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Who waits when? Age and interactional context shape turn-taking timing in sooty mangabeys (*Cercocebus atys*) in the wild

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Introduction: The evolution of language still remains a mystery. A recent hypothesis proposed that the cooperative mechanism of turn-taking may have predated language and represents an interactional scaffold from which language evolved. Testing this hypothesis requires systematic studies of turn-taking systems in closely related species that examine features directly comparable to human conversational organization, including multimodal exchange, composite turns, and adaptation to recipient characteristics. However, methodological approaches for examining these features in nonhuman primates remain limited. To address this gap, we examined turn-taking in 21 adult female sooty mangabeys (*Cercocebus atys*) living in Taï National Park, Côte d'Ivoire. Sooty mangabeys provide a useful model system because vocal and multimodal turn-taking have been documented in this species, and social factors shape their interactions. We addressed two research questions: (1) How is turn-taking organized in interactions of adult female sooty mangabeys? (2) Is signal-based turn-taking timing influenced by socio-demographic factors?

Methods: We collected video and behavioral data across three field seasons, from May 2022 to March 2024. This resulted in 407.17 hours of focal observation, an average of 18.51 hours per female, 117.98 hours of video recordings, and an average of 5.36 hours per female. From these recordings, we analyzed a total of 226 interactions based on distinct selection criteria (mean of 20.55 interactions/female), across five different contexts (affiliative, agonistic, feeding, grooming, and sexual contexts). We used a novel approach that quantified composite turns composed of actions, gestures, facial expressions, and vocalizations. We examined turn size, turn composition, and turn transitions and gap durations within signal-based exchanges. We then tested whether timing within signal-based exchanges varied with initiator age and rank, social relationship strength, and interactional context.

Results: The results showed that turn-taking was organized differently across contexts. Signal-exchange gaps were generally short, and initiator age influenced gap duration in affiliative interactions only.
Discussion: These findings suggest that turn-taking in adult female sooty mangabeys is multimodal, context-dependent, and partly socially structured, consistent with the hypothesis that core organizational features of conversational turn-taking predate human language.

KEYWORDS
interactional coordination, language evolution, multimodal communication, response timing, social modulation

Introduction

How did language evolve? This question has captivated scientists for decades (Fitch, 2010; Hockett, 1960; Rodrigues et al., 2021). Competing theories have proposed different functional origins of language, suggesting, for example, that it emerged as vocal grooming (Dunbar, 1996) or as a tool to facilitate meat sharing between mothers and offspring (Deacon, 1997). Debates also concern structural evolution, especially whether syntax arose abruptly or gradually (Bickerton, 1998; Jackendoff, 1999). Recent work has asked whether ancestral communicative systems from which language evolved were primarily vocal, gestural, or multimodal (Fay et al., 2022; Fröhlich et al., 2019; Levinson, 2023; Lombrey et al., 2025; Oller and Griebel, 2021; Perlman, 2017).

Despite this theoretical landscape, empirical resolution on the origins of linguistic capacities remains limited (Fitch, 2017). A major challenge is the gap between nonhuman primate (hereafter primate) communication and human language (Fröhlich et al., 2019; Pika et al., 2018). Several scholars argue that language evolved relatively recently in evolutionary terms (Bolhuis et al., 2014; Diller and Cann, 2009; Miyagawa et al., 2025). If this timeframe was too short for the cognitive apparatus underlying language to evolve *de novo*, human linguistic capacity likely drew on pre-existing communicative abilities (Hewes et al., 1973; Jackendoff, 1999; Levinson and Holler, 2014). Although language is uniquely human, some foundational components may have deeper evolutionary roots (Hauser et al., 2002; Levinson and Holler, 2014; Tomasello, 2010). Conversational turn-taking, the rapid exchange of communicative acts between individuals, has been suggested as one such older ability (Levinson and Holler, 2014; Pika et al., 2018; Sacks et al., 1974).

Turn-taking lies at the heart of human interactions, from everyday conversation to social games (Sacks et al., 1974). In conversation, it functions as a system of signal coordination that allocates turns to participants (Sacks et al., 1974). Sacks et al. (1974) observed that substantial overlaps and long gaps were rare. They also noted that the system was flexible and that participants used turn-allocation techniques and repair mechanisms to manage interaction. Although human conversational research has often focused on speech, turn-taking has also been shown to rely on gestures, gaze, and facial displays. These modalities helped project turn completions, identify transition-relevance places, and regulate overlap (Holler and Levinson, 2019; Levinson and Holler, 2014).

Several lines of evidence suggested that turn-taking may predate language and form part of its evolutionary foundations (Levinson, 2016b). Developmental studies showed that infants coordinated gaze, facial expressions, and smiles with caregivers before speech developed (Bates et al., 1975; Bateson, 1975; Gratier et al., 2015). Cross-linguistic studies identified broadly similar turn-taking patterns across languages (Comrie, 1981; Pereltsvaig, 2023; Stivers et al., 2009). Response timing provided further evidence. Across 10 languages, replies peaked around 200 ms after a question. This was faster than the 600–1,000 ms typically required to plan speech and suggested that comprehension and production processes overlap during turn-taking (Bates et al., 2003; Indefrey and Levelt, 2004; Levinson, 2016; Levinson and Holler, 2014; Stivers et al., 2009). Comparative studies also suggested that turn-taking occurred in several primates (Katsu et al., 2019; Kolff and Pika, 2025; Rossano, 2013; Takahashi et al., 2013; van Boekholt and Pika, 2025). Examining turn-taking across species may therefore provide insight into communicative scaffolds from which language evolved (Abreu and Pika, 2022; Levinson, 2016b; Pika et al., 2018).

Primate turn-taking has been studied in several species. Gestural turn-taking was examined in wild bonobos (*Pan paniscus*; Fröhlich et al., 2016) and wild chimpanzees (*Pan troglodytes*; Fröhlich et al., 2016; Kolff, 2025). Vocal turn-taking was examined in captive western lowland gorillas (*Gorilla gorilla gorilla*; Pougnault et al., 2020), wild white-handed gibbons (*Hylobates lar*; Terleph et al., 2018), captive siamangs (*Symphalangus syndactylus*; Haimoff, 1986), and captive Campbell's monkeys (*Cercopithecus campbelli*; Lemasson, 2011). It was also examined in captive geladas (*Theropithecus gelada*; Richman, 1976), free-ranging Japanese macaques (*Macaca fuscata*; Katsu et al., 2019), captive common marmosets (*Callithrix jacchus*; Takahashi et al., 2013), captive pygmy marmosets (*Cebuella pygmaea*; Snowdon and Cleveland, 1984), and wild Milne-Edwards' sportive lemurs (*Lepilemur edwardsi*; Méndez-Cárdenas and Zimmermann, 2009).

The capacity to compare primate turn-taking with human turn-taking and thereby clarify its role in the evolution of language remains limited by three methodological gaps. First, most findings are derived from vocal exchanges (for reviews, see Abreu and Pika, 2022; Pika et al., 2018). This limits comparability because human communication relies on both vocal and non-vocal modalities (de Vos et al., 2015; Holler and Levinson, 2019; Levinson and Holler, 2014). Second, many studies examined turn-taking within a single interactional context or call type (Fröhlich et al., 2016; Katsu et al.,

2019; Kolff, 2025; Takahashi et al., 2013). Human turn-taking, by contrast, spans multiple contexts, behavior types, and modalities (Levinson, 2016; Sacks et al., 1974). Third, many studies focused on turns constituted by single gestures or calls (Chow et al., 2015; Katsu et al., 2016; Kolff and Pika, 2025; van Boekholt and Pika, 2025). Human conversational turns often comprise multiple communicative acts organized into larger units (Levinson and Torreira, 2015; Sacks et al., 1974). These dimensions have not been jointly examined within a single framework in primate turn-taking research.

A further gap concerns the social regulation of turn-taking dynamics (Pika et al., 2018). In humans, turn-taking is not only a coordination system but also reflects social structure (Bortfeld et al., 2001; Dewi et al., 2018; Yuan et al., 2006). Age and social relationships influenced conversational dynamics. Indonesian speakers interacting in English interrupted older people more cautiously than younger peers (Dewi et al., 2018). Older speakers in English and Mandarin used slower speech rates and more variable turn sizes (Yuan et al., 2006). In English, married couples overlapped less than strangers (Bortfeld et al., 2001). Interactions with strangers also involved longer turns and slower speaking rates in English and Mandarin (Yuan et al., 2006). Turn-taking further strengthened social closeness in English-speaking participants (Sprecher and Treger, 2015).

Related patterns have been reported in primates. Captive bonobos exchanged more calls with individuals of similar age (Levréro et al., 2019). In free-ranging Japanese macaques, older females contributed more to vocal exchanges and received more responses than younger individuals (Lemasson et al., 2013). In wild adult male eastern chimpanzees (*Pan troglodytes schweinfurthii*), turn transitions were more likely when initiated by older individuals and more frequent with younger recipients (Kolff and Pika, 2025). Social bonds also influenced turn-taking. Vocal turn-taking occurred more often between close partners in free-ranging Japanese macaques and captive bonobos (Katsu et al., 2016; Levréro et al., 2019). Duet structure differed with pair-bond status in captive coppery titi monkeys (*Callicebus cupreus*; Müller and Anzenberger, 2002). Stronger pair bonds were also associated with more consistent and temporally stable duets in captive siamangs (Geissmann and Orgeldinger, 2000).

However, evidence remains scarce and focuses largely on vocal interactions (Katsu et al., 2016; Lemasson et al., 2013; Levréro et al., 2019; but see Kolff and Pika, 2025), neglecting the multimodal nature of primate and human communication (Fröhlich et al., 2019; Holler and Levinson, 2019). Prior work also often focused on response rates. These provide limited comparability with human conversational dynamics, where responses are strongly expected and variation instead lies in timing and turn length (Schegloff, 2007; Yuan et al., 2006). The reliance on captive groups may further constrain variation in social structure and partner choice. This may limit the range of socially driven variation observed (Bortfeld et al., 2001; Dewi et al., 2018; Harrison and van de Waal, 2022; Yuan et al., 2006). No study has examined whether signal-based turn-taking timing in wild-living primates is shaped by socio-demographic factors across vocal and non-vocal signal sequences and multiple contexts. Addressing this gap is essential for assessing whether conversational turn-taking may have emerged from socially regulated coordination rather than more general coordination mechanisms (Kolff and Pika, 2025; Pika et al., 2018; van Boekholt and Pika, 2025). It is also relevant for cross-species comparisons because differences in interaction patterns may reflect variation in social organization rather than cognitive capacity (Freeberg et al., 2012; Harrod et al., 2020).

This study addresses these gaps by examining sooty mangabeys (*Cercocebus atys*) living in their natural environment. This species belongs to the Papionini tribe within the Cercopithecidae family and occurs along Africa's west coast (Groves, 1978; Groves, 2001). Sooty mangabeys form multi-male, multi-female groups of roughly 70–120 individuals. Females remain in their natal groups, whereas males disperse. The species is terrestrial and feeds mainly on hard seeds, invertebrates, and plant material (Range and Noë, 2002; Range and Noë, 2005). Sooty mangabeys are suitable for investigating socio-demographic influences on turn-taking for several reasons. Vocal turn-taking has been documented (Range and Fischer, 2004), multimodal turn-taking between single-unit turns has been shown in grooming interactions (Tibesar et al., 2026), and social factors influence their behavior (Mielke et al., 2018; Mielke et al., 2020; Range and Noë, 2002). In adult females, aggression is directed down the dominance hierarchy. Grooming occurs more frequently between individuals with smaller rank differences and is positively correlated with spatial proximity (Range and Noë, 2002). Dyadic association is more likely between kin and individuals with similar age, dominance rank, and female reproductive state (Mielke et al., 2020). Grooming partner choice is influenced by partner rank and prior interaction history (Mielke et al., 2018). We focused on adult females because they interact frequently and have completed their developmental learning (Mielke et al., 2018).

This study addresses the following two research questions: (1) How is turn-taking organized in interactions of adult female sooty mangabeys? To investigate this question, we observed the behavior of a group of sooty mangabeys living in Taï National Park, Côte d'Ivoire, and collected data in five distinct contexts (affiliative, agonistic, feeding, grooming, and sexual contexts). We applied a novel approach in which composite turns refer to turns composed of one or more consecutive behaviors produced by the same individual within an interactional exchange. These behaviors could be facial, vocal, gestural, or action-based (for definitions, see Methods). This contrasts with previous studies which have typically examined turn transitions between single actions or signals (e.g., Kolff and Pika, 2025; Tibesar et al., 2026; Vlaeyen et al., 2026). By doing so, we more closely approximated the structure of human turn-taking and provided an initial account of natural turn-taking behavior across observed contexts and behavior types. Given the descriptive nature of this research question, we first extended the analysis beyond signals to include action-based behaviors (Kolff and Pika, 2025; van Boekholt and Pika, 2025). This allowed us to characterize the overall organization of the interactions before narrowing the analysis to signal exchanges specifically. We focused on the distribution of composite turns and signal–signal turn transitions (involving gestures, facial expressions, and vocalizations) within interactions, and the duration of gaps. (2) Is signal-based turn-taking timing in adult female sooty mangabeys influenced by socio-demographic factors? Because age, rank, and social

relationship strength are known to structure social interactions in primates, we hypothesized that these factors could also influence signal-based turn-taking timing (Kolff and Pika, 2025; Lemasson et al., 2013; Levréro et al., 2019; Smuts et al., 1987). Detecting such effects would be consistent with the view that flexibility in turn-taking organization, including sensitivity to socio-demographic factors, may be part of an evolutionarily older interactional capacity predating human language (Levinson, 2016; Pika et al., 2018). We focused specifically on the exchange of signals rather than actions, because human conversation primarily involves the production and interpretation of signals (Bühler, 1934; Sacks et al., 1974). This distinction is relevant because signal-based and action-based turn-taking may follow different coordination rules (Ivarsson and Greiffenhagen, 2015). This may be due to the mechanical effectiveness of actions, which creates physical constraints and allows actions to achieve their outcome without necessarily requiring a response from the recipient (Liebal and Call, 2012; Prieur et al., 2018; van Boekholt and Pika, 2025).

Materials and methods

Study site and species

The data for this study were collected in the Taï National Park, located in Côte d'Ivoire. The park covers an area of 3,500 km^2 and contains the largest remaining tract of primary forest in West Africa (Boesch and Boesch, 1983). It supports a diverse array of large mammal species as well as various primate species (Boesch and Boesch, 1983). The focus of this study was a group of approximately 70 sooty mangabeys, habituated to human observers since 2013 (Mielke et al., 2017). All members of the study group could be reliably identified, with long-term behavioral and genealogical data recorded for most of them. Because the animals were well habituated to human observers and to video equipment, they could be followed and filmed with minimal disturbance to their natural behavior.

Data collection

From May to September 2022 and from January to July 2023, PT collected video data, and from December 2023 to March 2024, KK (research assistant) collected video data by observing focal individuals from 06:30 to 18:00. Focal sampling was performed continuously for one hour per session on 28 adult individuals, including 22 females and six males (Altmann, 1974). Because of the limited number of adult males and their frequent absences during the mating season, data from males were excluded from the final analyses. To avoid timing bias, the order in which focal individuals were observed was randomized, using a new random order after all subjects had been observed once. Care was taken to maintain consistent data collection for each subject across every month. A focal hour was considered valid only if the individual had not been out of sight for more than 30 minutes in total or absent for more than 10 consecutive minutes. Video footage was captured at a distance of three to five meters by using a digital camera (Sony Handycam FDR-AX100E) paired with an external microphone (Sony ECM-CG60). Recordings focused on instances in which at least one other group member was within five meters of the focal animal. Additionally, behavioral data were collected by field assistants SK and CK from May 2022 to August 2023 through direct observation (Altmann, 1974). Half-day focal follows were conducted between 06:30 and 18:00.

Data coding

Video recordings were transferred to a computer (Dell Latitude 5420) and coded using the software ELAN (6.4; Hellwig and Sloetjes, 2021) with respect to the outlined research questions. Videos were selected for coding based on recording quality and interaction completeness. In addition, to ensure dyad diversity, we coded a maximum of one video per dyad per context. Selection was conducted independently of the variables used to address the two research questions. The collected data set included a total of 525 videos for the affiliative context, 489 videos for the agonistic context, 997 videos for the grooming context, 2,538 videos for the feeding context, and 1,183 videos for the sexual context. The availability of codable interactions varied across contexts depending on how easily interactions could be filmed and how often interactions between adult females occurred in each context. For example, grooming interactions were relatively easy to film, whereas aggression was more difficult to record. Although many feeding videos were available, relatively few contained social interactions. Play and travel contexts were not included because social interactions in those contexts were too rare. One female disappeared during the first year of data collection, resulting in the exclusion of her data from the analysis. Operational definitions of behaviors were based on existing ethograms of chimpanzees (Goodall, 1986; Grund et al., 2024; Hobaiter and Byrne, 2014; Kolff and Pika, 2025; van Boekholt and Pika, 2025) and sooty mangabeys (Le Floch et al., 2026; Range and Noë, 2002). The coding tiers and the list of coded behaviors are described in detail in the Supplementary Material of Tibesar et al. (2026), and the list of gestures and facial expressions is reported in Tibesar et al. (submitted). A subset corresponding to 11% of the video material was independently annotated by a second observer who was unaware of the study's research questions. Interobserver reliability was assessed using ELAN's modified Cohen's Kappa coefficient implemented in the "EasyDIAG" package, applying a 60% temporal overlap criterion, and yielded agreement levels ranging from substantial to almost perfect (Actions: K = 0.74, Gestures and facial expressions: K = 0.97, Vocalizations: K = 0.89, Gaze: K = 0.93) (Holle and Rein, 2015).

Definitions

In this study, turn-taking was defined as the structured and coordinated exchange of communicative signals or actions between two or more individuals, governed by principles that determine how turns are transferred, resulting in observable temporal regularities (Pika et al., 2018; Sacks et al., 1974; Tibesar et al., 2026; Vlaeyen et al., 2026). The organization may be species-specific and vary

along multiple dimensions (Pika et al., 2018; Sacks et al., 1974; Tibesar et al., 2026; Vlaeyen et al., 2026). Actions were defined as mechanically effective, socially directed embodied behaviors. They involved either direct manipulation of another's body or body parts, or movements of one's own body to achieve the outcome (Kolff and Pika, 2025; van Boekholt and Pika, 2025; Tibesar et al., 2026). On the other hand, signals were socially directed behaviors that do not achieve the outcome through direct mechanical effects, but instead affect the behavior of a recipient (Kolff and Pika, 2025; van Boekholt and Pika, 2025; Tibesar et al., 2026). This distinction was made at the behavioral category level and was not determined on a case-by-case basis, with the exception of push and pull. For these behaviors, classification depended on whether the initiator exerted sufficient force to move the recipient. Composite turns were defined as one or more behaviors (actions, gestures, facial expressions, or vocalizations) produced by an individual and separated by less than 1 s of inactivity (Figure 1). This definition follows established methodological practice in primate communication research, whereby behaviors separated by less than one second are treated as part of a single communicative bout rather than separate events (Genty et al., 2009; Graham et al., 2017; Le Floch et al., 2026; Hobaiter and Byrne, 2011; Sigmundson et al., 2025). In addition, responses between single-unit turns during grooming in adult female sooty mangabeys typically occurred within 1 s (Tibesar et al., 2026), suggesting that behaviors produced within this interval may still represent a continuation of the initiator's sequence rather than evidence that the initiator had yielded the floor and was waiting for a response. Units were defined as individual behaviors (actions, gestures, facial expressions, or vocalizations) within a turn (Kolff and Pika, 2025; van Boekholt and Pika, 2025; Vlaeyen et al., 2026). Turn transitions were operationalized as the shift from one individual's composite turn to another's (Sacks et al., 1974). More specifically, the turn transitions were located at the onset of the next composite turn, occurring after the initiation of the final unit of the preceding composite turn. Gestural sequences have been interpreted as pursuing a single communicative goal (Hobaiter and Byrne, 2011; Hobaiter and Byrne, 2014). Thus, by assigning the response as the first composite turn that followed the final unit of the preceding composite turn, this operationalization was intended to capture responses contingent on that preceding composite turn. Signal–signal turn transitions were defined as turn transitions in which both composite turns contained at least one signal. Gaps were defined as the duration of time from the end of one individual's composite turn to the beginning of the next composite turn produced by the other individual (Lemasson et al., 2013; Stivers et al., 2009; Takahashi et al., 2013). Negative values indicated temporal overlap.

Socio-demographic factors

To test our second research question, 'Is signal-based turn-taking timing in sooty mangabeys influenced by socio-demographic factors?', we quantified socio-demographic variables as follows.

Ranks were established following the methodology by Mielke et al. (2018) and based on non-aggressive supplants, with the supplanted individual considered the loser and the supplanting individual the winner (Mielke, 2023; Mielke et al., 2018). The resulting interaction matrix was analyzed using the **linhier.test()** function to assess the dominance hierarchy linearity (Neumann et al., 2011). This test produces an index of linearity ranging from 0 (completely non-linear) to 1 (perfectly linear). Hierarchy steepness was then calculated using the Improved Steepness Index (ISI) method, which provides a bias-corrected estimate of steepness (De Vries et al., 2006). The steepness index ranges from 0 (completely egalitarian) to 1 (completely despotic). From the ISI results, we extracted the final rank order of individuals, ranking females from highest (rank 1) to lowest (rank 22). To evaluate the statistical significance of the observed steepness, we conducted a permutation

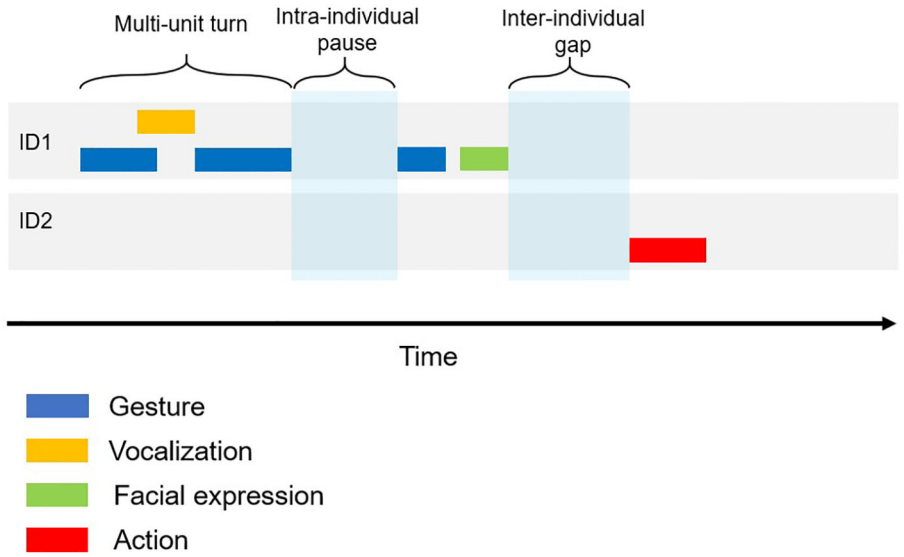

FIGURE 1
Schematic representation of a turn-taking interaction between two individuals. ID1 first produces a turn composed of several units, separated by short within-turn pauses (<1 s). A longer pause (>1 s) follows, marking the start of a new turn by ID1. After an inter-individual gap, ID2 initiates a new turn, marking the turn transition. Colored bars represent different modalities of behavior. The horizontal axis represents time.

test using the **steeptest()** function, which randomized the interaction data repeatedly to generate a null distribution of steepness values, enabling us to determine whether the observed steepness was greater than expected by chance (Dwass, 1957; Fisher, 1949).

The respective ages of individuals were established based on their ages at the start of data collection. Individuals older than 10 years were assigned estimated ages, as they were born before the group habituation. This also applied to one immigrated female who was not born into the group.

The social relationship strength was assessed for each dyad. For each dyad, we assessed how frequently they groomed each other and how frequently they were observed resting or feeding at less than one meter from each other (Mielke et al., 2018; Mielke et al., 2020). We combined these measures into a composite sociality index (DSI) using the following formula (Luef and Pika, 2017):

$$DSI = \left(\left(\frac{G_{AB}}{G_{AB} + G_A + G_B}\right) + \left(\frac{P_{AB}}{P_{AB} + P_A + P_B}\right)\right) \times 100$$

G_{AB} represents the number of grooming interactions observed between the two individuals in the dyad. G_A and G_B stand for the total grooming events involving each individual separately. Similarly, P_{AB} reflects the instances of the two individuals in the dyad resting or feeding at less than one meter from each other, while P_A and P_B represent the total occurrences of resting or feeding at less than one meter from any individual by each individual individually. A scaling factor of 100 was applied to improve the interpretability of small values.

Statistics

To address our first research question, 'How is turn-taking organized in adult female sooty mangabeys?', we first examined whether interactional contexts differed in the size and composition of composite turns and in the frequency of signal–signal turn transitions. Because multiple observations could come from the same individuals or dyads, analyses were conducted on aggregated data to avoid pseudoreplication (Norscia et al., 2021; Schoen et al., 2023).

Composite turn size was defined as the number of units constituting a turn. For each individual in each context, we calculated the mean composite turn size. For turn composition, we calculated, for each individual in each context, the proportion of turns belonging to each turn type. These individual-by-context values were compared across contexts using Friedman tests, which compare contexts within the same individual. Because Friedman tests require the same individuals to be represented in all contexts, two individuals were excluded from these analyses. For turn composition, separate Friedman tests were conducted for each turn type, with Benjamini-Hochberg correction applied across turn types. When an overall Friedman test indicated context-related variation, *post hoc* paired Wilcoxon signed-rank tests with Benjamini-Hochberg correction were used to identify which contexts differed from each other.

For signal–signal turn transitions, we calculated, for each dyad in each context, the proportion of turn transitions in which a signal was followed by another signal. The data were aggregated at the dyad level because transitions involved both interaction partners. These dyad-by-context proportions were compared across contexts using a Kruskal-Wallis test. When the overall test indicated context-related variation, we identified which contexts differed from each other using *post hoc* Dunn's tests with Benjamini-Hochberg correction. Some dyads contributed values in more than one context, meaning that dyad-by-context observations were not fully independent. However, repeated dyads across contexts were limited, as 59.2% of dyads were represented in only one context and no dyad was represented in all five contexts.

To test our second research question, 'Is signal-based turn-taking timing in adult female sooty mangabeys influenced by socio-demographic factors?', we modeled the effects of initiator age, initiator rank, dyad social relationship strength and their interactions with interaction context on signal–signal gap duration. Feeding interactions were excluded because no signal–signal transitions occurred in this context. Gaussian mixed-effects models were fitted using the *glmmTMB* package, with initiator identity and dyad included as random effects. To reduce skewness in the distribution while retaining information about whether values were positive or negative, the turn transition timing variable was subjected to a signed cube-root transformation. *Post hoc* analyses were conducted using the *emmeans* package.

As a sensitivity analysis, we assessed the influence of extreme observations by identifying raw gap durations classified as outliers using Tukey's 1.5 × IQR criterion. This procedure identified 36 observations (16.1% of the dataset). The final model was then refitted after excluding these observations, and the resulting *post hoc* tests were compared with those from the full dataset. The pattern of results remained largely unchanged. Only the contrast between agonistic and grooming contexts, which was significant in the full dataset, became non-significant after excluding outliers. All conclusions regarding context-specific age and rank effects were unaffected. We therefore concluded that the reported findings were not driven by a small number of extreme observations.

Our dataset involved 3 females aged 10–13 years, 4 females older than 13 years, and one immigrant female. The estimates of the individuals aged 10–13 years were considered reliable because these individuals were juveniles when the group was habituated (Altmann et al., 1981). However, the two latter categories had the most uncertain estimated ages and represented the upper end of the age distribution. Excluding them would have substantially reduced the age range available for analysis. Instead, we conducted a sensitivity analysis and randomly varied the ages of these females within a ±2-year range. The model was refitted 500 times. The ±2-year range was intended to capture plausible uncertainty without generating unrealistic age values or substantially altering the observed age distribution. The affiliative age effect remained positive across simulations and was statistically significant in 98.6% of model refits, indicating that this result was robust to uncertainty in the exact estimated ages.

Full model specification, transformations, and diagnostics are provided in the Supplementary Material.

All statistical analyses were conducted in R (version 4.3.2).

Results

Across the study period, we collected a total of 407.17 hours of focal observation across the 22 females (mean ± SD = 18.51 ± 3.82 hours per female), yielding 117.98 hours of video recordings (mean ± SD = 5.36 ± 1.00 hours per female). From this dataset, 226 interactions involving 21 females were selected for analysis (mean ± SD = 20.55 ± 8.78 interactions per female), covering a total of 5.9 hours.

How is turn-taking organized in adult female sooty mangabeys?

Concerning the first research question, we found several characteristics of the turn-taking organization in the studied adult female sooty mangabeys. Across all focal individuals, a total of 1,453 composite turns were observed. Of these, 184 occurred in affiliative contexts, 172 in agonistic contexts, 85 in feeding contexts, 813 in grooming contexts, and 199 in sexual contexts. Across individuals, the mean number of composite turns was 69.19 (SD = 24.47). Units were primarily composed of actions (mean ± SD = 53.7 ± 12.1% per individual), followed by gestures and facial expressions (mean ± SD = 38.2 ± 10.8% per individual) and vocalizations (mean ± SD = 8.0 ± 5.2% per individual). Pure action turns constituted a mean of 47.5% of all composite turns (SD = 8.95, n = 682), multicomponent turns a mean of 16.1% (SD = 7.49, n = 233), and pure signal turns a mean of 36.4% (SD = 11.8, n = 538). Affiliative interactions included a larger proportion of signal (49%) than action (38%) or multicomponent composite turns (14%). Agonistic interactions included signal (42%), action (33%), and multicomponent composite turns (24%). Feeding interactions were mainly composed of action composite turns (85%), with lower proportions of signal (8.9%) and multicomponent composite turns (5.6%). Grooming interactions included 45% action, 39% signal, and 16% multicomponent composite turns. Sexual interactions were mainly composed of action composite turns (61%), with lower proportions of signal (24%) and multicomponent composite turns (15%). Composite turns consisting of more than one unit occurred in 33.3% of cases. Overall, composite turns were typically short (mean = 1.7 units, median = 1, max = 14).

At the individual level, composite turn size differed significantly across interactional contexts (χ^2 = 33.05, df = 4, p = 1.17 × 10^{-6}, Figure 2). Grooming composite turns contained significantly more units than affiliative (p = 1.1 × 10^{-3}), agonistic (p = 2.13 × 10^{-2}), sexual (p = 1.1 × 10^{-3}), and feeding (p = 1.1 × 10^{-3}) composite turns. Composite turns in the agonistic context also comprised a higher number of units than affiliative (p = 2.13 × 10^{-2}), sexual (p = 5.2 × 10^{-3}), and feeding (p = 1.32 × 10^{-2}) composite turns. No significant differences were found between affiliative and feeding (p = 0.6121), affiliative and sexual (p = 0.2062), or feeding and sexual (p = 0.7112) composite turns.

Across individuals, composite turn composition varied significantly across contexts (action: χ^2 = 34.24, df = 4, pBH = 2.00 × 10^{-6}; multicomponent: χ^2 = 18.75, df = 4, pBH = 8.82 × 10^{-4}; signal: χ^2 = 26.98, df = 4, pBH = 3.01 × 10^{-5}). Signal composite turns were significantly more common in affiliative than in feeding (p = 1.9 × 10^{-2}) and sexual contexts (p = 2.0 × 10^{-2}), more common in agonistic than in feeding (p = 2.0 × 10^{-2}) and sexual contexts (p = 3.1 × 10^{-2}), and more common in grooming than in feeding (p = 2.0 × 10^{-2}) and sexual contexts (p = 3.8 × 10^{-2}). Sexual contexts also had a higher proportion of signal composite turns than feeding contexts (p = 4.0 × 10^{-2}). Pairwise *post hoc* comparisons for action and multicomponent composite turns are reported in Supplementary Table 2.

We observed 223 signal–signal turn transitions, including 38 in affiliative contexts, 36 in agonistic contexts, 133 in grooming contexts, and 16 in sexual contexts. Across dyads, the mean number of signal–signal turn transitions was 2.69 (SD = 2.12). Signal–signal turn transitions occurred most frequently in affiliative (45.8%) and agonistic interactions (42.4%), less frequently in grooming (29.4%), and rarely in sexual interactions (17.0%), while no signal–signal transitions were observed in feeding interactions (Supplementary Figure 2).

The proportion of signal–signal turn transitions per dyad differed significantly across contexts (χ^2 = 36.97, df = 4, p = 1.83 × 10^{-7}). Affiliative and agonistic contexts did not differ in the proportion of signal–signal turn transitions (p = 0.536). Both affiliative and agonistic interactions exhibited higher proportions of signal–signal transitions than feeding (affiliative: p = 4.16 × 10^{-6}, agonistic: p = 5.34 × 10^{-5}) and sexual contexts (affiliative: p = 1.69 × 10^{-4}, agonistic: p = 3.07 × 10^{-3}). Neither affiliative nor agonistic interactions differed significantly from grooming interactions (affiliative: p = 0.078, agonistic: p = 0.321). Grooming interactions showed higher proportions of signal–signal transitions than feeding interactions (p = 1.73 × 10^{-4}). Finally, sexual and feeding contexts did not differ significantly in the proportion of signal–signal turn transitions (p = 0.077).

Signal–signal gap durations had a mean of 6.64 s (SD = 18.77 s), a median of 0.43 s, and ranged from −16.11 s to 131.59 s (Figure 3; see Supplementary Figure 1 for the other types of turn transitions).

Is signal-based turn-taking timing in adult female sooty mangabeys influenced by socio-demographic factors?

Concerning our second research question, analyses revealed a significant interaction between initiator age and context, indicating that age effects differed across contexts. *Post hoc* trend analyses showed that in affiliative interactions, initiator age had a significant positive effect on gap duration (β = 0.389, SE = 0.148, df = 201, t = 2.62, p = 9.4 × 10^{-3}), such that older initiators were associated with longer response gaps (Figure 4). In contrast, initiator age had no detectable effect in agonistic (β = −0.003, SE = 0.148, df = 201, t = −0.02, p = 0.986) or grooming contexts (β = 0.048, SE = 0.104, df = 201, t = 0.46, p = 0.646). In sexual interactions, the effect of initiator age was negative but did not reach statistical significance (β = −0.488, SE = 0.339, df = 201, t = −1.44, p = 0.152).

Gap duration also differed across interaction contexts. Estimated marginal means indicated that affiliative interactions were characterized by shorter gaps than agonistic (estimate = −0.600, SE = 0.160, p = 1.3 × 10^{-3}), grooming (estimate = −1.085, SE = 0.138, p < 1.0 × 10^{-3}), and sexual interactions (estimate =

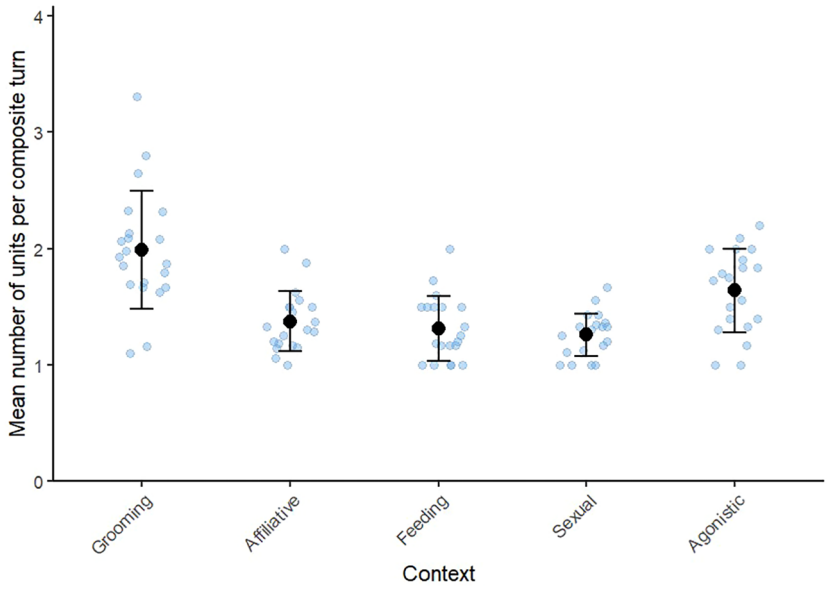

FIGURE 2
Turn size across interactional contexts. Turn size is defined as the number of units in a turn, where units are facial expressions, gestures, vocalizations, or actions. Each dot represents the mean turn size of one individual in one context. Black points indicate context-level mean values and error bars show ± SD. Turn size differed significantly across contexts.

−0.611, SE = 0.221, p = 3.17 × 10^{-2}). Agonistic interactions also showed shorter gaps than grooming interactions (estimate = −0.485, SE = 0.146, p = 5.7 × 10^{-3}). No other pairwise differences between contexts were statistically supported (Supplementary Figure 3).

Finally, there was no significant effect of rank (β = −0.053, SE = 0.103, df = 201, t = −0.51, p = 0.611) or social relationship strength (β = −0.006, SE = 0.162, df = 201, t = −0.04, p = 0.968) on gap duration (Supplementary Table 1). However, the precision of these estimates varied across contexts. Confidence intervals were widest in contexts with fewer observations, especially sexual interactions, indicating greater uncertainty and reduced statistical power to detect subtle rank or social relationship effects on turn-taking timing.

Discussion

This study investigated turn-taking interactions in adult female sooty mangabeys living in their natural environment, and assessed how turn-taking is organized beyond the vocal domain and across contexts. It also examined how the socio-demographic factors of age, rank, and social relationship strength shaped its temporal organization. Establishing the socio-demographic conditions under which turn-taking emerged is useful for refining hypotheses about the origins and evolutionary precursors of human language (Levinson, 2016; Levinson, 2019; Pika et al., 2018). Specifically, we addressed two research questions: (1) How is turn-taking organized in interactions of adult female sooty mangabeys? (2) Is signal-based

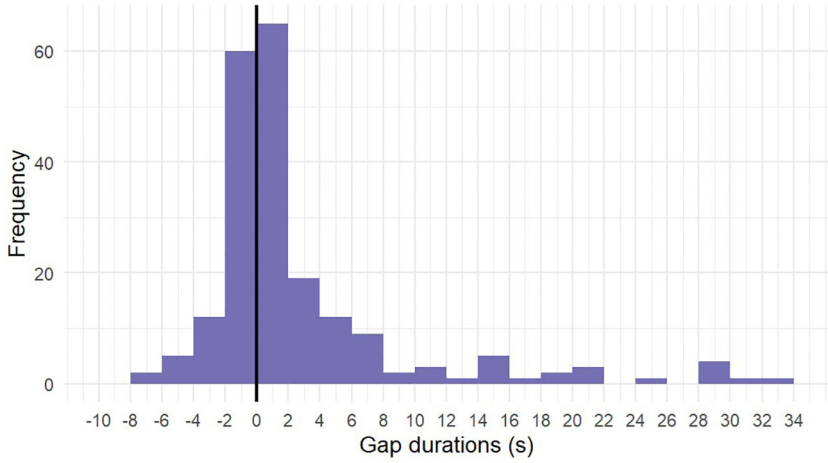

FIGURE 3
Gaps (seconds) for signal–signal turn transitions as a histogram. The x-axis is restricted to gaps from −10 to 34 s for visualization purposes, and the y-axis indicates the frequency of events in 2-second bins.

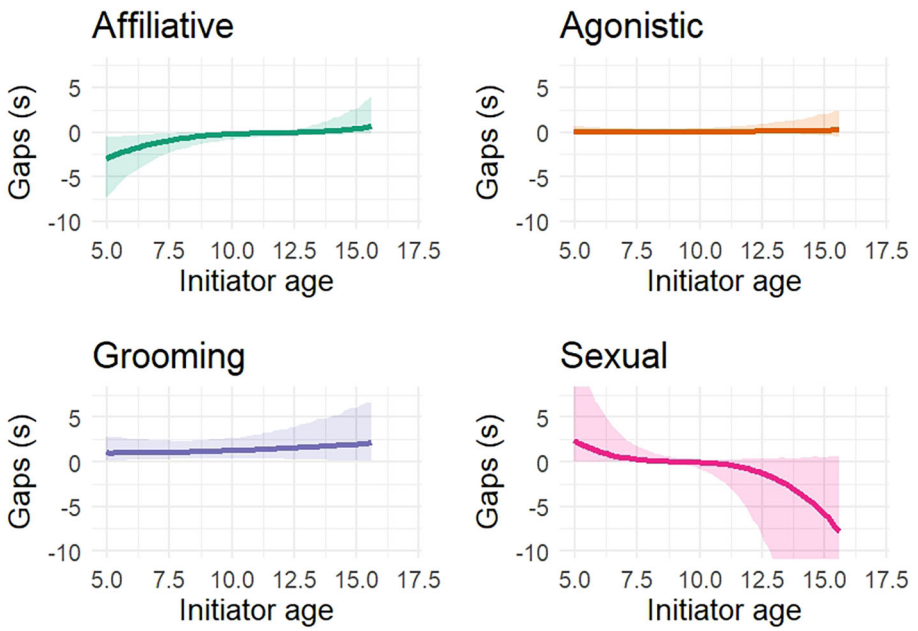

FIGURE 4
Predicted gaps, converted back to seconds from the model's transformed scale, as a function of initiator age across four social contexts. Colored lines represent the model-predicted timing for each context, and shaded ribbons indicate the 95% confidence intervals. Each panel shows one context: affiliative, agonistic, grooming, and sexual.

turn-taking timing in adult female sooty mangabeys influenced by socio-demographic factors?

Overall, we found that composite turn sizes, composite turn types, and the distribution of signal–signal turn transitions varied systematically across the studied contexts. Gap duration showed a relatively wide distribution, with notable differences in gap durations across contexts. The analysis of the role of socio-demographic factors in signal-based turn-taking indicated that age influenced gap duration in affiliative interactions, but not in the agonistic, sexual, and grooming contexts. Additionally, we found no effect of rank or social relationship strength. In the following paragraphs, we discuss these findings in the context of previous research in humans and other primates.

How is turn-taking organized in adult female sooty mangabeys?

In this study, we aimed to fill a gap in the comparative analysis of turn-taking in primates by analyzing composite turns rather than isolated communicative units. Within Tomasello's framework, composite utterances are central because they constitute the proposed precursor to grammar, emerging when combinations of communicative acts become organized and conventionalized into stable structures (Tomasello, 2010). Accordingly, this method provides a tool for documenting how primates produce composite sequences, which may generate data bearing on hypotheses about the evolutionary precursors of grammatical organization and language evolution.

Regarding our first research question, we found that composite turns were generally short, with most consisting of a single unit, indicating a segmented organization of interaction. Composite turn composition varied across contexts. Grooming interactions showed more units per composite turn than affiliative, agonistic, feeding, and sexual interactions. This result reflects that in the studied adult female sooty mangabeys, grooming often involved successive grooming actions directed to different body locations, as well as actions related to positioning the recipient's body. Agonistic interactions also exhibited more units than affiliative, feeding, and sexual interactions. This suggests that extended composite turn composition is not restricted to cooperative contexts, defined in evolutionary biology as contexts involving behaviors that provide a benefit to a social partner and are selected in part because of that benefit (West et al., 2007). In agonistic contexts, this organization may reflect high arousal and the risk that communicative behavior could escalate into physical harm (Tempelmann and Liebal, 2012). Extended composite turns may allow signal refinement, in which subsequent signals clarify the interpretation of preceding ones (Fröhlich and van Schaik, 2018; Genty and Zuberbühler, 2014), or reinforcement, whereby signals are repeated or combined to increase their salience or impact (Fröhlich and van Schaik, 2018; Møller and Pomiankowski, 1993; Partan and Marler, 1999). In sooty mangabeys specifically, aggression is often mild, with low rates of serious physical harm, suggesting that it may function less to injure opponents than to negotiate social conflicts, assert dominance, or regulate access to resources while avoiding costly escalation (Gust and Gordon, 1994; Quintero, 2025).

Affiliative, agonistic, and grooming interactions further stood out by showing higher proportions of signal–signal turn transitions, which may reflect the role of signal exchange in maintaining social relationships and managing coordination and social tension

(Dunbar, 1991; Enquist, 1985; Sprecher and Treger, 2015). Previous studies on sooty mangabeys showed increased signal complexity during approaches to mothers with infants and in post-conflict situations, presumably to manage social uncertainty (Grampp et al., 2023; Le Floch et al., 2026). This aligned with the hypothesis that social complexity drives the evolution of complex communication (Humphrey, 1976; McComb and Semple, 2005). A limitation of the analysis is that context-related differences in signal–signal turn transitions could partly reflect differences between dyads rather than context alone. This is relevant because previous work on wild adult male chimpanzee grooming interactions found that turn transition type was influenced by age and dominance rank (Kolff and Pika, 2025). Future work could therefore test whether dyadic characteristics, such as social relationship strength, dominance rank, age, or kinship, predict signal–signal turn transitions in sooty mangabeys.

Overall, these results provide evidence for structured social interaction in the studied adult female sooty mangabeys, with turn-taking exchanges varying across interaction contexts. This may reflect the differing interactional demands and goals of different social situations. Tomasello (2010) hypothesized that human communication is grounded in prosocial motives, especially helping, sharing, and bonding. Turn-taking organization may vary across contexts that differ in the extent and form of those motives. Additionally, context-specific mechanical constraints, such as maintaining close tactile coordination during grooming, may place different demands on response timing and coordination. Identifying the contexts in which rapid, signal-based turn-taking is observed may therefore help generate hypotheses about the interactional pressures associated with its evolution. Overall, our findings are consistent with the view that the turn-taking mechanism is an ancient one possibly predating the dawn of human language (Levinson, 2016; Pika et al., 2018). We highlighted interaction contexts characterized by long composite turns, frequent signal exchange, and flexible timing, which could be relevant comparative models for investigating the evolutionary precursors of human-like turn-taking. Rather than indicating mechanisms specific to language, they may reflect broader interactional capacities on which conversational turn-taking could later have been built. Future work could also examine the internal composition of turns to determine whether particular combinations or ordering of behaviors are associated with specific meanings. Such analyses would provide a basis for assessing whether composite turns show rule-like organizational properties bearing on discussions of syntax in animal communication (Suzuki and Zuberbühler, 2019; Zuberbühler, 2020).

Comparisons with previous studies are limited because most work focused on a single signal modality and did not include actions (but see Fröhlich et al., 2016; Kolff and Pika, 2025; van Boekholt and Pika, 2025). Our results are consistent with reports that, in red-capped mangabeys, agonistic sequences defined as multiple signals within an 8 s window were more complex, with complexity referring to structural diversity within a sequence (Aychet et al., 2021). Other studies in chimpanzees and orangutans documented context-related variation in primate signal sequencing, with gestural sequences occurring most frequently in play contexts (Liebal et al., 2004; Tempelmann and Liebal, 2012).

With respect to timing, turn-taking was generally fast, with a median gap duration of approximately half a second, although gap durations varied. This may reflect the integration of multiple communicative modalities, which have been suggested to exhibit distinct timing patterns in humans (Coates and Sutton-Spence, 2001; Emmorey et al., 2009; Holler et al., 2021). Some of the observed variation was accounted for by socio-demographic factors and interactional context, while additional sources of timing variation remain to be identified.

The median gap duration observed here (0.43 s) was longer than that reported in previous work on the same group of adult female sooty mangabeys, which analyzed the same dataset but was restricted to grooming interactions and single-unit turns (median gap = −0.09 s; Tibesar et al., 2026). When examining single-unit turns, timing measures capture coordination between individual actions, gestures, or vocalizations occurring in rapid succession. By contrast, analyzing composite turns shifts the temporal reference point to the end of an interactional phase, such as a grooming bout, thereby measuring gaps between successive phases. Differences in reported gap durations likely therefore reflect the scale at which turn-taking was operationalized rather than differences in interactional coordination. Comparability with other studies thus depends on whether species produce composite turns within turn-taking. If such turns are absent or rare, timing estimates from single-unit and composite turns should converge. Because this remains unestablished outside adult female sooty mangabeys, cross-study comparisons remain provisional.

In comparison with Afro-Eurasian monkeys, the median gap observed in this study was shorter than typical response times reported for vocal exchanges in red-capped mangabeys, Japanese macaques, and Campbell's monkeys (0.5–2 s; Katsu et al., 2019; Lemasson et al., 2010; Meunier et al., 2023). Compared with great apes, turn-taking in adult female sooty mangabeys was slower than in adult chimpanzee grooming interactions, which showed near-zero delays (Kolff and Pika, 2025), and faster than mother–infant joint travel coordination in chimpanzees and bonobos, where delays approached 1 s (Fröhlich et al., 2016a). However, it is not yet possible to isolate the contributions of species, context, modality, and methodological differences.

Our results showed that adult female sooty mangabey interactions exhibit some basic features associated with conversational turn-taking organization, namely structured alternation of turns across modalities and rapid temporal coordination. The median gap duration in the present study was comparable to that reported for human conversation (median = 0.10 s; Stivers et al., 2009). These findings are consistent with growing evidence that rapid timing may reflect an evolutionarily ancient element of the turn-taking organization that predates the emergence of human language (Levinson, 2016; Levinson, 2019; Levinson and Holler, 2014; Pika et al., 2018). However, the findings also highlight a clear divergence from human conversational turn-taking. In humans, turns can be longer and may contain multiple words organized into grammatically structured clauses. Pragmatic content also depends on speakers'

intentions and shared context rather than on the literal meaning of individual words (Levinson and Torreira, 2015; Sacks et al., 1974). In human spoken language, median turn length ranges from 8.5 to 18.5 words and mean turn length from 1.6 to 11 words, with variation associated with conversational topic, language, and interactional setting (Polzehl et al., 2011; Portele, 2002; Yuan et al., 2006). This pattern aligns with Levinson's hypothesis that ancestral turn-taking systems were comparatively simple, whereas human conversational turn-taking has been pushed toward the limits of cognitive processing, allowing rapid responses despite increasingly complex turn content (Levinson, 2016; Levinson and Torreira, 2015). From this perspective, the short turns observed in adult female sooty mangabeys are consistent with an interactional organization that preceded the forms characteristic of human language while retaining core principles underlying turn-taking (Levinson, 2016; Levinson and Torreira, 2015).

Is signal-based turn-taking timing in adult female sooty mangabeys influenced by socio-demographic factors?

Regarding the second research question, we found that an effect of age on gap duration was present but context-dependent. This pattern is consistent with the *Communication Accommodation Theory*, which predicts that interactants adjust communicative behavior to social partner characteristics (Giles and Powesland, 1975). In affiliative interactions, older initiators were associated with longer gaps. Research on social aging in primates shows that older individuals experience shifts in social interactions, including receiving less aggression and, in some species, being less often targeted for social engagement by group mates (Machanda and Rosati, 2020; Nakamichi, 2003; Rathke and Fischer, 2021; Zhang et al., 2023). By contrast, no age effects were observed in agonistic, grooming, or sexual interactions. Affiliative interactions in sooty mangabeys may allow greater socio-demographic modulation of turn-taking timing because they often occur in lower-risk contexts, such as approaching, greeting, embracing, or maintaining social contact, where responses may be adjusted according to the partner without immediately disrupting the interaction (Range and Fischer, 2004). In such contexts, response timing may reflect how the recipient evaluates the signaller or the social opportunity. Grooming, by contrast, requires coordination within an ongoing interaction, including access to the partner's body. These mechanical and interactional constraints may leave less room for partner-dependent variation in turn-taking timing. Agonistic interactions in female sooty mangabeys may similarly leave less room for partner-dependent timing adjustment because they are potentially costly. Females form linear dominance hierarchies, aggression increases over food, and agonistic behavior is influenced by audience size and audience rank composition (Quintero, 2025; Range and Noë, 2002). Timing flexibility thus appeared tolerated primarily in low-pressure social interactions, whereas contexts involving conflict or coordination constrained gap duration more tightly (Clark et al., 2022; Vesper et al., 2011).

We also found an effect of interaction context on gap duration. Grooming interactions showed longer gaps than affiliative and agonistic interactions, whereas affiliative interactions showed shorter gaps than agonistic and sexual interactions. Longer gaps in grooming may reflect negotiation between interactants with partially divergent preferences, such as over bout structure (van de Waal et al., 2013). Consistent with this interpretation, communication during grooming interactions in adult female sooty mangabeys was largely centered on coordinating access to specific body parts and determining which body part would be groomed (Tibesar et al., 2026). A similar pattern has been documented in conversational interaction of English speakers, where longer gaps often preceded dispreferred actions such as disagreement or refusal (Pomerantz, 1984). As opposed to grooming, affiliative interactions may involve more behaviorally aligned outcomes, while agonistic interactions constitute a more urgent context in which faster responses are expected (Schülke et al., 2020). Overall, affiliative interactions showed the shortest gap durations. The affiliative context therefore represents a particularly informative setting for studying turn-taking in primates and assessing its relevance to language evolution, as it combines frequent signal exchange, timing flexibility, and rapid responses. This perspective aligns with the *vocal grooming hypothesis* and the *platform of trust hypothesis*, both of which propose a central role for cooperative, affiliative interactions in the emergence of language (Dunbar, 1996; Wacewicz and Żywiczyński, 2018). These findings also have comparative implications, because timing differences may reflect contextual variation rather than species-level differences.

Earlier studies in primates have also reported effects of social and demographic factors such as age, rank, or social bonds on turn-taking structure, including response rates, frequency of call exchanges, and duet alternation patterns (Arlet et al., 2015; Geissmann and Orgeldinger, 2000; Kolff and Pika, 2025; Lemasson et al., 2013; Levréro et al., 2019; Müller and Anzenberger, 2002). In this study, we found a limited effect of socio-demographic factors on turn-taking timing, which differs from reports in adult eastern chimpanzees where such factors showed no effect on timing (Kolff and Pika, 2025). A similar influence of interactional context on turn-taking timing has been reported in mother–infant chimpanzees, with faster responses observed in the joint travel context (van Boekholt and Pika, 2025). Overall, the empirical evidence on how social and demographic factors shape turn-taking timing remains too limited to support strong conclusions. Further studies are needed to determine whether primate turn-taking shows human-like sensitivity to such factors or a more restricted pattern, thereby clarifying the ancestral state in the evolution of primate turn-taking abilities (Kolff and Pika, 2025; Pika et al., 2018; van Boekholt and Pika, 2025).

The pattern observed in this group of adult female sooty mangabeys shows some correspondence with human conversational turn-taking, where social and demographic factors, including age, status, and interpersonal relationships, influence timing (Bortfeld et al., 2001; Dewi et al., 2018; Yuan et al., 2006). Previous studies showed that sooty mangabeys adjusted their social behavior according to partner and audience characteristics, including dominance rank, relationship quality, reproductive state, sex, and the presence of socially important bystanders (Range and Noë, 2002; Range and Fischer, 2004; Mielke et al., 2017; Mielke et al., 2018; Quintero et al., 2022; Quintero, 2025). However, in sooty mangabeys the age effect on turn-taking timing was strongly context-dependent, whereas in humans related effects have been reported across laboratory,

classroom, and telephone settings (Bortfeld et al., 2001; Dewi et al., 2018; Yuan et al., 2006). Turn-taking timing in Swedish and Dutch speakers has also been shown to vary with interactional context (Heldner, 2011; Holler et al., 2021). Additionally, rank and social relationship strength showed no detectable effects on turn-taking timing, contrasting with findings in humans, where social relationships have been shown to influence turn-taking timing (Bortfeld et al., 2001; Yuan et al., 2006). Further studies with larger datasets are needed to determine whether these null findings reflect species-level differences or limited statistical power to detect subtle effects. Overall, these results are consistent with the proposal that flexibility in turn-taking timing may represent an element of turn-taking organization that predates the emergence of human language (Pika et al., 2018). In the studied adult female sooty mangabeys, however, such flexibility appeared more restricted than in humans.

This study focused on a single group of adult female sooty mangabeys living in a wild population, limiting the generalizability of our findings concerning several aspects. For instance, sex- and age-related differences in communicative patterns have been reported across several primate species, including great apes (Fröhlich, 2017; Pika et al., 2018; Liebal et al., 2004) and monkeys (Molesti et al., 2020; Villa-Larenas et al., 2024). While our study focused especially on adult individuals to gain insights into fully developed turn-taking abilities, studies of other age classes and dyads will be useful for getting an informed understanding of the variety, complexity, and development of turn-taking behavior (Abreu and Pika, 2022; Fröhlich et al., 2016; van Boekholt and Pika, 2025). Future studies on turn-taking abilities in sooty mangabeys could therefore broaden the study sample to include males, juveniles, and additional groups.

Conclusion

Focusing on adult female sooty mangabeys in their natural habitat, this study explored the organization of turn-taking across modalities and assessed how socio-demographic factors contributed to signal-based turn-taking timing. By doing so, it aimed to provide comparative evidence relevant to identifying communicative structures that may have preceded language and to understanding the social foundations of conversational timing in human evolution. We characterized turn-taking organization by analyzing composite turns composed of actions, gestures, facial expressions, and vocalizations. Composite turn size and turn transition types were not random but reflected the interactional demands of different contexts. Turn-taking timing was influenced by socio-demographic factors in a context-dependent manner: age affected gap duration only in affiliative interactions. Overall, the findings are in line with the view that core organizational principles of turn-taking, including rapid structured alternation across modalities and context- and partner-dependent timing variation, may have predated the emergence of human language (Levinson, 2016; Pika et al., 2018). They also provide insight into the types of interactions in which human-like turn-taking may have developed, with some contexts showing composite turns composed of more units, more frequent signal exchange, and greater flexibility in timing.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://doi.org/10.6084/m9.figshare.32060811.

Ethics statement

Ethical approval was not required for the study involving animals in accordance with the local legislation and institutional requirements because in line with Section V, Article 7 of the German Animal Welfare Act (May 25, 1998), it was categorized as a non-animal experiment and thus did not necessitate prior approval from an ethics committee.

Author contributions

PT: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. CC: Data curation, Writing – original draft, Writing – review & editing. AL: Data curation, Writing – original draft, Writing – review & editing. SP: Conceptualization, Data curation, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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