GREAT APE VOCAL REPERTOIRES ARE ALL SIMILAR IN SIZE: NOW WHAT?

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There is an uncanny similarity between the size of nonhuman great ape vocal repertoires and that of the phonological inventories documented in human languages. Great ape repertoires vary from a conservative estimate, and lower-bound, of 18 calls in both species of gorillas (*Gorilla*), to the low-to-mid 20s in chimpanzees and bonobos (*Pan*), to the mid 30s in orangutans (*Pongo*). These numbers are in line with the average number of contrastive speech sounds in modern and in ancient and reconstructed languages. See Table 1 for details.

This observation suggests a common evolutionary pressure for a two digit system repertoire, one that existed before the origin of language, and present at the split with our evolutionary ancestors. The difference between systems is well documented – language combines speech sounds (or signs) into an open-ended communication system that *infinitely* produces new words and meanings. And although we do not yet know what led to the cognitive abilities that gave rise to this system in *Homo*, there are many similarities between the vocal repertoires of great apes and those in languages left to explore.

Like language, great ape calls are produced in non-random combinations (Lameira et al., 2021; Girard-Buttoz et al., 2022). Like speech, orangutan vocal repertoires are composed of consonant- and vowel-like calls (Lameira, 2014; Lameira, Maddieson, & Zuberbühler, 2014; Lameira et al., 2017). Orangutan vocalizations also involve modest airstream and articulatory control (Wich et al., 2008; Lameira et al., 2013, 2015) and experiments done in captivity show precise vocal fold motor control, including voicing (Lameira & Shumaker, 2019). And along with other cognitive skills, e.g., tool making, some great ape vocalizations are arguably learned (Hopkins, Taglialatela, & Leavens, 2007; Taglialatela, Reamer, Schapiro, & Hopkins, 2012; Wich et al., 2012; Russell, McIntyre, Hopkins, & Taglialatela, 2013; Lameira et al., 2015; Lameira, Hardus, Mielke, Wich, & Shumaker, 2016; Lameira & Shumaker, 2019) with some groups in captivity reportedly transmitting raspberries to their young, which they use to get the attention of caretakers (Hopkins et al., 2007; Taglialatela et al., 2012; Russell

et al., 2013). Finally like languages, the call repertoires of great apes are shaped by socio-cultural factors (Lameira et al., 2022), they have dialects (Crockford, Herbinger, Vigilant, & Boesch, 2004; Lameira, Delgado, & Wich, 2010; Lameira et al., 2017), change through contact (Mitani & Gros-Louis, 1998; Watson et al., 2015b, 2015a), and their existence and diversity are under the threat of extinction (Meijaard et al., 2011; Wich et al., 2012, 2016; Estrada et al., 2017).

We conducted an extensive review of the existing literature (66 published articles) and found that call repertoires are similar in size across extant great apes. However, we also discovered that there is little in terms of a comparative articulatory and acoustic analysis of these vocalizations. This is because there is a serious gap in the descriptions of the articulatory features of great apes in the literature, including for both vocal and gestural data.

A step towards a comprehensive comparative phonetic analysis of articulations of all great apes is needed to shed light on the similarities between vocal communication systems and how each evolved in its own right over the last 6-7 million years of divergent evolution. It is crucial for language evolution research that we have articulatory and acoustic phonetic analyses, of the sort conducted by Perlman and Clark (2015) through audio-visual recordings, for all great ape species (and ideally for each community). This would allow, for example, more studies along the lines of Grawunder et al. (2022), who explored the evolution of the vowel space in chimpanzees. The challenge, however, is not trivial because it is difficult to collect the necessary field data – unlike in linguistics, in which fieldworkers have access to speakers and can also ask them questions directly.

So far we have identified the gaps in the literature and created an ontology of the disparate terminology used in great ape studies.[1] Our research suggests that one pertinent area to explore for acoustic analysis is the spectral envelope (Boë et al., 2019; Grawunder et al., 2022), so that we can ask whether prosodic features can be modified to give information to the receiver (Zimmermann, Leliveld, & Schehka, 2013; Pell et al., 2015; Pisanski, Cartei, McGettigan, Raine, & Reby, 2016). Such findings will shed light on whether paralinguistic features are shared across all great apes. Another area ripe for investigation is what effects exist due to sexual dimorphism, e.g., in orangutans and gorillas, and to understand how to categorize these vocalizations.

We know that the size of great ape vocal repertoires are similar across all extant great apes and that we share eight innate vocalizations, e.g., screaming, crying, laughing (Anikin, Bååth, & Persson, 2018). However, there is still much to learn about what we share vocally, and gesturally (Liebal, Slocombe, & Waller, 2022), and how and when we diverged linguistically.

[1] https://github.com/bambooforest/great_ape_vocal_repertoires

Table 1. Vocal repertoire sizes (see also McComb and Semple (2005)).

Genus	Species	Mean repertoire size	Main references
Gorilla	*beringei*	18	Fossey (1972), Hedwig, Robbins, Mundry, Hammerschmidt, and Boesch (2014), Luef, Breuer, and Pika (2016)
	gorilla	18	Salmi, Hammerschmidt, and Doran-Sheehy (2013), Hedwig et al. (2014), Luef et al. (2016)
Pan	*troglodytes*	21	Marler, Tenaza, and Sebeok (1977), Goodall (1986), Crockford and Boesch (2005), Taglialatela et al. (2012), Dezecache, Zuberbühler, Davila-Ross, and Dahl (2020), Grawunder et al. (2022)
	paniscus	19	De Waal (1988), Bermejo and Omedes (1999)
Pongo	*pygmaeus*	29	Hardus et al. (2009), Mackinnon (1974)
	abelii	28	Hardus et al. (2009)
Homo	*sapiens* (modern)	31	Maddieson (1984), Maddieson and Precoda (1990), Moran and McCloy (2019)
	sapiens (ancient)	30	Marsico (1999), Marsico, Flavier, Verkerk, and Moran (2018), Grossman, Eisen, Nikolaev, and Moran (2020)

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