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Vocal Tract Modeling Techniques: From Human Voice to Non-Human Primates Vocalizations

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Introduction

The Source-Filter Theory (Fant, 1960) offered a powerful frame for the interpretation of human vocal production. Two main events take place in the human apparatus during vocal production. The first happens at a glottal level. Vocal fold vibration generates the fundamental frequency of a voice and its harmonics. These characteristics are known collectively as the voice source. The source is then modified by the shape and length of the vocal tract. The vocal tract acts as a resonator, adjusting the relative intensities of the frequencies of the source. The column of air vibrates in a complex manner that is influenced by the length and the shape of the vocal tract. One or several resonant frequencies of the vocal tract correspond to prominent spectral peaks called “formants”. The position and variation of the formants have been found to have a significant impact on the way humans recognize speech sounds. Even if a model of vocal production based on the relationship between the vocal tract area function and the formant output has been the most common framework for understanding speech production in humans, the study of vocal tract resonance in non-human primates has not comparably developed. This is probably due to several reasons. First, the study of formants in non-human primates started as an attempt to demonstrate that primates could not produce human speech sound. Once the pioneering studies of Lieberman and colleagues (Lieberman, 1968; 1969; Lieberman *et al.*, 1969; 1972) showed that the anatomy and morphology of the non-human primate vocal tract prevented the production of human-like sounds, this field of investigation immediately ceased its activity. Some years later, the work of Andrew (1976) and then Hauser (Hauser *et al.*, 1993; Hauser, 1996) brought back some attentions to the meaning of formants in primate intra-specific communication. In more recent years, a number of studies have shown that formant-based semantic communication is also present in non-human primates, for instance in Diana monkey alarm calls (Riede and Zuberbuhler, 2003 a, b; Rendall *et al.*, 2005). These findings were strengthened when it was found that macaques could, without training, discriminate differences in the formant

structure of their conspecific calls (Fitch and Fritz, 2006). Thus, is now widely accepted that the calls of many non-human primates, and mammals in general (Taylor and Reby, 2010), possess formants.

A further extension of the importance of vocal tract filtering in primates is the application of computational models to describe their phonation processes. From an acoustic and physiological point of view, human vocal communication is far better known than any other mammal communication system, and techniques from speech science have often been applied to the study of vocal production in other mammals, especially non-human primates (Riede *et al.*, 2005; Gamba and Giacoma, 2006). The purpose of this paper is to introduce a framework for future studies of the relation between vocal-tract shape and acoustics in human and non-human primates. Showing the potential of using vocal tract modeling in non-human primates, we highlight differences and similarities compared to vocal tract modeling in humans.

Materials and Methods

Various imaging techniques are now available for researchers to derive information about the configuration and the morphology of the vocal tract. The two most common options are magnetic resonance imaging (MRI) and x-ray computed tomography (CT). They have the advantage of high resolution of image acquisition and they are potentially useful to study non-human primates too. However they are rarely available in non-human primates range countries, and they may not contrast properly organs of partially de-frozen specimens (Gamba, unpublished data). Because of this, data used in this paper comes from different sources. On one side, we are using vocal tract area functions of human vocal tracts available in the VTAR program default vocal tract configurations (Zhou *et al.*, 2001). On the other side, we will use vocal tract area functions determined by measuring cross-sectional areas with 1 cm increment from the vocal folds toward mouth opening and nostrils. These measures were taken over a silicon cast of the entire vocal tract (glottis to lips for the oral tract and glottis to nostrils for the nasal tract respectively) of a large *Lemur catta* male, whose cadaver belonged to the collection of dead animals at the Parc Botanique et Zoologique Tsimbazaza, Antananarivo,

Madagascar. All length and dimension measurements of the cast were taken with a Mitutoyo digital caliper (accurate to 0.01 mm). We measured an average diameter because the cross-section of the vocal tract cast was not generally circular and cross-sectional areas were computed starting from these measures in Microsoft Excel. In both human and non-human primate vocal tract models, computational representations of the vocal tract were built using concatenated tube models [a system comprising a series of concatenated tubes of fixed length, each showing a specific cross-sectional area] (Story *et al.*, 1996; Gamba and Giacoma, 2006). Cross-sectional areas were used to build the cross-sectional area function that represents the input of the vocal tract modeling software VTAR, a Matlab-based computer program for vocal tract acoustic response calculation (Zhang and Espy-Wilson, 2004). VTAR is capable of simulating complex frequency-domain models for the vocal-tract acoustic response where the vocal tract is decomposed into various modules such as simple tubes, branching, and lateral channels. We did two separate models for the oral tract and the nasal tract on the basis of the assumption that non-human primates produce

vocalizations through the nose, or the mouth, but not both (Fitch, 2000). For human nasal resonance models, we used a couple area of 1.04 cm (default value) and we modeled the tract using one nostril to shorten calculation times.

Results

Computational models of the vocal tract simulate the morphology of a specific configuration of the vocal apparatus and attempt to calculate the resonance properties of its cavities.

The models used real data about the vocal tract morphology to virtually recreate it, and hence calculate the resonance frequencies that would be observed from the original emitter.

We constructed models representing the vibrating air cavity in the vocal tract between the glottis and the lips for two typical sounds of human speech /AA/ and /M/, and those of *Lemur catta* in two species-typical utterances, 'tonal call' and 'grunt'. Fig. 1a shows the vocal tract area function of a typical male /AA/ with a vocal tract length of 17 cm. Fig.

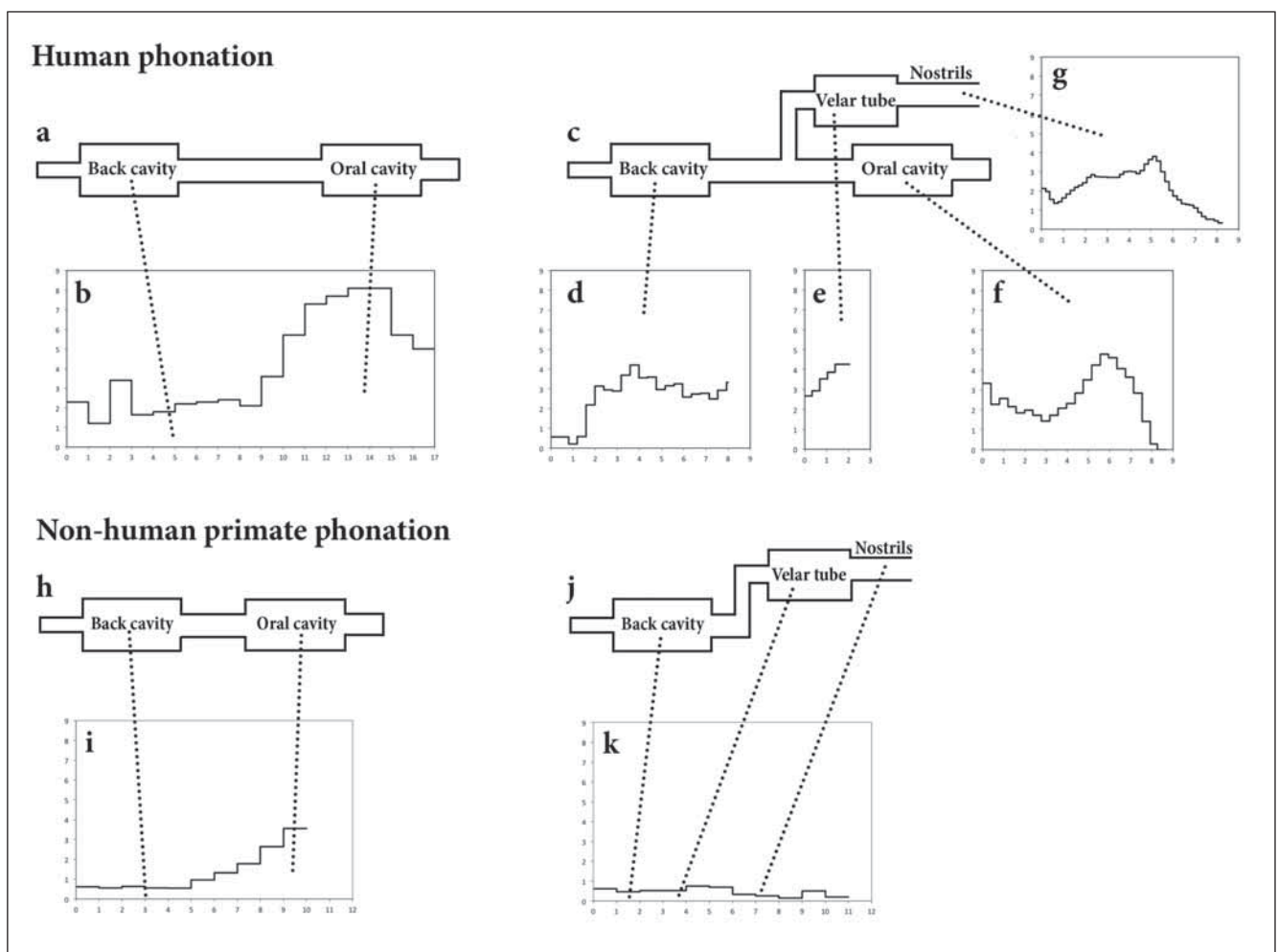


Fig. 1. Human phonation: (a) schematic representation of the human vocal tract during phonation through the oral tract; (b) vocal tract area function during the emission of /AA/; (c) schematic representation of the human vocal tract during phonation through the nasal and the oral tracts; vocal tract area functions during the emission of /M/: (d) back cavity, (e) velar tube, (f) oral cavity, (g) nostrils. Non-human primate phonation: (h) schematic representation of the vocal tract during phonation through the oral tract; (i) vocal tract area function during the emission of a tonal call in *L. catta*; (j) schematic representation of the vocal tract during phonation through the nasal tract; (k) vocal tract area functions during the emission of a nasal grunt in *L. catta*. Schemes are not in scale. Diagrams show distance from the origin (e.g. glottis) in cm on the x-axis and vocal tract area in cm² on the y-axis.

1b shows the vocal tract area function of a male ring-tailed lemur 'tonal call' with a vocal tract length of 10 cm. Both human's /AA/ and lemur's 'tonal call' are emitted with open mouth, with the column of air resonating in the oral tract. The main differences between humans and non-human primates lie in the interaction between the nasal and the vocal tract. The human speech apparatus is a complex system and the full model of the vocal tract for a typical nasal sound like /M/ should include various branches: the back cavity, the velar tube, the oral cavity and one or two nostrils. Figure 1 shows the vocal tract area function of a typical male /M/ with a length of 7.99 cm for the back cavity (d), 2.04 cm for the velar tube (e), 8.66 cm for the oral tract (f) and 8.25 cm for the nostrils (g). In the typical /M/ of the human voice the column of air resonates both in the oral and in the nasal cavities. Fig. 1h shows the vocal tract area function of a male ring-tailed lemur nasal 'grunt' with a vocal tract length of 11 cm. Lemur's 'tonal call' are emitted with open mouth with the column of air resonating in the oral tract.

Acoustic response of the vocal tract models is shown in Fig. 2. The longer, L-shaped tube of a typical human male produces lower resonance frequencies in both simulations (Fig. 2a and c). For the ring-tailed lemur, the slightly longer nasal tract and the narrow, spongy chambers of the nasal airways produce a remarkably lower first formant (F1, Fig. 2d) when compared with that showed by the simulation of the oral tract resonance (Fig. 2b). Third (F3), fourth (F4) and fifth (F5) formants also showed lower frequencies; meanwhile second formant (F2) has an invariant location across the two simulations (Fig. 2b and 2d).

Discussion

In despite of the difference between humans and non-human primates, which anatomically lie in the morphology of the upper airways and in the interaction between the nasal and the vocal tracts, the ability of using formants to extract information related to the physical characteristics (e.g. species, sex, body size, identity) of the emitter may be one functional link between the vocalizations of human and nonhuman primates. Vocal tract models attempt to simulate the behaviour of sound waves in the vocal apparatus and are particularly useful to understand the resonance properties of a specific vocal tract configuration. Understanding the morphology of the vocal tract framework is a crucial step in mapping resonance properties of both humans and animals. It is also a necessary step toward quantitative modeling of species-specific abilities, which requires accurate dimensions of all structures of the vocal apparatus.

Output from the simulations produced by VTAR can be used to gain an understanding of the differences in the application of computational modeling of the vocal tract in humans and in non-human primates, and vocal tract modeling in general may represent a powerful tool to investigate differences and similarities in the encoding of communication sounds in humans and in non-human animals.

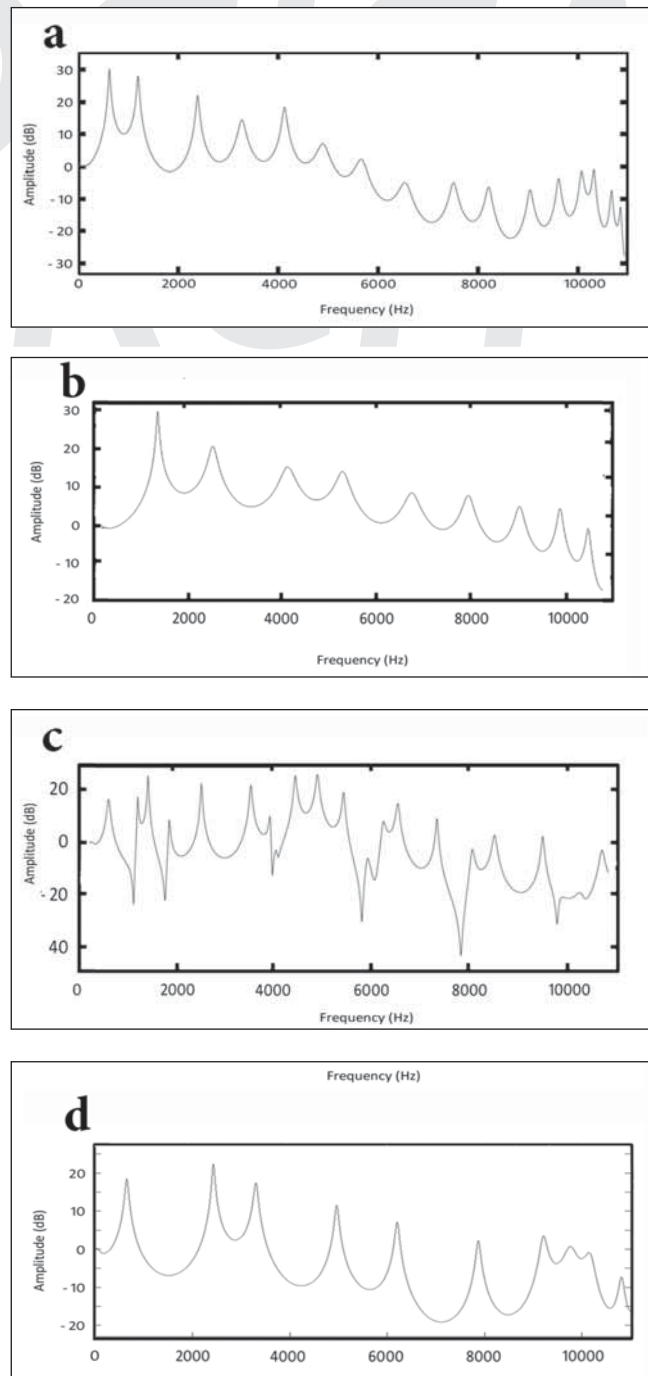


Fig. 2. Acoustic response of the vocal tract models. First 5 formants calculated for the emission of (a) /AA/ in a standard male human vocal tract: 671 Hz, 1245 Hz, 2440 Hz, 3327 Hz, 4182 Hz; (b) a tonal call in *L. catta*: 1223 Hz, 2422 Hz, 4050 Hz, 5245 Hz, 6750 Hz; (c) /M/ in a standard male human vocal tract: 410 Hz, 1029 Hz, 1247 Hz, 1697 Hz, 2380 Hz; (d) a nasal grunt in *L. catta*: 652 Hz, 2431 Hz, 3303 Hz, 4964 Hz, 6206 Hz. Diagrams show resonance frequency in Hz on the x-axis and amplitude on the y-axis.

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How Do Great Apes Acquire Information on Unusual Feeding Behaviors? The Role of Sociality and Physiology on Learning Process: A Window to Understand Origins of Self-Medication In Humans

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Introduction

Chimpanzees are known to consume some plants with low nutritional value and high bioactive compounds possibly to maintain and improve their health suggesting a self-medicating role (e.g. Huffman, 2003). How the great apes learn to consume bioactive plants has been little investigated.

Primates evolved neophobia (reluctance) towards novel foods (Visalberghi and Fragaszy, 1995) probably in parallel, but independently, of the unpalatable taste of certain plant parts (e.g. bitter taste) indicating the presence of toxic secondary compounds (Freeland and Janzen, 1974). Similar to our modern drugs, if certain secondary substances are ingested in small quantities they can have beneficial effects towards maintaining health (Krief et al., 2006).

The balance between beneficial and toxic effects also depend on the animal's body size and physiology (ability to detoxify toxins; Freeland and Janzen, 1974). Varying physical and physiological tolerances towards toxicity may thus lead to different levels of neophobia (Visalberghi et al., 2003).

The higher is the level of sociality of a taxon, the more learning animals can overcome the adaptive reluctance to novelty relying on social information (e.g. co-foraging and observational learning; Agostini and Visalberghi, 2005).

While chimpanzees (*Pan troglodytes*) remain mainly frugivorous throughout the year (Tutin and Fernandez, 1993) the longer gut retention time and enlarged hindgut with more cellulose-digesting ciliates (Chivers and Hladik, 1980) allow gorillas (*Gorilla gorilla*) to digest foods high in fibre and toxins, and to shift to a herbivorous diet when fruit is scarce (Rogers et al., 2004; Masi et al., 2009). Moreover, while chimpanzees develop foraging tools relying on social learning (e.g. Ueno and Matsuzawa, 2005;

Lonsdorf, 2006; Boesch, 1991), it is not clear whether gorillas develop such "traditions" (Byrne et al., 2011; Masi, 2011) or rely on a mixture of genetic predisposition and individual learning (Tennie et al., 2008).

This study focus on ape consumption of "unusual" foods, food that is rarely fed upon with low energetic/ nutritional content and/or known bioactivity. If an unusual food is toxic and consumed for other reasons than nutrition (e.g. disease), we predict: 1) a higher frequency of unusual food consumption in chimpanzees than in western gorillas, since western gorillas are more herbivorous and already likely to ingest a larger quantity/diversity of secondary compounds daily; 2) regardless of species a higher frequency of unusual food consumption in larger size individuals given their higher tolerance towards toxins than smaller individuals. If consumption of unusual food is socially learnt we expect 3) a higher frequency of inter-individual observations among the highly social chimpanzees than in gorillas and 4) immature individuals watching more frequently older individuals, who play a role as demonstrators.

Material and Methods

Chimpanzee data were collected every 15 minutes (January-August 2008, October-December 2008) by S.K. and field assistants on a habituated community (41-44 individuals) at Kanyawara, in the north-west of Kibale National Park, Uganda ($N_{\text{Days}}=237$, $N_{\text{Hours}}=2000$). Focal animal sampling of all age/sex classes was carried out at Bai-Hokou by S.M. (April-July 2008, November 2008-March 2009) on a habituated group of western gorillas ($N=11-13$) in the Dzanga-Ndoki National Park, Central African Republic ($N_{\text{Days}}=214$, $N_{\text{Hours}}=818$).

A list of unusual and bioactive foods (UBF), defined as rarely eaten food items, was established on the base of low consumption frequency, low energetic value, results of bioassays, phytochemical literature and/or traditional

uses in local medicine. Individuals present within 15m from consumers were recorded at each UBF consumption.

All occurrences of watching behaviour of food consumers and the duration of this event were recorded whilst feeding on both usual and unusual food.

When investigating the possible influence of body size on the consumption of UBFs, the individuals were pooled in two broader classes: 1) immature size individuals (juveniles and infants) and 2) mature size individuals (adults and sub-adults). To investigate the effect of age on social learning we modified the classes considering that: 1) overall infants, juveniles and sub-adults are expected to have a lower degree of neophobia with respect to adults, and 2) males do not disperse at adulthood in chimpanzees and in gorillas males emigrate at least five years later than females. Therefore, sub-adult females were moved into the immature class.

Results

Daily frequency of UBFs consumption (F_{UBF}) was twice as high in chimpanzees as in gorillas (F_{UBFs} : 0.27 vs. 0.14; Mann-Whitney U, $N_{Chimpanzees}=232$, $N_{Gorillas}=214$, $z=-8.45$, $P<<0.001$; Fig. 1). While older chimpanzees consumed UBF plants more frequently than younger ones ($N_{Immature}=16$, $N_{Mature}=27$, median UBF plant consumptions: Immature=0.80 $Q_{1-3}=0.00-4.60$, Mature=23.00 $Q_{1-3}=13.00-41.00$, $z=-5.43$, $P<<0.001$; Fig. 1a), no differences were found in gorillas ($N_{Immature}=6$, $N_{Mature}=7$,

Immature=0.14 $Q_{1-3}=0.13-0.17$, Mature=0.09 $Q_{1-3}=0.08-0.17$, $U=14.00$, $P=0.317$; Fig. 1b). Watching frequency per day during consumption of UBF plants did not differ between the two species (chimpanzees=0.00 $Q_{1-3}=0.12-0.35$, gorillas=0.00 $Q_{1-3}=0.14-0.26$, $z=0.29$, $P=0.769$). In comparison to gorillas, chimpanzee consumers of UBFs were 1) more often alone (chimpanzees: 72% of total of UBF consumptions, $N=351$, range $N=0-6$; gorillas: 12%, $N=50$, 0-11), 2) less individuals present within 15m (chimpanzees=1.00 $Q_{1-3}=0.00-2.00$, gorillas=3.00 $Q_{1-3}=1.25-4.00$, $z=6.53$, $P<<0.001$), and were watched for longer bouts (Chimpanzees: $N=185$; median=90.00 sec $Q_{1-3}=60.00-120.00$ sec; Gorillas: $N=20$; 17.50 sec $Q_{1-3}=9.25-32.50$ sec, $z=6.031$, $P<<0.001$). During UBF plant consumptions, no differences were found in watching frequency between the two age classes ($N_{Immature + Sub-Adult Females}=22$, $N_{Mature}=21$) in chimpanzees (median of watching frequency: "Immature + sub-adult females"=7.12 $Q_{1-3}=0.00-15.44$, Mature=10.28 $Q_{1-3}=7.06-14.03$, $z=0.68$, $P=0.272$). In contrast immature gorillas observed conspecifics more frequently than mature individuals ($N_{Immature + Sub-Adult Females}=8$, $N_{Mature}=5$; "Immature + Sub-Adult Females"=0.04 $Q_{1-3}=0.03-0.06$, Mature=0.00 $Q_{1-3}=0.00-0.03$; $z=2.34$, $P=0.019$). In chimpanzees the majority of watching events occurred from immatures towards matures (54%, $N=140$) and within matures (39%), while in gorillas within immatures (70%, $N=20$). In chimpanzees consumers of 29-35 years old were the most observed (Linear Regression with quadratic effect: multiple $r^2=0.627$, $F=17.66$, $P<<0.001$, $P_{(age\ consumer)^2}<0.001$; Fig. 2).

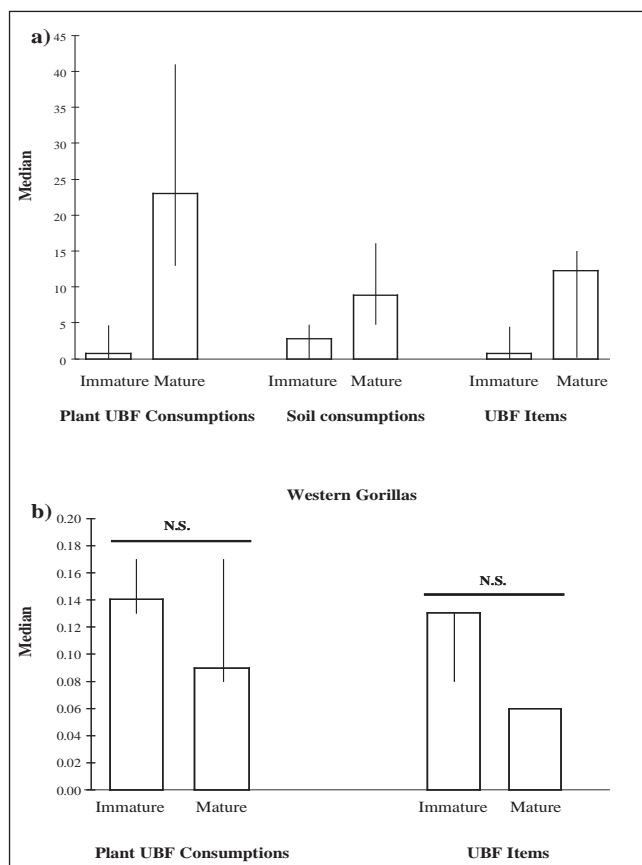


Fig. 1 a-b. Comparison of UBF consumptions and number of items consumed per age class in chimpanzees (a) and gorillas (b). Bold boxes: medians; bars: 1st and 3^d quartiles.

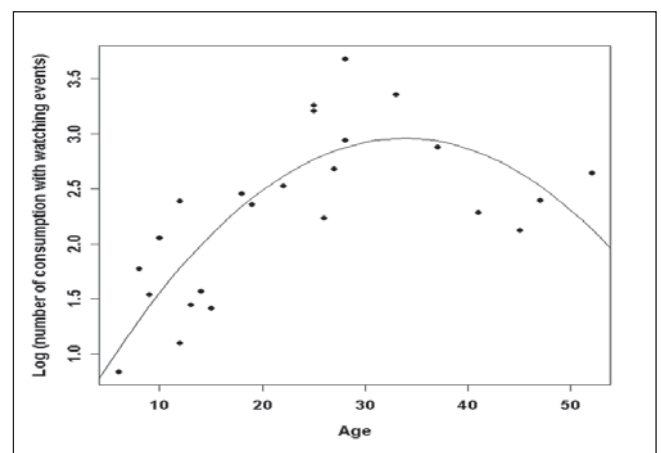


Fig. 2. Quadratic relationship between the number of consumptions with watching events per individual and the age of consumers in wild chimpanzees.

Discussion

Chimpanzees consumed UBFs twice as frequently as western gorillas. In contrast to chimpanzees, the more diverse and herbivorous diet and gut specialization with greater detoxification abilities (Chivers and Hladik, 1980) probably allow western gorillas to ingest more secondary compounds per day, alongside bioactive substances, to maintain their health. In comparison, the mainly frugivorous

chimpanzees may need to balance their diet with prophylactic plants beneficial for health but ingest them in lower amount to avoid toxicity. These opposing needs may have led chimpanzees and their common ancestors with humans to consume bioactive plants in association with certain stimuli (e.g. malaise) originating the subtle differences between food and medicine (Johns, 1990).

In contrast to immature individuals, adult chimpanzees consumed more frequently UBF items, while in gorillas this difference was not significant. The potentially higher content of toxic bioactive substances may explain the higher UBF consumptions by larger individuals who have greater toxin tolerance in chimpanzees. Sampling of UBFs in young western gorillas likely reflects random sampling of plants during adult diet acquisition (Watts, 1985).

No differences were found between the two species in the frequency of watching behavior nor in the number of observers per consumer. However, chimpanzees seemed to take more advantage than gorillas of having a “demonstrator” close to them as they: 1) had less opportunity to observe conspecifics while feeding on UBFs, 2) watched conspecifics in association with UBF consumption and not with usual food, and 3) observed consumers for longer bouts. The higher cautiousness and reliance on social interactions of chimpanzees during consumption of UBFs suggest UBF selection may be more dangerous or complex.

Observational learning occurs in chimpanzees during the entire life of an individual, while in western gorillas it seems to be a typical trait of immatures and adolescent females. The higher level of social tolerance in feeding contexts in chimpanzees compared to western gorillas (Masi *et al.*, 2011), may allow them to acquire information watching closely consumers of all age classes, particularly adults before senescence with better fitness and health. Since western gorillas are more protective of their food (Masi pers. observ.), watching among immatures may result from a more relaxed feeding competition.

Results of this study suggest that reasons for the consumption of plants with bioactive properties other than nutrition may have appeared on the evolutionary timescale in association with greater level of social tolerance and flexibility, and lack of herbivorous gut specialization which was probably absent in the common ancestors of humans and chimpanzees (Milton, 1999). This study highlight also potentially different roles of observational learning in the two apes: 1) a major role of horizontal knowledge transmission in gorillas similar to that found among children in some human hunter-gather populations (Mingot, 2000), and 2) a major role of vertical transmission in highly social chimpanzees who continually acquire feeding information throughout their life following like humans the strategy of “copying successful individuals” (Laland, 2004)

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Primate Play Laughing: a Comparison Between Immature Great Apes and Humans

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KEY WORDS: playful facial expressions, contact physical play, play face homology, chimpanzees, *Pan troglodytes*.

Introduction

In primates, playful interactions are often accompanied by specific facial expressions (van Hooff and Preuschoft, 2003). In the great apes, these expressions can be performed in two different ways: play face, where the mouth is opened with only the lower teeth exposed, and full play face, where the mouth is opened with upper and lower teeth exposed (Loizos, 1967). The use of the two expressions is plastic as a function of different factors such as play intensity (van Lawick-Goodall, 1968), playmate identity (Flack et al., 2004), and context (Palagi and Mancini, 2011). Playful facial displays may have a role in signaling non-agonistic intent to a playmate and in expressing emotion both during social and solitary play sessions (Palagi, 2006; van Hooff and Preuschoft, 2003). The non-human primate play face is homologous with human laughter (van Hooff and Preuschoft, 2003) which, across the diverse cultures, is the external manifestation of joy and happiness (Sauter et al., 2010). Primate laughter is considered a multifunctional behavior, because it reduces stress in subjects that face new situations, mitigates social ambivalence within a group, and triggers play interactions (see Gervais and Wilson, 2005 for an extensive review). If in the great apes, like it occurs in humans, playful facial expressions cover different roles and convey different information, we expect that they vary in frequency and form in relation to play intensity (Contact or Locomotor-Rotational play), playmate identity (sex of playmate), and number of players (dyadic or polyadic bouts). To test these hypotheses we collected data on two chimpanzee colonies (*Pan troglodytes*) and contrasted our findings with those coming from human literature on play facial communication.

Materials and Methods

The study was carried out on two groups of *Pan troglodytes* hosted at the ZooParc de Beauval (France) and the Dierenpark Amersfoort (The Netherlands). The Beauval colony was composed by 10 adults, 5 immature males, and 4 immature females. The Amersfoort colony was

made up of 11 adults, 2 immature males, and 4 immature females. Both colonies lived in large enclosures of about 500 m². Observations took place over a 6-hour period, 6 days per week (Beauval: October 2001- February 2002; Amersfoort: May-October 2004). Data on play were collected by focal animal sampling method (Beauval: 31 hrs per individual; Amersfoort: 35 hrs per individual) (Altmann, 1974). A play session began when one partner directed any playful behavior towards a playmate and ended when the participants stopped their activities or one of them moved away (Palagi, 2008). If the bout started again after a delay of 10 s it was counted as a new play session. We recorded: i) playmates' identity, ii) playful patterns iii) circumstance in which play took place (e.g. feeding, sexual). Social play patterns included: object manipulation, bite, pirouetting/somersaults, acrobatic play, run, slap, tickle, push, and recovering a thing. We distinguished between locomotor-rotational (LR-play, absence of any pattern involving physical contact, Palagi and Paoli, 2007) and contact play (C-play). We also recorded the number of playmates and distinguished between dyadic (two players involved) and polyadic (more than two players involved) play. For Play Faces (PF) and Full Play Faces (FPF), we registered signaler and receiver identity (directionality).

To analyze the preferential use of PF or FPF respect to the total amount of playful signals performed, we used the following index $[(FPF)/(PF+FPF)]$.

Data analysis focused on the 15 immature individuals. Due to the small sample size nonparametric statistical tests were applied. We made use of exact tests according to the threshold values suggested by Mundry and Fischer (1998). All the analyses were two-tailed and the level of significance was set at 5%.

Results

We found no evidence for directionality of signals (PF + FPF) as a function of sex (Mann-Whitney's $U=28$, $N_{F,M}=8$, $N_{M,F}=7$, $p=1.0$).

Play signals had comparable frequency in dyadic (D) and polyadic (P) play sessions (Wilcoxon's $T=44$, $N=15$, $p=0.389$). To evaluate the incidence of FPF in both D and P sessions we compared the following indices: (FPF_D/FPF_D+PF_D) vs (FPF_P/FPF_P+PF_P) . We found no significant

difference between such indices (Wilcoxon's $T=43$, $N=15$, $p=0.893$).

Play signals were more frequent during C- than LR-play sessions (Wilcoxon's $T=0$, $N=15$, $p=0.00001$). Moreover, the incidence of FPF during C-play (FPF_C/FPF_C+PF_C) was higher compared to the incidence of FPF during LR-play ($FPF_{LR}/FPF_{LR}+PF_{LR}$) (Wilcoxon's $T=0$, $N=15$, $p=0.00001$) (Fig. 1).

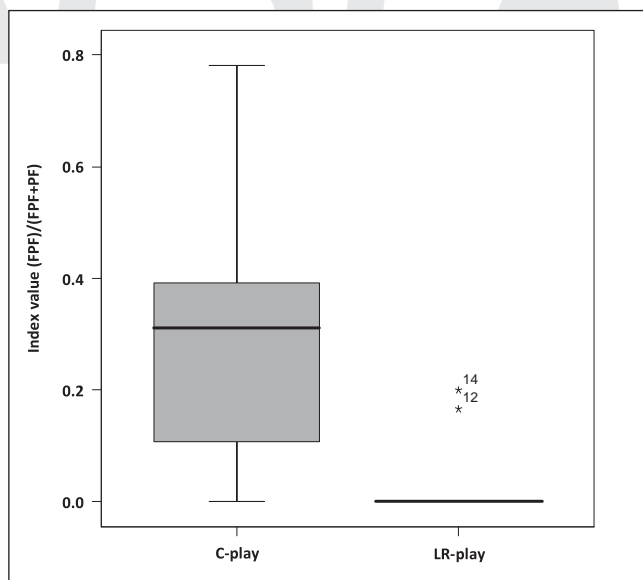


Fig. 1. Index value distribution ($FPF/FPF+PF$) as a function of the two different types of playful interactions (LR-play and C-play). Thick horizontal lines indicate medians; height of the boxes corresponds to inter-quartile range; thin horizontal lines indicate range of observed values.

Discussion

In immature chimpanzees, playful signal rates did not differ according to the sex and number of players involved in the session. The main factor affecting the play face distribution appears to be the intensity of play (C-play). Our data fit with findings coming from children literature; in fact, no difference was found in the laughing activity of boys and girls (preschoolers and toddlers) in different social contexts (Gervais and Wilson, 2005).

Even though there are no data on humans and other primates about the use of smiles according to the number of playmates, many efforts have been done in studying the role of such facial expression according to the roughness of play.

When play becomes more competitive, as it occurs in chimpanzees and humans, there needs to be clearer signaling (like full play faces) to maintain the session and to avoid it turning into overt aggression (Pellegrini, 2009). Also the other apes, like bonobos (*Pan paniscus*, Palagi 2008) and lowland gorillas (*Gorilla gorilla gorilla*, Palagi et al., 2007), perform more full play faces during their riskiest playful contacts (e.g. during play fighting and when it occurs under reduced escape conditions), thus suggesting that animals are perfectly aware of the potential dangerous situations they are living. Therefore, like true human laughter, the playful expressions in apes seem to have a role

in advertising cooperative intentions, thus increasing the likelihood of engaging in solid social relationships. Is contact physical play just a “useless” activity, or is it really important in apes’ and children’s development? Primates (including humans) need to understand the meaning of play faces to enjoy such physical contact play. Pellegrini (2009) found that in children the frequency of peer contact play correlated to ability to understand play signals. Although it is difficult to prove a cause/effect relationship, it might be that children and apes with more difficulty in understanding others’ emotional expressions engage in contact physical play less frequently and efficiently. This deficiency is not adaptive as, through contact play, immature animals can acquire the social competence that will be necessary to them later in life.

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Chromosomal Dynamics in Platyrrhinae by Mapping Bacs Probes

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KEY WORDS: molecular cytogenetics, cloned DNA probe, new evolutionary centromeres, Human synteny 4, phylogeny.

Introduction

Molecular cytogenetics by chromosome painting permits to detect, at molecular level, chromosomal homologies and interchromosomal rearrangements occurred during genomes evolution. Chromosome painting does not permit the detection of intrachromosomal rearrangements (inversions, activation of new centromere); those rearrangements, can be detected at molecular level using cloned DNA such as Bacterial Artificial Chromosomes (BACs) (Ventura *et al.*, 2004).

In the present work we selected probes derived from human chromosome 4 because comparative cytogenetic data showed that this synteny is less conserved than previously thought (Picone *et al.*, 2010). At the begins of the cytogenetics era the orthologues to human synteny 4 in Primates has been considered a conserved single submetacentric chromosome (Haig *et al.*, 1999) but by painting approach too many exception have been showed (Dumas, 2011). Stanyon and colleagues (2008) by mapping BACs probes showed different centromeres positions in the homologues to human chromosome 4 in New word monkeys and Old word monkeys. We mapped an appropriate human BACs probe set on the homologues of human chromosome 4 in *Saimiri sciureus*, *Saguinus oedipus*, Platyrrhinae, and on *Pongo pygmaeus*, Catarrhinae, used as out-group, with the aim to study fine chromosomal evolution in New Word monkeys.

Materials and Methods

Metaphases from non human primates were obtained from lymphoblast or fibroblast cell lines of: common squirrel monkeys (*Saimiri sciureus*, SSC), cotton-top tamarins (*Saguinus oedipus*, SOE), borneo orangutan (*Pongo pygmaeus pygmaeus*, PPY). The human BAC probes a) RP11-1150b4, b) RP11-637n1, c) RP11-166k6, d) RP11-70L18, e) RP11-443J23 clones were selected on the UCSC and mapped on the platyrrhinae species and on *P. pygmaeus* (Tab. 1).

Standard FISH protocols were applied. Hybridizations were performed in 50% formamide, 10% dextran sulfate, 2 × SSC at 37°C, in the presence of human Cot1 DNA (Gibco-BRL). Post-hybridization washing included 50% formamide, 2 × SSC at 42°C, or 50% formamide, 1 × SSC at 37°C, followed by three washes in 1 × SSC at 42°C. The chromosomes were stained with DAPI (4',6-diamidino-2- phenylindole). Digital images were obtained using a Leica DMRXA2 microscope equipped with a cooled CCD camera (Princeton Instruments) and arranged using Adobe Photoshop software.

Probes	Species
a) RP11-1150b4,	SSC, CJA, SOE, PPY
b) RP11-637n1,	SSC, PPY
c) RP11-166k6,	SSC, PPY
d) RP11-70L18,	SSC, SOE, PPY
e) RP11-443J23	SSC, SOE, PPY (CJA -Stanyon <i>et al.</i> , 2008)
f) RP11-455K3	(CJA -Stanyon <i>et al.</i> , 2008)

Tab.1. Titolo tabella?

Results

All hybridization experiments are repeatable, signals are bright and in agreement with painting data regarding the orthologues of human chromosome 4 in Platyrrhinae (SSC1- Stanyon *et al.*, 2000, SOE7, CJA3-Neusser *et al.*, 2001).

We have mapped BAC probes a), b), c), d) and e) on *S. sciureus* and *P. pygmaeus*. Probe a), e) and d) have been mapped also on *S. oedipus* (Fig.1).

Probe a) maps in a q arm position on *C.jacchus* chromosome 3, on chromosome 1 of *S. sciureus*, on chromosome 7 of *S. oedipus*; in p arm position on chromosome 3 of *P. pygmaeus*. Probes b), c), d), and e) map in the p arm on chromosome 1 of *S. sciureus* and in the q arm position of *P. pygmaeus* chromosome 3. Probe e) maps in a p arm position and probe d) in a q arm position on chromosome 7 of *S. oedipus*. The obtained results have

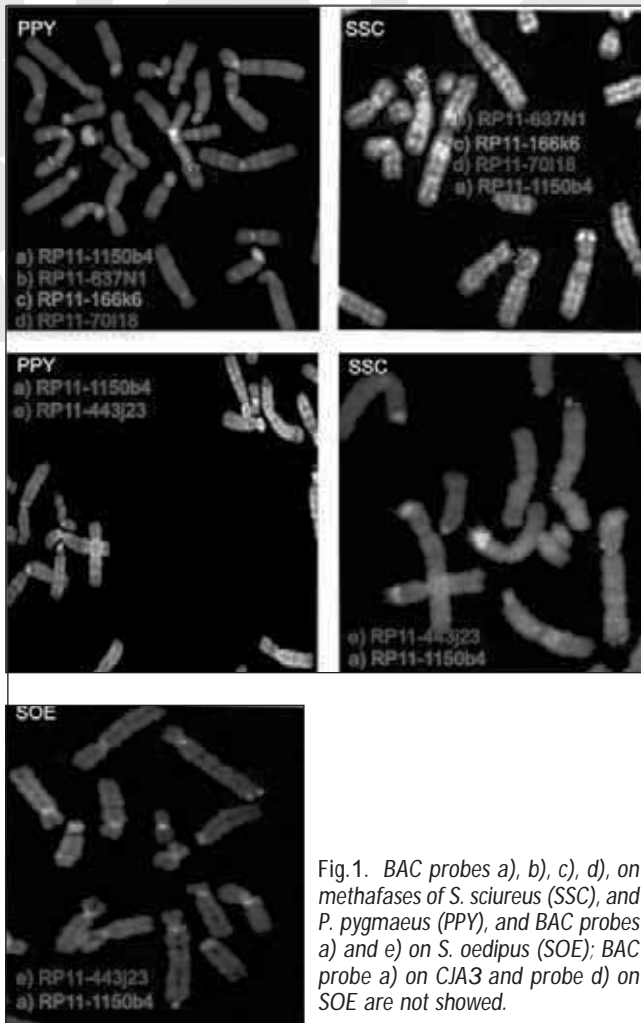


Fig. 1. BAC probes a), b), c), d), on metaphases of *S. sciureus* (SSC), and *P. pygmaeus* (PPY), and BAC probes a) and e) on *S. oedipus* (SOE); BAC probe a) on CJA3 and probe d) on SOE are not showed.

been compared with probe e) and f), previously, mapped on *Callithrix jacchus* chromosome 3 (Stanyon *et al.*, 2008).

Discussion

Our results permits us to identify, at a high level of resolution, intrachromosomal rearrangements on the homologues of human chromosome 4, not easily detectable by painting. The orthologues of human synteny 4 in Primates has been considered a conserved single submetacentric chromosome (Haig *et al.*, 1999) but many exceptions have been showed (see Dumas, 2011 for a review). By banding analysis Dutrillaux (1979) hypothesized a pericentromeric inversion or a centromeric shift occurred on *C. jacchus* synteny 4. Stanyon and colleagues (2008) studying chromosomal marker orders in primates showed by BACs mapping a new evolutionary centromere on the homologous of human chromosome 4 in *C. jacchus*, and two more in *L. lagotrica* homologues. Our probes mapping permitted us to show different rearrangements: probes a) falls on opposite position in the species analysed, in a p arm position on chromosome 3 of *P. pygmaeus* and in a q arm position in Platyrrhinae (CJA3, SSC1, SOE7) (Fig. 2). The apparent different position of the BAC signals, as previously demonstrate is the result of the occurrence of a new evolutionary centromere (between probe e and f)

without any change in markers order (Stanyon *et al.*, 2008, Rocchi *et al.*, 2009).

A new rearrangement never showed before is demonstrated considering the mapping of probe b) to e) on *S. sciureus* and previous data present in literature on *C. jacchus* (Fig. 2). Probes b) to e) do not fall (as it is possible to suppose looking *C. jacchus*) in a q arm position but in a p arm position on chromosome 1 of *S. sciureus* with a different orientation allowing us to propose the occurrence of an inversion in *S. sciureus* chromosome 1. Furthermore, the hybridization of BAC probes e) and d) on the homologues of human chromosome 4 in *S. oedipus*, chromosome 7 and in *S. sciureus* permits to show another rearrangement (Fig. 2). Both probes e) and d) map in a p arm position on chromosome 1 of *S. sciureus*;

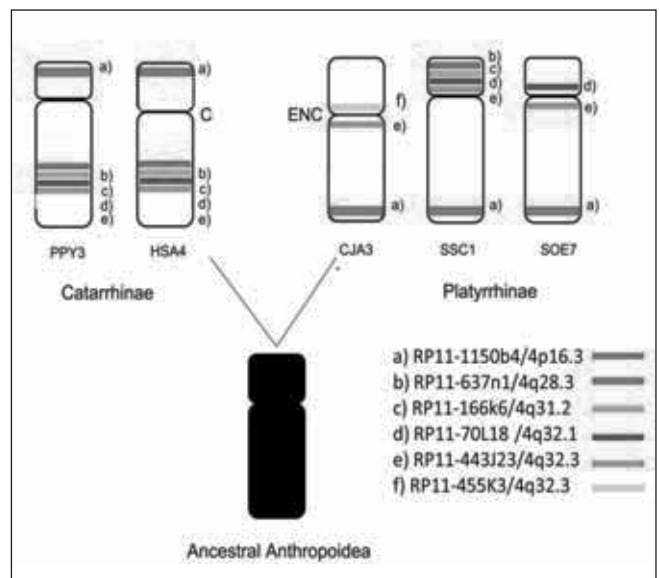


Fig. 2. BAC probes localization in the homologues of human chromosome 4 in New and Old World monkeys. The apparent different position of probe a) in Platyrrhinae (CJA3, SSC, SOE7) and Catarrhinae (PPY3, HSA4) is the result of a new evolutionary centromere (ENC) formation showed by Stanyon *et al.*, 2008 between probes e) and f). Probe b), c), d), and e) in SSC1 fall, not as it is possible to extrapolate from CJA3 in a q arm position, but in a p arm position as a result of an inversion. Probe e) and d) location in SSC1 and SOE7 show a different centromere position in the two species as result of another inversion or a ENC.

on the contrary those probes map in different arms on chromosome 7 of *S. oedipus*, probe d) falls in a p arm position and e) in a q arm, both close to the centromere. This result shows different centromeric positions in the two species (with the centromere below probe e) in *S. sciureus* and over e) in *S. oedipus* indicating presumably the occurrence, in the ancestor of the species, of the same pericentric inversion, and a successive new centromere formation or a little inversion in *S. oedipus*.

Conclusion

Ours results and data from literature permits to show a high level of intrachromosomal rearrangements in the dynamics of human synteny 4 in Platyrrhinae. Two new

evolutionary centromeres have been identified on two of the tree fragments homologues to human synteny 4 in *Lagothrix lagotricha* (Stanyon *et al.*, 2008). Even where human synteny 4 is conserved as a single chromosome is possible to show intrachromosomal rearrangements: a new evolutionary centromeres has been found in *C. jacchus* chromosome 3. We show the occurrence of an inversion on the homologues of human chromosome 4 in *S. sciureus* and *S. oedipus*, and the occurrence of a successive, other, little pericentric inversion or a new evolutionary centromeres in *S. oedipus* chromosome 7. More BAC mapping should be performed to better discriminate rearrangements and clarify synteny 4 intrachromosomal dynamics in Platyrrhinae. Through this work is showed the usefulness of the BAC mapping approach in the identification of intrachromosomal rearrangements utilizable as markers in phylogenetic studies.

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The Primate Ear Bone Collection of the University of Turin: Revision and Improvement

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KEY WORDS: ear bone collection, Primates, morphometry.

Introduction

In 1878, Alban H.G. Doran (1849-1927) first published the most comprehensive study on comparative anatomy of the auditory ossicles in Mammals, including Primates. This author illustrated the features of those *ossicula*, with the purpose of demonstrating if and how far the ear bones can retrace the systematic of this class.

Since the '60s, in addition to the monographic work on the comparative anatomy of middle and inner ear of Werner (1960), Masali (1964, 1971) and Masali and Chiarelli (1965a,b) conducted morphometric studies on human and non-human Primate ear bones, confirming their taxonomic and systematic utility. Further research have focused on the possibility of characterizing ancient human populations with the help of such cranial structures (Siori *et al.*, 1995; Masali and Micheletti Cremasco, 2006). Ear ossicles have also been important sources of palaeobiological information about the evolutionary history of Primates and Man, when analyzed together with the other auditory structures and their biomechanical functions (Arensburg and Nathan, 1972; Rak and Clarke, 1979; Masali *et al.*, 1992; De Ruiter *et al.*, 2002; Moggi-Cecchi *et al.*, 2002). It is evident, therefore, the importance of such cranial elements and their unfortunately scarce collections.

The main contribution of this work is the improvement of the collection of Primate ear bones stored in the University of Turin. To this end, the existing material has been reorganized, revised and supplemented with new specimens and *taxa*. Today, the overall picture of the diagnostic features, at generic and/or specific level, as well as the data-base of metric characters are more complete. The rearrangement of the collection has also offered the possibility of identifying some pathological ossicles that are currently under study.

Materials and Methods

The primatological ear bone series has been collected since the '60s at the Institute of Anthropology of the University of Turin, and now is kept in the Life Sciences and Systems Biology Department of the same University. Unfortunately,

during these 50 years, several specimens have been lost or broken and this has led to a discrepancy between the current size of the collection and the morphometric data collected.

Given the small size and the fragility of the sample, we have used a stereoscopic microscope equipped with a *camera lucida* for the observation and the reproduction of the ossicles.

The measurements were obtained following the methodology described by Masali (1964), and Quam and Rak (2008) (Fig.1). For the nomenclature and systematics of the Primates refer to Gippoliti e Visalberghi (2001).

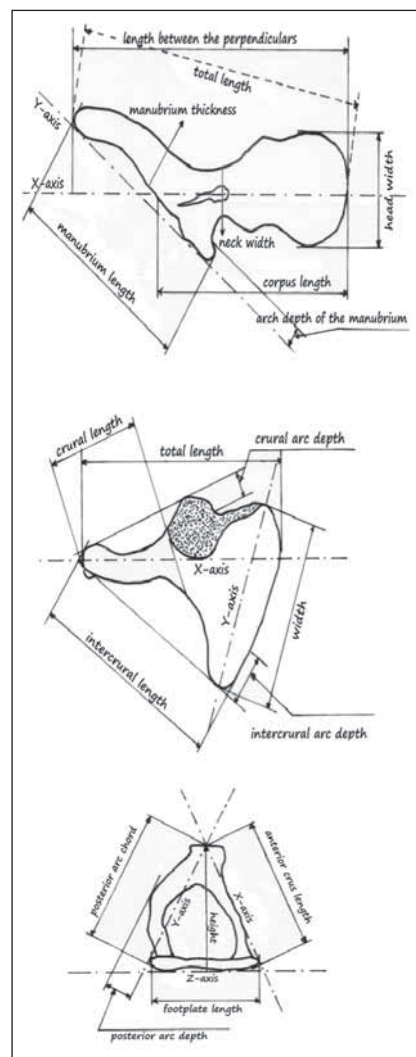


Fig. 1. Measurements according to Masali (1964), modified.

FAMILY	SPECIES	MALLEUS		INCUS		STIRRUP	
		right	left	right	left	right	left
Lemuridae Gray, 1821	<i>Eulemur fulvus</i>		1				1b
	<i>Lemur catta</i>	1b	3		3		1b
Galagonidae Gray, 1825	<i>Galago sp.</i>	1+1b	2	2	2		1
Callithricidae Thomas, 1903	<i>Callimico goeldi</i>	1		1pat	1		
	<i>Callithrix jacchus</i>	2		1			
	<i>Callithrix sp.</i>	1	1	1pat	1pat		
	<i>Leontopithecus rosalia</i>	1		1			
	<i>Leontopithecus sp.</i>		1		1		
Cebidae Bonaparte, 1831	<i>Alouatta caraya</i>	1b		1	1		
	<i>Alouatta seniculus</i>	3	1	1	1		
	<i>Alouatta palliata</i>	1+1b	1	3	2+1b		
	<i>Alouatta sp.</i>	1	1	1	2	1b	
	<i>Aotus trivirgatus</i>	2	2	2	2	2b	1b
	<i>Ateles hybridus</i>	1	1+1b	1+1b	4	1	
	<i>Ateles paniscus</i>			1	1b		
	<i>Ateles mona</i>	1		1			
	<i>Ateles sp.</i>	1		1	1b		1
	<i>Lagothrix sp.</i>		2		2		
	<i>Callicebus donacophilus</i>	1		1	1		
	<i>Callicebus sp.</i>		1			1b	
	<i>Cebus albifrons</i>	4	3	4	5	2+2b	1
	<i>Cebus capucinus</i>	1+1b	1	2	2		
	<i>Cebus apella</i>		1	1+1b		1	
<i>Cebus sp.</i>	2+1b	2	2	2		1	
Saimiri sciureus	<i>Saimiri sciureus</i>	1	1	1	1		
	<i>Saimiri sp.</i>	1r		1			
Cercopithecidae Gray, 1821	<i>Cercocebus atys</i>	1	1	1	1		
	<i>Cercopithecus mona</i>	1		2		1	
	<i>Cercopithecus sp.</i>	1	1		1		1
	<i>Chlorocebus aethiops</i>	1	1	1	1		1b
	<i>Chlorocebus pygerythrus</i>	1pat	1pat				
	<i>Chlorocebus sabaues</i>			1+1b		1	
	<i>Macaca fascicularis</i>	2+2b	2+2b	2+1b	3		
	<i>Macaca mulatta</i>	3	3	1	2		
	<i>Macaca nemestrina</i>	4+1b	4	1	1		
	<i>Macaca sylvanus</i>	3	1	3	1		
	<i>Macaca ochreata</i>	1	1	1	1		
<i>Macaca sinica</i>	2	2	1	2			

FAMILY	SPECIES	MALLEUS		INCUS		STIRRUP	
		right	left	right	left	right	left
	<i>Macaca sp.</i>	4	3	2	2	2	1
	<i>Mandrillus leucophaeus</i>	1					
	<i>Papio sp.</i>	3	6	4+1pat	5		
	<i>Colobus guereza</i>	2	1		1		
	<i>Colobus polykomos</i>		1			1	
	<i>Nasalis larvatus</i>	1	1b	1			
	<i>Procolobus badius</i>	1b	1	1	1		
	<i>Semnopithecus entellus</i>	2	2	2pat	2pat	1	
	<i>Semnopithecus sp.</i>		1				
	<i>Trachypithecus obscurus</i>		1b		1		
Hylobathidae Gray, 1871	<i>Hylobates moloch</i>	2	1	1b	1		
	<i>Hylobates syndactylus</i>	2	1	2	1		1
	<i>Hylobates sp.</i>	1			1		
Hominidae Gray, 1825	<i>Gorilla gorilla</i>	1					
	<i>Pan troglodytes</i>	1					
Cercopithecidae/Hylobatidae N.D.		20+1b	14+1b	16	10+1pat	2	2
		97	79	78	75	18	13
	Total for each bone	176	153	31			

Tab. 1. The consistency of the Primate ear bone collection (pat=pathological; b=broken).

Results

1) *The consistency of the collection.* The consistency of the ear bone collection is shown in Tab.1. The total number has been recorded for each ossicle. The ear bones belong to 52 species, 28 genera, including Lemuridae (2), Galagonidae (1), Callithricidae (5), Cebidae (17), Cercopithecidae (21), Hylobatidae (3) and Hominidae (3) families. The ossicles that in the historical collection were generically referred as “*Scimmia*” are still subject to revision, and therefore counted separately.

2) *Criticalities of the methodologies and additional measurements.*

The most common morphometric techniques show criticalities when applied to ear bones of Primates, particularly of Platyrrhines and Prosimians. Specifically, the *length of the manubrium* and *corpus length* of the malleus required a slight effort of interpretation both because of the lack of the short apophysis and the particular alignment of the head and body. Similarly, due to the noteworthy morphological variability of the articular surface of the incus, it was difficult to identify the landmarks to trace the *y-axis* and thus measure the *incus width*. Some measurements used for human bones were considered useful also for non-human Primates: *manubrium mediolateral thickness* and *neck width* of the malleus; *articular facet height* of the incus; *total height* of the stapes and *depth* of its footplate. These new measurements are shown in Fig. 1.

3) *Diagnostic and taxonomy.* An important result of this work relates to the diagnostic capabilities of the auditory ossicles to various ranks of the taxonomy. Unlike what was stated in the literature, the malleus and the incus were indeed useful in the distinction of Primates not only at the level of infraorder but also of genus. The detailed description of the diagnostic characters will be subject to further future studies.

Future developments

Future developments of this research could be: redefinition of some measurements for the application of metrical method to Prosimians and Platyrrhines; definition, description and statistical analyses of morphometric data for taxonomic utility; study and pathological evaluations of injuries and/or alterations in shape and size.

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Pathological Skeletal Changes in a Specimen of Pan Troglodytes from the Primate Collection of the Museum of Anthropology and Ethnography, University of Turin

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POSTERS

KEY WORDS: primate, *Pan troglodytes*, osteological collection, paleopathology.

Introduction

The non-human primate osteological collection of the Museum of Anthropology and Ethnography (Department of Life Sciences and Systems Biology, University of Turin) was collected at the beginning of the 20th century by the museum's first director, Professor Giovanni Marro (1875-1952), a medical doctor and anthropologist. It comprises 52 virtually complete skeletons, most of them referring to Cercopithecoidea (*Papio* and *Macaca*), with only two great ape specimens (*Pan* and *Pongo*). The assemblage was recently re-arranged in long-term storage in order to assess the preservation condition, to monitor the status of biological samples and to devise a conservation plan. All biological data that can improve our understanding of the origin and evolution of some diseases have also been recorded.

During the scientific investigation, several gross pathological skeletal changes, visible by naked eye, were described in a specimen of *Pan troglodytes* (n. 10342 DBAU).

The lesions suggest a severe hematological disorder.

This paper presents some of the results of the ongoing paleopathological research.

Materials and Methods

The skeleton of *Pan troglodytes* belongs to a young individual about 10-12 years old (Nissen and Reisen, 1964; Smith *et al.*, 1994). It was not possible to determine the sex from macroscopic observations.

In the study of the specimens, our approach included a physical examination of the bones by direct observation, also with a magnifying lens. Direct inspection of the endocranial surface of the skull was possible through the coronal section of the calvaria. ,

Case Report

The subject is affected by extensive porotic hyperostosis, symmetrically distributed.

The calvaria and oro-maxillo-facial components are considerably remodeled. The overall size of the skull is bigger than non-pathological individuals approximately of the same age. Cranial lesions involve the frontal and parietal bones, the occipital squama and zygomatic processes of the temporal, the palatine and the alveolar processes of the maxillary bone. Deep symmetrical depressed areas in the outer table of the parietals are observed. The parietal and nuchal crests are heavily developed and show evident radial bony spicules on the top.



Fig. 1. Left: *Pan troglodytes* (10342DBAU): general thickening of the bones and widened diploë. Right: non-pathological individual.

All sutures are prematurely fused (craniosynostosis). Direct inspection through the coronal section of the calvaria revealed a general thickening of the bones and widened diploë, with hair-on-end appearance of the outer table (Fig. 1). There is also involvement of the facial skeleton resulting in prominence of the malar bone, with severe maxillary hypertrophy, spacing and displacement of teeth, malocclusion, enamel hypoplasia and porosity of the palate (Fig. 2). The swelling of the facial bones, maxillary

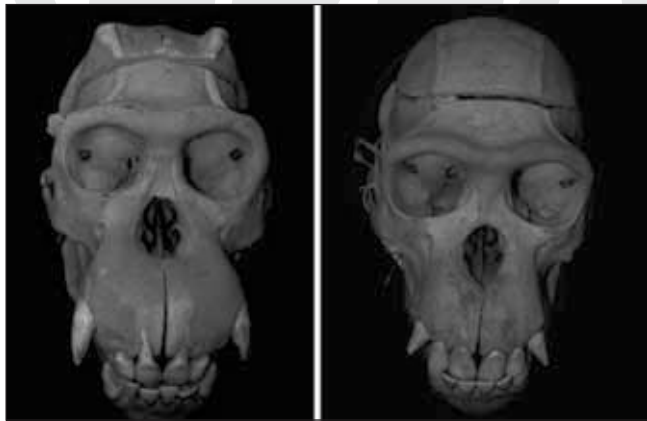


Fig. 2. Left: *Pan troglodytes* (10342DBAU): severe maxillary hypertrophy. Right: non-pathological individual.

overbite, ocular hypertelorism and the upper central incisors displaced forward give rise to peculiar features of the face that the specific literature identifies by the term “rodent facies”, characteristic of thalassemia major. No signs of cribra orbitalia were detected. This sort of skeletal pathology has never been described in non-human Primates except by Schultz (1956, p. 971).

On macroscopic examination, the post-cranial skeleton is less affected than the skull. Localized porosity is present on the proximal metaphysis of the upper limbs and on the coxal bones, and slight bone deposition is clearly visible in areas of tendon attachments along the limb diaphyses.

Discussion

The osteological evidence suggests a diagnosis of a hematological disorder, in particular an iron deficiency or hereditary anemia (hemolytic anemia) (Mann and Hunt, 2005; Fornaciari and Giuffra, 2009). A variety of factors, including the age of the subject, the severe manifestations of marrow hyperplasia and the distribution of the lesions, might indicate a disorder related to hemolytic anemias, such as thalassemia; in human pathology, facial bone involvement is seen in Cooley's anemia and is an important

diagnostic finding (Angel, 1964; Moseley, 1974; Resnick and Niwayama, 1988; Hes *et al.*, 1990; Hershkovitz *et al.*, 1997; Hollar, 2001; Hazza and Al-Jamal, 2006, Lagia *et al.*, 2007). As differential diagnosis,

we propose a hematological disorder related to an infectious disease caused by parasites, which is surprisingly common in wild monkeys and apes.

The next step of the research will be the molecular detection of possible genetic mutations (for example β -thalassemia). A complete radiological examination of the skeleton is also planned.

In the same time, in order to detect for possible genetic mutations (β -thalassemia), DNA extraction and sequencing of the coding region of β -globin gene are implementing in collaboration with the Genetic Service “IRCCS Burlo Garofolo” of Trieste. A complete radiological examination of the skeleton is also planned.

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Non-Human Primates in the Work of Ulisse Aldrovandi (1522-1605)

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POSTERS

KEY WORDS: *Simia*, history of Primatology, renaissance, Italy.

Introduction

In the second half of 16th century a group of scholars and natural philosophers, interested in collecting and transmitting the *summa* of natural knowledge that had been produced so far, appeared in Europe. They worked on the knowledge of ancient authors trying to reaffirm the exact meaning of the ancient texts correcting the distortions of the medieval tradition.

They also added and included into their work the new contemporary information from researches on local nature and from travel literature, especially that of the recently discovered worlds. The medieval contributions continued to be followed, as well as some fantastical reports (“*monstrua*”) of the oral tradition, but all within a context of critical attitude. Among them Ulisse Aldrovandi, an Italian physician and an “encyclopedic naturalist” native of Bologna, was one of the most important. This research shows a revision of his work about non-human primates (NHP).

Materials and Methods

All the works (books, manuscripts and iconographic samples) of Aldrovandi which include or mention NHP were examined. Particular attention was given to the literary sources used by Aldrovandi. Many of them were identified after an accurate analysis of the American and African travel literature of the 16th century (see Veracini, 2010). The *Tavole* (watercolour plates of the Aldrovandi’s Museum) were obtained by the official web-site of the Bologna University: <http://www.filosofia.unibo.it/aldrovandi/>. The *taxa* identification of NHP was based upon morphological keys for taxonomic rank, according to the descriptions available in literature. As a general reference, primate taxonomy follows Groves (2005).

Results and Discussion

Aldrovandi’s works about NHP include 10 watercolour plates (*Tavole*) and the Chapters *De simia*, *De*

cercopitheco, *De cynocephalo* and *De papione* of the book *De quadrupedibus digitatis viviparis* published after his death in 1637. Some of the watercolour plates were engraved and then printed in the *De quadrupedibus* as a complement to the text. In the *Tavole* 9 different primate *taxa* were depicted: 5 African monkeys (genera *Papio*, *Cercopithecus*, *Macaca* and *Chlorocebus*) and 4 Neotropical primates (genera *Callithrix* and *Cebus*). Starting from the watercolours’ analyses and from the names used by Aldrovandi to describe these primates, it is possible to recognize the taxonomy and the sources he used. Each of these primate categories will be deeply explored in the *De quadrupedibus*. The watercolours showing African monkeys are rich of inscriptions explaining their characteristics. Very interesting are the author’s lists of all the names used so far to describe such primates, where he tries to resume their features in the name, a similar method will be improved later with the Linnean Binomial system. For example as regards baboons he utilized: *Cepos*, *Cynocephali species*, *Cynoprosopos*, *Simia porcaria*, *Kiber Avicenna* etc., where *Cepos* are monkeys with tail, *Cynocephali* are the dog-headed species and the others names are the descriptions given by Aristotele and other authors. The Barbary macaque (*Macaca sylvanus*) is called *Simia pithekos*; the term *simia* had been used to indicate monkeys without tail since ancient time, but in general it was always associated to this species. In this case Aldrovandi associated the word *pithekos* to the category *Simia*, probably for a better definition. The word *pithekos* might originate from the Proto-Berber language (see Groves, 2008) thus the binomial *Simia pithecus* seems very appropriate for this Northern African species. The vervet monkey *Cercopithecus aethiops* is described as *Cercopithecus*, monkey with long tail or “sea cat” from their overseas provenience. Also *Cercopithecus diana vel roloway*, is fairly classified as *Cercopithecus*; Aldrovandi also cited its German name which remembers its long beard. Moreover the author uses the popular Portuguese name *buxio* (or *bugio*) used by Lusitan people to design monkeys in 16th century. This monkey had been probably known in Europe since the Portuguese discovery of Western Africa in 15th century. All Aldrovandi’s Neotropical primates are included in the category *Cercopithecici*, as shown by the *Tavole* and after in the *De quadrupedibus* in which the author reports detailed morphological and behavioral descriptions taken by the travel chronicles of the New World and Africa. Aldrovandi’s

citations include among others Pedro Martire de Anghiera, Henry Levy and Hans Staden. In the Aldrovandi's work three species of Platyrrhines are depicted for the first time in Europe, they are: *Callithrix geoffroyi*, *Cebus capuchinus* and *Cebus* cfr. *apella*. It should also be mentioned one of the first scientific description of *Cebus xanthosternus*, a rare Brazilian primate threatened with extinction. Two of the three capuchin monkeys were called *Simia barbata* though one of them has the adjective *caudata* (with tail); also the third capuchin called *Cercopithecus facies senis, cauda longissima nigra* is observed to have a very long tail and an old man face, perhaps due to the peculiar wrinkles of this species. Therefore two of capuchins are described as *Cercopithecus* and two as *Simia*. The fact that there is no further information and that the classification is sometimes confused leads us to believe that Aldrovandi never saw these animals alive. The marmoset's depiction is without inscription though the author will give a great description of it in the Chapter *De cercopitheco* observing that "this monkey lives in Brazil and it's called *sagoin*" (this word probably came from the tupi-guarani family language). The *Tavole* anticipated the classification used in the book *De quadrupedibus* where NHP are divided in four groups: *Simias*, *Cercopitheci*, *Cynocephali* and *Papioni* in accordance with the classical tradition, especially following Aristotele, and, in some parts, the naturalist Konrad Gesner. The *simia* identifies a wide category and the referring Chapter includes citations of Aristotele, Herodoto, Plinio, Strabone, Aeliano among the others, and Middle Age authorities such as Albertus Magnum. Aldrovandi tried to resume and include everything he knew to describe these monkeys: their names, synonyms and etymologies, places of origin, habits, biology and their magical, symbolical and moral meanings. The Chapter on *De cercopitheco* is very interesting because the author gives information just arrived in Europe

including African and Neotropical species. The brief Chapter *De Papione* reports the case of the probably first mandrill arrived in Europe; this specimen had been already described by Gesner in the *Thierbuch* (1551). Aldrovandi discusses his characters and notes his similarity with other baboons.

Conclusions

The Author classifies monkeys on the basis of external criteria and common features, but also on their provenance when available. The poorly known Neotropical primates were included in the group of *cercopitheci* namely tailed monkeys and "sea cats". Although Aldrovandi's work was still influenced by the medieval tradition, there are not many fantastic NHP in his work. In conclusions Aldrovandi's work on NHP seems very logical and rigorous. His work is a *summa* of the knowledge about monkeys available so far. Each monkey becomes a sort of pattern around which a complex network of texts and visual associations are inter-related.

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Enrico Hillyer Giglioli and His Contribution to the Primatology of the 19th Century

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KEY WORDS: history of Primatology, Italy, 19th century, *Troglodytes schweinfurthii*.

Introduction

A recent analysis of the primatological works of the Italian zoologist and anthropologist Enrico Hillyer Giglioli (London 1845 - Florence 1909) revealed the important contribution he gave to primatology. He attended the Royal School of Mines (1861-1863) in London, where he met T. H. Huxley, C. R. Darwin, R. Owen and C. Lyell and obtained his graduation degree at the University of Pisa in 1864 (Barbagli *et al.*, 1996). He took part in the voyage around the world sponsored by the Italian Government in 1865 embarking on the Royal Navy warship *Magenta*. Later he got the direction of the Zoological and Anatomical Cabinet of the Natural History Museum *La Specola* of Florence and was involved in the activities of the Florence School of Anthropology. He was a great supporter of Darwinism and a pioneer of ethnological studies along with Luigi Pigorini and Ettore Mantegazza. In 1901 he established the Laboratory of Anthropometry attached to the Museum of Anthropology in Florence.

Our work aims to give a description of Giglioli's primatological works highlighting his contribution to evolutionary aspects.

Material and Methods

As an historical work all the papers about mammals by Giglioli including or mentioning non-human primates were examined. The activity of Giglioli as Director of the Zoological and Anatomical Cabinet of Natural History Museum *La Specola*, was re-examined during the revision of the primatological collection of this Museum (Veracini *et al.*, in press).

Results and Discussion

Giglioli was an eminent ethnologist and zoologist who worked on various groups of animals. He published around 400 papers on different topics (Barbagli *et al.*, 1996). Although his works on primates are not so numerous

(Giglioli, 1872, 1887, 1888) they represented a valuable contribution to the 19th century primatology. When he was director of *La Specola* Vertebrate Collections, he started the general collection of Italian vertebrate and the assessment and re-organization of the entire vertebrate collection. It should be underlined that thanks to his efforts this museum received several specimens of orangutan currently identified as belonging to two distinct species: *Pongo pygmaeus* (Linnaeus, 1760) and *Pongo abellii* (Lesson, 1827). The work of Giglioli, combining scientific accuracy with a wide range of international contacts, led the Museum to its period of greatest increase as regards the primatological collection (Veracini *et al.*, in press). An important work was the scientific description of a new Ethiopian species of guenon, the Boutourlini's Blue Monkey (Giglioli, 1887): *Cercopithecus boutourlinii* currently *Cercopithecus mitis boutourlinii* (Giglioli, 1887). In another work he described the mammal taxa of the same geographical area of this monkey, the Scioà region. These vertebrates were collected by Augusto Boutourline and by Doctor Traversi (Giglioli, 1888). Here Giglioli discussed his previous work on *C. boutourlinii* giving the exact descriptions of the specimens. Moreover, he studied the specimens of *Colobus guereza* observing the individual variations of the tail's length and morphology and argued against the subspecies *Colobus guereza caudatus* described by Thomas in 1885 (Giglioli 1988). But his most important work was the essay: "*Studi craniologici sui cimpanzè*" (1872) where he conducted a detailed study of the chimpanzee skulls collected by his friend Georg August Schweinfurth in the region which is today Southern Sudan. He measured and compared the skulls of chimpanzees and of other apes observing that the skulls of the Eastern chimpanzee had a greater cranial capacity in comparison with the other great monkeys he could observe. In this work he gave the scientific description of the species *Troglodytes schweinfurthii*, (Giglioli, 1872), currently a subspecies of *Pan troglodytes* (Blumenbach, 1775). In order to evaluate the differences among skulls Giglioli used the methodology that Mantegazza, the famous Florentine anthropologist, had used for humans. Moreover he discussed on the importance of certain cranial features as diagnostic traits to evaluate species and subspecies and included a thorough essay on the comparative anatomy of the different primate genus also describing some ontogenetic variations of the Order of Primates.

He explained the meaning of species and subspecies saying that: “*T. schweinfurthii* deve per ora considerarsi una razza di Cimpanzè, una specie in via di formazione, o, come dicono taluni, una sottospecie, con decisa tendenza antropoide”. And he continued: “Il lettore avrà osservato che parlando del *Troglodytes schweinfurthii* e di quelli che abitano l’Africa occidentale mi sono sempre astenuto di far uso della parola specie; non ho fatto questo casualmente, come ora vedremo. Per chi accetta come faccio io l’ipotesi Darwiniana quella parola non ha più un significato assoluto; anzi la specie come l’intendiamo noi varia talmente che credo nessuno ne possa dare una diagnosi netta e definita. Nello studio della biologia abbiamo bisogno di quella parola classificatrice: la specie è necessaria ed io la serbo per indicare l’insieme di certi caratteri collettivi che riuniscono un numero d’individui separandoli da altri e che predominano sui caratteri individuali e quali tendono ad isolare ciascuno. Limitando i miei confronti ai primati superiori la specie è variabilissima. Si hanno così varietà e si hanno anche vere razze o sottospecie. Ora per me il *Troglodytes schweinfurthii* deve per ora considerarsi una razza di Cimpanzè, una specie in via di formazione, o come dicono taluni, una sottospecie”. He added another very interesting part saying “la scoperta di *T. schweinfurthii* rende più probabile l’ipotesi di Darwin, diminuendo la distanza che separava sin qui l’Uomo ed i Trogloditi. Ma l’anello di congiunzione manca ancora [...] e cioè quell’essere che non essendo ancora scimmia possa dirsi Uomo; credo però che questo essere giacché è più probabilmente estinto, debba ricercarsi nell’Africa centrale”. He gave a very important definition of species stating that *T. schweinfurthii* was actually still developing, that is the variability which differentiated it from other chimpanzees was not so remarkable. It should be underlined that the concept of species and sub-species among primates is still today under discussion. These considerations sounded very important at that time just when Darwin’s ideas were establishing

themselves throughout Europe and Giglioli joined the Italian evolutionary debate of the second half of the XIX century.

Conclusions

Enrico H. Giglioli was one of the first Italian supporter of Darwinism and an advocate of the origin of man from apes. He discussed on evolution and variability of chimpanzee species and subspecies showing the problems deriving from a clear-cut application of the concept of species which is still under discussion. He named the species *Cercopithecus boutourlinii* currently *Cercopithecus mitis boutourlinii* (Giglioli, 1887) and *Troglodytes schweinfurthii* today *Pan troglodytes schweinfurthii* (Giglioli, 1872) the Eastern chimpanzee. Up to now he is the only Italian scientist who named two taxa of primates.

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