction of invariant facial features more difficult, the infant's discrimination is strongly affected for all infants. However, the results show an exception for 8-month-olds tested with their mother. Despite the nonoptimal (negative) viewing condition, infants at this age appear to benefit from motion information. As for adults, 8-month-olds show that the combination of motion and familiarity compensates for the nonoptimal viewing condition of the face.

Research using point-light displays that specify biological motion shows that motion information and familiarity detection based on prototypes or canonical representations are evident from at least 3 months of age (see Bertenthal et al., 1984; Bertenthal et al., 1985). These findings fit nicely with the suggestion that from around the same age, face discrimination might begin to be based on prototypical representations of integrated features (de Haan et al., 1999). However, in relation to the findings reported here, it appears that it is only by 8 months that infants are able to use available motion information to compensate for the nonoptimal viewing condition in their detection of familiar faces.

The fact that this applies only to a familiar (i.e., mother's) face, and not the face of a new stranger, emphasizes the role of learning in such compensatory phenomenon. We can speculate that the information carried by motion requires some learning or representational template of the idiosyncratic, invariant ways a person moves. In other words, it could possibly require the learning and representation of the familiar person's motoric signature in moving her face while talking and interacting. From at least 8 months of age, motion information would contribute to infants' discrimination of their mother. The data reported here show that motion information does indeed contribute to 8-month-olds' discrimination of their mother when viewing conditions are not optimal. We did not find any signs of such contribution for faces that are less familiar.

An alternative account, however, would be that motion helps the infant to overcome the hindrance of the negative, nonoptimal viewing condition, by enhancing the features of the face. However, the fact that 8-month-olds are not helped by the addition of motion in the nonoptimal viewing condition when a new stranger is involved suggests that the effect of motion is more than a simple enhancement of facial features. It is more likely that motion information actually supplements feature information based on past learning and the opportunity to recognize how a person moves (here the mother). Presumably, because of the lack of feature information, infants relied on their past learning of invariant motion information that specifies their mother. Our data corroborate the fact that infants were not able to do so when a new stranger was involved; the addition of motion information was not enough to just enhance the facial features in the negative, nonoptimal viewing condition. Future research should be specifically designed to test the interpretation that by 8 months, infants begin to use motion information to recognize familiar individuals, especially when facial and other feature information is not readily available to them. In particular, research should explore further the extent to which infants by 8 months, and presumably not prior, could acquire motion information from brief dynamic exposure with a stranger and use this information cue to eventually recognize this person in an impoverished, nonoptimal condition.

In summary, the data reported here show that by 8 months infants are able to adjust to nonoptimal conditions of face discrimination by tapping into motion information that specifies people who are familiar and more meaningful to the child. Much more research is needed to understand the role of motion information in the early development of face discrimination, ultimately social knowledge and relations.

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