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Citation: Journal of comparative psychology (2012), 126(4): 388-398

Issue Date: 2012-11

URL: http://hdl.handle.net/2433/172546

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Type: Journal Article

Textversion: author

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Face and eye scanning in gorillas (Gorilla gorilla), orangutans (Pongo abelii), and humans (Homo sapiens): unique eye-viewing patterns in humans among hominids

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Abstract

Because the faces and eyes of primates convey a rich array of social information, the way in which primates view faces and eyes reflects species-specific strategies for facial communication. How are humans and closely related species such as great apes similar and different in their viewing patterns for faces and eyes? Following previous studies comparing chimpanzees with humans, this study used the eye-tracking method to directly compare the patterns of face and eye scanning by humans, gorillas, and orangutans. Human and ape participants freely viewed pictures of whole bodies and full faces of conspecifics and allospecifics under the same experimental conditions. All species were strikingly similar in that they viewed predominantly faces and eyes. No particular difference was identified between gorillas and orangutans, and they also did not differ from the chimpanzees tested in previous studies. However, humans were somewhat different from apes, especially with respect to prolonged eye viewing. We also examined how species-specific facial morphologies, such as the male flange of orangutans and the black–white contrast of human eyes, affected viewing patterns. Whereas the male flange of orangutans affected viewing patterns, the color contrast of human eyes did not. Humans showed prolonged eye viewing independently of the eye color of presented faces, indicating that this pattern is internally driven rather than stimulus dependent. Overall, the results show general similarities among the species and also identify unique eye-viewing patterns in humans.
Introduction

Human and non-human primates have highly sophisticated forms of facial communication. Faces and eyes convey a wide variety of information such as identity, age, sex, emotion, and direction of attention. Thus, primates perceive faces and eyes differently from the way they perceive other visual stimuli (Emery, 2000; Tomonaga, 2010). Moreover, primates often engage in prolonged face-to-face interactions that are accompanied by eye contact (looking into another individual’s eyes) or its avoidance (Gomez, 1996; Kleinke, 1986; Thomsen, 1974). How and when such unique forms of facial communication evolved in primates have long been of interest, particularly from a comparative perspective (Chevalier-Skolnikoff, 1973; Darwin, 1872/1999; van Hooff, 1967).

Humans and great apes such as chimpanzees, gorillas, and orangutans are known to share several forms of facial communication with one another. For example, prolonged eye contact indicates mild threat, and thus gaze avoidance indicates submission (Goodenough, McGuire, & Jakob, 1993; Redican, 1975). Eye contact is also used in an affiliative context, such as the solicitation of play/sex and post-conflict appeasement (de Waal, 1990; Goodall, 1986; Kano, 1980; Yamagiwa, 1992). Gaze following (looking in the same direction) frequently occurs after the establishment of eye contact with another individual (Bräuer, Call, & Tomasello, 2005; Itakura, 2004; Okamoto-Barth, Call, & Tomasello, 2007; Tomasello, Hare, Lehmann, & Call, 2007). Additionally, studies have suggested that these species use eye contact ostensively (i.e., viewing another individual’s eyes with communicative intent) (Gomez, 1996).

On the other hand, notable differences among the species have also been identified. For example, although close-range long-bout affiliative communication typically accompanies intense eye contact in humans, this kind of communication seems to occur more frequently in tactile than in visual forms in great apes (e.g., grooming; Goodall, 1986; Shaller, 1963). Several studies have suggested that mutual gaze (returning another individual’s gaze) is uncommon and that gaze avoidance is frequent in
gorillas (Shaller, 1963; but see Yamagiwa, 1992) and orangutans (Kaplan & Rogers, 2002). Kobayashi and Kohshima (2001) found that, compared with other primates, humans have exceptionally large white sclera that clearly contrasts with the colors of their iris and skin. These authors hypothesized that human eyes have evolved to enhance gaze signals such as eye direction. Tomasello et al. (2007) found that great apes (chimpanzees, bonobos, and gorillas) were less sensitive than human infants were to the eye direction of a human experimenter when the experimenter’s head was immobile. Okamoto-Barth et al. (2007) found that, compared with chimpanzees, bonobos, and gorillas, orangutans were less sensitive to gaze (head) directions and more attracted to target objects.

These results suggest that, although humans and great apes share a basic set of facial communicative skills, significant species differences characterize their habitual styles. Direct comparisons are necessary to reveal such differences among these species. Kano and Tomonaga (2009, 2010) used the eye-tracking method to measure how humans and chimpanzees scanned the faces and eyes of conspecifics and allospecifics. Both species were presented with pictures of whole bodies and faces, and they viewed the pictures freely. The species were strikingly similar in their patterns of face and eye scanning. For example, both species fixated on faces and eyes more frequently than on other parts of bodies and faces. However, several species differences were also identified. For example, chimpanzees viewed faces and eyes more briefly than did humans; typically, chimpanzees only glanced at eyes, whereas humans viewed both eyes (left and right eyes) alternately. Additionally, when presented with facial expressions including conspicuous mouth actions, humans viewed the eyes rather than the mouth, and chimpanzees viewed the mouth rather than the eyes. Thus, previous studies have shown both striking similarities among the species and unique eye-viewing patterns in humans.

At present, such face- and eye-scanning data are not available for other ape species. Thus, this study aimed to obtain a broader comparative picture about this issue. Following previous studies comparing chimpanzees with humans (Kano & Tomonaga, 2009, 2010), we compared the patterns of
face and eye scanning by humans, gorillas, and orangutans. We had three primary reasons for examining the patterns of face and eye scanning in gorillas and orangutans. First, gorillas and especially orangutans are phylogenetically more distant from humans than are chimpanzees. Thus, this study enabled us to test whether the unique eye-viewing patterns of humans indicate general differences between humans and great apes or isolated differences among species. Based on previous studies showing intense eye contact, especially in humans, it would be expected that humans would view eyes for longer durations than do gorillas and orangutans. Second, several of the previous studies have reported a high probability of gaze avoidance in gorillas and orangutans (Kaplan & Rogers, 2002; Shaller, 1963). Additionally, orangutans lead semi-solitary lives in their natural habitats, which is the least socially specialized form among the great apes. The simple experimental design of this study (presenting facial pictures) enabled us to test gorillas’ and orangutans’ default motivation for viewing eyes (i.e., in the absence of social interaction).

Finally, each species has species-specific morphological facial features that have presumably evolved for purposes of communication. This study enabled us to test the role of these facial features in visual perception. For example, humans have a color contrast between the dark iris and white sclera in their eyes (Kobayashi & Kohshima, 2001), adult male gorillas have a high crest on the top of their heads, and adult male orangutans have developed flanges on the sides that are thought to be sexual signals (Ankel-Simons, 2000; Kuze, Malim, & Kohshima, 2005). Infant and juvenile orangutans have pale coloring around their eyes and mouth, thought to signal immaturity (Kuze, et al., 2005). As those facial features are visually conspicuous, they would be expected to automatically attract viewers’ attention. That is, the viewing patterns would be expected to be dependent on the presence/absence of such conspicuous facial features. However, if viewing patterns were independent of the types of faces presented, such patterns would be internally driven rather than stimulus dependent.
Following previous studies comparing chimpanzees with humans (Kano & Tomonaga, 2009, 2010), this study used the eye-tracking method to perform direct comparisons among humans, gorillas, and orangutans with regard to their patterns of face and eye scanning. We employed a cross-species design, presenting both conspecific and allospecific pictures. We initially presented whole-body pictures and examined how humans and apes scanned faces versus bodies. We then presented facial pictures and examined how they scanned each facial feature (e.g., eyes, nose, and mouth). Picture models included both conspecific and allospecific individuals, males and females (adults), and familiar and unfamiliar individuals. To examine the effect of species-specific facial morphologies on viewing patterns, juvenile faces of gorillas and orangutans were prepared in addition to male adult and female adult faces, and the viewing patterns for all types of faces were compared with one another.
Five gorillas (*Gorilla gorilla*), 10 orangutans (*Pongo pygmaeus*), and 12 humans (five males and seven females; all European adults; 21–52 years, mean: 30.5 years) participated in this study. All apes were housed in semi-natural indoor and outdoor enclosures (total 2,564 m² for gorillas, 1,910 m² for orangutans) at the Wolfgang Köhler Primate Research Center (WKPRC), Leipzig Zoo, Germany. All apes received regular food, enrichment, and water *ad libitum*. They were not deprived of food or water. All apes and humans voluntarily participated in the study. Animal husbandry and research complied with the EAZA Minimum Standards for the Accommodation and Care of Animals in Zoos and Aquaria and the WAZA Ethical Guidelines for the Conduct of Research on Animals by Zoos and Aquariums, respectively. Informed consent was obtained from all human participants. Table 1 lists the sex, age, and rearing history of each ape. Most of the ape participants were reared by their biological mothers. All apes and humans had extensive and regular experience interacting with both apes and humans at the zoo and were thus highly familiar with both kinds of faces.

| Table 1 about here |

- Apparatus

All apes were tested in a chamber that separated the ape from the eye-tracking apparatus and the experimenter with transparent acrylic panels. The gaze movements of the apes were non-invasively recorded while their heads were unrestrained. We were able to implement this
unrestrained eye-tracking method by using two devices. First, we employed a table-mounted infrared
eye tracker with wide-angle lenses (±40 degrees in the semicircle above the camera; 60 Hz; Tobii
X120, Tobii Technology AB, Stockholm, Sweden). This eye tracker recorded both eyes of participants
(the average value was used to estimate the single gaze point) and allowed relatively large head
movements by participants. Second, the eye tracker and the 17-inch LCD monitor (1280 × 1024
pixels) were mounted on a movable platform, and the distance between the platform and the
participants was adjusted by the experimenter to the point at which the gaze could be most accurately
recorded (approx. 60 cm). This adjustment was performed before each trial if necessary (but not
during the trial).

To encourage the apes to sit still in front of the acrylic panel and face the eye tracker, the
experimenter offered small pieces of fruit *ad libitum*. These were given to the apes before each trial if
necessary (but not during the trial). However, eight of the 15 apes tested (Gorgo, Louna, Zola, Batak,
Kila, Maia, Suaq, and Tanah; mostly juveniles) had difficulty in approaching the acrylic panel upon
the request of the experimenter. We thus used a nozzle and tube attached to the acrylic panel, which
produced regular drops of grape juice during the experiment; this motivated the apes to keep their
heads in front of acrylic panel (Fig. 1a and b). The eye tracker was unable to track both eyes of one
male adult gorilla (Gorgo) due to the wide distance between his eyes, and of one juvenile female
gorilla (Louna) due to her strabismus. Therefore, we concealed the left eye of these apes from the eye
tracker by attaching opaque tape to the panel and tracked only the right eye. Although these apes
viewed stimuli only with their right eyes, they still had a full view of all stimuli with the typical 60-cm
viewing distance. The preliminary analysis revealed no specific pattern of face and eye scanning in
these two apes, so we did not exclude their data from the analysis. Although experiments were
conducted for apes in the presence of the experimenter, the apes rarely attended to the experimenter
during the presentation of stimuli. Also, the apes who received grape juice during the presentation of
pictures did not look at the nozzle but freely viewed the pictures.

Humans were tested using the same apparatus but in another room with no panel between the eye tracker and participants. Our preliminary tests for accuracy revealed that the acrylic panels (1.5–2 cm thick, with no scratches or dirt) had no influence on the eye-tracking data. Each participant’s gaze was recorded as a relative coordinate with respect to the monitor size (i.e., not as the gaze angle). One degree of gaze angle corresponded to approximately 1 cm on the screen at a typical 60-cm viewing distance.

Calibration

An automated calibration process was employed. Several reference points were presented sequentially at different locations on the screen to guide the participants to look at those points. The system then automatically matched the raw-gaze data of participants with those reference points. Humans were instructed to view the small dots that appeared on the screen, whereas a short video clip or a piece of fruit was presented to attract the apes’ gaze. Five reference points were used for humans, whereas two were used for apes to reduce the time required for each calibration process.

After completing the calibration process, the calibration accuracy at five points on the screen was inspected by attracting the participants’ gaze to those points in the same way. The calibration process was repeated if necessary (the calibration was usually repeated more frequently for apes than for humans because of the limited calibration conditions mentioned above.). The accuracy check was conducted before every session and occasionally during the session (between the trials). In a preliminary session, we estimated the error value (the average distance between recorded and intended gaze positions) with two gorillas, six orangutans, six chimpanzees, and six humans. We found that the error was small and comparable among the species (average ± s.e.m. 0.61 ± 0.06, 0.72 ± 0.04, and 0.52 ± 0.05 degrees at the typical 60-cm viewing distance, respectively).
Stimuli

Figures 2a and 2b present examples of the stimuli. Color still pictures were prepared for this study, including 16 whole-body and 56 facial pictures. Gorillas and orangutans viewed eight human and eight conspecific whole-body pictures (total of 16 whole-body pictures) and eight human and 24 conspecific facial pictures (32 facial pictures); each ape viewed a total of 48 pictures. Humans viewed pictures of both apes and humans (16 whole-body and 56 facial pictures). Half of the pictures were of familiar apes/humans that interacted with the participants on a daily basis, and the other half included unfamiliar apes/humans that had been never exposed to the participants. Pictures were taken when the models were in calm, relaxed states. Their eyes were open, and their mouths were closed. The facial pictures of gorillas and orangutans consisted of three types of faces (eight stimuli for each type): adult male face, adult female face, and juvenile face. Whole-body pictures were converted to 1280 × 1024 pixels (37 × 30 degrees at a typical 60-cm viewing distance). Facial pictures were converted to 768 × 1024 pixels (22 × 30 degrees at a typical 60-cm viewing distance) with a gray frame around the background (total 1280 × 1024 pixels). The internal parts of faces (eyes, nose, and mouth) were thus approximately 10–15 degrees in size at a typical 60-cm viewing distance.

Procedure

In each trial, a picture was presented after participants fixated on a red mark that appeared at the center of the screen. Participants then scanned the picture freely (without any training or instruction). They never kept gazing at the point where the initial red mark appeared, and sequential scanning of the picture was almost always observed. Each stimulus was presented for 3 sec. No
specific instructions were given to humans except to view the pictures freely.

The presentation order of the pictures was randomized for each participant. The entire
session was conducted over 2 days for humans (36 pictures each day), but the session was divided
across 12 days for apes (four pictures each day). The purpose of dividing the entire session for apes
was to reduce the time required for daily sessions and to maintain the apes’ interest in the pictures.

Daily sessions lasted 10–15 min for apes and 15–20 min for humans. Trials in which participants
viewed a picture for less than 1 sec were repeated after the whole session, and the original trials were
replaced by the new trials; otherwise, those trials were eliminated from the analysis. As a result, we
excluded 6.2% and 8.7% of the trials of the whole-body pictures and 10.0% and 7.1% of the trials of
the facial pictures for gorillas and orangutans, respectively (no trials were eliminated for humans). The
exclusion of trials (especially those of facial pictures) was largely attributable to two male
human-raised individuals, Gorgo (gorilla) and Bimbo (orangutan). These individuals sometimes
averted their heads from facial pictures. The reason for this behavior is uncertain; it could have been
active gaze avoidance in response to the social stimuli or simply a lack of interest in the pictures.

Data analysis

Fixation definition

Fixation was defined as a stationary gaze within a radius of 50 pixels for at least 75 ms (more
than five measurement samples). Otherwise, the recorded sample was defined as part of a saccade.

Records during the first 200 ms were eliminated from the analysis, thereby eliminating fixations that
might have begun before the onset of stimuli.

Area of interest (AOI)

Each stimulus was divided into areas of interest (AOI) for quantitative comparison. Each
whole-body picture was divided into background, face, and body. Each AOI was defined to be 20
pixels larger than the precise outline of the features to compensate for error in gaze estimation. The AOIs were generated in the following order: background, body, and face. If two or more AOIs were duplicated, gaze samples were added to the last AOI. Each facial picture was divided into background, eyes, nose, mouth, and periphery (ears, cheeks, chin, forehead, hair; see Fig. 2c).

**Proportion of viewing time**

The proportion of viewing time for each AOI was calculated with respect to the viewing time for the entire scene. Out-of-scene fixations were excluded from the analyses (less than 5% of all fixations in all species when participants were presented with whole-body pictures; 6.1%, 6.0%, and 1.9% of all fixations in gorillas, orangutans, and humans, respectively, when participants were presented with facial pictures). To compensate for the differences in area size between AOIs, viewing time was normalized for area size by subtracting the proportion of viewing time from the proportion of area size. The chance level was thus set at zero.

**Probability of fixation across fixation order**

To examine the time course of face viewing in whole-body pictures and of eye viewing in facial pictures, we calculated the probability of fixation on faces/eyes across fixation order (first through fifth fixations). The results were calculated as the proportion of fixations with respect to the total number of sampled fixations for each fixation order.
Results

Figure 3 shows examples of scanning paths in each species. First, it is important to note that none of the ape participants exhibited a fear response to facial pictures, even though some apes (especially juveniles) had never been exposed to facial pictures before this study.

Figure 4 about here

Whole-body pictures

Proportion of viewing time. Figure 4a shows the proportion of viewing time for each AOI when participants were presented with whole-body pictures. We conducted a repeated-measures ANOVA with species, AOI, stimulus species, and familiarity as factors. We found a significant main effect of AOI ($F(2, 48) = 446.59, P < 0.001, \eta^2 = 0.94$). All species viewed each AOI in a different way [humans ($F(2, 22) = 382.82, P < 0.001, \eta^2 = 0.97$), gorillas ($F(2, 8) = 50.41, P < 0.001, \eta^2 = 0.92$), orangutans ($F(2, 18) = 178.01, P < 0.001, \eta^2 = 0.95$)]. Post hoc tests (Bonferroni correction) revealed that they viewed faces most intensely, followed by bodies and then backgrounds ($P < 0.001$).

We found a significant interaction between species and AOI ($F(4, 48) = 18.64, P < 0.001, \eta^2 = 0.60$). We found significant species differences in viewing patterns for faces ($F(2, 24) = 28.69, P < 0.001, \eta^2 = 0.70$), bodies ($F(2, 24) = 5.15, P = 0.014, \eta^2 = 0.30$), and backgrounds ($F(2, 24) = 24.50, P < 0.001, \eta^2 = 0.67$). This is explained by the fact that humans viewed faces more intensely than did apes ($P < 0.001$). Although we were not able to analyze the effects of age and sex because of the small numbers of juveniles and males, excluding juveniles or males from the analysis did not change the
overall pattern of results [juveniles (main AOI: \(F(2, 40) = 396.84, P < 0.001, \eta^2 = 0.95\); species ×
AOI: \(F(4, 40) = 20.20, P < 0.001, \eta^2 = 0.66\), males (main AOI: \(F(2, 44) = 391.20, P < 0.001, \eta^2 = 0.94\); species × AOI: \(F(4, 44) = 17.34, P < 0.001, \eta^2 = 0.61\)]. To examine whether participants showed differential patterns over the course of an entire session, we separated the whole session into two blocks and included that factor in the ANOVA. However, we did not find any effect of session block (block × AOI: \(F(2, 23) = 0.76, P = 0.47, \eta^2 = 0.06\); block × AOI × species: \(F(4, 48) = 1.19, P = 0.32, \eta^2 = 0.09\)).

We found a significant interaction between stimulus species and AOI \(F(2, 48) = 4.72, P = 0.013, \eta^2 = 0.16\). The effect of stimulus species was significant in viewing patterns for faces \(F(1, 24) = 10.56, P = 0.003, \eta^2 = 0.30\) and bodies \(F(1, 24) = 6.09, P = 0.021, \eta^2 = 0.20\). This is explained by the fact that all species viewed conspecific faces longer than allospecific faces. Additionally, we found a significant interaction between familiarity, species, and AOI \(F(4, 48) = 2.93, P = 0.030, \eta^2 = 0.19\). The interaction between familiarity and AOI was significant only in humans \(F(2, 22) = 4.34, P = 0.026, \eta^2 = 0.28\). Humans viewed faces of familiar individuals somewhat longer than those of unfamiliar individuals (0.65 vs. 0.60).

**Probability of fixation on faces across fixation order.** Figure 4b shows the time course of face-viewing patterns for whole-body pictures. A repeated-measures ANOVA with species and fixation order as factors revealed a main effect of fixation order \(F(4, 96) = 18.23, P < 0.001, \eta^2 = 0.43\). This is explained by the fact that they fixated on faces at an earlier rather than a later time. We also found a significant interaction between species and fixation order \(F(8, 96) = 4.22, P < 0.001, \eta^2 = 0.26\). This is explained by the fact that humans fixated on faces at an earlier time than did apes.

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**Figure 5 about here**
Facial pictures

Proportion of viewing time. Figure 5a shows the proportion of viewing time for each AOI when participants were presented with facial pictures. We conducted a repeated-measures ANOVA with species, AOI, stimulus species, and familiarity as factors. Only adult faces of the three species were used in this analysis. We found a significant main effect of AOI ($F(3, 69) = 238.75, P < 0.001, \eta^2 = 0.91$). All species viewed each AOI in a different way; humans ($F(3, 33) = 146.57, P < 0.001, \eta^2 = 0.93$), gorillas ($F(3, 12) = 100.94, P < 0.001, \eta^2 = 0.96$), and orangutans ($F(3, 24) = 65.90, P < 0.001, \eta^2 = 0.89$). Post hoc tests (Bonferroni correction) revealed that they viewed eyes most intensely, followed by nose/mouth and periphery ($P < 0.001$). We found a significant interaction between species and AOI ($F(3, 69) = 3.14, P = 0.009, \eta^2 = 0.21$). We found significant species differences in viewing patterns for the eyes ($F(2, 23) = 4.00, P = 0.032, \eta^2 = 0.25$) and the periphery ($F(2, 23) = 6.27, P = 0.007, \eta^2 = 0.35$). This is explained by the fact that humans viewed the eyes more intensely and viewed the periphery less intensely than did orangutans. Although we were not able to analyze the effects of age and sex because of the small numbers of juveniles and males, excluding juveniles or males from the analysis did not change the overall pattern of results [juveniles (main AOI: $F(3, 57) = 174.85, P < 0.001, \eta^2 = 0.90$; species × AOI: $F(6, 57) = 3.20, P = 0.009, \eta^2 = 0.25$), males (main AOI: $F(3, 66) = 218.51, P < 0.001, \eta^2 = 0.90$; species × AOI: $F(6, 66) = 3.13, P = 0.009, \eta^2 = 0.22$)]. To examine whether the participants showed differential patterns over the course of entire session, we separated the whole session into two blocks and included that factor in the ANOVA. However, we did not find any effect of session block (block × AOI: $F(3, 22) = 1.87, P = 0.16, \eta^2 = 0.20$; block × AOI × species: $F(3, 22) = 1.49, P = 0.20, \eta^2 = 0.16$).

We found a significant interaction among stimulus species, AOI, and species ($F(6, 69) = 6.62, P < 0.001, \eta^2 = 0.36$). This is explained by the fact that, whereas gorillas and orangutans viewed the conspecific eyes more intensely than the allospecific eyes, humans exhibited an opposite tendency.
viewing the allospecific eyes more intensely than the conspecific eyes. The effect of familiarity was not significant ($P > 0.05$).

**Probability of fixation on eyes across fixation order.** Figure 5b shows the time course of eye viewing for facial pictures. A repeated-measures ANOVA using species and fixation order as factors revealed a main effect of fixation order ($F(4, 96) = 35.03, P < 0.001, \eta^2 = 0.59$), which is explained by the fact that they fixated on eyes at an earlier rather than a later time. The interaction between species and fixation order was not significant ($F(8, 96) = 1.69, P = 0.11, \eta^2 = 0.12$).

**Viewing patterns for the eyeball region.** Differences between apes and humans in eye viewing were not as clear as those previously found between chimpanzees and humans (Kano & Tomonaga, 2009, 2010). However, this possible inconsistency may be attributable to the definition of the eye AOI. That is, the visual inspection of each scanning path (Fig. 3) suggested that humans more directly fixated on eyes than did apes (i.e., fixation on eyeballs rather than on the region around the eyes). Therefore, we also delineated an eyeball AOI, which was inside the eye AOI and included only the eyeball, and compared the viewing times for eyeballs between the species. We found significant species differences in viewing patterns for eyeballs ($F(2, 23) = 8.09, P = 0.002, \eta^2 = 0.41$). This is explained by the fact that humans viewed eyeballs more intensely than did apes ($P < 0.05$). We also analyzed the probability of fixation on eyeballs across fixation order. We found a significant interaction between species and fixation order ($F(8, 96) = 2.28, P = 0.028, \eta^2 = 0.16$). This is explained by the fact that, whereas humans showed an increasing tendency for viewing eyeball regions, apes showed a decreasing tendency in this regard.

**Probability of saccade destination.** Visual inspection of the scanning data (Fig. 3) suggested...
that humans viewed left and right eyes alternately, whereas apes did not. To clarify this issue, we quantified the typical scanning path of each species when participants were presented with facial pictures. We divided the eye AOI into right and left eye AOIs (i.e., right eye, left eye, nose, mouth, and periphery) and calculated the probability of saccade destination. Each saccade (the path that joins two consecutive fixations) was classified based on the two AOIs in which the saccade started and ended; thus, each saccade was classified into one of 10 possible combinations of beginning and ending AOIs. Saccades for out-of-face start or end points were excluded from analyses. The results were calculated as the proportion of the total number of sampled saccades. Data for conspecific and allospecific faces were combined. As suggested, humans shifted their gaze between the left and right eyes more frequently than did gorillas ($t(15) = 2.26, P = 0.039$) and orangutans ($t(20) = 4.82, P < 0.001$) (Fig. 6).

The effect of face type. Figure 7 shows the proportion of viewing time for each AOI as a function of face type in gorillas and orangutans. A repeated-measures ANOVA with face type and AOI did not reveal an effect of face type in gorillas ($F(6, 24) = 1.97, P = 0.10, \eta^2 = 0.33$), whereas it did in orangutans ($F(6, 54) = 6.09, P < 0.001, \eta^2 = 0.40$). Post hoc tests revealed that orangutans viewed the juvenile eyes more intensely than the male or female eyes ($P < 0.05$). We also found that they viewed the periphery of male faces (i.e., cheek flange) more intensely than that of female or infant faces ($P < 0.05$). Human participants did not demonstrate this pattern (gorilla faces: $F(6, 66) = 0.08, P = 0.99, \eta^2 = 0.008$; orangutan faces: $F(6, 66) = 1.53, P = 0.18, \eta^2 = 0.12$).
First, it is important to note that humans and great apes showed striking similarities in their patterns of face and eye scanning. All species viewed faces for longer durations and at earlier times than they viewed bodies and backgrounds when presented with whole-body pictures. Additionally, all species viewed inner features of faces, especially eyes, for longer durations and at earlier times than they viewed the periphery when presented with facial pictures. The same patterns were observed for chimpanzees in previous studies (Kano & Tomonaga, 2009, 2010) (Table S1 and S2). Selective attention to faces as opposed to complex naturalistic backgrounds clearly eliminated the possibility that viewing patterns were simply dependent on visual saliency (e.g., color, shape, contrast). In support of this notion, a previous study demonstrated that the chimpanzees’ viewing patterns for faces were not explained by the saliency model of Itti and Koch (2001) (Kano & Tomonaga, 2011).

None of the ape species avoided viewing eyes in this study. Rather, they viewed eyes predominantly, regardless of the type of face (conspecific/allo specific, male/female) presented. A possible inconsistency between these data and previous findings that gorillas and orangutans frequently avoided viewing faces/eyes during natural interactions may exist (Kaplan & Rogers, 2002; Shaller, 1963). However, this apparent inconsistency may be explained by the fact that this study presented apes with faces in the absence of interactive contexts. Previous studies have also shown that eye contact (or its avoidance) is highly dependent on the interactive contexts in which such eye contact occurs. Thus, this study’s finding that all great ape species are similar in their eye-viewing tendencies may indicate that the ape species do not differ in their default motivation for viewing eyes. However, it should be noted that two adult males in this study frequently averted their heads when presented with facial pictures (see Methods). It is possible that notable sex, age, rank, or individual differences characterize their eye-viewing tendencies (cf. Yamagiwa, 1992)

Although no significant differences were found between gorillas and orangutans, humans
differed from apes in their patterns of face and eye scanning. Humans viewed faces for longer durations than did apes when presented with whole-body pictures. Additionally, humans viewed eyes, especially eyeballs, for longer durations than did apes when presented with facial pictures. Furthermore, humans often alternated their gaze between the left and right eyes, whereas apes rarely showed this gaze movement (Fig. 3, 6). By alternating their gaze between the left and right eyes and shifting their gaze occasionally to the mouth, humans exhibited triangular scanning paths in response to faces. As the upper component of this triangular shape was absent in apes, their scanning paths appear to be more linear than those of humans. A similar species difference was observed between chimpanzees and humans in previous studies (Kano & Tomonaga, 2009, 2010). Therefore, active, prolonged eye viewing is a unique characteristic of humans as compared with great apes.

One possible interpretation for this species difference is that eyes may have evolved additional communicative functions not found in ape species. Compared with those of other primates, human eyes have a notable dark–white contrast between the iris and sclera (Kobayashi & Kohshima, 2001), which enhances directional cues. Moreover, fine motor control of the muscles around the eyes (Ekman & Friesen, 1978) enables humans to communicate a variety of emotional cues. As these cues are subtle, the active and prolonged eye-viewing patterns of humans may benefit them by facilitating the efficient retrieval of such communicative information. That is, humans may employ eyes for bidirectional communication between senders and receivers. Tomasello et al. (2007) hypothesized that the importance of close-range joint attentional and communicative interactions may have shaped the unique eye morphology of humans. It is also possible that the behavioral tendency to actively collect eye information has evolved along with eye morphology.

Humans and apes viewed conspecific faces for longer durations than they viewed allospecific faces when presented with whole-body pictures. This may indicate their greater interest in conspecific than in allospecific individuals. However, their patterns of face and eye scanning were, in general,
highly consistent across stimuli despite the fact that various types of faces were presented. This was also the case for chimpanzees and humans in the previous study. Thus, their viewing patterns may reflect general responses to face-like configurations rather than specific responses to particular facial information. This result may be explained by the fact that study participants were not required to collect particular information from the faces (free viewing). Thus, we would expect that their viewing patterns would be more variable if they viewed faces under an experimental situation in which they were required to sort faces based on certain facial information or in an interactive situation in which they reacted emotionally to faces. Further studies are necessary to test these possibilities.

Although orangutans’ viewing patterns were generally consistent across stimuli, they were clearly affected by species-specific facial features. They viewed the periphery of adult male faces (flange on the sides) for longer durations than those of adult female or juvenile faces. Furthermore, they viewed the eyes of juvenile faces (surrounded by pale coloring) for longer durations than those of adult faces. These results suggest that these conspicuous facial features are indeed visually appealing. Human participants who viewed the same orangutan faces did not follow the same patterns, perhaps because their viewing patterns are more standardized than are those of orangutans.

The color contrast in human eyes did not attract viewers’ attention to the eyes. That is, apes did not view human eyes for longer durations than they viewed conspecific eyes, and humans showed prolonged eye viewing for both conspecific and allospecific faces. Thus, unlike the male flange and the skin color of juvenile orangutans, the color contrast in human eyes is not particularly conspicuous. Humans showed prolonged eye viewing independently of the effect of eye color. Thus, this pattern is internally driven rather than stimulus dependent. We speculate that the color contrast of human eyes conveys information most efficiently when the eyes receive such active attention.

Further comparative studies on face and eye scanning may reveal similarities and differences between apes and other primate species. For example, this study demonstrated a remarkably strong
tendency for apes and humans to view the internal features of faces, and successive fixations on internal features were frequent (i.e., successive on-feature fixations rather than repetition of on- and off-feature fixations; see Fig. 3). It remains unclear how apes and monkeys differ in this regard when tested using the same experimental settings. Further studies using the eye-tracking method are also necessary to perform direct comparisons between humans and great apes in terms of gaze-following tendencies. Previous studies have shown that humans, chimpanzees, gorillas, and orangutans show differential gaze-following tendencies in response to a human experimenter’s gaze (Okamoto-Barth, et al., 2007; Tomasello, et al., 2007). It remains unclear how these species differ from one another when tested using a cross-species design (presenting both conspecific and allospecific faces).

The aim of this study was to reveal how humans and great apes are similar and different in their pattern of face and eye scanning. Following a previous study comparing chimpanzees with humans, we directly compared the viewing patterns of gorillas, orangutans, and humans in response to whole-body and facial (full-face) pictures of conspecifics and allospecifics. The general conclusion is that all species are strikingly similar in patterns of face and eye scanning. However, we also identified unique eye-viewing patterns among humans. Unlike the species-specific facial features of orangutans (e.g., male flange), the black–white contrast in human eyes, a unique trait of humans, did not attract viewers’ attention. Humans showed prolonged eye viewing independently of the eye color of presented faces. Thus, active eye viewing may be a unique characteristic of humans as compared with great apes, and given that humans have unique eye morphology, facial communication among humans may be specialized for the eyes.

Acknowledgements

This research was financially supported by the Japan Society for the Promotion of Science (JSPS) and the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan Grants-in-Aid
for Scientific Research (nos. 16002001, 19300091, 20002001, 212299), the JSPS/MEXT global COE programs (D07 and A06), and the JSPS institutional program for young researchers overseas. We thank C. Rahn, F. Stock, H. Knofe, J. Corbit, R. Pieszek, and the other members of WKPRC for their help with experiments. We also thank the Leipzig Zoo, Germany, and the Centre for Human Evolution Modelling Research at the Primate Research Institute, Japan, for the daily care of the apes. Pictures of apes are courtesy of A. Bania, A. Girndt, A. Sato, J. Call, J. Kalbitz, N. Kuze, S. Ross, and T. Stoinski.
References


Table 1. Age, sex, and rearing history of each ape.

<table>
<thead>
<tr>
<th></th>
<th>Sex</th>
<th>Age (years)</th>
<th>Rearing History</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gorilla</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gorgo</td>
<td>M</td>
<td>29</td>
<td>Nursery</td>
</tr>
<tr>
<td>Kibara</td>
<td>F</td>
<td>6</td>
<td>Mother</td>
</tr>
<tr>
<td>Louna</td>
<td>F</td>
<td>4</td>
<td>Mother</td>
</tr>
<tr>
<td>Viringika</td>
<td>F</td>
<td>15</td>
<td>Mother</td>
</tr>
<tr>
<td>Zola</td>
<td>F</td>
<td>2</td>
<td>Mother</td>
</tr>
<tr>
<td><strong>Orangutan</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Batak</td>
<td>M</td>
<td>1 (+ 1 month)</td>
<td>Mother</td>
</tr>
<tr>
<td>Bimbo</td>
<td>M</td>
<td>30</td>
<td>Nursery</td>
</tr>
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<td>Dukana</td>
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</tr>
<tr>
<td>Kila</td>
<td>F</td>
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<td>Mother</td>
</tr>
<tr>
<td>Maia</td>
<td>F</td>
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<td>Mother</td>
</tr>
<tr>
<td>Padana</td>
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<td>Mother</td>
</tr>
<tr>
<td>Raja</td>
<td>F</td>
<td>7</td>
<td>Mother</td>
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<td>Suaq</td>
<td>M</td>
<td>1 (+ 6 months)</td>
<td>Mother</td>
</tr>
<tr>
<td>Tanah</td>
<td>F</td>
<td>1 (+ 5 months)</td>
<td>Mother</td>
</tr>
</tbody>
</table>
Figure 1. Apes and apparatus. (a) Eye-tracking apparatus. An eye tracker and a monitor are mounted on the movable platform (front). The experimenter controlled the apparatus using the computer mounted on the other platform (behind). See also: http://www.youtube.com/watch?v=zHx2KwQEHq0. (b) A juvenile gorilla drinking grape juice via a tube attached to the transparent acrylic panel. (c) An adult female orangutan on the apparatus.

Figure 2. Examples of stimuli: (a) whole-body pictures; (b) facial pictures; (c) areas of interest (AOI) for facial pictures.

Figure 3. Examples of scanning paths for facial pictures. The scanning paths of five participants from each species were superimposed on the facial pictures. The pictures were dimmed for clarity.

Figure 4. Scanning pattern for whole-body pictures in each species. (a) Proportion of viewing time for each AOI with respect to the total scene-viewing time. (b) Probability of fixation for each AOI across fixation order. All data are normalized for area sizes. Error bars represent the upper and lower bounds of the 95% confidence intervals.

Figure 5. Scanning pattern for facial pictures in each species. (a) Proportion of viewing time for each AOI with respect to total face-viewing time. (b) Probability of fixation for each AOI across fixation order. All data are normalized for area sizes. Error bars represent the upper and lower bounds of the 95% confidence intervals.
Figure 6. Typical scanning paths for facial pictures. Probabilities of saccade destination are presented in percentages and scaled to size. If a human participant is currently looking at the right eye of a human face (top center), he/she would re-fixate the right eye with a probability of 2.6, the left eye with a probability of 15.6, the nose with a probability of 7.7, etc. (see text for details).

Figure 7. The proportion of total face-viewing time spent viewing each AOI as a function of face type in gorillas and orangutans. All data were normalized for area sizes. Error bars represent the upper and lower bounds of the 95% confidence intervals. Asterisk indicates $P < 0.05$ in post hoc tests.

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Figure 1
Figure 2
Figure 3
Figure 5

(a) 

(b)
Figure 6
Figure 7

Prop. viewing time (normalized for area size)

eye  nose  mouth  periphery

female  male  juvenile  female  male  juvenile

face type  face type
Table S1. Proportion of viewing time for each part of a scene (not normalized for size) in each species across studies.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Conspecific scene</th>
<th>Allospecific scene</th>
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<tbody>
<tr>
<td></td>
<td>Face</td>
<td>Body</td>
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<tr>
<td>Human (1)</td>
<td>0.7</td>
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<tr>
<td>Gorilla (1)</td>
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<tr>
<td>Orangutan (1)</td>
<td>0.45</td>
<td>0.29</td>
</tr>
<tr>
<td>Human (2)</td>
<td>0.57</td>
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</tr>
<tr>
<td>Chimpanzee (2)</td>
<td>0.37</td>
<td>0.43</td>
</tr>
</tbody>
</table>

(1) This study
(2) Kano and Tomonaga (2009)
Table S2. Proportion of viewing time for each part of a face (not normalized for size) in each species across studies.

<table>
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<tr>
<th>Participant</th>
<th>Conspecific face</th>
<th>Allospecific face</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eye (Eyeball)</td>
<td>Nose</td>
</tr>
<tr>
<td>Human (1)</td>
<td>0.64 (0.23)</td>
<td>0.23</td>
</tr>
<tr>
<td>Gorilla (1)</td>
<td>0.48 (0.18)</td>
<td>0.2</td>
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<tr>
<td>Orangutan (1)</td>
<td>0.36 (0.15)</td>
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<tr>
<td>Human (2)</td>
<td>0.44 (0.27)</td>
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<tr>
<td>Chimpanzee (2)</td>
<td>0.37 (0.11)</td>
<td>0.16</td>
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</tbody>
</table>

(1) This study
(2) Kano and Tomonaga (2010)
Table S3. Average fixation duration (ms) for each AOI of whole-body/facial pictures.

<table>
<thead>
<tr>
<th></th>
<th>Human (1)</th>
<th>Gorilla (1)</th>
<th>Orangutan (1)</th>
<th>Human (2)</th>
<th>Chimpanzee (2)</th>
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</thead>
<tbody>
<tr>
<td><strong>Whole Body</strong></td>
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<td></td>
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<tr>
<td>Face</td>
<td>821</td>
<td>375</td>
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<td>1002</td>
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<tr>
<td>Body</td>
<td>299</td>
<td>212</td>
<td>286</td>
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<tr>
<td>Background</td>
<td>237</td>
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<td>280</td>
<td>289</td>
<td>224</td>
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<tr>
<td>Whole Scene</td>
<td>607</td>
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<td>318</td>
<td>739</td>
<td>259</td>
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<td><strong>Face</strong></td>
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<td>Eye</td>
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<tr>
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<td>464</td>
<td>255</td>
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</table>

(1) This study
(2) Kano and Tomonaga (2009/2010)