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Case Report

Importance of feeding branches to gorillas under human care

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Abstract: In this study, we investigated the holding duration of various food types consumed by gorillas in captivity, focusing on the dominance of branches among the provided food items. In the welfare practices of gorillas under human care, extending the time spent on feeding activities was emphasized by referencing time budgets observed in the wild. Additionally, from a nutritional perspective, the provision of leaves and bark was prioritized. In this investigation, the duration from grasping with the hand, performing various manipulations, placing the item in the mouth, to releasing was defined as "holding duration", which was compared between branches and other food types supplied simultaneously at the same enclosure. The study was conducted between 2017 and 2018 at Tokyo's Ueno Zoological Garden, in Japan, involving five gorillas kept in the same enclosure. Data from a total observation time of 63 hours across 17 survey days were analyzed. Additionally, a young female was observed modifying a twig to retrieve food that had fallen into a crevice in the rock. The author analyzed the relationship between food types and individual variations in holding duration using a non-parametric two-factor analysis and conducted comparisons across different branch types using t-tests. As a result, the holding duration for branches was significantly longer than that for vegetables across all individuals, and no interaction between individuals and food types was observed.

Keywords: branch and leaves; enrichment; foraging; holding duration; tool use behavior

1. Introduction

Animal welfare practices for animals under human care, spanning from livestock and poultry to experimental animals, have evolved from addressing the basic needs for freedom from hunger, pain, and disease, as outlined in the "Five Freedoms" [1], to incorporating evaluations of improved mental states [2]. In zoos, efforts to enhance the physical and psychological conditions of captive animals

have been implemented through environmental enrichment initiatives and evaluations [3]. For captive animals, the comparison of behavioral repertoires observed in the wild has served as a key indicator for welfare assessments [4–6]. In the case of primates, several studies have been conducted to infer welfare conditions by comparing the state of behavioral expression with that in the wild. Observations of wild western gorillas (*Gorilla gorilla*) have revealed that considerable time is spent searching for food, and they feed on a wide variety of things, including fruit, stems, leaves, bark, and insects [7,8]. Therefore, efforts have been made to innovate the types of food provided in zoos, and these initiatives are classified as feeding enrichment. Focusing on manipulative behavior during feeding, various behaviors such as breaking branches are performed. If the purpose of feeding enrichment is to encourage animals to search for preferred food items and extend the time spent on complex manipulative actions, providing a variety of branches in the enclosure can be considered a meaningful practice in animal welfare.

A review of 227 studies conducted between 1978 and 2019 regarding enrichment for primates in captivity identified research on western lowland gorillas (*Gorilla gorilla gorilla*) as the second most studied species after chimpanzees, with all studies conducted within zoos. Many of these researchers examined the effects of feeding enrichment and manipulative enrichment using frequency or duration as an indicator [9]. Furthermore, there have been reports that the provision of branches to gorillas reduced stereotypic behaviors and promoted satiety [10–12]. The holding duration on feeding branches includes activities influenced by the type and form of food offered, such as exploration, inspection, handling, transportation, plucking edible parts, and gnawing on bark, which involve the modification of food forms prior to consumption [10].

According to the Care Manual of Gorillas in Captivity [13], branches can be manipulated into a shape of choice and be used in making a bed. Therefore, branches are excellent tools that can induce feeding and manipulative behavior, and holding may include foraging and various uses. However, compared to the handling of branches and leaves, the duration from grasping to bringing vegetables or easily graspable grass to the mouth is expected to be shorter. Moreover, feeding enrichment tools requiring time to retrieve food from boxes are utilized in various zoos and have been implemented at the study site. Therefore, comparisons are made between holding duration of branches, vegetables, grass, and these tools. Therefore, our aim of this study is to compare the holding duration of branches and other foods in gorillas and to comprehensively understand the effect of branches as feeding enrichment. Additionally, tool use involving branches observed during the study is also reported.

We investigate the significance of providing branches in comparison to vegetables and other types of food, using holding duration as an indicator. The study was conducted between 2017 and 2018 at Tokyo's Ueno Zoological Garden, in Japan, involving five gorillas kept in the same enclosure. Data from a total observation time of 63 hours across 17 survey days are analyzed.

2. Materials and methods

The research site for this study was the "Gorillas' Forest" in Ueno Zoological Gardens in Tokyo and the subjects of the study are shown in Table 1.

The enclosure contained artificial trees of different heights, numerous hollow sections, and sufficient branches, leaves, grass, and vegetables; therefore, the individuals were able to forage simultaneously.

Table 1. Subjects.

name	male (M) / female (F)	year of birth	notes
Haoko	M	1993	Silver back
Toto	F	1978	
Momoko	F	1983	Gave birth in Oct. 2017
Komomo	F	2009	Momoko's daughter
Momoka	F	2013	Momoko's daughter

The five gorillas were free to forage in the enclosure from 9:30 to 13:10 and from 13:30 to 15:50. Between 13:10 and 13:30, the gorillas entered the holding area, during that time vegetables, green grass (Italian), hay, and abundant branches with leaves were placed around the enclosure by the keepers. At about 13:30, the gorillas moved back into the enclosure to forage for their favorite food. Highly palatable primate biscuits were placed in plastic containers.

When the containers were shaken, they came out of the small opening. In some cases, the cut vegetables were placed in multiple locations in jute bags and other containers.

The research site had two large acrylic glass windows for visitors at the observation path, a rocky hill that the gorillas can climb, various heights of artificial trees, a wall against which they could lean, a grotto where they could hide from the strong sunlight, and multiple shrubs (Figure 1).

The survey was conducted over a 17-day period from March 24, 2017 to December 12, 2018. Only morning or afternoon observations were conducted for 6 days during this period because of bad weather, etc. In October 2017, a baby was born, and all gorillas were given the freedom to choose between the enclosure and backyard, which caused different conditions.

Additionally, enclosure construction lasted for 6 months, from December 2017 to May 2018, resulting in a total of 17 survey days, and the total observation time was 63 h. The number of researchers varied from two to four per day, and the number of individuals tracked per day varied in accordance with the number of researchers. A total of seven types of branches and leaves, two types of grass, and 19 types of vegetables and beans were fed during the survey period (Table 2).

Table 2. Feeding list for Gorillas at Ueno Zoological Park.

branch (evergreen)	Japanese white oak, Japanese chinquapin, Japanese privet, Japanese bayberry
branch (deciduous)	Japanese zelkova, Trident maple, Quercus serrata
grass	Hay (Alfalfa), Italian ryegrass
vegetable	Cabbage, Lettuce, Celery, Napa cabbage, Green onion, Carrot, Bell pepper, Cucumber, Eggplant, Broccoli, Bok choy, Daikon radish, Zucchini, Japanese mustard spinach, Cauliflower, Turnip, Tomato, Green beans, Mung bean

Figure 1. Survey site "Gorilla Forest" at Ueno Zoological Park. a: Enclosure, the dimly lit area in the back right corner is a grotto. b: Shaking a plastic box to get a biscuit out (Young female)**.** c: Holding branch on artificial tree (Silver back)**.** d: Carrying branch in her mouth (Adult female).

2.1. Data collection

The survey team consisted of an author, four graduate students, and two undergraduate students who studied zoo animal behavior. After confirming the survey method using a sample video, the team conducted preliminary observations of individual identification and various feeding behaviors for around 2 h at the survey site. Then, the team split into pairs to follow the same individual, measure the holding duration, and record whether the branches were evergreen or deciduous.

Because the enclosure was mostly surrounded by high walls, limiting the viewpoints available for observation, the focal sampling involved monitoring the target's mouth to confirm eating or not. Two investigators per one target were assigned to ensure accuracy by dividing tasks between them. Preliminary investigations confirmed that Haoko rarely curled up in dark grottos or hid in blind spots, making it easy to confirm whether he was eating branches or not. Thus, to improve data collection efficiency with limited observers, priority was given to observing Haoko.

Even if various manipulations were performed on branches and leaves, if they were not confirmed to be put into the mouth, they were not included in the holding duration. The definition of duration for each type of food is presented in Table 3.

Table 3. Definition of the holding duration for each food type.

Item	Duration	
	Start	End
Branch and leaves	Picks up or starts to hold it*	Placed on the ground or leaves
Vegetables, Italian ryegrass, hay	Picks up or starts to hold it*	The items disappeared (the swallowing is confirmed, or when it is released or and placed on the ground)
Enrichment tools (usually biscuit in box/bag)	'Contact' is confirmed	Leaves the scene

* Including cases where the item was carried in the mouth or on the back.

The holding duration was measured using a stopwatch and a compact camera or smartphone. The duration was determined as follows: Differences of less than 2 seconds between the two investigators were resolved by adopting the shorter duration, and differences of 3 seconds or more were reviewed using video data to confirm and finalize the duration between the two investigators. In addition, the species of branches were identified and recorded as either evergreen or deciduous.

2.2. Analysis

In determining differences in holding duration among food types, after confirming the variance of each group, statistical analyses were conducted by two-factor (food type and individual) analysis conducted using the "R" software, version 2024, and the comparison between deciduous trees and evergreen trees was performed using a t-test by the analysis tool pack in Microsoft Excel 2021.

3. Results

3.1. The number of observation scenes per individual and the total observation time

Number of observation scenes (shown in boldface) and the total holding duration for each individual were as follows: Haoko: 83; 11,013 s, Momoka: 82; 5,099 s, Momoko: 44; 6,549 s, Komomo: 55; 4,171 s, and Toto: 38; 6,538 s. Momoka's holding time was shorter than that of the other individuals; thus, the number of observations of these two individuals was higher than the others. In 2017, as Momoko gave birth in October, frequent crouching for nursing and caring for her baby often hindered the observation of hand actions during feeding, resulting in a slightly reduced number of observations. Toto was often difficult to observe compared with the other individuals because it would move away from the viewing path or hide. Consequently, the number of observations for Toto was lower than that for the other individuals.

3.2. Comparison of holding duration between each food

The average holding duration of branch for every individual showed that Haoko had the longest holding duration at 215 s, while Momoka had the shortest at 86s. Due to limited access data and high variance values for alfalfa, hay, and enrichment tools, and due to the large variation in the data (Table

4), a comparison of holding duration across the five individuals for two types of food (branches and vegetables) revealed that branches was significantly longer ($p<0.001$). However, a two-factor analysis investigating the interaction between holding duration for branches and vegetables with individuals showed no significant interaction ($p=0.152$). Therefore, it can be concluded that specific combinations of individuals and food types did not lead to notably longer or shorter durations (Figure 2).

Table 4. Number of observations by subjects and average holding duration between each food type.

Type of foods	Total	Number of observations by subjects					Average of holding duration (sec.)	S.D.	variance
		Haoko	Momoko	Toto	Komomo	Momoka			
branch	164	44	28	20	29	43	159.8	209.3	43533.6
vegetable	72	16	12	15	14	15	68.3	65.4	5047.5
alfalfa hay	22	12	1	0	4	5	58.9	124.3	7210.9
italian ryegrass	16	0	3	3	5	5	68.6	84.9	14386.3
enrichment tool	13	2	0	0	9	2	52.1	28.7	1008.4

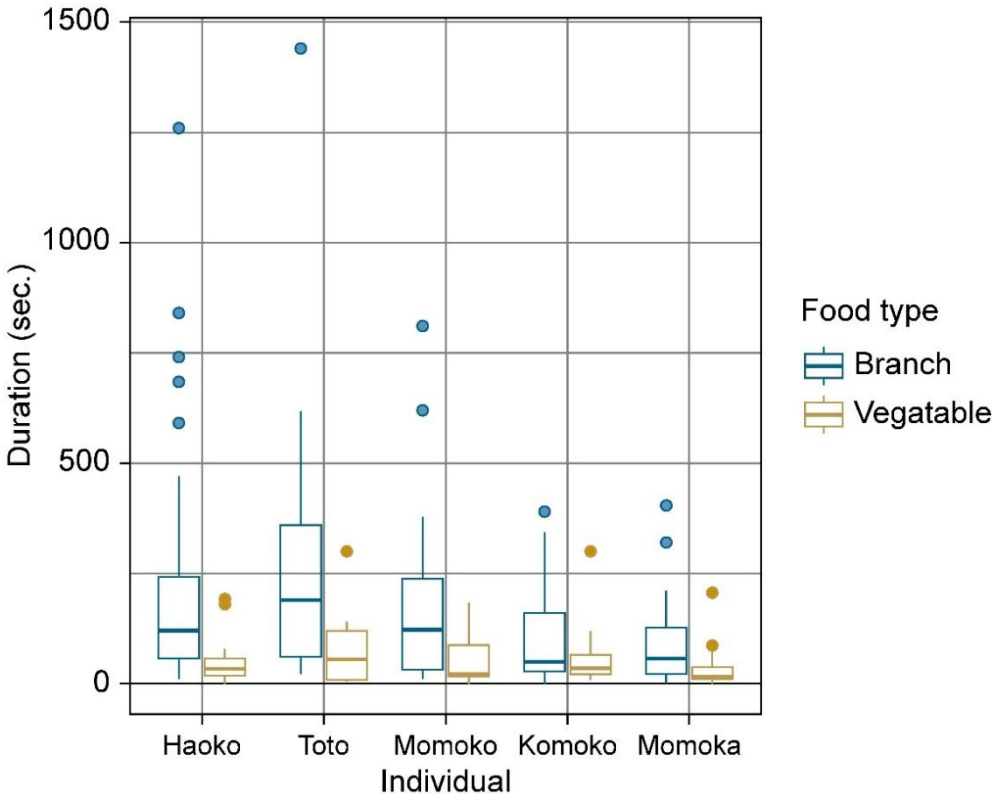

Figure 2. Holding duration of "branches and leaves" and "vegetables" for each individual. The top of the box is the third quartile, the bottom is the first quartile, and the line in the middle is the median. The top and bottom of the line represent the maximum and minimum values excluding outlines.

3.3. Comparison of the holding duration of the branch between evergreen and deciduous trees

When comparing evergreen and deciduous trees, the former had an average holding duration of 195 s, whereas the latter had an average holding duration of 147 s, with no significant difference between the two groups (t-test: $p>0.05$).

3.4. Various behaviors included in the holding duration and other behaviors using branches

The holding duration of the branches included various foraging-related behaviors, such as picking up, smelling, stripping the leaves from the branches to make them easier to eat, picking only the small fruit, and peeling off the bark with teeth or fingers. Other behaviors included the following: Adults bringing branches into the grotto (resting area) to use as bedding, resting with their arms on the branches such as a walking stick, and placing branches on their heads or carrying them on their backs into the backyard area. The juvenile Momoka frequently held short branches in their mouth and drummed lightly on their chest. In the case of the young female Komomo, she was making a racket by swinging the branches and hitting them against rocks and the floor; running with a thin, short branch in her mouth; and showing off to other gorillas by lightly hitting them.

3.5. Other feeding behaviors

In the case of adult individuals, they moved around while holding hay and grass (Italian). Although every individual was observed swallowing the cut vegetables in a few mouthfuls, the holding duration of leafy vegetables such as Chinese cabbage, cabbage, and celery included the time spent moving to a preferred location while carrying them around. However, the number of observed cases was extremely limited. The behavior of holding the enrichment tool was mostly shaking the container to drop the biscuits by Komomo.

3.6. Example of a thin branch being used as a tool

During the observation process, an instance was observed where a young female (Komomo) used the thin branch to obtain other food sources, which is worth noting. Toward the latter half of feeding, leaves were consumed, and small branches that were broken off were scattered throughout the enclosure. The branches being held were not direct food items but were used as tools to retrieve biscuits that were lodged between the artificial rocks. This tool-use behavior was counted as part of the holding duration for branches (Figure 3).

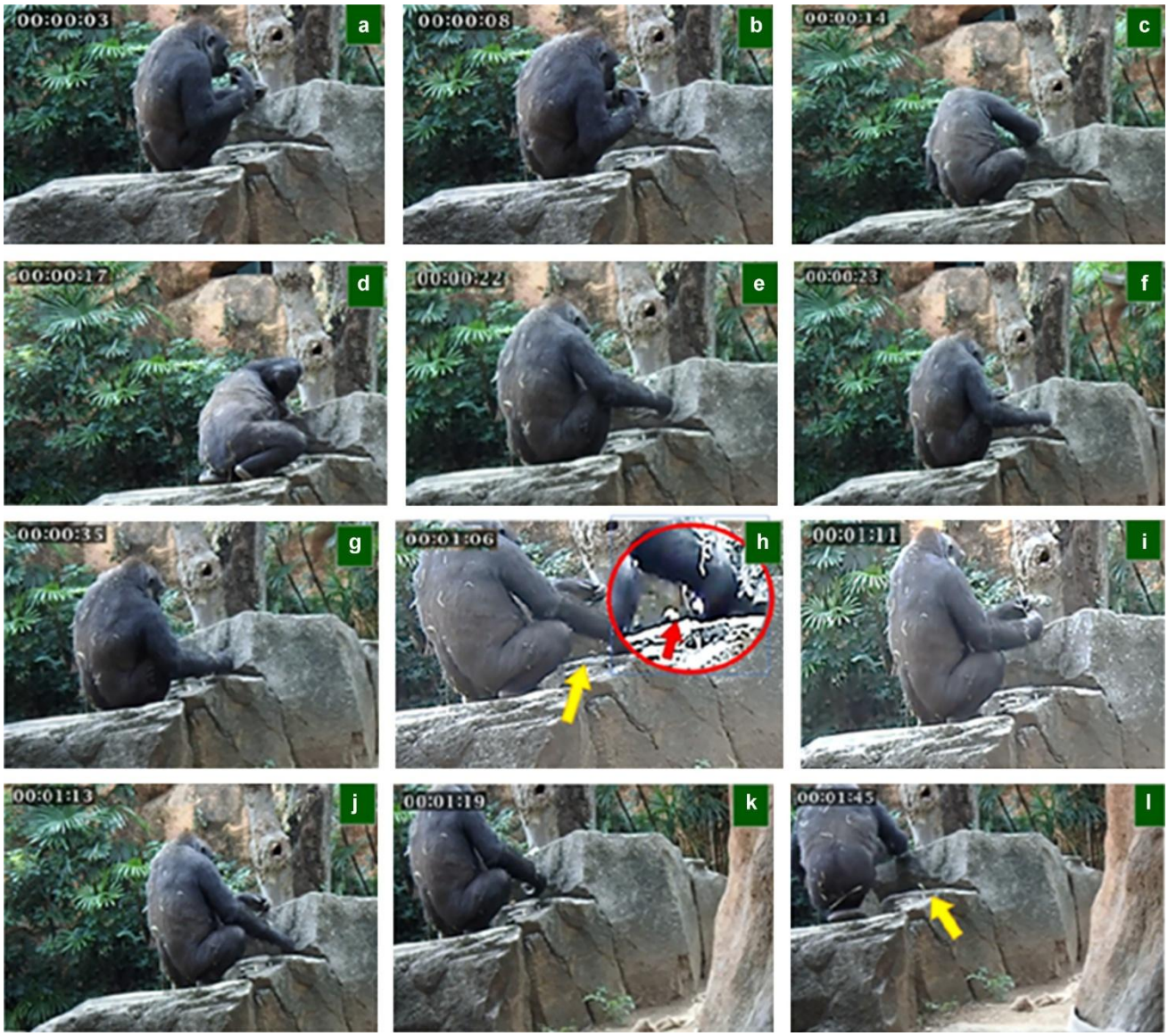

Figure 3. An example of using a branch as a tool in the foraging behavior of a captive gorilla from 10:44 AM on October 26, 2018. a: Licking the tip of the right-hand; b: attempting to pick up the pellet in the crack in the rock; c: looking down at the bottom left; d: picking up the twig from the bottom; e: moving the twig to the right-hand; f: inserting the twig into the gap; g: moving the inserted twig from side to side; h: the pellet pops out (yellow) and the enlarged pellet area (red); i: holding the twig in her left hand and the tip of the twig in her right hand; j: holding the twig in her left hand and the base of the twig in the gap with her right hand; k: holding the base of the twig in the gap with her right hand and shaking it from side to side, but the pellets do not come out; and l: leaving the used twig (yellow).

4. Discussion

The practice of feeding enrichment is important to increase the exploratory behavior of gorillas so that each gorilla can spend time in their preferred location [14,15]. In the comparison of holding durations between branches and vegetables, all individuals exhibited longer durations for branches.

This is likely influenced by the time required to select edible parts from the branches and process them into an appropriate size for consumption, with adults exhibiting a longer holding duration compared to younger individuals. However, potential implications of extended holding duration should be carefully considered. In the case of Toto, the eldest in the group, who held branches for over 24 minutes, physical factors such as tooth problems [16] may have contributed to the prolonged holding time. In this investigation, manipulations that did not involve putting the item into the mouth were recorded but excluded from this analysis. Branches were found to fulfill two categories of enrichment: "Feeding" and "manipulation", simultaneously.

The purpose of the observation is to measure holding duration, but in Momoka and Komomo, behaviors that can be classified as social behaviors are considered necessary to analyze the role of branches and leaves as mediators of social behavior in the future. Therefore, creating a detailed ethogram that not only determines whether feeding occurs but also identifies the purpose of branch manipulation, including social relations, would be meaningful.

Although statistical significance was observed between evergreen and deciduous trees, the duration tended to be longer for the former. This may not only be attributed to the time required for chewing tough leaves but also to the ease of peeling bark seen in deciduous trees like Zelkova [17], which likely influences the holding duration of branches.

Furthermore, confirming the tool use of branches and leaves is important. Komomo successfully used a twig to retrieve highly preferred food (primate biscuits) that she had dropped into a crack in the rock. This behavior may be the result of this individual imagining what would be good to have between her hand and the object in her surroundings because of her strong will to pick up the biscuits again. In the wild, gorillas use branches as walking sticks when crossing flowing rivers [18]. In zoos, gorillas use other gorilla's body as stepping stones to reach food that is out of reach [19]. In long-term observations at the Prague Zoo, gorillas use a variety of natural and artificial objects for enrichment, including baskets to make a pyramid, plastic boxes as weapons, and sticks made by branches to make contact with the silverback [20]. Moreover, according to observations at the San Diego Zoo, some gorillas have been reported to make sticks by removing leaves from branches and using them to knock down nuts from high trees [21]. Our investigation is an example of a potential cognitive ability to process natural objects in accordance with the purpose being confirmed in the same way as these.

Research is being conducted on feeding programs for animals in captivity from the perspectives of nutrition, disease, and behavior [22,23].

This study also has a limitation. No comparison was made between the proportion of the holding duration of the branches and the time budget for the overall behavior in the enclosure. Moreover, it has been reported that placing sufficient branches and foliage in the enclosure has reduced aggression rates [24]. Furthermore, the use of branches has many purposes, such as foraging, inviting or appealing to other individuals to play, and transporting materials for bedding. It is known that there is competition among individuals over attractive food [7,25]. We did not investigate the relationship between the weight of the edible parts of the branches and the holding duration. Therefore, a detailed ethogram of the time budget is necessary. Specifically, the relationship between branch manipulation duration and activities such as resting, exploring, and playful interactions observed among younger individuals should be further investigated [26]. Specifically, the proportion of branch manipulation within the overall activity time warrants examination. This would enable a broader interpretation of the role of branches and foliage as enrichment tools.

5. Conclusion

Various feeding methods are being tested to improve the welfare of gorillas in captivity, and it is important to evaluate the effects of different food types. Here, we clarified the role of branches and leaves, which are commonly provided in many zoos, as enrichment for gorillas. Therefore, providing abundant branches may induce diverse behaviors, including feeding, manipulation, and social interaction, and promote the welfare of gorillas in captivity. Future challenges include establishing detailed ethograms of branch use and clarifying their welfare significance. However, this report highlights the necessity of qualitative analysis regarding the enrichment role of branches and leaves, suggesting that they have the potential to expand behavioral possibilities beyond merely focusing on feeding behavior. Such challenges are likely to deepen our understanding of the lives of gorillas from the view point of animal welfare [5] and contribute to enhancing the role of zoos in widely disseminating this knowledge to visitors [27].

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The authors declare no conflicts of interest associated with this manuscript.

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