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A Collective Exploration : Unveiling Elephant Memory Capacities Through Community Experience

Koo Huang Qing Yuan[1], Nazirah Mohamad Abdullah[1 2*], Lok Huey Kei[1], Phoo Qiao Lin[1], Nur A'alia Atierah Bakri[1], Huda Khalidah Khairunizan[1]

[1] *Department of Mathematics and Statistics, Faculty of Applied Sciences and Technology, UTHM Kampus Cawangan Pagoh, Hab Pendidikan Tinggi Pagoh, KM 1, Jalan Panchor, 84600 Pagoh, Muar, Johor, MALAYSIA.*
[2] *Environmental Management and Conservation Research, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA.*

*Corresponding Author: nazirah@uthm.edu.my
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Abstract

This study investigates the memory capabilities of elephants through a collective exploration framework, emphasizing community observations and ecological implications. This research was conducted in Kampung Lukut by using qualitative methods, that are interviewing with 20 villagers, and an ethogram-based observations of an elephant named Nina in Johor Elephant Sanctuary. This study aimed to: (i) analyse the adaptive significance of memory in elephant social dynamics and survival strategies through communities, (ii) identify the social interactions that shows the effect of elephant memory within their communities, and (iii) uncover multifaced aspects of elephant memory, including social, spatial, and cognitive dimensions. Finding highlighted elephant's locomotion, social structures, and interactions with humans. Behavioural responses to stimuli, such as bee sounds, were recorded, together with the community interview, insights into special memory and emotional intelligence. The study identifies the adaptive significance of memory in survival strategies and gives recommendations for enhancing conservation efforts.

1. Introduction

Elephants exhibit extraordinary intelligence and memory, influencing their social behaviour and survival. Their memory enables them to navigate vast landscapes, remember sources of food and water, and maintain complex social relationships among their community [1]. Most of the research studies have been conducted on individual elephants in controlled or semi-captive settings, had present a significant gap in understanding collective memory within natural and community contexts [2][3]. This study aimed to uncover the multifaced aspects of elephant memory, focusing on its cognitive, social, and spatial dimension. It looked at how memory affects elephants' social behaviour and their interactions with human communities. It also investigated how memory helps elephants survive and how it influences conservation efforts. The research combined villagers' observations and perspectives of elephant memory from Kampung Lukut, with ethogram- based behavioural data collected at Johor Elephant Sanctuary (JES). By combining these two methods, the study aimed to better understand how memory shapes elephants' actions and decisions. The goal was to show how memory plays a key role in their social structure and survival, and how this understanding can improve conservation practices.

2. Methodology

2.1 Study Areas

In this study, research was conducted at two primary sites, that are Kampung Lukut and Johor Elephant Sanctuary (JES) in Kota Tinggi, Johor. Kampung Lukut, located near forested areas where wild elephants live, is a key site for studying human-elephant interactions (Fig. 1). It highlights the role of migration routes and cultural stories in shaping local conservation efforts. On the other hand, the Johor Elephant Sanctuary, created to protect endangered Asian elephants, provides a controlled setting to study their behaviour and reactions to various stimuli [4] (Fig. 2). Together, these two locations offer a clear understanding of how elephants' memory influences their actions. This includes their ecological roles and social behaviour, both in natural environments and in controlled conditions.

Fig. 1 Map of Johor Elephant Sanctuary in Kota Tinggi, Johor, Malaysia

Fig. 2 Map of Kampung Lukut that near Johor Elephant Sanctuary

2.2 Method of Data Collection

2.2.1 Ethogram Observation

Behavioural of an elephant named Nina had been observed for two days in JES. On the first day, bee sounds were used as a stimulus to see her reactions. On the second day, a drone was added to observed her responses to both stimuli. Her behaviour was recorded in an ethogram and analysed to find patterns linked to her memory. The study revealed how Nina recognized threats, adapted to changes in her surroundings, and showed emotional reactions based on past experiences. These observations gave valuable insights into how memory influences her behaviour.

2.2.2 Interview

Interviews were conducted with 20 villagers living in Kampung Lukut, a community located near the Johor Elephant Sanctuary to achieve first objective (Fig. 3). Open-ended questions were used during interviews to gain a better understanding on villagers' perception of elephant's behaviour and memory. The questions addressed elephants' memories of migration routes, villagers' perceptions of elephant memories, and elephants' reactions to previous encounters. Villagers also shared myths and personal experiences, offering valuable information about how elephants navigate, communicate, and adapt using their memory. This qualitative approach provided a broad range of experiences that implied the integral role of elephants' memory in their interactions with humans and the environment.

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Fig. 3 Interview session with one of the villagers living in Kampung Lukut

2.2.3 Research Study

To achieve the third research objective, that is exploring the diverse aspects of elephant memory, a detailed review of previous studies was conducted. The analysis looked at how elephants use memory to navigate their environment, form social bonds, and face challenges. Elephants use spatial memory to remember routes taken and resources found over long periods of time. Such social memory helps maintain strong bonds among group members and is used to make decisions, often made by experienced matriarchs. Elephants also remember negative experiences, which affects their interactions toward humans and potential threats. Combining these findings with field observations and insights from the villagers showed how important memory is in shaping elephant behaviour. This knowledge can help inform better conservation strategies that focus on the role of memory in their lives.

3. Results and Discussion

3.1 Interview Transcript Coding

The interview with 20 villagers from Kampung Lukut provided valuable insights into elephants' memory and behaviours. After created transcripts and analysed the narratives, the findings were grouped into three main themes, each with subthemes that explain how elephants' memory influences their actions and interactions with the community in simple and clear terms, as listed in Table 1.

Table 1 Themes, subthemes, and the data sources of analysis

Theme	Subtheme	Data Source
Rituals and Beliefs Related to Elephants	Cultural Respect	Interview Document Analysis
	Supernatural Associations	
Elephant Behaviour and Social Structure	Memory and Recognition	Elephant Behaviour and Social Structure
	Group Dynamic	
Aggression and Human-Elephant Conflict	Triggers of Aggression	Interview Document Analysis
	Adolescent Male Behaviour	

In the first theme 'Ritual and Beliefs Related to Elephants', there are two subthemes that had been analysed through the interview transcripts, which are cultural respect and supernatural associations. Community members of Kampung Lukut viewed elephants as intelligent beings capable of forming emotional and social memories. One of the villagers highlighted the cultural practice of showing respect to elephants, stated that "We cannot be angry or scold the elephants, or else they will attack us". Such beliefs align with the scientific evidence of elephants' capacity to

associate past interactions with humans to shape their responses. For example, elephants are known to recall past interactions with humans and adapt their behaviour accordingly, showcasing their advanced cognitive abilities [1]. These memories are crucial for survival, helping elephants navigate complex social and environmental challenges. Elephants' ability to remember is strongly connected to their social structures. They rely on learned experiences to keep harmony within their herds [1][5]. Villagers observed this and emphasized the importance of cultural stories in understanding elephants' behaviours. These stories often link elephants' actions to deeper meanings, showing their intelligence and memory. By aligning traditional beliefs with ecological science, elephants can be seen not only as animals with remarkable memory, but also as a symbol of intelligence and adaptability in their ecosystems.

Elephants were also seen as carriers of spiritual messages. Villagers believed that certain behaviours displayed by elephants, such as returning to specific locations or acting unusually, had a symbolic meaning. For instance, Encik Yusri shared, "Each time the elephants entered village, they must be telling us some messages that we need to take alert." This belief connects the cultural understanding of elephants with their observed behaviours in nature, aligned with research suggesting that elephants' advanced memory that enable them to revisit meaningful places and adapt their behaviour based on past experiences [6].

In the second theme 'Elephant Behaviour and Social Structure', the two subthemes analysed are memory recognition and group dynamic'. As memory recognition of elephants are the most interesting part to be discussed, there is strong evidence by villagers, where they observed that elephants consistently followed familiar paths to access food and water resources, demonstrating the elephants' exceptional spatial memory. One of the villagers, Puan Sariah remarked' "They always walk the same pathway to get food", highlighting their reliance on long-term memory of navigation. This behaviour matches scientific findings that stated that elephants' ability to navigate to their well-developed hippocampus, and the greatest volume of cerebral cortex that available for cognitive processing of all land mammals [7]. Spatial memory not only facilitates access to resources, but also enhances survival in challenging environments. Elephants are also known to travel over large areas, using memory to find seasonal water resources and safe migrating routes [8]. The Kampung Lukut community has observed that elephants follow consistent paths. This shows how elephants use their memory in practical ways. It is likely that this ability developed over time because the mammals with better memory had a better chance of survival.

Elephants' social structures are closely linked to their memory, especially in maintaining group cohesion and following matriarchal leadership. Villagers in Kampung Lukut observed that elephant herds usually consist of five to six individuals. The matriarch leads the group who brings knowledge of the herd's social structure and ecological needs. Elephants rely not only on their memory for finding their way, but also for recognizing other members of their group and building strong connections. These bonds are crucial for cooperation, like protecting the young and protecting against threats. Social memory also plays an important role in helping the herd move together during migration or when facing danger.

While in the third theme 'Aggression and Human-Elephant Conflict', it explores how human activities affect elephants' behaviour, particularly aggression caused by negative experiences or habitat disruption. Elephants' memory plays a key role in shaping their responses to these stressors. The first subtheme 'Triggers of Aggression', examines how habitat destruction and human actions lead to defensive or aggressive behaviours. Villagers observed that elephants remember areas where they faced harm, such as the places where firecrackers were used to scare them away. These actions often led to angry and retaliatory attacks of elephants. The evidence shows how memory influences their reactions to threats and increases human-elephant conflict. Scientific research supports this evidence. They found that elephants have a strong long-term memory. This can allow them to recall both positive and negative experiences with humans [1]. Habitat destruction makes the issues worsens by forcing elephants into closer contact with humans, heightening the chance of conflict [6]. Elephants may also develop aggression as a defence mechanism to protect themselves and their herds from perceived danger, underscoring the need for strategies to reduce conflict and promote peaceful coexistence.

The second subtheme 'Adolescent Male Behaviour,' focuses on the aggression seen in young male elephants, often separated from their herds. Villagers noted that when these elephants get lost or separated, they feel scared and become aggressive. Research shows that adolescent males are more likely to be aggressive due to the absence of the social structure provided by their herds [9]. Their aggressive behaviour is also influenced by past experiences of stress or danger. In addition, testosterone levels in young males can make them more prone to aggression [10].

3.2 Ethogram Observation

The observations were conducted over a two-day period at the Johor Elephant Sanctuary (JES), focusing on an elephant named Nina, to examine her responses to bee sound playback at varying and explore the relationship between her behaviour and memory. On Day 1, the observation of Nina was conducted in a confinement area at the Johor Elephant Sanctuary (JES). Fig. 4(a) shows that Nina was chained and had no access to food during the sessions. Her behaviour for Day 1 was recorded in response to bee sound playback at low, medium, and high volumes, with the frequency range of 200 Hz to 400 Hz, during two sessions: morning from 9.45 a.m. to 10.45 a.m. and evening from 2.50 p.m. to 3.40 p.m. (see Table 2). Meanwhile on Day 2, as seen in Fig. 4(b), Nina's behaviour was observed under

different conditions at JES. In the morning session, from 9.35 a.m. to 10.20 a.m., she was chained to a tree for safety, and in the evening session from 2.50 p.m. to 3.40 p.m., she was allowed to roam and feed in a wild setting. Bee sound playback and the addition of drone activity were used to study her responses, and the observation was listed in Table 2.

(a) Photo of Nina observed in Day 1 (b) Photo of Nina observed in Day 2

Fig. 4 Photos of the observed elephant named Nina in JES

Table 2 Ethogram of Nina's behavioural for Day 1

Day	Time	Technique of Threaten	Level of Sound Volume (Frequency: 200 Hz – 400 Hz)	Elephant Behaviour
Day 1	Morning (9.45 a.m.-10.45a.m.)	Bee sound speaker	Low	Head and trunk lifting, move backward from sound source
			Medium	Ear flapping, tail upwards, trunk lifting, communicate with another elephant beside it.
			High	Head swinging and banging
				Communicate with another elephant beside it
	Evening (2.50p.m.-3.40p.m.)	Bee sound speaker	Low	Head lifting, static
				Ear flapping, Trunk lifting
			Medium	Ear flapping, communicate with another elephant beside it
				Head swinging, eating
			High	Static, eating

In the morning session, Nina's responses varied with sound volume. At low volumes, she lifted her head and trunk and moved backward, showing alertness and avoidance. Medium volumes caused more active behaviours, including ear flipping, tail lifting, and attempts to interact with another elephant, indicating heightened arousal. High volumes led to head swinging, banging, and increased social communication, showing agitation. In the evening session, Nina's responses were calmer. At low and medium volumes, she remained static, lifted her head, and flapped her ears. At high volumes, she began eating, which suggests she was habituating to the sounds and no loner perceiving them as a threat.

Nina's behaviour in Day 1 demonstrates the role of memory and learning in elephants. Her initial avoidance and agitation likely reflect recognition of bee sounds as a threat, either from past experiences or innate memory. Over time, she adapted to the stimulus, especially during the evening session, where her responses became less defensive. Her social interaction during moderate volumes highlights how elephant use memory and social bonds to respond to perceived threats collectively.

Table 3 Ethogram of Nina's behavioural for Day 2.

Day	Time	Technique of Threaten	Level of Sound Volume (Frequency: 200 Hz – 400 Hz)	Elephant Behaviour
Day 2	Morning (9.30 a.m.-10.30a.m.)	Bee sound speaker (with drone movement)	Low	Head shaking, move backward away from the sound source, trunk lifting, trumping
			Medium	Head shaking, ear flapping, move away from drone, communicate with another elephant beside it
			High	Hide from drone, bathing, move out to the open area
	Evening (2.50p.m.-3.40p.m.)	Bee sound speaker (with drone movement)	Low	Ear flapping, static, trumpeting
			Medium	Move away from drone, hide from drone
			High	Ear flipping, interact with another elephant.

In the morning of Day 2, low-volume bee sounds, combined with the drone, caused Nina to shake her head, move backward, and trumpet, indicating stress and alertness. Medium volumes led to ear flapping, head shaking, and retreating from the drone, along with attempts to communicate with another elephant. At high volumes, Nina avoided the stimuli by hiding, bathing, and moving to an open area, showing increased agitation. While in the evening session, Nina's responses were less intense. Low volumes resulted in static postures and trumpeting, while medium and high volumes caused her to hide and move away briefly, followed by short social interactions. Her prolonged trumpeting and hiding at higher volumes suggested she remained sensitive to the sounds, likely due to her survival memory. However, her eventual calmer behaviours, such as social interactions, hinted at habituation as she reassessed the perceived threat.

Nina's reactions on Day 2 showed her strong memory and adaptability. She appeared to associate the bee sounds and drone activity as combined threats, demonstrating her ability to integrate new stimuli. Over time, she showed signs of learning and habituation, adjusting her behaviour to better assess the actual risk. This highlights the role of memory in guiding elephants' adaptive responses in changing environments.

3.3 Analysis of Research Study

The analysis of previous studies highlights the significant role of memory in elephants' survival and social behaviour. One major finding involves the role of the hippocampus in spatial memory of elephants. McComb explain that elephants use their well-developed hippocampus to recall large home range, water sources, and migration route with remarkable accuracy, even after years [1]. Research further highlight that this spatial memory of elephants is critical during droughts or resources shortage, allowing them to locate essential resources [11] [12].

Another key finding connects memory to social organization. Elephants live in matriarchal groups, where older matriarchs use their memories to guide the herds, avoid threats, and make survival-critical decision [9]. These memories help ensure the herd's cohesion and survival. Observations from Kampung Lukut support this, with villagers noting that elephants remember human interactions and respond based on past experiences. Memory also influences elephants' behaviour during human-elephant conflicts. Fernando in 2005 found that elephants remember negative experiences, such as firecrackers or habitat destruction, associating them with specific locations or people. As a result, this often leads to defensive or aggressive behaviour of the elephants [14].

4. Conclusion

At the end of this study, it was found out that elephants have a remarkable ability to remember both the physical environment around them, as well as their social interaction, which supports the villagers' observations about their intelligence and emotional understanding. The research showed how important memory is for elephants' survival and social behaviour. The first objective of study, to analyse the adaptive significance of memory in elephant social dynamics and survival strategies through communities, was achieved by exploring villagers' stories about how elephants use their memory to deal with challenges, keep safe from threats, and respond to stress. The second objective, identify the social interactions that shows the effect of elephant memory within their communities, was met with an analysis of an ethogram, that gave evidence that memory assists elephants to recognize and respond to threats. Observations confirmed that elephants use memory to adapt to their environment, and thus ensured their survival by recognizing patterns, learning, and working together socially. The third objective, uncover multifaced aspects of elephant memory, including social, spatial, and cognitive dimensions, was addressed by reviewing existing

research, which showed the complexity of elephant memory in their social and emotional interactions. Overall, this study highlights how advanced elephant memory is and how it plays a key role in their social structure and survival. Understanding this better can lead to improvement of conservation efforts and better relationships between humans and elephants.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Koo Huang Qing Yuan;* ***data collection:*** *Koo Huang Qing Yuan, Lok Huey Kei, Phoo Qiao Lin, Nur A'alia Atierah Bakri, Huda Khalidah Khairunizan;* ***analysis and interpretation of results:*** *Koo Huang Qing Yuan, Nazirah Mohamad Abdullah;* ***draft manuscript preparation:*** *Koo Huang Qing Yuan, Nazirah Mohamad Abdullah. All authors reviewed the results and approved the final version of the manuscript.*

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