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ORIGINAL PAPER

Behavior of Asian Elephant (*Elephas maximus*) in a Land-Use Mosaic: Implications for Human-Elephant Coexistence in the Anamalai Hills, India

M.A. Kumar[1,2,*] & M. Singh[2,3]

[1] Rainforest Restoration Research Program, Nature Conservation Foundation, 3076/5, 4th cross, Gokulam Park, Mysore 570 002, Karnataka, India.
[2] Biopsychology laboratory, Department of Psychology, University of Mysore, Mysore 570 006, Karnataka, India.
[3] E-mail: mewasingh@bsnl.in
* Corresponding author: E-mail: anand@ncf-india.org,Tel: +91 821 2515601, Fax: +91 821 2513822.

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Elephant behavior, fragmented habitats, human population, human distance, landscape matrix, management implications, plantations.

Abstract
Understanding behavior of elephants in human-dominated landscapes can facilitate creation of management tools for conflict resolution and help foster human-elephant coexistence. We studied behavior of Asian elephants (*Elephas Maximus*) in the Valparai plateau, a 220 km² landscape matrix of rainforest fragments, tea, coffee, and *Eucalyptus* plantations in the Anamalai Hills of the Western Ghats of India. We studied the nearest neighbor distance among elephants within the herd and their feeding behavior in habitat mosaics. We also recorded reactions of elephants to human proximity and number of people in the vicinity. We employed scan sampling for data collection. Feeding by elephants was lowest in open canopy habitat of tea, and it gradually increased in canopy covered plantations of coffee and *Eucalyptus* and in densely covered natural vegetation. Vigilance behavior of elephants was lowest in forest fragments and riverine vegetation as they could avoid encountering humans. This behavior peaked in tea plantations due to intense human activity there. Elephants maintained closer inter-individual distances in tea and this distance gradually increased in canopy habitats of coffee, *Eucalyptus* and natural vegetation. More humans in the vicinity and closer proximity to elephants reduced feeding and increased agitation in elephants, while proximity to settlements did not have any influence. We, therefore, suggest that protection and non-conversion of canopy habitats, restoration of rivers with native species, and maintaining distance from elephants would foster normal activities of elephants and help promote human-elephant coexistence in such landscapes.

Introduction

Forest fragmentation often restricts wild species to 'islands' or fragments and conserving such fragmented landscapes, is therefore a key priority, especially in the tropics [1,2] Fragmentation of natural habitats and human disturbance negatively influence survivorship, forage efficiency, and distribution of mammals in altered landscapes [3-6]. Human disturbance is perceived similar to predation risk [7] and it induces stress by influencing behavioral patterns to alert responses in animals [8]. The relationship between behavioral science and wildlife management practices is vital for understanding stress coping mechanisms in species due to human disturbance [9]. It is now widely recognized that such behavioral investigations are essential for the management of wild populations [10,11].

The wide-ranging movement of elephants in human modified landscapes frequently creates opportunities for contact and conflict with people. The long-term survival of elephants in such landscapes may depend on their ecological and behavioral adaptations to changed conditions [12]. Impacts of human activities determine elephant distribution [13,14], may seriously lower infant to female ratios [15], and

inhibit long-term survival of elephant populations in areas outside the protected areas [16]. Human pressures decrease foraging ability [17] and induce physiological stress in elephants [18]. An often overlooked aspect in human-elephant conflict studies in Asia is the lack of understanding of the behavior of elephants and its implication in the population management and conflict resolution in human-dominated habitats [19]. The emerging points from these studies indicate that elephants in persistently amended environments have to adapt behaviorally to changed ecological conditions and respond to human pressures.

Of the 34 'biodiversity hotspots' in the world, the Western Ghats of India and central highlands in Sri Lanka face elevated risks due to high human population density [20]. The Asian elephant (*Elephas maximus*), a globally endangered species, is now facing threats for its survival in the wild in India due to intense human-elephant conflicts [2,14,16]. Studies have indicated that land-use practices in modified elephant landscapes adversely affect elephant populations and human pressures influence behavioral responses of elephants [21,22]. Understanding effects of land-use mosaics and the influence of humans on behavior of elephants, thus, become necessary for the management of human-elephant coexistence in altered landscapes. The present study focused on behavior of elephant herds in a plantation-dominated landscape of the Valparai plateau in the Anamalai hills. In this study, our objectives were to find out (1) how land-use mosaics affect behavioral activity budgets of elephants, (2) how does nearest neighbor distance in elephant herds vary in relation to habitat types, and (3) the impact of human density and proximity on behavioral responses of elephants.

Materials and Methods

Study area

The present study was carried out in the Valparai plateau in the Anamalai hills which contains over 2000 km² of protected tropical forests and harbors the second largest Asian elephant population in India [16].

Over the last century, 220 km² of prime tropical rainforests on the Valparai plateau were clear-felled for tea, coffee, and *Eucalyptus* plantations [23]. The plateau is surrounded by the Anamalai Tiger Reserve (958 km², Figure 1). Tea is a dominant crop which covers nearly three fourth of the plateau followed by coffee and *Eucalyptus* plantations [unpublished data]. Tea is grown in open areas with no canopy cover while coffee is grown under mixed species of native and exotic tree species. *Eucalyptus* is raised in thickets in most estates to meet energy requirements of tea factories. The natural vegetation is in the form of rainforest fragments and riparian vegetation along streams and rivers are the only refuges for many endangered and endemic species including elephants. There are around 40 rainforest remnants varying in size from 0.3 ha to over 100 ha distributed across the plateau [24]. The plateau receives around 3500 mm of rainfall annually from the southwest and northeast monsoons. The forest is classified as mid-elevation tropical wet evergreen forest of the *Cullenia-Mesua-Palaquium* type [25] with an altitude ranging between 1000 and 1450 m mean sea level. Due to undulating terrain, the Valparai plateau has been historically used by elephants to move between surrounding protected areas [23]. There are about 100,000 people

living in widely scattered human habitations across the plateau (population density, c. 455 people/km²). Human settlements, reservoirs, vast extensions of plantations and human activity have not only hindered elephant movement but also have resulted in close encounters between elephants and humans [26,27].

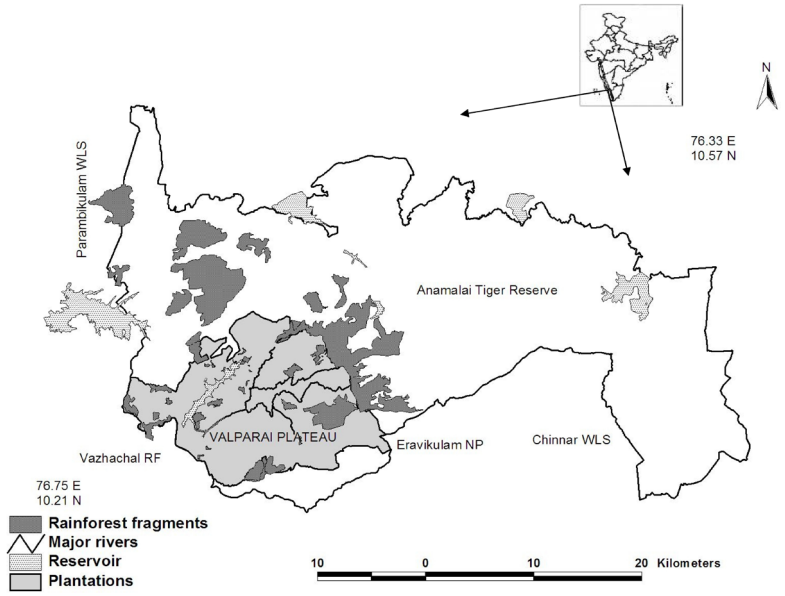

Fig.1. Valparai plateau with plantations (light grey) and rainforest fragments (dark grey) surrounded by wildlife sanctuaries (WLS), National Parks (NP), and Reserved Forests (RF).

Study animals

The Valparai plateau has been intensively used by two elephant herds apart from several peripheral herds which occasionally come into plantations. In the present study, we report behavior of these two focal elephant herds, namely Herd 1 and Herd 2 which roamed most parts of the Valparai plateau [28]. These two herds have been in frequent interactions with humans spending nearly eight months in a year, leading to high incidence of human-elephant conflicts on the plateau [26]. Each individual in elephant herds was identified based on characteristics such as physical markings including holes on the ear lobes, lumps, cuts, shape of tusks, individual behavior, and position of young within the herd [29,30]. The age-sex composition of individuals differed in these herds (Table 1).

Table 1. Age-sex distribution and herd size in the Herd 1 and Herd 2.

Age-sex class	Herd 1	Herd 2
Adult female	3	11
Adult male	1	0
Sub adult female	0	1
Juvenile female	1	2
Juvenile male	1	1
Calves	2	4
Total	8	19

Methods

This study was carried out for one-year period between 2006 – 07. Direct surveys, fresh signs such as dung, and information from local informants were used to detect elephant herds within the plantations. Once an elephant herd was located, it was followed on subsequent days until they moved out of the private plantations into surrounding protected areas. Behavioral observations were carried out during day time using scan sampling with an interval of 10 minutes on all visible individuals in each elephant herd [31,32]. Data recorded included individual identity, age-sex of the animal, activities (such as feeding, locomotion, passive, and social behavior), type of habitat (tea, coffee, *Eucalyptus*, and natural vegetation), identity of nearest neighbor, distance from nearest neighbor, distance from humans, number of people in close proximity and distance of nearest human settlement. The behavioral activities of elephants and responses to humans were categorized into six categories. These included contact, play, avoidance, alert/warning (stretching ears, stare, tail lifting, move away and face away from people), assurance (placing trunk over others, body contacts), and offensive behaviors including mock charges, chase etc [33]. Observations were made from a distance of 50 m from elephants in order to reduce the impact of observer on behavior of elephants [34]. Activity was recorded as follows:
Feeding: When an animal ingested or searched for plant food such as leaves, grass, bark of a tree, roots, fruits etc.
Movement: Any movement between feeding areas and travelling.
Resting: When an animal showed passivity either standing or sleeping on ground without involving any kind of interactions with other individuals in a herd.
Social behaviors: Social behaviors such as play and agonistic interactions within the members of the group, exhibiting alertness, assurance, avoidance, and offensive behaviors towards human presence and their proximity.

Data analysis

G-test of independence was used to calculate significant differences in the activity budgets of Herd 1 (n = 1047 scans) and Herd 2 (n = 1068 scans). Significant differences in activity budgets of elephant herds in relation to habitat type were calculated using chi-square test of independence (Objective 1). We examined distance to nearest neighbors in different habitats using Kruskal-Wallis test followed by a series of post hoc procedures [35] in Herd 1 and Herd 2 (Objective 2). A multinomial logistic regression was carried out to find out influence of predictor variables (number of people in close proximity, their nearest distance from elephants, and distance of nearest settlements) on major behavioral activities of elephants (feeding, resting (passive), movement, play, and agitation) (Objective 3).

Results

Activity budgets

A total of 2115 scans were used in the analysis. We calculated percent of scans for different behaviors in the two herds of elephants. Feeding was the major activity in both herds (n = 539 for Herd 1 and n = 473 for Herd 2, respectively; Figure 2). There was a significant overall difference in proportion of scans on various activities

between Herd 1 and Herd 2 ($G = 19.24$, $df = 5$, $p < 0.01$). This difference was mainly due to percentage of feeding observed in total number of scans being higher in Herd 1 and movement and agitation in Herd 2.

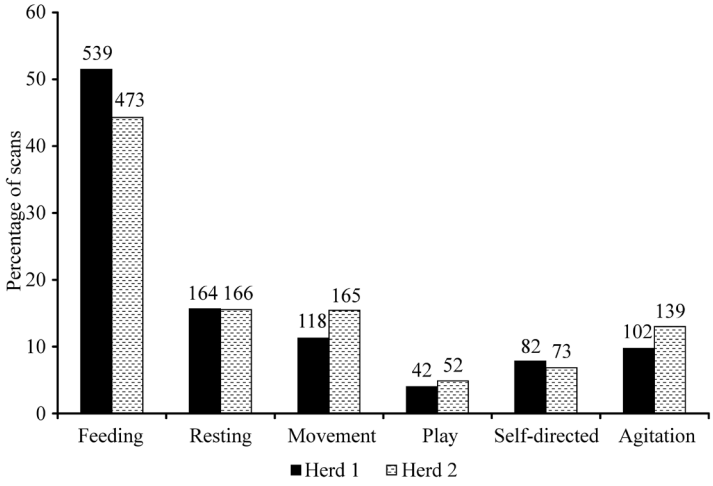

Fig.2. Behavioral activity budget for two identified elephant herds in a plantation-forest mosaic of the Valparai plateau. Note: values above bars indicate number of scans (n) under each behavior category.

Behavioral activity patterns of elephants in a land-use mosaic

Significant differences were observed in proportion of scans for activities in different habitats ($\chi^2 = 141.71$, $df = 18$, $p < 0.000$, Figure 3). Feeding by elephants was highest (57.7%) in natural vegetation and it decreased gradually in *Eucalyptus* (45.5%), coffee (43.8%) and tea (39.5%). Elephants rested more in *Eucalyptus* and least in coffee plantations. The movement was high in tea (17.8%) and low in natural vegetation (10.6%) and *Eucalyptus* patches (10.1%). Agitation behaviors were high in completely open habitats of tea (17.2%) and lowest in rainforest fragments and riverine vegetation (6.4%).

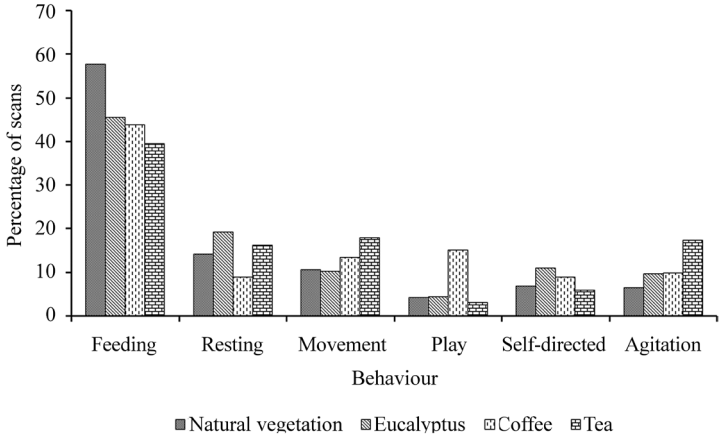

Fig.3. Activity patterns of elephants in different habitats of the Valparai plateau.

Nearest neighbor distance

Distance of nearest neighbor differed significantly across habitats for individual herds of Herd 1 (Kruskal Wallis Test: χ^2: 13.005, df = 3, $p < 0.01$) and Herd 2 (Kruskal Wallis Test: $\chi^2 = 30.904$, df = 3, $p < 0.01$). Multiple comparisons between habitat types for focal herds revealed that nearest neighbor distance significantly higher in *Eucalyptus* than in natural vegetation for Herd 1 (Mann–Whitney U-test: $p < 0.0085$) and Herd 2 (Mann–Whitney U-test: $p < 0.0085$), and also compared to tea for Herd 1 (Mann–Whitney U-test: $p < 0.0085$). But the nearest neighbor distance was found significantly higher in natural vegetation than in tea for Herd 2 (Mann–Whitney U-test: $p < 0.0085$).

Table 2. Showing the mean distance (meters) with standard error for nearest neighbor from focal animal in elephants across habitats.

	Habitat	N	Mean	SE
Over all	Tea	790	1.61	0.11
	Coffee	112	1.86	0.23
	Eucalyptus	404	2.04	0.2
	Natural vegetation	809	2.41	0.18
Herd 1	Tea	326	1.36	0.11
	Coffee	17	0.94	0.29
	Eucalyptus	200	1.81	0.16
	Natural vegetation	504	1.58	0.13
Herd 2	Tea	464	1.79	0.17
	Coffee	95	2.03	0.27
	Eucalyptus	204	2.27	0.37
	Natural vegetation	305	3.77	0.4

Factors influencing behavior

In Herd 1 resting by number of animals was significantly negatively related to number of people in close vicinity and positively related to distance of people from elephants. Movement was positively influenced by distance of people in close proximity (Table 3). Other behaviors such as feeding, play, and agitation behaviors in Herd 1 were not significantly affected by the predictors. In Herd 2, feeding reduced significantly as the distance between humans and elephants decreased and agitation increased with increase in number of people in vicinity and it decreased as human distance from elephants increased.

Table 3. Effect of anthropogenic factors on behavior of elephants in Herd 1 and Herd 2 based on the multinomial logistic regression.

	Herd 1		Herd 2	
Predictor variables	B (SE)	Exp (B)	B (SE)	Exp (B)
		Feeding		
No. of humans	-4.06E-02 (0.023)	0.96	2.92E-03 (0.013)	1.003
Distance of humans	1.76E-03 (0.003)	1.002	-4.19E-03 (0.001)**	0.996
Distance of settlement	2.29E-04 (0.001)	1.0	-1.09E-04 (0.0)	1.0
		Resting		
No. of humans	-0.116 (0.03)**	0.89	3.04E-03 (0.014)	1.003
Distance of humans	7.29E-03 (0.003)*	1.007	5.90E-04 (0.001)	0.996
Distance of settlement	7.46E-04 (0.001)	1.001	5.76E-04 (0.0)	1.0
		Movement		
No. of humans	-5.06E-02 (0.028)	0.951	2.35E-02 (0.013)	1.024
Distance of humans	7.40E-03 (0.003)*	1.007	1.18E-03 (0.001)	1.001
Distance of settlement	-4.20E-04 (0.001)	1.0	3.20E-04 (0.0)	1.0
		Play		
No. of humans	-8.60E-02 (0.047)	0.918	1.21E-02 (0.016)	1.012
Distance of humans	4.12E-03 (0.005)	1.004	-5.21E-03 (0.003)	0.995
Distance of settlement	5.69E-05 (0.001)	1.0	1.20E-04 (0.001)	1.0
		Agitation		
No. of humans	2.07E-03 (0.028)	1.002	4.74E-02 (0.013)**	1.048
Distance of humans	7.40E-04 (0.004)	1.001	-1.13E-02 (0.003)**	0.989
Distance of settlement	-1.28E-03 (0.001)	0.999	4.99E-05 (0.0)	1.0

Significance levels: * $p < 0.05$, ** $p < 0.001$

Discussion

Human induced disturbances in altered habitats may force elephants to respond behaviorally by reduced home ranges, avoidance of human frequented places, increased variability in their daily ranges, and decreased intra-herd sociability [36]. Investigating impact of landscape elements, human disturbance, and human density is suggested to be an important area of research in human-elephant conflict resolution [37]. Pressures from humans in altered landscapes may push animals into frequent interactions with humans with varying degrees of coping mechanisms to adapt to landscape changes [4].

The two elephant herds which covered most part of the Valparai plateau exhibited significant variation in their behavioral activities but feeding was the major activity of elephants as elephants are known to feed for more than 16 hours of a day with little time for other social activities [14]. Both herds were agitated by the presence of humans, but Herd 1 less so than Herd 2.

Fragmentation of natural habitats in elephant range countries decrease foraging efficiency of elephants and induce nutritional stress in severely fragmented forests due to human pressures [17] besides affecting their social behaviors [38]. Influence of habitat type on the behavior of elephants was apparent in feeding and agitation behaviors in the present study. Feeding by elephants was highest in the natural vegetation in rainforest fragments and riverine vegetation despite their low availability on the plateau. It gradually declined in *Eucalyptus* and coffee and reached lowest

in tea. Our data on habitat use by elephants in this land-use mosaic also indicates that rainforest fragments and riverine vegetation are most preferred than plantation habitats such as tea and coffee [28]. Among monoculture plantations, coffee and *Eucalyptus* seemed to play important roles as foraging and sheltering grounds for elephants due to regeneration of secondary vegetation and availability of grass. Coffee is an annual crop where intensive coffee picking by people remains for few months in a year (November - February) whereas logging of *Eucalyptus* is carried out once in seven years, thus human activity in these habitats is minimal. Therefore, the elephants exhibited relatively higher percent of feeding and resting in *Eucalyptus* and coffee than in tea.

Tea, an unpalatable crop, is not preferred by elephants but presence of weeds and availability of grassy swamps in tea fields attracted elephants. Elephants were seen stranded in tea fields for long hours during the day due to constant activity of workers, when the elephants were attempting to reach distant forest patches. This would obstruct elephant movement even when people are not noticed close to elephants. At such occasions, elephants were noticed engaging in resting and in play in tea fields. When human activity in surroundings calmed down, elephants moved swiftly to reach safe places of closed canopy habitats of forest fragments and riverine vegetation as seen in African elephants [39,40].

Such constant human induced pressures on elephants and their movement through vast expansion of open habitats may have serious consequences on long-term survival of elephant population in altered landscapes [17,41]. Two reasons may be attributed to the heightened agitation in elephants in tea fields. One, intensive human activity may provoke elephants to be more vigilant, exhibiting alarm behaviors such as ear stretching, restlessness, move away, facing away etc., than devoting their time to other activities such as feeding, resting, and play. The incidence of such disturbed behaviors in elephants decreased gradually in coffee and *Eucalyptus* plantations and was lowest in natural habitats. Secondly, lack of canopy cover in tea fields may expose elephants to humans more frequently than in other habitats and this would force animals to feel less secure and more alarmed. Such vigilance behaviors in elephants lessened in canopy habitats of coffee, *Eucalyptus*, and natural habitats where they could avoid direct encounters with humans.

Nearest neighbor distance.

Distance to nearest neighbor in fragmented habitats may be an indicator of responses by animals to habitat and human disturbance. Elephants in focal herds' maintained close proximity to each other in open habitat of tea and nearest neighbor distance gradually increased as canopy cover increased in coffee, *Eucalyptus* plantations and in natural vegetation habitats. However, we found inter-herd differences in the distances of nearest neighbor in relation to the type of habitat. In Herd 1, the nearest neighbor distance was low in rainforest fragments and riverine vegetation as compared to *Eucalyptus* plantation. The proximity of small sized forest fragments to human settlements and wood cutting by people may have forced elephants in Herd 1 to be closer to each other in natural vegetation than in *Eucalyptus*. Presence of large and numerous *Eucalyptus* patches and fewer but large patches of forest fragments within

the movement range of Herd 2 would have facilitated wider spatial dispersion of individual elephants with increased distance of nearest neighbor from focal animals.

Effect of human disturbance

Human presence affects animal behavioral activity with a shift to alert responses in animals [42,43] . Herd 1 and Herd 2 spend nearly eight months in a year on the Valparai plateau [27]. Individual herds showed differences in their responses to number of humans in the vicinity of elephants and distance of humans. Human density and close proximity of humans had negative effect on resting and movement but feeding, play, and agitation did not seem to be affected by these anthropogenic factors in Herd 1. This is perhaps due to smaller herd size, fewer calves well protected by adults, and avoidance of human activity areas by elephants, as Herd 1 was noticed hiding in less disturbed areas of plantations such as *Eucalyptus*. On the other hand, feeding and agitation in Herd 2 seemed to be sensitive to number of people in vicinity and their distance from elephants. Herd 2, with its large herd size and more calves had to move through more open habitats of tea and frequent encounters with people resulted in less feeding and more vigilance. Human habitations did not have significant impact on the behavior of both herds as these settlements have been present for the past 120 years and elephants may have been habituated to the presence of habitations. It appears that fewer people who maintain > 50m from elephants may reduce agitation and facilitate feeding and resting behaviors in elephants [personal observations]. Such distances of people at > 50m from elephants have been strongly recommended in the tourism zone of Pilanesberg National Park, South Africa [44].

Conservation implications

Increasing interface between humans and elephants over resources has led to high incidences of human-elephant conflicts in Asia. The historical change in prime rainforests to commercial plantations altered ecological and behavioral modifications in elephants on the Valparai plateau. Natural vegetation areas such as rainforest fragments and riparian vegetation played important role in the behavior of elephants. Restoration of forest fragments and development of natural vegetation along major rivers would not only enhance feeding besides reducing human pressures on elephants but will also facilitate free movement across plantations in the Valparai plateau. Protection of rainforest fragments from further degradation, discouraging extension of tea, and non-conversion of *Eucalyptus* and coffee to open canopy habitats of tea would help free dispersal of elephants. Establishment of corridors with native vegetation in swamps in tea habitats along frequently moved elephant paths would reduce impact of humans on elephants. Continuous disturbance to elephants might result in loss of fear of humans and sore human-elephant relationships in the Valparai region. If elephants are allowed to feed without causing disturbance by people during the day, they are unlikely to cause damages to human property at night when they search for food. Active steps are required by the plantation management to allocate work for tea pickers to fields devoid of elephants. This would reduce pressures on elephants without causing disturbance to normal behavioral activities.

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