Tools and food on heat lamps: pyrocognitive sparks in New Caledonian crows?

Ivo Jacobs\textsuperscript{a,\textdaggerdbl,\textasteriskcentered}, Auguste M.P. von Bayern\textsuperscript{b,c} and Mathias Osvath\textsuperscript{a}

\textsuperscript{a} Department of Cognitive Science, Lund University, Helgonavägen 3, 22100 Lund, Sweden
\textsuperscript{b} Max-Planck-Institute for Ornithology, Eberhard-Gwinner-Strasse, 82319 Seewiesen, Germany
\textsuperscript{c} Max-Planck Comparative Cognition Research Station, Loro Parque Fundación, 38400 Puerto de la Cruz, Tenerife, Spain

\textsuperscript{a} Corresponding author's e-mail address: ivo.jacobs@lucs.lu.se
\textsuperscript{\textdaggerdbl} ORCID: https://orcid.org/0000-0002-2182-7686

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Abstract
Fire has substantially altered the course of human evolution. Cooking kindled brain expansion through improved energy and time budgets. However, little is known about the origins of fire use and its cognitive underpinnings (pyrocognition). Debates on how hominins innovated cooking focus on archaeological findings, but should also be informed by the response of animals towards heat sources. Here, we report six observations on two captive New Caledonian crows (\textit{Corvus moneduloides}) contacting heat lamps with tools or placing raw food on them. The tools became singed or melted and the food had browned (and was removed). These results suggest that New Caledonian crows can use tools to investigate hot objects, which extends earlier findings that they use tools to examine potential hazards (pericular tool use), and place food on a heat source as play or exploration. Further research on animals will provide novel insights into the pyrocognitive origins of early humans.

Keywords
tool use, fire, cooking, pyrocognition, cognitive evolution.
1. Introduction

Fire has played a pivotal role in human evolution by providing light and heat, and is universal to all human cultures (Fessler, 2006; Wrangham, 2017; McCauley et al., 2020). Cooking — processing food with heat — offers many benefits by decreasing chewing time and pathogen load and improving digestive speed and bioavailability of nutrients. A growing reliance on cooked foods has significantly altered hominin morphology, such as reduced molars and enlarged brains (Fonseca-Azevedo & Herculano-Houzel, 2012; Wrangham, 2017). Despite the archaeological evidence of hearths from numerous locations and periods, little is known about how earlier hominins interacted with wildfire and innovated cooking (Twomey, 2013; Wrangham, 2017; McCauley et al., 2020; Sistiaga et al., 2020). The behaviour of animals towards fire and other heat sources can inform this question (Jacobs, 2021).

*Pyrocognition* is the suite of cognitive abilities required for various heat- and fire-related behaviours, ranging from associating and interacting with wildfire to cooking and controlling fire. Although pyrocognition is hardly investigated in any species — including humans — and its conceptual framework is in development, recognizing fire as potentially dangerous constitutes a core component. People avoid getting burnt by using cooking utensils to stir hot food and control fire with tools such as sticks or pokers. This exemplifies what we call *periculul tool use*: tool use to avoid touching or getting close to something perceived to be risky or dangerous (from the Latin ‘periculum’: danger, hazard or risk).

Wildfires were likely a common sight for African hominins, as they still are for savannah chimpanzees (*Pan troglodytes*). At least 75% of their range is burnt every year, and they safely travel and forage near fire (Pruetz & LaDuke, 2010; Pruetz & Herzog, 2017). Zoo-housed chimpanzees remove burning cloth from their enclosures, carefully dispose of lit cigarettes in wet patches, use fruit peels to handle hot ashes, and use sticks to inspect fire or retrieve food from it (Köhler, 1927; Brink, 1957; Chamove, 1996). They generally favour cooked over raw food, which they can inhibit eating to exchange it later for its cooked equivalent (Warneken & Rosati, 2015; Beran et al., 2016).

Great apes are the optimal living models of extinct hominins due to their behavioural, ecological, social, developmental, morphological and phylogenetic similarities (Duda & Zrzavý, 2013; Beran et al., 2016). The cognitive
abilities of apes are mirrored by those of corvids (i.e., birds of the crow family) and parrots, despite their distant relatedness and different anatomy — notably their brains (Olkowicz et al., 2016; Jacobs et al., 2019; Lambert et al., 2019; Ksepka et al., 2020). Australian raptors have been observed to pick up burning sticks and drop them elsewhere, which may cause more prey to flee that can be hunted (Bonta et al., 2017). Broadening the phylogenetic perspective can therefore reveal a more general pattern of animal pyrocognition, and how it may have evolved independently in distantly related taxa (Osvath et al., 2014; Jacobs et al., 2019).

Whereas many animals avoid fire, others associate and interact with it (Jacobs, 2021). Some corvids are attracted to wildfire and ‘bathe’ in smoke and heat (Ridley, 1948; McMeeking, 1949; Whitaker, 1957; Ivor, 1958; Burton, 1959; Komarek, 1969). They sometimes press smouldering matches or sticks against their plumage (Miller, 1952; Ivor, 1958; Burton, 1959; Hori, 1961), learn to light matches by striking the heads with their beaks (Burton, 1959), and cause fires by caching burning candles in leaf litter (Higuchi, 2003).

New Caledonian crows (‘NC crows’, Corvus moneduloides) use and manufacture multiple kinds of tools in the wild to extract wood-boring insects (Rutz & St Clair, 2012), and they are prolific tool users in captivity (Shumaker et al., 2011; McGrew, 2013; Jacobs & Osvath, 2016). Like chimpanzees (Povinelli et al., 2010), they use sticks to retrieve directly accessible food when an alarming object is nearby, or to investigate such objects (Wimpenny et al., 2011; Taylor et al., 2012). This particular tool use and the response of other corvids to fire make NC crows suitable candidates for pyrocognitive potentials.

2. Methods

We made independent observations of two adult New Caledonian crows (4–5 years old) interacting with heat lamps: Liane (female) and Mango (male). They were wild-caught at approximately 5 weeks (Liane) and 6 months (Mango) of age. They were housed in different aviaries at the Avian Cognition Research Station associated with the Max Planck Institute for Ornithology in Seewiesen, Germany. They were kept in pairs or family groups in outdoor aviaries (15–32 m²) with constant access to heated indoor compartments (7 m²) where food and water were available ad libitum. The
crows’ daily diet consisted of a mixture of raw minced meat, dried insects, oats, curd, vitamins and oils, supplemented by eggs, fresh fruit, nuts and Versele Laga® Beo pearls. Each compartment was visually isolated from other compartments and had a grid-protected ceramic heating lamp bulb in an aluminium casing mounted above a perch. Despite the grid, the crows inadvertently managed to reach the bulb with elongated objects and possibly even their beak to place objects against them or onto the casing. The heat lamps were Artas or Kerbl aluminium casing heat radiator holders for animals (230 V, max 250 W, ca. 25 cm diameter) with an Elstein ceramic bulb (150 W, 22/230 V, 9 cm diameter) and a protective cage/basket guard (ca. 13 cm distance to bulb). The bulbs were always switched on and reached a surface temperature of 410°C (wavelength of 3–10 μm) without emitting visible light.

‘Experimental’ observations were made during an unrelated study (I.J., A.v.B & M.O., unpublished data) that involved tool selection among familiar objects from earlier studies (Jacobs et al., 2014, 2016). Each experimental trial consisted of a tool-selection phase (12 min), a 50-min break outside without access to the indoor compartment, and a tool-use phase with an apparatus (14 min). Although these sessions were video-recorded, the heat lamp was out of frame in all but one observation. Non-experimental observations refer to different contexts, and were either directly observed or inferred by the experimenter (I.J.). The observations are described chronologically and numbered per crow (‘L’ for Liane and ‘M’ for Mango), followed by descriptions of how the materials reacted to contact with the hot bulb in separate interventions. No follow-up studies were possible since the birds became unavailable.

3. Results

L1: 3 March 2014, experimental, inferred (see Figure 1a). In the first phase, Liane selected a wooden stick (length 12 cm, diameter 0.5 cm) and flew out of camera view. During the final 3 min, she appears to have touched the stick against the casing and bulb of the heat lamp because intermittent sounds of wood against metal and ceramic can be heard in the audio clip that can be accessed at 10.6084/m9.figshare.16896415. She dropped the stick when the experimenter entered, and was ushered outside for the break without access to the tool. In the second phase, she retrieved the stick from the floor and
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deposited it into the apparatus, where the experimenter found it with a singed end.

L2: 3 March 2014, non-experimental, observed (see Figure 1b). The experimenter observed Liane holding a plastic drinking straw (5 or 8 cm long), which was used in prior experiments (von Bayern et al., 2018), and pressing it against the heat lamp. She held the straw in centred grip, i.e. straight forward with the proximal end fully in the bill, which was her preferred technique (Martinho et al., 2014). The duration was not recorded but she quickly dropped it. The straw had a melted tip and was removed.

L3: 5 March 2014, non-experimental, inferred (see Figure 1c). The experimenter discovered three melted drinking straws on the floor. They were of the same type as the straw from L2. Two of them had melted on both ends. The tools were found on this day, but not seen on the experimental videos, and may have been melted on earlier days. It is therefore possible they were melted by Liane’s mate, but because the prior observations from this aviary can certainly be attributed to her, our conservative assumption is that it was her in this case too.

L4: March 2014, non-experimental, inferred. The experimenter noticed a burnt smell coming from Liane’s indoor compartment. After entering, he saw a clump of the meat mixture on the casing of the heat lamp, and Liane perching near it. The food clump had browned on the bottom and was promptly removed by the experimenter. There was no picture taken and no exact date recorded. Although not documented, the experimenter recalls finding the meat mixture on top of the heat lamp of this aviary on further occasions, when it may have been Liane or her mate placing it there.

M1: 8 March 2014, experimental, filmed (see 10.6084/m9.figshare.16896415). Mango took the wooden stick, which was the same kind as in L1, and flew to the perch next to the heat lamp. After 33 s, he erratically touched the tool against the casing and ceramic bulb for 4 s before dropping it. He held the tool in centred grip. In contrast to L1, the tool was not visibly singed.

M2: 16 March 2014, non-experimental, inferred (see Figure 1d). The experimenter had left Mango’s compartment but returned after less than 2 min because he detected a strong burnt smell. Mango held a feather (length 25.8 cm) of an Indian peafowl (Pavo cristatus), which were kept near the crow aviaries, such that the thicker proximal end (diameter 0.3 cm) touched the heat lamp. He immediately dropped it. The feather shaft was singed and
Figure 1. Objects singed or melted by two New Caledonian crows. (a) L1, wooden experimental stick. The same object type was used in M1 (see the video clip that can be accessed at 10.6084/m9.figshare.16896415). (b) L2, plastic drinking straw. (c) L3, three plastic straws, of which two melted on both ends. (d) M2, peafowl feather (measuring tape in cm, only to scale in this panel) with inset of singed proximal end and chipped shaft where the crow possibly held it during use (marked by arrow).

emitted an unpleasant smell. It had already largely been stripped of its barbs, presumably by one of the crows. Although Mango’s gripping technique was not recorded, he likely held it diagonally due to the length and thin distal end of the feather, the angle of the singed tip (see Figure 1d) and his preference for the diagonal grip (Martinho et al., 2014).

Another experimenter independently witnessed a crow (unknown identity) holding a plastic drinking straw against a heat lamp (L. O’Neill, pers. commun.). In addition, we examined how the materials reacted to being pressed against a hot bulb. Wooden sticks (L1 and M1) started to singe after 10–15 s, and produced smoke after circa 50 s without igniting. Plastic straws (L2 and L3) melted after 2–3 s, and started to smoke after 5 s. The minced meat mixture (L4) started to blacken, smoke and sizzle after 3 s on contact, and other layers slowly browned. The shaft of peafowl feathers (M2) singed and browned after circa 6 s, produced smoke after 9 s and left distinctive dark marks on the bulb. Such spots were found on the bulb in Mango’s aviary (see Figure 2), but not Liane’s. These results establish plausible timeframes and corroborate the reported observations.

4. Discussion

One NC crow singed a wooden stick, melted four plastic straws — two of which on both sides — and placed food on the heat lamp. The other crow singed a wooden stick and peafowl feather. They could not have learned
Figure 2. Marks on the bulb in Mango’s aviary — likely caused by prolonged contact with feather shafts.

This behaviour socially because their compartments were visually isolated. They appear to have innovated this behaviour individually, but it is unknown whether pericular tool use towards other targets may be in the behavioural repertoire of wild NC crows. These observations were unplanned and made during a short time span after which these birds became unavailable to us. Otherwise, a greater quality and quantity of observations could be realised by filming these captive NC crows interacting with ceramic heat lamps under controlled conditions. Nevertheless, we consider our anecdotes to be data in Bates & Byrne’s (2007) criteria on experienced observers, original records, and multiple independent observations: (1) the observer had over five full months of experience working with NC crows; (2) unless stated otherwise, the observations are described as they were originally recorded and include pictures and videos; and (3) multiple records were made of the same phenomenon and the photographic evidence can be assessed independently.

The crows’ use of tools to touch heat lamps fits earlier findings of captive individuals using pericular tools towards potentially dangerous objects such as rubber snakes (Wimpenny et al., 2011; Taylor et al., 2012). However, it is currently unclear whether they regard heat lamps as risky. Thermoreception was likely the primary sense used, since the other senses appear less suitable to discern the activity level of a heat lamp that did not emit visible
light. The stimulating effect of heat may explain why some corvids interact safely with fire, rest in hot smoke and steam, and press smouldering objects against their plumage (similar to anting behaviour; Ridley, 1948; McMeeking, 1949; Miller, 1952; Whitaker, 1957; Ivor, 1958; Burton, 1959; Hori, 1961; Higuchi, 2003). Novelty does not explain our observations because the crows were highly familiar with the heat lamps and objects. NC crows have a strong proclivity to cache objects and use tools, even in safe contexts that involve familiar inedible objects that are directly reachable in their personal space (Kenward et al., 2011; Jacobs et al., 2014, 2016; Auersperg et al., 2015). Thus, future research should investigate whether they consider heat lamps (and other heat sources) as simply another target of casual tool use, as potentially dangerous objects that demand tool use from a safe distance, or as means to create effects or modify objects.

Cooking in its widest sense is defined as processing food with heat (Wrangham, 2017; Sistiaga et al., 2020). We do not claim that Liane was deliberately cooking when she placed raw food on the heat lamp. Playful object combination or exploration are more likely explanations (Kenward et al., 2011; Jacobs et al., 2014; Auersperg et al., 2015), with both the object (raw food) and target (hot surface) not necessarily having any particular relevance. She contacted the heat lamp with objects on earlier occasions, and in this observation she may have simply tried something else or the preferred tools may not have been available. Caching is an unlikely explanation for this behaviour because NC crows favour sites that are small and hidden — such as in crevices or under leaves — over large and open — such as on the flat cover of a heat lamp (Kenward et al., 2011; Jacobs et al., 2014; Auersperg et al., 2015). Crucially, deliberate cooking should only be considered as such if it improves the food, that is, if the cooked version is preferred over the raw. Great apes prefer cooked food, likely because it is softer and sweeter (Wobber et al., 2008; Warneken & Rosati, 2015). Future studies should look for similar preferences in NC crows and other animals.

These observations do not provide conclusive evidence that NC crows recognize heat lamps as potentially dangerous objects that require tool use for safe exploration, or that they place raw food on heat lamps for deliberate cooking. Although the crows’ motivations are unclear, their resulting behaviours are nonetheless informative for designs of controlled studies. These individuals were particularly manipulative and innovative in earlier studies (e.g., Jacobs et al., 2014, 2016; von Bayern et al., 2018). Their
exploratory tendency may explain these object combinations that resulted in unusual effects — singeing, melting, browning, marking, sizzling, and smoking. Playing with fire is an important step in the development of pyrocognition in children (Fessler, 2006; Murray et al., 2015), and likely its innovation in extinct hominins, similar to other forms of play (Riede et al., 2018). Much like chimpanzees (Köhler, 1927; Brink, 1957; Chamove, 1996; Pruetz & LaDuke, 2010; Pruetz & Herzog, 2017), these hominins may have approached and interacted with fire — foraged safely near it and used tools to explore it — which sparked their understanding of this unique and dangerous phenomenon. It is difficult to conceive how they may have started to deliberately cook without first aimlessly exploring and playing with fire. This motivation may similarly be found in distantly related NC crows interacting with heat lamps. Even if just a playful expression, they produced exceptional interaction effects such as singeing by repeatedly establishing contact between objects and a heat source, which we hypothesize to have been a critical precursor to kindling complex pyrocognition and eventual cooking in our own lineage.

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