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Qualitative Differences in the Exploration of Upright and Upside-Down Faces in Four-Month-Old Infants: An Eye-Movement Study

Mathieu Gallay; Jean-Yves Baudouin; Karine Durand & Christelle Lemoine and Roger Lécuyer

Four-month-old infants were habituated with an upright or an upside-down face. Eye-movement recordings showed that the upright and upside-down faces were not explored the same way. Infants spent more time exploring internal features, mainly in the region of the nose and mouth, when the face was upright. They also alternated as frequently between the face's internal features (eyes vs. nose/mouth) as between external and internal features. When the face was upside down, the infants spent half of their time exploring external features, and preferentially alternated between external features and internal features. The main effect of inversion was a decrease of the looking time to the nose/mouth region and of the number of shifts between the eye region and the nose/mouth region

For some time now, scientific literature has considered the human face to be a specific object, leading some authors to propose that adults are experts in face processing (e.g., Diamond & Carey, 1986). It has been suggested, moreover, that the explanation for this expertise might have to do with the type of information adults use to recognize a face (see Diamond & Carey, 1986; Maurer, Le Grand, & Mondloch, 2002). In standard presentation conditions (upright faces), two types of information can be extracted from a face: componential information (obtained by way of local or analytic processing) and relational information (obtained by way of configural, holistic, or global processing). Componential information pertains to physical properties like the shape, texture, and color of the different elements of the face. Relational information pertains to the relative positions of the different elements (first-order relations: there are constant properties of human faces, such as the eyes being above the nose, itself above the mouth, and so forth) and to the distance between those elements (second-order relations; see Maurer et al., 2002). Several phenomena observed in adults have shown that configural information plays a crucial role in the high face-processing abilities of humans (for reviews, see Farah, Wilson, Drain, & Tanaka, 1998; Maurer et al., 2002). In particular, many studies reported a stronger inversion effect in face processing than in object processing (e.g., Yin, 1969; for a review, see Valentine, 1988). This observation was interpreted as resulting from the inability to process configural information in upside-down faces.

What about infants? Are they able to process faces configurally? There is considerable evidence of an ability to recognize faces in the hours or days following birth, especially the mother's face (Bushnell, 2001; Bushnell, Sai, & Mullin, 1989; Field, Cohen, Garcia, & Greenberg, 1984; Walton, Bower, & Bower, 1992), but also newly familiar faces (Pascalis & de Schonen, 1994). This ability is limited, however. Infants need both internal and external features to recognize their mother during the 1st month of life. They become able to recognize her from internal features alone at around 5 weeks, and from external features alone starting from the age of 4 months (Bartrip, Morton, & de Schonen, 2001; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995). They fail to recognize their mother from her profile alone before 2 months (Sai & Bushnell, 1988), but are able to recognize other kinds of faces through various expressions and poses at around 3 – 6 months (Pascalis, de Haan, Nelson, & de Schonen, 1998). There is also some evidence that infants process internal features early. Salapatek (1975) reported that 2-month-olds scanned internal features, notably the eyes and the mouth. One-month-olds mainly concentrated on external features (chin and hairstyle). More recently, Hunnius and Geuze (2004) reported that 6- to 26-week-

old infants spent more than half of the time on either the mouth or eye region of their mother's face when she was looking, smiling, and nodding at them. A preference for attractive faces in 2- or 3-month-old infants (Langlois et al., 1987) or in newborns (Slater et al., 1998) further indicates that infants at these ages attend to internal features. They are also sensitive to changes in the componential properties of these internal features very early in development. For example, they can discriminate local changes in schematic facial stimuli in the hours following their birth (Simion, Farroni, Macchi Cassia, Turati, & DallaBarba, 2002; Turati & Simion, 2002). They can also discriminate open versus closed eyes (Batky, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000).

There is also early evidence of configural processing of facial information by infants. They can discriminate faces on the basis of configural changes by the age of 4 months (Deruelle & de Schonen, 1998; for the same observation with 7-month-olds, see also Thompson, Madrid, Westbrook, & Johnston, 2001). Six-month-old infants can also discriminate upright Thatcherized faces (eyes and mouth reversed on the face) from non-Thatcherized ones, even though only relational aspects of the features differentiate the two kinds of faces (Bertin & Bhatt, 2004). Cashon and Cohen (2003) reported that 4-month-old infants look longer at a "switched" face made up of the internal features of a familiar face and the external features of another familiar face than at each whole familiar face. This result was interpreted as indicating that infants process the configuration made up of internal and external features. Cashon and Cohen (2003; see also Cohen & Cashon, 2001) even described an N-shaped pattern of development for upright faces, with the reaction to switched face emerging around 4 months, disappearing around 6 months, and emerging again around 7 months. Schwarzer and Zauner (2003) extended Cashon and Cohen's observation (2003; Cohen & Cashon, 2001) to 8-month-old infants by switching single features rather than all internal features; infants reacted when only the eyes, nose, or mouth of a familiar face were put into another familiar face.

Seven months was the age at which the result pattern differed for the first time for upright and upside-down faces in the study by Cashon and Cohen (2003): infants did not look longer at the switched face when it was upside down from this age on. Before that, the authors described a reaction for switched upside-down faces at around 4 or 5 months but neither before nor after that was similar to the reaction reported for upright faces. Nevertheless, there are also some observations that suggest that infants process upright and upside-down faces in a different way at an earlier age than that reported in the study by Cashon and Cohen (2003). For example, newborns looked longer at attractive faces when the face was upright, but this preference disappeared when the faces were upside down (Slater, Quinn, Hayes, & Brown, 2000). In 3- to 4-month-olds, Quinn, Yahr, Kuhn, Slater, and Pascalis (2002) observed a preference toward female faces that is abolished when the faces are presented upside down. Turati, Sangrigoli, Ruel, and de Schonen (2004) studied the influence of face orientation on face recognition: they habituated and tested 4-month-old infants with either upright or upside-down faces. In their first experiment, infants recognized the familiar face (i.e., they preferred a new face) whether upright or upside down when the point of view was not varied. In a second experiment, however, they recognized a face familiarized from various points of view and shown on the test from a new point of view, only when it was presented upright. Thus, infants processed upright and upside-down faces differently; the processing they used for upright faces but not that used for upside-down faces allowed them to recognize faces across various viewpoints. The deterioration of this

ability after inversion strongly suggests that this ability relies on the processing of configural information.

The way infants process upright faces allows them to extract a more stable representation of the face, and, consequently, its subsequent recognition is facilitated despite variations such as a change in viewpoint. The fact that this ability was no longer reported for upside-down faces further suggests that the mechanism subtending upright face processing has to do with configural information. One way of understanding the difference in the processing of upright and upside-down faces is to study how infants explore both types of faces. This can be done by way of an eye-movement study: knowing how infants look at faces can tell us about the kind of processing they implement for each orientation (see Haith, 2004; Johnson, Slemmer, & Amso, 2004). The purpose of the present study is to find out if 4-month-old infants process upright and upside-down faces in the same way, by recording eye movements during a habituation phase. Different processing modes for upright and upside-down faces should give rise to an exploration pattern that is qualitatively different (how infants explore a face), if not quantitatively different (how long infants explore a face). In other words, even if infants spend the same amount of time exploring upright and upside-down faces and, as a consequence, if traditional measures do not allow evidencing differences in the processing of faces under the two orientations (e.g., Experiment 1 in the study by Turati et al., 2004, see also Cashon & Cohen, 2003), infants may pay attention to different parts of the face under the two orientations, and the way they explore these facial parts may differ. To test these hypotheses, we used an eye-tracking system at the same time as we recorded looking times by means of a classical manual method. The eye-tracking system was expected to enable us not only to record the same quantitative indicators as in the classical manual method (i.e., amount of stimulus exploration time) but also to see whether there were any qualitative differences between the various experimental conditions by determining whether infants looked at the same features in the same order.

Experiment

Method

Participants

Forty-four 4-month-old Caucasian infants (27 girls and 17 boys, $M = 118.67$ days, $SD = 54.23$) were tested. They were healthy and had no known medical problems. Parents were contacted by mail and phone, and all gave their written consent. Twenty infants were not included in the final sample because of fussing or crying, or because of technical problems during the experiment. The final sample contained twenty-four 112- to 128-day-old infants (16 girls and 8 boys, $M = 119.33$, $SD = 54.18$).

Material

Photographs of two brown-eyed females (21 and 27 years old) were used. The photograph dimensions were 565 _ 565 pixels, which corresponded to a face of approximately 28 cm (i.e., 29.51 of visual angle) in height once on the screen. The experimental apparatus was composed of two computers, three control screens, a presentation monitor (70 cm flat screen), and an eye-tracking system developed by ASL (model R6). This system included a remote optics eye camera that allowed the infant approximately one square foot of head movement and eliminated the need for head restraint. The camera was placed in front of the

infant, below the monitor, at a distance of approximately 50 cm. The infant's line of gaze was measured by computing the pupil-corneal reflection at a sampling rate of 50 Hz. The accuracy level was about 0.51 of visual angle, and the resolution was about 0.251 of visual angle.

Procedure

The experiment took place in a quiet room of the Henri Pieron Center at the Paris 5 University. The infants were seated in a car seat with the head between two pillows, in an experimental box facing the monitor at a distance of 60 cm from its center. Once the infant was positioned, a curtain was drawn so that the only visual stimulations that could attract his or her attention were the ones displayed on the screen. The parents were present but were asked to remain quiet during the entire experiment. An experimenter was behind the camera in the dark outside the experimental box, so as to face the infant. He kept his hand on the computer mouse to control the presentation time during habituation (the experimenter held the mouse button down while the infant looked at the screen and released it when the infant moved his/her eyes away). We used a habituation paradigm. Each infant was tested in two experimental sessions: one with upright faces and one with upside-down faces. The order of the upright versus upside-down sessions was alternated across infants. Each session included two phases: calibration and habituation. Calibration. A clown was presented in the center of the screen. When the infant started to look at it, the clown moved to the top left corner of the screen and remained in this position until the infant fixated it. Then, it moved to the bottom right corner and remained in this position. These three positions were used to compute the pupil-corneal reflection characteristics for three points on the screen. These characteristics were used to derive the gaze direction during the habituation.

Habituation.

We used an infant-control procedure. A habituation face was displayed until the infant looked in another direction for more than 1 s. When the infant did not look at the face for 15 s, the next trial was run. If she or he never looked elsewhere for 1 s, the face was presented for a maximum of 15 s. During all the habituation trials of a session, the infant saw exactly the same face in the same orientation, with the same presentation criterion, until she or he was habituated. Cohen's (1972) habituation criterion was used, that is, the infant was considered to be habituated when the mean looking time for 3 consecutive trials was less than half the mean looking time for the first 3 trials. The minimum number of trials was 6. If the infant did not reach this criterion after 15 trials, the habituation was stopped. Between each trial, a blue screen was presented for 1 s. The infants were first habituated with one photograph, in such a way that different infants performed the habituation phase with the different photographs. During the second session, the infants were habituated with a photograph of the other female under the other orientation. The data were collected both by manual recording and by the eye-tracking system.

Results

Quantitative Data

Manual recording of gaze direction.

First, the total time spent exploring upright versus upside-down faces across all trials, and the number of trials needed to reach the habituation criterion were computed. T tests were then performed to find out whether there was a significant difference between upright and upside-down faces. The total looking time across all trials was 61.6 s (SD 535.2) for upright faces and

52.5 s (SD524.3) for upside-downfaces. The mean number of trials was 8.75 (SD53.05)for upright faces and 8.79 (SD52.95) for upsidedownfaces. Neither the total looking time nor thenumber of trials differed significantly between uprightand upside-down faces, $t(23)51.10$ and, $t(23)50.05$, respectively.For each infant, the total time spent looking at thescreen during the first three trials and during the last three trials was computed. The means for each experimentalcondition are presented in Table 1. Thesedata were input into a 2 _ 6 ANOVA with orientation(upright vs. upside-down) and trial (1 vs. 2 vs. 3vs. _3 vs. _2 vs. _1) as within-subject factors. Themain effect of trial was significant, $F(5, 115)575.78, po.0001$. Infants looked significantly longer at thescreen during the first three trials (10.5, 8.8, and 8.2 s, respectively) than during the last three trials (4.5, 3.8,and 3.2 s, respectively), $F(1, 23)5270.98, po.0001$.

Table 1
Manual and Oculometric Recording of Duration and Percentage of Looks During Habituation

Orientation trial	Upright						Upside down					
	1	2	3	-3	-2	-1	1	2	3	-3	-2	-1
<i>Manual recording (N = 24)</i>												
In seconds	10.9	8.7	8.4	5.0	3.8	3.2	10.0	8.8	8.0	4.0	3.8	3.2
SE	0.7	0.8	0.9	0.6	0.4	0.3	0.7	0.8	0.8	0.4	0.5	0.3
<i>Quantitative oculometric data (N = 21)</i>												
Looking at the screen												
In seconds	11.1	8.0	7.8	5.3	3.7	3.6	10.3	7.7	6.8	4.3	3.6	4.1
SE	0.8	0.9	1.0	0.9	0.4	0.4	0.9	1.0	0.9	0.5	0.5	0.5
Looking at the face												
In seconds	10.6	7.4	7.1	4.9	3.4	3.2	9.3	7.0	5.9	3.7	3.0	3.5
SE	0.8	0.9	0.9	0.9	0.4	0.4	0.9	0.9	0.9	0.4	0.5	0.5
<i>Qualitative oculometric data (N = 21)</i>												
Looking at internal features												
In seconds	7.7	5.5	4.9	3.2	2.2	2.1	5.3	3.5	3.3	1.7	1.6	2.1
SE	0.8	0.9	0.9	0.8	0.4	0.3	0.7	0.5	0.7	0.2	0.3	0.5
In %	69.1	63.9	62.2	58.2	58.8	65.9	56.5	51.6	50.3	48.4	51.2	52.9
SE	4.6	6.1	5.7	6.0	6.0	6.8	4.6	4.4	5.8	5.3	5.9	7.0
Looking at the eye region												
In seconds	3.3	2.4	2.3	1.9	0.9	1.2	2.8	1.5	2.0	0.7	0.5	1.0
SE	0.7	0.7	0.7	0.7	0.3	0.3	0.6	0.3	0.5	0.1	0.1	0.3
In %	29.3	24.6	26.8	28.0	24.4	30.6	31.7	26.4	30.3	21.0	20.7	23.8
SE	5.0	5.2	5.4	5.3	6.9	5.7	5.6	4.6	6.0	4.5	5.2	5.5
Looking at the nose/mouth region												
In seconds	3.9	2.8	2.1	1.0	1.0	0.8	1.6	1.3	0.9	0.5	0.8	0.8
SE	0.8	0.6	0.5	0.3	0.3	0.2	0.3	0.4	0.2	0.1	0.3	0.2
In %	34.5	34.5	26.9	24.5	28.4	28.1	15.9	15.0	13.3	14.6	22.2	21.3
SE	5.5	5.1	4.9	6.1	5.7	5.8	2.5	3.6	1.9	3.3	4.3	5.5

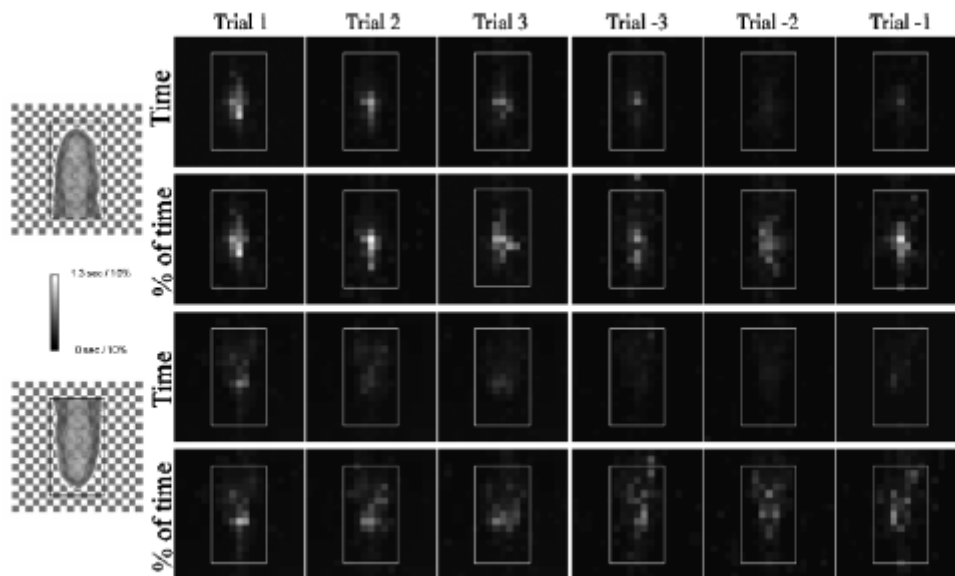


Figure 1. Time in milliseconds and percentage of time spent by infants in each of the 361 areas during habituation.

The main effect of orientation was nonsignificant, $F(1, 23)50.55$, as was the interaction between orientation and trial, $F(5, 115)50.39$. The manual recordings suggested that there was no difference in habituation between the two face orientations; the infants needed a similar number of trials to reach the habituation criterion, and they spent a similar amount of time exploring the screen for both orientations and on all trials. Oculometric data: how long the infants explored the face. The data from three infants were not included because of calibration problems. The oculometric data were used first to collect similar quantitative measures as with manual recording. For this, we computed the total looking time for each trial and each orientation. The correlation between total looking time on each trial measured by the experimenter and by the oculometer for these 21 infants was $r=0.84$, $p=0.0001$. The data limited to the infants' looks at the faces were also analyzed. For this, we computed the time each infant spent looking at the photograph of the face (as illustrated in Figure 1) without considering the time she or he spent on other parts of the screen. Table 1 gives the mean looking times for the screen and the face collected with the eye-tracking system. These data were analyzed by 2 \times 6 ANOVAs with orientation (upright vs. upside-down) and trial (1 vs. 2 vs. 3 vs. 3 vs. 2 vs. 1) as within-subject factors. As regards looking at the screen, the main effect of trial was significant, $F(5, 100)538.18$, $p=0.0001$. Infants looked significantly longer at the screen during the first three trials (10.7, 7.9, and 7.3 s, respectively) than during the last three (4.8, 3.6, and 3.8 s, respectively), $F(1, 20)5211.30$, $p=0.0001$. The main effect of orientation was nonsignificant, $F(1, 20)50.42$, as was the interaction between orientation and trial, $F(5, 100)50.57$. Concerning looking at the face, the main effect of trial was also significant, $F(5, 100)536.79$, $p=0.0001$. Infants looked significantly longer at the face during the first three trials (9.9, 7.2, and 6.5 s, respectively) than during the last three (4.3, 3.2, and 3.3 s, respectively), $F(1, 20)5143.43$, $p=0.0001$. The main effect of orientation was nonsignificant, $F(1, 20)51.25$, as was the interaction between orientation and trial, $F(5, 100)50.76$. The quantitative oculometric data replicated the manual recording data by showing no effect of orientation on habituation. They also extended this observation to the cases in which the looks at other parts of the screen than the face were removed from the analysis. Thus, the manual as well as the oculometric data suggest that 4-month-old infants are not sensitive to face orientation and that they become

habituated in the same way to upright and upside-down faces.

Qualitative Data

Oculometric data: how the infants explored the face. In order to find out whether the infants' exploration differed qualitatively across experimental

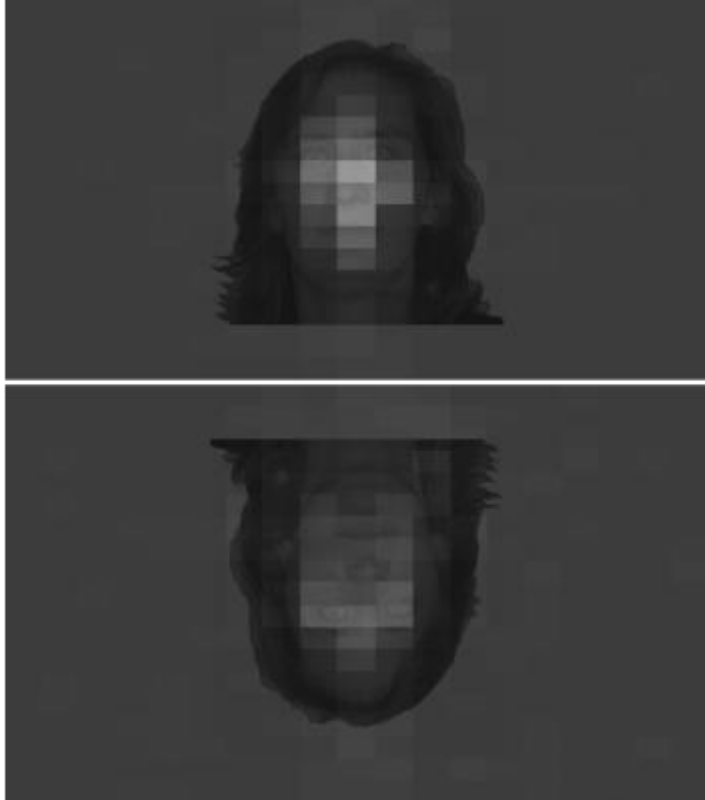


Figure 2. Mean percentage of time looking at each area for upright versus upside-down faces. The higher the area, the more the time the infants spent looking at it.

conditions, we defined a matrix of 361 areas (19 rows by 19 columns) that covered the whole screen. Then, for each of the 21 infants, we computed (i) the time the infant's gaze was in each area during a trial and (ii) the percentage of time she or he spent in each area as compared with the time spent looking at the screen. The total time and the percentage for each area were then averaged across all infants and all trials. This procedure allowed us to visualize the patterns of areas explored by the infants in each experimental condition. The patterns for the first three and the last three trials in each orientation are presented in Figure 1. The mean percentages in each area on these six trials are illustrated in Figure 2 for upright versus upside-down faces. Being able to see where (rather than how long) the infants looked allowed us to set forth and test hypotheses about infants' qualitative exploration of faces. The visual inspection of Figures 1 and 2 first supports the findings of the quantitative analyses. When we considered the time spent in the different areas (first and third rows in Figure 1), it appeared that the infants spent less and less time exploring the face as the number of trials increased. This decrease was similar for both upright and upside-down faces. Qualitatively, the percentages of time spent in each



Figure 3. Areas of interest: internal features (overall rectangle *a*), eye region (rectangle *b*), and nose/mouth region (rectangle *c*). External features are the regions in the photograph other than

area indicate that the main areas of interest were those corresponding to the face, and more precisely to internal facial features (second and fourth rows in Figure 1; see also Figure 2). They also suggest that there were some qualitative differences in the exploration of upright versus upside-down faces; infants seemed to spend more time looking at internal features when the face was upright than when it was upside down. Moreover, when they looked at internal features, the infants seemed to focus on the eye region when the face was upside down, whereas they seemed to focus on the regions of both the eyes and the nose/mouth when the face was upright. To test the hypothesis that exploration of some facial features (internal features, eyes, nose/mouth) differs for upright and upside-down faces, we defined three facial regions and then computed two indexes for each infant and each trial: (i) the total time she or he spent exploring that region and (ii) the percentage of time she or he spent in that region during face exploration (i.e., in the rectangular zone around the face shown in Figure 1). An illustration of the three regions considered is presented in Figure 3. The sizes of the areas in terms of visual angle were 10.51 high by 13.91 wide for the internal feature region, 4.71 high by 13.91 wide for the eye region, and 7.1 high by 7.91 wide for the nose/mouth region. The mean looking times and percentages for these three regions are presented in Table 1. For some infants in certain conditions, the percentage could not be computed because they spent no time on the face during certain trials (2.4% of the data). We replaced these data by the average of the mean percentage for other infants in that condition and the mean percentage for each of those infants in other conditions. Then, the mean time and the mean percentage for each region were analyzed in 2 × 6 ANOVAs with orientation (upright vs. upside-down) and trial (1 vs. 2 vs. 3 vs. 4 vs. 5 vs. 6) as within-subject factors.

Exploration of internal features.

Concerning looking time at internal features, the main effect of orientation was significant; infants looked longer at internal features when the face was upright (4.3 vs. 2.9 s for upside-down faces), $F(1, 20) = 57.98$, $p < 0.05$. The main effect of trial was also significant,

F(5, 100)521.53, $p < .0001$; looking time decreased between the first and last trials (6.5, 4.5, 4.1, 2.5, 1.9, and 2.1 s). The interaction between orientation and trial was nonsignificant, F(5, 100)51.84. For the percentage of time spent looking at internal features, the main effect of orientation was significant; infants spent a greater amount of time on internal features on upright faces (63.0% vs. 51.8% for upside-down faces), F(1, 20)511.78, $p < .01$. Neither the main effect of trial, F(5, 100)50.87, nor the interaction between orientation and trial, F(5, 100)50.85, were significant. Exploration of the eye region. For looking time at the eye region, the main effect of trial was significant, F(5, 100)511.09, $p < .0001$; eye-looking time decreased between the first and the last trials (3.0, 1.9, 2.1, 1.3, 0.7, and 1.1 s). Neither the main effect of orientation, F(1, 20)51.28, nor the interaction between orientation and trial, F(5, 100)50.75, were significant. For the percentage of eye-looking time, the main effect of orientation, F(1, 20)50.08, the main effect of trial, F(5, 100)51.12, and the interaction between orientation and trial, F(5, 100)50.73, were all nonsignificant.

Exploration of the nose/mouth region.

For looking time at the nose/mouth region, the main effect of orientation was significant; infants looked longer at the nose/mouth when the face was upright (1.9 vs. 1.0 s for upside-down faces), F(1, 20)56.43, $p < .05$. The main effect of trial was also significant, F(5, 100)513.51, $p < .0001$; looking time decreased between the first and the last trials (2.9, 2.0, 1.5, 0.8, 0.9, and 0.8 s). The interaction between orientation and trial was also significant, F(5, 100)53.61, $p < .01$. Linear comparisons indicated that the trial effect was significant for upright faces, F(5, 100)59.80, $p < .0001$, and for upside-down faces, F(5, 100)53.05, $p < .05$, but that the nose/mouth looking time decreased faster for upright faces. The orientation effect was significant on the first trial, 3.9 s for upright faces vs. 1.6 s for upside-down faces, F(1, 20)56.33, $p < .05$, the second trial, 2.8 s for upright faces vs. 1.3 s for upside-down faces, F(1, 20)54.51, $p < .05$, and the third trial, 2.1 s for upright faces vs. 0.9 s for upside-down faces, F(1, 20)54.92, $p < .05$, but not on the other trials (all $F < 3.70$). For the percentage of time in the nose/mouth region, the main effect of orientation was significant; infants spent a greater amount of time on the nose and mouth for upright faces (29.5% vs. 17.1% for upside-down faces), F(1, 20)58.02, $p < .05$. Neither the main effect of trial, F(5, 100)50.97, nor the interaction between orientation and trial, F(5, 100)51.16, were significant. Qualitative analyses showed that, although the quantitative exploration of upright and upside-down faces was similar (i.e., infants spent the same amount of time exploring the face), the two types of faces were not explored in the same way. For upright faces, infants mainly explored internal features (63% of the face-exploration time), with a great amount of time spent on the nose/mouth region (29.5% of the face-exploration time, which corresponds to 46.8% of the time spent on internal features). For upside-down faces, infants spent less time on internal features (51.8%), which means that they spent nearly half of their time exploring external features. They were also less interested in the nose and mouth (17.1% of the face-exploration time, which corresponds to 33.0% of the time spent on internal features). Thus, the main internal-feature area explored in upside-down faces was the eyes. However, the infants spent the same amount of time on the eyes as they had done for upright faces.

Time course of the exploration. Qualitative analyses indicated that the infants did not look at the same facial features for the two face orientations. We analyzed the time course of the exploration behavior in order to find out whether different features were explored in a uniform way across infants. The percentage of infants looking at each of the five areas (nose/mouth region, eye region, other internal regions, external feature region, other;

see Figure 3) was calculated at 20-ms intervals. The category “other” includes infants who no longer looked at the screen. Changes in these percentages were considered over a period of 10 s that started, for each infant, when she or he first looked at the face (rectangular area in Figure 1) for at least 100 ms. The time course of these percentages for each trial and each orientation is presented in Figure 4a and b, 990 Gallay, Baudouin, Durand, Lemoine, and Lécuyer which can be read as follows: (i) If the face exploration path is the same across infants, then one can expect them to look at the same region at the same time, with this region changing over time. In this case, oscillations should appear in Figure 4a and b. If, on the other hand, the exploration of the different features varies randomly across infants, no oscillation is expected because the infants’ looks at the different regions should be randomly distributed over time. (ii) In the case of oscillations, the different periods of oscillation are indicative of the exploration path. If, for example, the majority of the infants looked at the eyes during a specific period of time, and at the nose and mouth after that, then this should show up as an initial eye-exploration period, followed by a shift to the nose and mouth at the transition between the two periods. For our 21 infants, we considered two percentages (at different times or for different regions) to be significantly different (using a t test) at $p < 0.05$ for a difference above 19%, at $p < 0.01$ for a difference above 33%, at $p < 0.001$ for a difference above 42%, and at $p < 0.0001$ for a difference above 57%. Figure 4a and b appear to support the static qualitative data; a greater proportion of the infants looked at the nose/mouth region when the face was upright rather than upside down, and at external features when the face was upside down rather than upright. No particular difference is found for the eyes. Oscillations in the same time course also indicated some regularity in the exploration path. On the first trial, for example, most infants started to look at external features, whatever the orientation of the face. A great number of them also looked at the nose/mouth region. Approximately 500 ms after the beginning of the exploration, most infants got to the eyes and remained there for 2,000 – 2,500 ms.

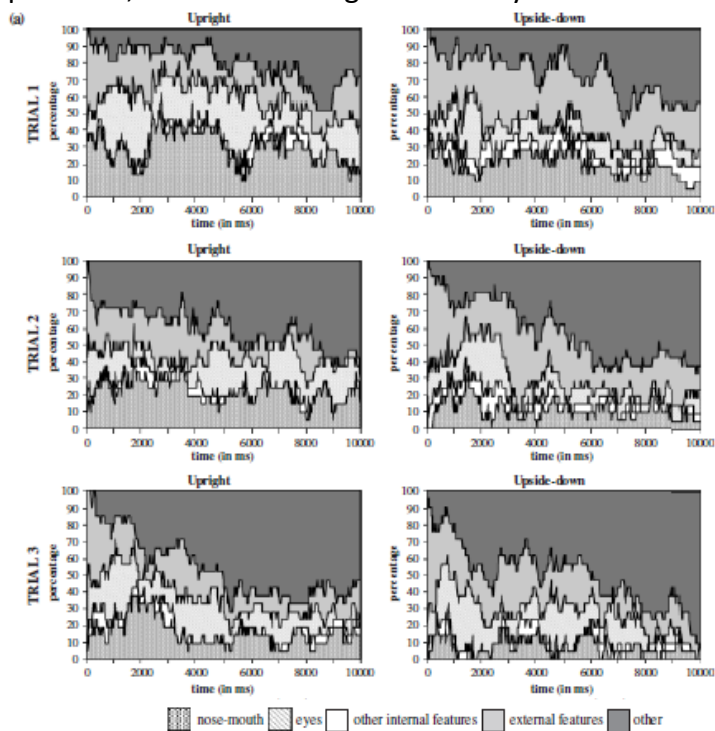
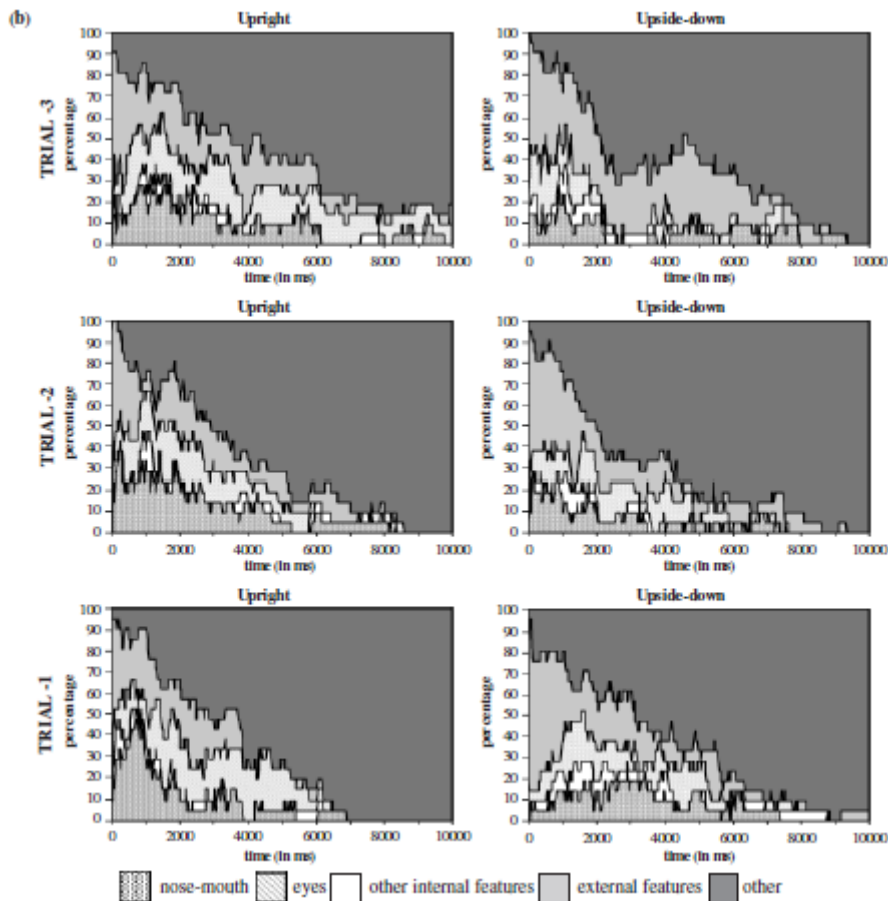


Figure 4. (a) Time course of the percentage of infants looking at the different regions on the first three trials. (b) Time course of the percentage of infants looking at the different regions on the last three trials.



The first difference between upright and upsidedownfaces showed up between 1,000 and 1,500 ms; whereas some infants tended to go from the eyes to the nose and then return to the eyes for upright faces, the pattern was not so apparent for upside-downones. The difference between upright and upsidedownfaces became clear-cut at 2,000 – 2,500 ms. For upright faces, most infants arrived at the nose/mouth region between 2,500 and 4,500 – 5,000 ms, and many of them looked at the eye region also. Later, an increase in eye-region looking showed up between 4,500 and 5,000 ms, concurrent with a decrease in the percentage of infants who looked at the nose/mouth from there, suggesting that most infants went from the nose/mouth to the eyes. At 6,000 ms, the percentage of infants looking at the nose/mouth increased again, whereas the percentage of infants looking at the eyes decreased. The percentage of infants who looked at external features was quite low and stable during these periods. For upside-down faces, the main variation after 2,000 ms was in the percentage of infants looking at external features, which was also greater than for upright faces. However, it is not clear whether the infants alternated between external features and one specific region, either the eyes or the nose/mouth. A similar pattern emerged to various extents on other trials, with many infants who looked at external features first, and then at the eyes during the first few seconds. Then, they alternated between the nose/mouth and eye regions for upright faces, with a predominance and variation of looks at external features for upside-down faces. Figure 4a and b thus indicated quite a congruent exploration path across infants, at least on the first trial, with different paths for upright and upside-down faces. Thus, there appears to be a common rule about which features were explored, the order in which they were explored, and the moment the infant switched from one to the other. The apparent lack of variation during certain periods (e.g., between 2,500 and 5,000 ms on the first upright-face trial) did not rule out changes in the infants' region of interest. It

is possible that they alternated between two regions they were exploring (e.g., eyes and nose/mouth), but without being synchronized one with the others (e.g., some infants went from the eyes to the nose/mouth, whereas others did the opposite). Thus, Figure 4a and b point out a common exploration rule, but do not tell us about individual back-and-forth shifts. However, when the percentages for two regions are high at the same time, we can hypothesize that the infants were making asynchronous back-and-forth shifts between these two regions.

Shifts between facial features in each face orientation.

Figure 4a and b suggest that while the exploration of upright faces gave rise to back-and-forth shifts between the eyes and the nose/mouth, the exploration of upside-down faces gave rise to back-and-forth shifts between external features and other features. To further test this hypothesis, we computed the number of times the infant shifted from one feature to another, or inversely, for each trial and infant. The features considered here were the eyes versus the nose/mouth, the eyes versus external features, and the nose/mouth versus the external features, as defined in Figure 3. An infant was said to change between two features when she or he looked at an area of interest for at least 100 ms during a 200 ms period, and to the other region for at least 100 ms during the subsequent 200 ms period. This criterion was used to take into account shifts from one region to another, even when the infants crossed another region on the way. With this criterion, situations where infants spent less than 180 ms in another region than the ones we were interested in between the two previous regions were considered as shifts between these two regions. This time was chosen because it is long enough to do a saccade and short enough to discard situations where the infant did two saccades with a fixation in another region between the two saccades. The data for the number of shifts from one region to another and inversely were analyzed in a 2_6_3 ANOVA with orientation (upright vs. upside-down), trial (1 vs. 2 vs. 3 vs. 3 vs. 2 vs. 1), and type of shift (eyes-nose/mouth vs. external features-eyes vs. external features-nose/mouth) as within-subject factors. The means for the number of shifts in each experimental condition are presented in Table 2.

The main effect of trial was significant, $F(5, 100) = 15.74$, $p < 0.0001$; the number of shifts decreased between the first and the last trials (2.3, 1.7, 1.5, 1.1, 0.6, and 0.8). No other effects or interactions were significant. To further test the hypothesis of different types of shifts for upright and upside-down faces, we performed linear comparisons to test both the effect of the type-of-shift factor in each orientation and the effect of the orientation factor for each type of shift. The main type-shift effect was nonsignificant for upright faces, $F(2, 40) = 1.58$, but significant for upside-down faces, $F(2, 40) = 55.66$, $p < 0.01$. For upside-down faces, infants made fewer shifts between the eyes and the nose/mouth region than between the eyes and external features (0.9 vs. 1.5), $F(1, 20) = 59.04$, $p < 0.01$, and between the nose/mouth and external features (0.9 vs. 1.2), $F(1, 20) = 55.46$, $p < 0.05$. There was no difference between these last two conditions, $F(1, 20) = 2.20$. Moreover, orientation had a significant effect on the number of shifts between the eyes and the nose/mouth (1.7 for upright faces vs. 0.9 for upside-down faces, $F(1, 20) = 56.11$, $p < 0.05$), but not on the number of shifts between the eyes and external features, $F(1, 20) = 0.67$, or on the

Table 2
Mean Number of Shifts Between Eyes, Nose/Mouth, and External Features, by Orientation and Trial

Orientation	Upright							Upside down						
	Trial	1	2	3	-3	-2	-1	Mean	1	2	3	-3	-2	-1
Eyes versus nose/mouth	2.9	2.1	1.7	1.3	0.5	1.3	1.7	1.0	1.4	1.0	0.4	0.7	0.8	0.9
SE	0.8	0.4	0.5	0.6	0.2	0.5	0.8	0.3	0.3	0.3	0.1	0.2	0.4	0.3
External features versus eyes	3.0	1.9	2.0	2.2	0.5	0.8	1.8	3.1	1.3	1.8	0.8	0.9	1.0	1.5
SE	1.0	0.5	0.4	0.7	0.2	0.3	0.8	0.7	0.4	0.6	0.2	0.3	0.4	0.5
External features versus nose/mouth	1.9	1.3	1.4	0.8	0.5	0.5	1.1	1.7	2.4	1.1	1.0	0.6	0.2	1.2
SE	0.5	0.3	0.5	0.2	0.2	0.2	0.5	0.4	0.7	0.3	0.2	0.2	0.1	0.4

number of shifts between the nose/mouth and external features, $F(1, 20) = 50.16$. Thus, the analysis of the number of shifts indicated that when the face was upright, infants moved as frequently from one region to the other, no matter what regions were considered. When the face was upside down, they went back and forth more often between external features and the eyes or the nose/mouth than between the eyes and the nose/mouth. The main effect of face inversion was a decrease in the number of shifts between the two kinds of internal features. Orientation did not affect the number of shifts between external features and either the eyes or the nose/mouth.

Conclusions

The results of the present study showed that no quantitative difference was found for upright and upside-down faces during habituation (i.e., the infants spent the same amount of time and needed the same number of trials to habituate to upright and upside-down faces), whether measures were performed using traditional recording methods or an eye-tracking system. Nevertheless, the eye-movement recordings showed that the infants did not explore the faces in the same way under the two orientations. They spent more time on internal features, mainly in the nose and mouth region, when the face was upright than when it was upside down. The time spent looking at the eyes was equivalent for the two orientations, suggesting that face inversion mainly results in a transfer from nose/mouth looking to external-feature exploration. The infants considered as a group tended to all use the same exploration strategy, at least for the first few trials of habituation, but that strategy depended on the orientation of the face. When the face was upright, they generally started by exploring the eyes for about 1 s; next they looked at the nose/mouth, and then they alternated between periods of nose/mouth looking and eye looking. When the face was upside down, the infants also tended to look at the eyes during the first few seconds, but after that they preferentially alternated between external features and internal features, whether the eyes or the nose and mouth. The analysis of back-and-forth gaze shifts between the features also showed that 4-month-old infants shifted to an equal extent between the eyes, the nose/mouth, and external features when the face was upright. When the face was upside down, however, they preferentially alternated between external and internal features, with the number of internal-feature shifts being lower than for the upright face. Thus, the main effect of face inversion was a decrease in internal-feature gaze shifts.

General Discussion

The present study indicated that 4-month-old infants do not explore upright and upside-down faces in the same way. These findings extend the previous researches, suggesting that 4-month-old infants process configural/invariant information (Cohen & Cashon, 2001;

Deruelle & de Schonen, 1998; Turati et al., 2004), and that this ability is altered by inversion (Turati et al., 2004). The different ways in which these infants explored upright and upside-down faces are good candidates to explain the behavior that underlines the extraction of such configural/invariant information. As inversion mainly influences the time the infants spend on internal features such as the nose and mouth region, or the number of times the infants shift between this latter region and the eye region, both these behaviors may have to do with configural/invariant processing of the face. Thus, the present study highlights the interest of a qualitative approach to understand how infants process faces. In our study as in the first experiment by Turati et al. (2004), there was no difference in the time the infants took to habituate to upright and upside-down faces. The impact of inversion in face processing was observable only via the more qualitative approach that consisted in considering where and how the infants were looking at the face during the habituation phase. The way 4-month-old infants explored upright and upside-down faces in our study sheds some new light on the results reported by Cashon and Cohen (2003), notably the lack of an inversion effect for switched faces at 4 months. Our results show that infants go back and forth many times between internal and external features when the faces are upside down, and that this kind of shifting is the principal one found for this orientation; the number of shifts between external features and either the eyes or the nose/mouth represented around 75% of all shifts between external features, the eyes, and the nose/mouth. For upright faces, this percentage was only about 63%. However, the total number of shifts was quite similar in the two orientations. Thus, if infants associate internal and external features via this shift behavior, one can expect the same reaction for upright and upside-down faces when the learned association is modified in switched faces. This is what Cashon and Cohen (2003) reported for infants of the same age as in our study. If this hypothesis is valid, then why does an inversion effect emerge at 7 months? The answer to

this question can probably be found by studying the development of exploration patterns during the 1st year of life. The infants in our study spent approximately two thirds of their time exploring internal features, which is quite a bit lower than in Hunnius and Geuze's (2004) study, where similar-age infants spent around 90% of their time in these regions. There are two main explanations for this difference: the face used by Hunnius and Geuze (2004) was moving, and it was the mother's face. Facial movements may have directed the infants' attention and gaze toward internal features, which are the most important source of change in a dynamic face. Second, the fact that the face was highly familiar to the infants may have directed them toward internal features. It has been reported for adults that internal features play a more important role in familiar than in unfamiliar face recognition (e.g., Ellis, Shepherd, & Davies, 1979; Young, Hay, McWeeny, Flude, & Ellis, 1985). The familiarity with the mother's face may have prompted the infants to explore its internal features longer. The way infants explore a face, and in particular the time they spend looking at internal features, thus clearly depends on a number of factors (face orientation, facial movement, familiarity). These factors no doubt also influence the efficiency of face encoding. The weight of eyes in face processing by infants has already been underlined in the literature (Batky et al., 2000; Emery, 2000; see also Farroni, Johnson, Brockbank, & Simon, 2000; Vecera & Johnson, 1995). A particular role of the eyes also appears in our study, whatever the orientation. The infants spend a large part of their time exploring them (one third of the time they spend exploring the face) and, above all, they tend to go to this region first. Therefore, the eyes appear to be key information and the

startingpoint of the exploration whatever the orientation of the face, i.e. whatever the exploration strategy the infants adopt. A reason for this behavior may be the fact that the eyes are the most contrasted region of a face. Thus, they can capture the attention and look of infants and allow them to locate the other less contrasted facial parts, relative to the position of the eyes. The relative position of the other facial regions being altered by face inversion, the infants will change their exploration strategy by altering between eyes and external features, whose relations (central internal feature versus external part) are less altered by inversion. Beyond the theoretical question that was the purpose of the present study, face processing in infants, this study clearly shows the interest of a qualitative approach, notably by the use of eye movement recording, in addition to traditional quantitative methods. To know how the infant explores the world (i.e. where does she or he look, in which order does she or he explore different parts, does she or he explore the parts) may shed new light on the cognitive processes that underline her or his developing abilities.

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