Nest architecture as overlooked material culture: the case for systematic study of construction behaviour across nest-building primates

Short title:

Nest architecture as overlooked material culture

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Abstract

Frans de Waal's work highlighted an uncomfortable question: not whether animals have complex cognitive lives, but why we are so reluctant to recognise them. Nest building in great apes is perhaps the most striking example of this problem. Every great ape builds a nest, every day, for the entirety of its adult life. The behaviour has been documented ecologically for decades. Yet the internal structure of a single nest has never been systematically examined. Here I argue that this oversight has allowed us to badly underestimate both the structural sophistication and the cognitive demands of one of the most widespread forms of material culture in the primate order. Evidence from the first systematic reverse engineering of orangutan nests reveals consistent architectural patterns conserved across two species. These patterns require complex goal-directed manipulations, apparently vary culturally, and are consistent with published descriptions of chimpanzee nest frames, pointing to a shared hominid blueprint predating the divergence of great ape lineages some 14 to 18 million years ago. The same logic that justified decades of detailed study of primate tool use demands that nest construction be examined with comparable rigour across nest-building primates. Nest architecture is a new empirical domain for understanding the evolution of construction behaviour, cultural transmission, and the cognitive foundations of material culture.

Keywords: nest, nest-building; material culture; orangutan; cognition; construction behaviour; technology; hominid evolution

Introduction

Frans de Waal spent a career pointing out that the gap was never in the evidence. It was in our willingness to accept what the evidence showed. He found that gap wherever he looked: in chimpanzee reconciliation, in bonobo empathy, in the fairness judgements of capuchins, in the cultural traditions of wild ape communities. Each time, the cognitive complexity had always been observable. It simply required someone to describe it without the precondition that it could not be there (e.g. de Waal, 1982, 2016, 2019). Material culture was central to his arguments. He said the boundary between human technology and the object manipulations of our nearest relatives is one of degree rather than kind, and examining what animals actually do with objects in the wild consistently reveals far more than laboratory experiments anticipate (de Waal, 2016; Whiten et al., 1999).

Great ape nest building is the obvious domain in which this argument has not yet been applied. All great ape species build nests for sleep and rest, a behaviour that was probably already established in a common ancestor some 14 to 18 million years ago (Duda & Zravy, 2013; Fruth & Hohmann, 1996; Sept, 1992). Nests are constructed daily, vary between populations in ways that meet the criteria for cultural variants (van Schaik et al., 2003; 2006; Permana et al., 2025), and take years of observational social learning and practice to master (Permana et al., 2024; 2025; Schuppli et al., 2016). They are, by any reasonable definition, material culture. Yet while the cognitive demands of tool use in great apes have been studied exhaustively (McGrew, 1992; Whiten et al., 1999; de Waal, 2016), the internal structure of a nest has never once been systematically described until now. We have known what nests are for. We have not asked what building one actually requires.

This matters. If nest construction follows structural rules that require goal-directed planning, knowledge of material properties and the transmission of technique across generations, then nest building belongs in the same cognitive category as the tool-use behaviours that have defined our understanding of primate intelligence. Finding out whether it does or does not requires the same careful, direct observation that de Waal applied to everything else. For nests, that means taking them apart, layer by layer in a standardised and controlled way and recording what is found.

Here I present my findings from the first systematic reverse engineering of orangutan nests across two wild populations and argue that the results should fundamentally change how the field approaches nest construction across primates.

What nest deconstruction reveals

Between 2007 and 2010 my team and I systematically deconstructed 184 orangutan nests across two wild populations: *Pongo abelii* at Suaq Balimbing in the Gunung Leuser National Park, Sumatra, and *Pongo pygmaeus wurmbii* at Sabangau National Park, Central Kalimantan. Nests were directly accessed and deconstructed from the last-laid branch to the first. We included comfort elements, documented securing elements and the supporting frame. Field drawings, measurements, and behavioural notes were made at each step wherever the nest allowed it (Permana, 2022; Permana et al., in preparation).

Nests are not random. Reverse engineering revealed two distinct frame architectures: a criss-cross lattice of multiple branches, and an X-frame made from a single branch bent back over itself or another. Combined with peripheral rim branches and in some cases locking branches that hold the entire structure together, these elements resulted in seven architectural patterns at Suaq and one pattern at Sabangau. The dominant pattern at both sites was the lattice-rim, accounting for 40% of Suaq nests and 100% of Sabangau nests. Architectural pattern was significantly predicted by the complexity of the manipulations used in construction and complex combinatory manipulations (weaving and tucking), were associated with lattice frames rather than X-frames. Simple single-action manipulations predicted simpler X-patterns among the immature builders. Critically, architectural pattern is independent of nest tree species, wood density, tree branch architecture, nest position, and weather, suggesting that the pattern produced depends on the builder, not the tree.

The age and sex of the builder tell a further part of the story. Immatures built structurally simpler nests with fewer elements. Locks and weaving, the most cognitively demanding elements, were almost entirely absent from immature constructions despite being used frequently by the immatures' own mothers. This reflects not lack of opportunity for observation but lack of skill. The gap between watching a technique and being able to execute it is wide in nest building, as it is in tool use in orangutans (Meulman & van Schaik, 2013). It is only bridged by years of practice. Nest architecture follows the same developmental logic as other complex technical skills: sustained observation, extended practice, and late mastery of the most demanding components (Permana et al., 2024; 2025). That the most demanding architectural elements are also the last to appear may partly explain why full nest-building competence takes so long to acquire.

The only pattern at Sabangau and the dominant pattern at Suaq was the lattice-rim pattern. Goodall (1962, p. 460) described chimpanzee nest frames with roughly interwoven cross-pieces and rims have been described by Horn (1980), McGrew (1992), and van Lawick-Goodall (1968), suggesting that lattice frames and rims are a chimpanzee norm. The geographic, genetic and ecological distance between Asian and African great apes and their habitats makes it unlikely that an identical structural solution appeared independently on two continents among at least three species. I would argue that a more likely interpretation is that the lattice-rim is an ancestral nest architecture of the hominid clade, conserved since before the divergence of the great ape lineages. If that is correct, it would represent the earliest known instance of conserved material culture in our lineage, predating the stone tool record by more than ten million years.

Nest building as material culture

De Waal's most consistent argument was that resistance to recognising complex cognition in other animals is a failure of imagination rather than a shortage of evidence (de Waal, 2016). Tool use in great apes is the clearest illustration. Termite fishing, nut cracking, and spear use were each documented, studied, and eventually understood as evidence of cognitive capacities that were there all along. Nest building has not followed this path, despite being more phylogenetically widespread than any tool-use behaviour documented in great apes.

The reason is largely definitional. Beck's (1980) canonical definition of tool use requires the external deployment of an unattached object to alter another object or organism. Nests, as stationary constructions, do not fit. But this is a taxonomic distinction, not a cognitive one. Building a lattice-rim nest requires selecting branches with appropriate mechanical properties, following a multi-step spatial template, applying complex combinatory manipulations that require an operational-level understanding of what is being done and why (Hayashi et al., 2006; Parker & Gibson, 1977), choosing an architectural pattern based on the expected function and duration of the nest, and transmitting that architectural knowledge socially across generations (Permana et al., 2024; 2025). Each of these has been used as evidence for advanced cognition in the tool-use literature. The fact that the product does not move does not diminish what producing it requires.

Hansell & Ruxton (2008) argued that construction behaviour deserves to be treated as cognitive evidence independently of whether the product meets Beck's tool definition. My data make that argument concrete for orangutans. Nests meet the criteria for complex material culture described by Whiten (2017): skilled production, population-level variation unexplained by ecology, social transmission, and the capacity for innovation. The patterns found at Suaq but absent at Sabangau, X-frames, locks, and frameless nests, qualify as provisional innovations under the criteria of van Schaik et al. (2006). Pillow architecture shows the opposite pattern: five variants at Sabangau versus one at Suaq (Permana, 2022; Permana et al, in preparation). Innovation and cultural variation characterise nest architecture in exactly the way they characterise other domains of orangutan material culture (van Schaik et al., 2003). The complexity was always there. It simply required us to look carefully inside the nests.

A call for systematic study across nest-building primates

De Waal's comparative method was always the foundation. Understanding what one species does becomes meaningful only when placed in phylogenetic context: what is shared, what is derived, and what the pattern implies about evolutionary history (de Waal, 1982, 2016). The same logic applies here. My findings establish that consistent architectural design exists in at least one great ape lineage, and the parallel with published descriptions of African ape nests from over half a century ago suggests it may be more widespread. But systematic deconstruction has yet to be carried out in any other population of any species of nest-building primate.

The method introduced in Permana, 2022, layer-by-layer deconstruction with structural recording at each step, should be applied first to chimpanzee, bonobo, and gorilla populations. If the lattice-rim pattern is found across the clade, the conserved ancestor hypothesis is directly supported. If patterns differ systematically between lineages, the variation is itself informative about the evolution of cognition. Beyond the great apes, the question should extend to primates that construct sleeping platforms under specific conditions. If architectural design is present in more distantly related taxa, cognition which allowed hominids to develop technology has deeper evolutionary roots than anyone has supposed. If it is absent, that absence defines what the cognitive prerequisites for design behaviour actually are.

Nest architecture is not a marginal area of research. Van Casteren et al. (2012) showed that the physical properties of orangutan nests are biomechanically substantial. If architectural complexity affects the mechanical and thermal properties of sleeping platforms, variation in architecture between species and populations may have real fitness consequences via sleep quality. This connects nest architecture to life history, brain size, and the extended developmental periods that distinguish the great apes. Improved sleep quality from structurally sound nests may have directly supported the cognitive development that produced more sophisticated nest building in turn (Diekelmann, 2014; Samson & Nunn, 2015). The causation runs in both directions, and the starting point for understanding it is a clear picture of what is inside a nest.

Conclusion: what de Waal would have asked

Frans de Waal identified, again and again, the behaviours that forced a reassessment of what animals are capable of once someone looked at them properly. The cognitive complexity he described in reconciliation, empathy, culture, and fairness was observable all along. It required someone willing to report what they actually saw.

Great ape nests are built every night by every adult in the clade. They are the most widespread, persistent, and most frequently produced artefacts in non-human primate material culture. Their internal organisation has been treated as unknowable or unremarkable without ever being examined. My findings show that it is not unknowable and is highly remarkable.

The questions that follow are precisely the ones de Waal spent his career asking. How widespread is this capacity for design? What does nest design across the primate order tell us about the evolutionary history of technical intelligence? What does it imply about the cognitive lives of animals we have studied for decades without once looking inside their nests? I hope this perspective encourages the field to look.

Acknowledgements

I thank Junaidi Jaka Permana, Izumi, Fikar and Mudin for climbing support, lengthy discussions and their artistry in the field. I am grateful to the authorities for permission to work in Indonesia, including the Indonesian State Ministry for Research and Technology. the General Directorate of Natural Resources and Ecosystem Conservation and the Ministry of Forestry, the Ministry of Home Affairs and the Gunung Leuser National Park. In Sumatra, thanks to Yayasan Ekosistem Lestari, Sumatran Orangutan Conservation Programme (YEL-SOCP) and in Kalimantan the Borneo Nature Foundation. I am grateful to Universitas Nasional for their backing of the research and the local teams at both field sites for their collaboration and valuable support. Funding for nest deconstruction work was provided by the PanEco Foundation, the A.H. Schultz Fund (University of Zurich), the Orangutan Foundation UK, and the American Society of Primatologists. This paper is dedicated to the memory of Frans de Waal, who taught us to look carefully.

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