Review & Hypothesis

Darwin's road not taken: white sclera, shared intentionality, niche construction, predator fear, teams and Homo origins

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Statement of Relevance

The prevailing view is that genetic changes initiated the emergence of the human genus *Homo*. However, research on predator fear in songbirds and capuchin monkeys, along with its negative effects on social learning and cultural transmission, points to a non-genetic alternative. In this account, *Homo* arose when a group of *Australopithecus* found a way to gain predator shunning, not attack, freeing them from constant predation fear. Ending predator fear unlocked previously "wheel-clamped" cognitive and cultural potentials, triggering a phenotypic change dividing humans from other hominids.

Critically, a plausible mechanism must have enabled *Homo* to achieve predator shunning to end its predation. A comprehensive review provides a compelling argument that such a mechanism did indeed exist and that its past occurrence can be empirically established.

The proposed mechanism centres on two often-overlooked human traits: the conspicuous direction of our line-of-sight due to white sclera and our unique ability for split-second team coordination. The proposal posits that *Homo* emerged when white-sclera-eyed *Australopithecus* used their conspicuous line-of-sight to split-second coordinate as teams to get predators to shun them. This perspective challenges dominant genetic assumptions and identifies unexplored avenues to research human origins.

Abstract

Palaeoanthropologists have yet to pinpoint how *Homo* evolved from *Australopithecus*. I propose niche construction ending predator ambush and stalking attacks, white sclera, and ultrafast team cognition were key.

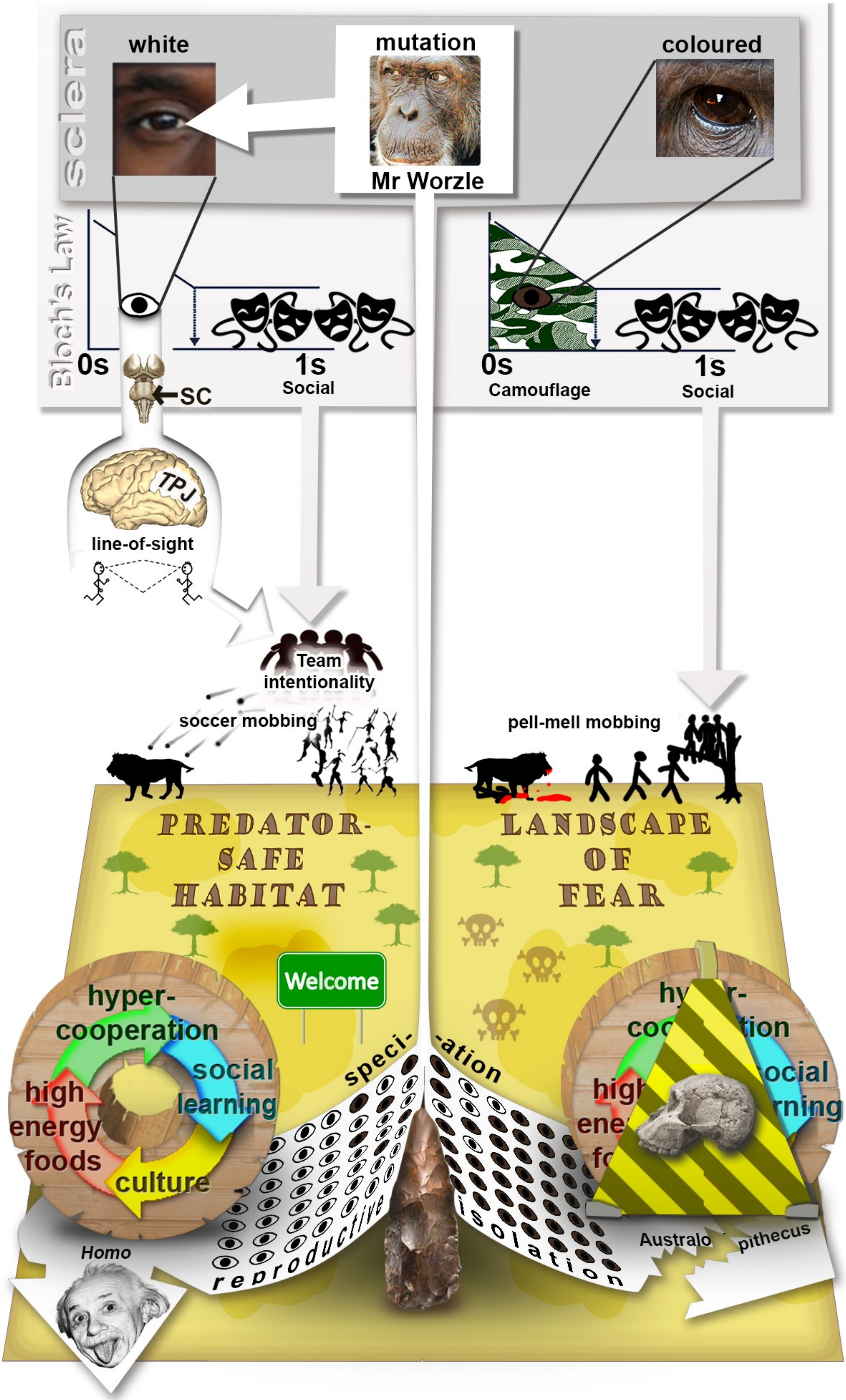
Human white sclera allows the quick, distant detection of line-of-sight. This is unique. In other primates, predators eliminate conspicuous-eyed individuals. Consequently, nonhuman primates have coloured sclera, hiding gaze direction broadcasting. Recognizing line-of-sight's split-second changes from a distance enables the ultrafast detection of attention shifts that support intercoupling cognitions (cognitive alignment, shared intentionality, and split-second coordination). Under certain conditions, such split-second coordinated teams can niche-construct predator-shunning safe habitats. Once shunning replaces hunting, it stops white sclera targeting, allowing it to persist.

Constructing predator-safe habitats ended the "landscape of fear" that limited *Australopithecus* foraging, health, and cognitive/cultural development. Once shunned and freed from fear, these safe habitats allowed previously "wheel-clamped" cognitive potentials, including social learning, to flourish, revolutionizing hominin capacity for cultural evolution and cumulative culture. Thus, predator-safe niche construction transfigured *Australopithecus*'s phenotype into *Homo*. White-eyed australopiths, I argue, were the first humans.

Highlights

- **Processes under 250 ms were critical to the origins of humans.**
- **The cooperative eye hypothesis gets quantitative support from psychophysics.**
- **Primate brains extract attention from others' gaze, reactions, and facial expressions.**
- **White sclera broadcasts coordinating attention through visible line-of-sight.**
- **Nonhuman primates use the initial 250 ms of vigilance to detect/ respond to predators.**
- **Humans use the initial 250 ms of vigilance to coordinate turn-taking and teams.**
- **Split-second team coordination lets humans change predator hunting to shunning.**
- ***Homo* genesis was kickstarted by predator-safe habitat niche construction.**
- **Without dark-toned skin aiding line-of-sight visibility, humans might not have arisen.**

Graphic abstract



1. **REVISITING HUMAN ORIGINS**—Presents core concepts on human uniqueness and origins: white sclera, team coordination, and shunning by predators.
2. **FIVE ACTS**—Uses a five-act format to explain how *Homo*’s conspicuous white sclera enabled split-second teamwork that created predator shunning.
3. **THREE RESEARCH OPENINGS**—Proposes new human-origin research avenues: psychophysics of line-of-sight, subsecond reactivity neuroscience, and turn-taking attention intercoupling.
4. **DARWIN’S ROAD NOT TAKEN**—Examines how predator fear “wheel-clamped” australopith cognition/ culture and why its ending initiated *Homo*.
5. **HUMANS: EASILY KILLED BUT SPURNED AS FOOD**—Highlights the enigma between *Homo*’s vulnerability to predator attacks and its shunning as prey.
6. **AUSTRALOPITH OLD WINE, HOMO NEW BOTTLE**—Split-second team coordination upgraded earlier australopith abilities enabling accurate throwing, chorusing, drumming and thorn weapons.
7. **THE SOCCER HYPOTHESIS**—Links football to *Homo’*s split-second teamwork, running endurance and nonviolent coordination contests against opponents.
8. **HUMAN SIDE OF STORY**—Details how *Homo*’s “don’t kill, win respect” team intimidating did what nonhuman “exterminate, ‘bloody nose’” mobbing could not.
9. **PREDATOR SIDE OF STORY**—Explains the neurological/ informational factors by which *Homo* intimation caused predators to shun them.

1. REVISITING HUMAN ORIGINS

Three quotes introduce the argument—geniuses seeing what others cannot see, predators shunning asleep humans as “not considered food”, and Mr. Worzel, a white sclera chimp and his conspicuous darting gaze. The proposal focuses on overlooked split-second team coordination and the conspicuous line-of-sight “broadcasting” of attention unique to Homo. *Key effects involve predator vulnerability and shared attention neurocognition derived from white sclera. It lists central statements and effects, with a graphic on predator mobbing coordination.*

Six key Australopithecus *traits are outlined: (1) coloured sclera like other primates; (2) lacked ultrafast team coordination; (3) chaotically and individually mobbed predators, unlike human split-second coordinated teams; (4) lived in constant fear of unpredictable attacks; (5) took better-safe-than-sorry precautions that wheel-clamped its cognitive and cultural potential; (6) maintained constant vigilance to split-second detect and react to predator attacks. Additional sections examine predator strike speed, teams, white sclera uniqueness and anatomy.*

Three foundational quotes:

> ***Schopenhauer’s Genius-As-Novel-Seeing Aphorism***
> Talent hits a target no one else can hit; Genius hits a target no one else can see. [1]
>
> ***Louis Leakey’s Homo’s Predation Anomaly***
> I myself have slept on the Serengeti plains with one African when we could not get back to camp because of a car breakdown. Five lions came and sniffed at our heads and around our faces. We were both awake and kept very quiet, but they did not attempt to kill and eat us. … we were not considered food to eat. [2]
>
> ***Goodall’s White Sclera Observation***
> Mr. Worzle had white sclerotics around the iris of his eyes, as do humans. It always seemed that he was unusually vigilant, for his gaze darted back and forth from side to side. In fact, such scanning is quite normal (unless the individual is very relaxed or concentrating on some task), but the white sclerotics drew attention to the movement. (Note the potential signaling value of the whites of the eyes in our own species, particularly in a person in a dark place or a dark-skinned individual.) [3]

Mr Worzle (*Pan troglodytes*) and Louis Leakey (*Homo sapiens sapiens*) were both hominids. Yet, their experiences with predators differed greatly.

The chimpanzee’s eyes darted side to side, alert for a predator that might leap out at 17 meters per second [4]. Although predation risk is low at Gombe [3], in other places like the Taï forest: “on average an individual will be attacked by a leopard once in 3 years and 4 months and will be killed within 18 years” [5]. In contrast, Louis Leakey (who had arranged for Jane Goodall to study chimpanzees at Gombe and who repaid the favour by naming Mr Worzle’s elder brother “Leakey”) could have five lions sniff around his face and “not considered food to eat”.

Louis Leakey’s *Homo’s Predation Anomaly* link to Jane Goodall’s *White Sclera Observation* is explained by Schopenhauer’s *Genius-As-Novel-Seeing Aphorism.*

Unlike other primates weighing over 0.5 kg (except for individuals like Mr. Worzle), humans have visible white sclera on either side of their irises (see **Box: Are white eyes unique to humans?**). These conspicuous eyes allow humans to broadcast and detect quick 200-250 ms changes in each other's line-of-sight at 10 metres or more. This ability to see attention in eyes enables *Homo* to "hit together" in split-second coordinated teams by getting the shunning that stops predators from hunting them as food. The human genus *Homo*, as a result, has a biological genius—the ultrafast seeing of each other's attention—and used this "genius" to radically rewrite the primate rulebook on how to coexist, adapt and prosper.

Box: Are white eyes unique to humans?

A study of 230 Ngogo chimpanzees in Uganda from 2017-2020 revealed more common white sclera than previously reported [6]. The data show white sclera primarily in infants (under 1.5 years, 17 of 29, 58.6%) but also some adults over 15 years (11 of 117, 9.4%). This adult prevalence contradicts earlier research, such as Goodall's documentation of only one or two partially white sclera individuals among approximately 100 adult chimpanzees at Gombe [3]. Christophe and Hedwige Boesch reported just five with white sclera among 123 individuals in the Taï Forest. However, this was attributed to conjunctivitis caused by caterpillar secretions that accidentally entered their eyes. No instances of white sclera were reported independent of this condition [6]. Neither Goodall nor other early ethologists studying chimpanzees reported widespread white sclera occurrences.

It is surprising that earlier studies did not note the high white sclera prevalence found at Ngogo, as it makes the chimpanzees appear more human-like, thus worthy of special reporting. However, the 2017-2020 Ngogo survey [7] was in an area where "Leopards probably preyed on chimpanzees historically, but are now absent" (The Ngogo Chimpanzee Project website). Despite a detailed account, the 2023 Netflix documentary *Chimp Empire* never mentioned predation at Ngogo. The absence of leopards has been suggested as an important factor in Ngogo chimpanzee lives, for example, in explaining their increased life expectancy [8]. Therefore, an alternative explanation for the recent adult white sclera findings [7] could be local predator extinction in Kibale National Park.

White sclera arises from a simple loss-of-function mutation in conjunctiva pigmentation, which occurs spontaneously at a low ≈1% rate (the Gombe incidence). However, this mutation makes individuals with depigmented conjunctiva more susceptible to targeted predator attacks. This phenomenon, termed "BROWS" (***B***ullseye ***R***emoval ***O***f ***W***hite ***S***clera), describes how predators specifically target conspicuous eyes and is detailed later. Predators, due to BROWS, continually "weed out" hominids with white sclera. The absence of predators at Ngogo raises the possibility that chimpanzees with white sclera now survive into adulthood and reproduce, unlike in the past when predators would have selectively killed them. This recent development could explain the current approximately 10% adult prevalence and their near absence in previous decades, as observed by Goodall and others.

Conspicuous eyes in nonhuman primate infants are unlikely to increase their predation risk. Infants have lighter facial skin, making their white sclera less noticeable. Additionally, their predation risk is more associated with their mothers, who carry them, rather than their own visibility.

White sclera is found in primates smaller than 0.5 kg, such as common and Goeldi's marmosets and cotton-top tamarins. However, although their eyeballs are proportionately larger than in bigger primates, they remain small. For example, the diameter of the common marmoset eyeball is 11 mm and its limbus width is 6.1 mm. Assuming no eyelid coverage, this leaves just 2.45 mm of exposed sclera on either side of the central iris and pupil [9]. Additionally, some of this sclera is coloured and described as having "had brown sclera with a white part in corner of the eye" [10].

What this proposal is about

This proposal addresses three crucial yet overlooked aspects of human origins:

(i) Our unmatched capacity for split-second team coordination.

(ii) Our unparalleled safety from unpredictable predator attacks.

(iii) Our conspicuous white sclera—while some research has touched on its origins, a comprehensive analysis of its biology and evolutionary implications is still lacking (see, for example, the **Box: The Anatomy Behind White Sclera**).

Key to my argument are two groundbreaking insights into the pros and cons of white sclera:

- The availability of psychophysics as a scientific method to quantitatively evaluate how coloured and white sclera affect line-of-sight conspicuity for observers.
- The "bullseye effect", whereby white sclera gives predators an attack target, particularly on eyes and necks. Coloured sclera, by muffling eye visibility, removes this attack advantage. Consequently, unless predation is absent, coloured sclera is selected, and white sclera is weeded out.

Central to my argument are the often-neglected roles of coordinated teams and split-second intercoupling cognition in human origins and daily life, an exception being Tomasello's work on "shared intentionality" [11–16]. Teams and the cognitive processes enabling their split-second coordination are at the heart of this proposal. Teams, as such, differ from mere collections of individuals cooperating on a task but lacking instantaneous motor or verbal coordination. Teams and split-second coordination are universally present across human cultures in activities from dance, instrumental music, choral singing, conversational turn-taking, and organised sports.

Moreover, individuals engage with observed coordination as spectators and audiences, aligning their attention with the rapid interactions between team-coordinating individuals. Observing quick interactivity also allows for assessing interaction quality, serving as a "polygraph-like" honesty indicator that could create the trust needed for human cooperative breeding and hypercooperativeness. I argue that humans' unique ability for team coordination is the "glue" that defines and unites our shared humanity.

Box: The Anatomy Behind White Sclera.

I use the terms "white sclera" and "coloured sclera" for simplicity. However, anatomically, the sclera is white in all primates, with colouration coming from the overlying conjunctiva. Similar to the skin's epidermis, the human conjunctiva contains melanocytes at a ratio of "approximately 5 to 15 basal epithelial cells … for every 1 melanocyte" [17]. These melanocytes create pigmentation and contribute to the eye's immune protection. Human white sclera results from depigmentation of conjunctival melanocytes.

Researching the molecular evolution of white sclera would be straightforward if funded. Conjunctival cells can be non-invasively collected on filter papers through impression cytology [18], a technique used in conjunctiva research and dry eye studies. Additionally, confocal laser scanning microscopy enables direct in vivo imaging of conjunctival cells [19], though neither method has been applied yet in primatology.

White sclera is a form of localized albinism specific to conjunctival melanocytes. Albinism stems from loss-of-function mutations disrupting melanin production. Mr. Worzel's lack of conjunctival pigmentation likely results from mutations in pathways responsible for pigmenting the conjunctiva. Human white sclera probably evolved via a simple loss-of-function mutation already occurring at low frequency in hominids.

Despite their pivotal societal role, the origins, antipredatory functions, and cultural influence of human teams and split-second coordination remain largely unexamined theoretically and empirically. I aim to address this gap, arguing that active participation in and spectating of split-second coordination underlies our unique biology, extraordinary origins, and unparalleled capacity for complex cooperation.

Nine statements and three consequences

To achieve this, I offer a hypothesis-driven review highlighting new research avenues in human neurobiology, predator-prey dynamics, and split-second neuroscience. I conjecture that approximately two million years ago, human abilities for team coordination and related cognition evolved through a sequence beginning with white sclera and culminating in coordinated predator mobbing.

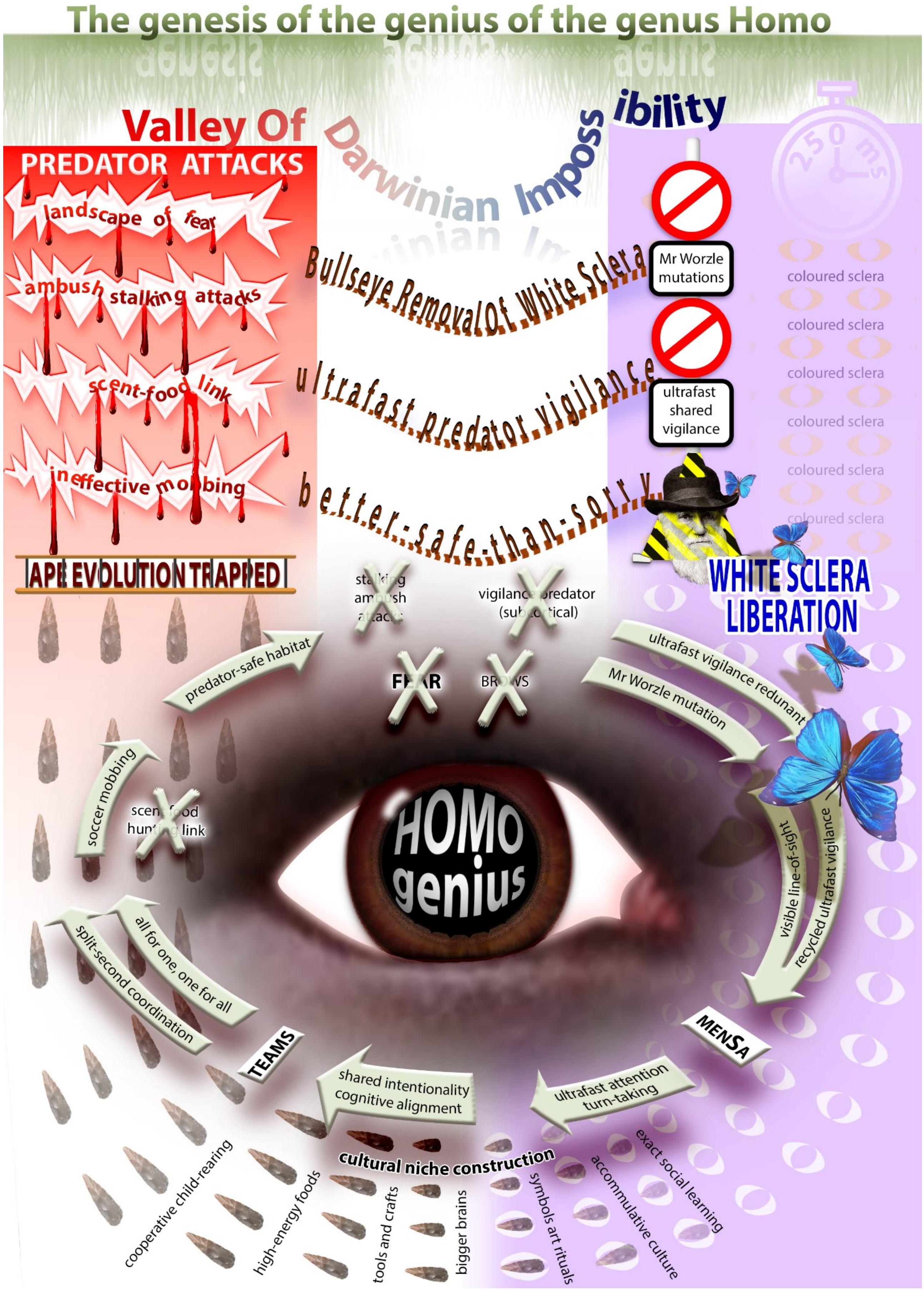
- All primates, including humans, use ***M***achinery ***E***xtracting ***N***eural ***A***ttention (MENA) to predict behaviour by observing ***O***rientations, ***R***eactions, and ***E***xpressions (ORE). This external ORE information, freely "broadcasted" by the brain in its body, reveals its inner priority workings. MENA essentially "reverse engineers" this information to discern split-second changes in the hidden neural priorities—attention—that drives behaviour.
- White sclera eyes offer high-quality visual cues for attention extraction. The contrast between the surrounding dark skin, white sclera, and central dark iris/pupil provides exact temporal and spatial information about an individual's line-of-sight and its factional second changes.
- Nonhuman primates have coloured sclera that muffles this high-quality visual information, serving as camouflage to prevent predators from using it as a "bullseye" for attacks. White sclera gets weeded out unless predators are removed or cease to consider such individuals as prey.
- Around two million years ago, human ancestors developed split-second team coordination that effectively ended predator attacks.
- This coordination emerged from an enhanced capacity for shared attention, made

possible by the ability to perceive each other’s rapid, 250-millisecond changes in line-of-sight.

- This quick detection of shared attention set the stage for coordinated turn-taking. In this process, the rapid attention shifts of one individual inform another, who then reciprocates. This interaction creates an attentional “tennis” exchanging reactions. This new form of turn-taking, facilitated by white sclera, turned MENA into MENSA.
- Critically, this transformation didn’t involve evolutionary brain changes but rather an adaptive use of the enhanced line-of-sight information made visible by white sclera.
- MENSA and shared attention form the basis for unique human intercoupling cognitions like cognitive alignment, team intentionality, and rapid team coordination. These traits enable humans to synchronise their actions in teams in split-second coordination.
- The role of white sclera in enabling teamwork allowed humans to eliminate predation, consequently creating predator-safe habitats. This safety, in turn, ended the weeding out of white sclera individuals by predators.

These changes, however, were only the start, as constructing predator-safe habitats set off a chain of events.

- This safety led to revolutionary enhancements in faithful social learning and heightened group cooperativity.
- They synergised with other factors to produce cumulative cultural evolution.
- As a result, human life has grown increasingly complex in cognition, technology, and society.



Explanatory graphic: The genesis of the genius of the genus *Homo*.

Predator attacks trapped primate evolution. White sclera-enabled team “soccer” coordinated mobbing, which creates predator-safe habitats. This graphic also touches on later-discussed concepts like the Landscape of Fear, Scent-Eat Link, Better-Safe-Than-Sorry Adjustments, Ultrafast Predator Vigilance, Attention Turn-Taking, BROWS, MENA, MENSA, and the All-for-One, One-for-All Team Ethos.

Meet the Ancestors—Traits of Australopithecus

To understand the proposal, we must first explore the biological "ground zero" that defined *Australopithecus*, the species from which *Homo* arose as an offshoot two million years ago.

Australopithecus differed from other nonhuman primates—and from *Homo*, I argue—in six key cardinal ways.

The first two foundational traits have already been mentioned:

(1) *Australopithecus*, like all large nonhuman primates over 0.5 kg, had coloured sclera, reducing the eye conspicuity that white sclera would offer predators.

(2) *Australopithecus*, like all nonhuman animals, at a distance could not detect split-second changes in line-of-sight, crucial for cognitive alignment and split-second team coordination.

The third, "ground zero" trait sets the stage for the others.

(3) *Australopithecus*, like all nonhuman animals, mobbed predators in a disorganised, emotionally charged, and ultimately ineffective "pell-mell" manner.

Unlike humans, who coordinate in teams, nonhuman animals confront predators individually and chaotically. (Since the terms "chaotic" and "disorganised" are common, I opt for the less frequent term "pell-mell" to serve as the antithesis of teamwork.) They engage with a burst of hatred that Konrad Lorenz [20] termed "hassen auf" ("to hate after" or "to put a hate on"). Importantly, while such disorganised and emotional attacks may offer temporary deterrence, they fail to completely halt predator stalking and ambushes. Consequently, individuals with white sclera continued to be selectively eliminated by predators through BROWS.

(4) *Australopithecus*, like all nonhuman animals, existed in a landscape of fear.

Because disorganised and emotional attacks are ineffective, *Australopithecus*, like modern hominids, constantly feared unpredictable predator attacks. While some areas might have been relatively safe, nowhere was entirely free of predator threats. Consequently, australopiths go about in heightened alertness, inhabiting what ecologists call a "landscape of fear" [21].

Ecologists typically examine the landscape of fear's environmental impact, e.g. less grazing where predator fear is higher, promoting plant growth. Here, I focus on its impact on the animals themselves.

Although ethologists since Darwin, in his *Voyage of the Beagle* [22,23], have described animal anxiety as "fear"—"upland geese, (*Anser leucopterus*,) which, from fear of them [Falkland Island wolves], like the eider-ducks of Iceland, build only on the small outlying islets". However, "fear" here encompasses two related but distinct phenomena:

(i) immediate physiological fear responses to a present predator and

(ii) ongoing anxiety due to potential predator attack.

In this context, the landscape of fear is essentially a landscape of "anxiety," but I will retain the traditional term "fear."

Living in a landscape of fear detrimentally affects an animal's health and limits its potential to evolve.

(5) *Australopithecus*, like all primates, adopts a better-safe-than-sorry approach to minimise predator attack risk.

Predators cause animals to engage in various survival strategies, including restricted foraging, using set routes, limited feeding times, and freezing or fleeing when sensing a nearby predator [21,24–26]. For example, moulting greylag geese, on average, pause feeding about every 90 minutes for around 19 minutes [27]. Animals may also form larger social groups despite suboptimal foraging numbers or increased disease risk [28,29]. This caution extends to sleeping habits, as in chimpanzees preferring tree nests over ground resting [30]. (One study challenges this, finding 1% of nests on the ground in 15 of 20 areas studied. It notes, however, an absence of ground nests where humans hunt [31].) More intelligent animals have increasingly sophisticated and effective better-safe-than-sorry behaviours. Any cognitive difference between *Australopithecus* and other primates is likely small rather than significant. I treat *Australopithecus* as adept, with chimpanzee or bonobo-like abilities. These precautions not only limit hominids but also indirectly cause harm as severe as direct predator attacks (discussed later).

(6) *Australopithecus*, like all nonhuman animals, maintained constant vigilance, reacting

to unpredictable attacks in under a quarter of a second.

As Goodall observed, Mr Worzle was perpetually alert: “his gaze darted back and forth.” This vigilance is vital for prey, as they may only get a fractional second to survive attacks (see **Illustration: Ultrafast**). Predators use stealth and speed to counter prey’s equally rapid responses. This escalating Red Queen Effect has led to faster, more intelligent predator and prey brains. I argue the critical timeframe for a survival response is under a quarter-second. A wild hominid’s approximately 32-year lifespan comprises about a billion seconds [8], so an *Australopithecus* brain would be ceaselessly alert at a quarter of a second or less resolution to its surroundings, including while asleep (such as to detect vibrations from a tree-climbing leopard). Such relentless vigilance is vital: an animal’s ultrafast response to a predator in any unexpected quarter-second could determine if its genes are passed on, or gets eaten. In contrast, Leakey and his colleague merely had to “keep calm and carry on.”

Specific uses of words and the prelanguage qualification

"Coordination" is used extensively and is central here. It is often qualified as "split-second". This distinction matters: coordination can mean cooperation, but that is not the meaning here. Instead, coordination refers to the precise synchronization of actions, like puzzle pieces fitting or a mortise and tenon joint. This temporal interlocking can occur between individuals or body parts. Cooperation, in contrast, means working toward a shared goal. Such cooperation often involves coordination, but cooperation can happen without split-second sensorimotor coordination. Some coordinated actions likewise can lack cooperation: opposing tennis players coordinate serves and returns but seek opposite outcomes. The only non-temporal "mortise and tenon" type coordination I can think of is information exchange in contract bridge bidding.

Split-second coordination manifests in two ways: turn-taking and teams. Broadly, turn-taking is split-second coordination enabling exchanges between two or more interacting participants. Teams are split-second coordinated single behavioural entities comprised of two or more individuals. In other words, turn-taking is individual-level coordination, and teams are group-level. Usually, team participation involves turn-taking, and turn-taking creates individuals acting as teams.

Here, vigilance specifically means reactive vigilance, not just sustained attention. Attacks require ultrafast reactions—a quarter second or less. Prey live in a world that can instantly become a lethal trap when stalking predators pounce. To survive, brains cannot just stay generally attentive; they must link vigilance to immediate explosive or freeze responses. I argue later, slightly slower cognitions continually fine-tune this ultrafast reactivity using top-down modulation to adapt it to ever-changing hidden threats—a skill I propose got adapted in humans for turn-taking. Such vigilance thus differs from sustained attention by generating constantly updated trigger-sensitive reactivity—which might be to predators—or keeping interactively alive an exchange.

A central concern is how processes at a quarter second or faster temporal resolution constrain or enable ecology and neuroscience phenomena. Such resolution involves both precision and duration limits, though here the focus is mostly on duration. For instance, animal attack onsets/offsets and survival response onsets/offsets often occur within a quarter second. Likewise, many neurological processes have quarter second durations (P100, N170, alpha, a- and b- retinal waves) while others do not (P300, N400, P600, theta, slow potentials). However, onsets/offsets over longer durations also matter, with their informativeness lying in the temporal precision of identified lags or anticipations determining these onsets/offsets. For example, when walking, gaze onset looks 800-1000ms (two steps) ahead of footstep offset [32]. Extracting attention information from such gaze orientation, reactions and expression depends on the high temporal precision of its onset (gaze) and offset (footstep) despite their roughly one second duration.

Fear, anxiety and respect differ. Fear is the brain’s response to an immediate threat. Anxiety is its response to an associated but not yet present danger. Respect is awareness of a threat taken seriously yet engaged calmly and confidently.

While some animals are defined as prey, nearly all, even most predators, can become victims. For example, “cheetah mothers and their families encountered lions, spotted hyenas, golden jackals, and other cheetahs of both sexes more often than they did other carnivore species, all of which were potential predators” [33]. Conversely, supposed “prey” can act as predators. Although their diets are mainly vegetation, most primates eat insects [34]. Larger primates, like chimpanzees, hunt, targeting other primates [3,35].

Everything argued here relates to prelanguage human evolution. Syntactically articulate language takes over many intercoupling functions of split-second coordination. While eye contact remains important to modern humans, due to language, it is far less so than in early *Homo*. When language first emerged in humans is unknown, as is how far earlier gestural vocal communication advanced. I take syntax-based communication to be a late development, with *H. sapien sapiens*.

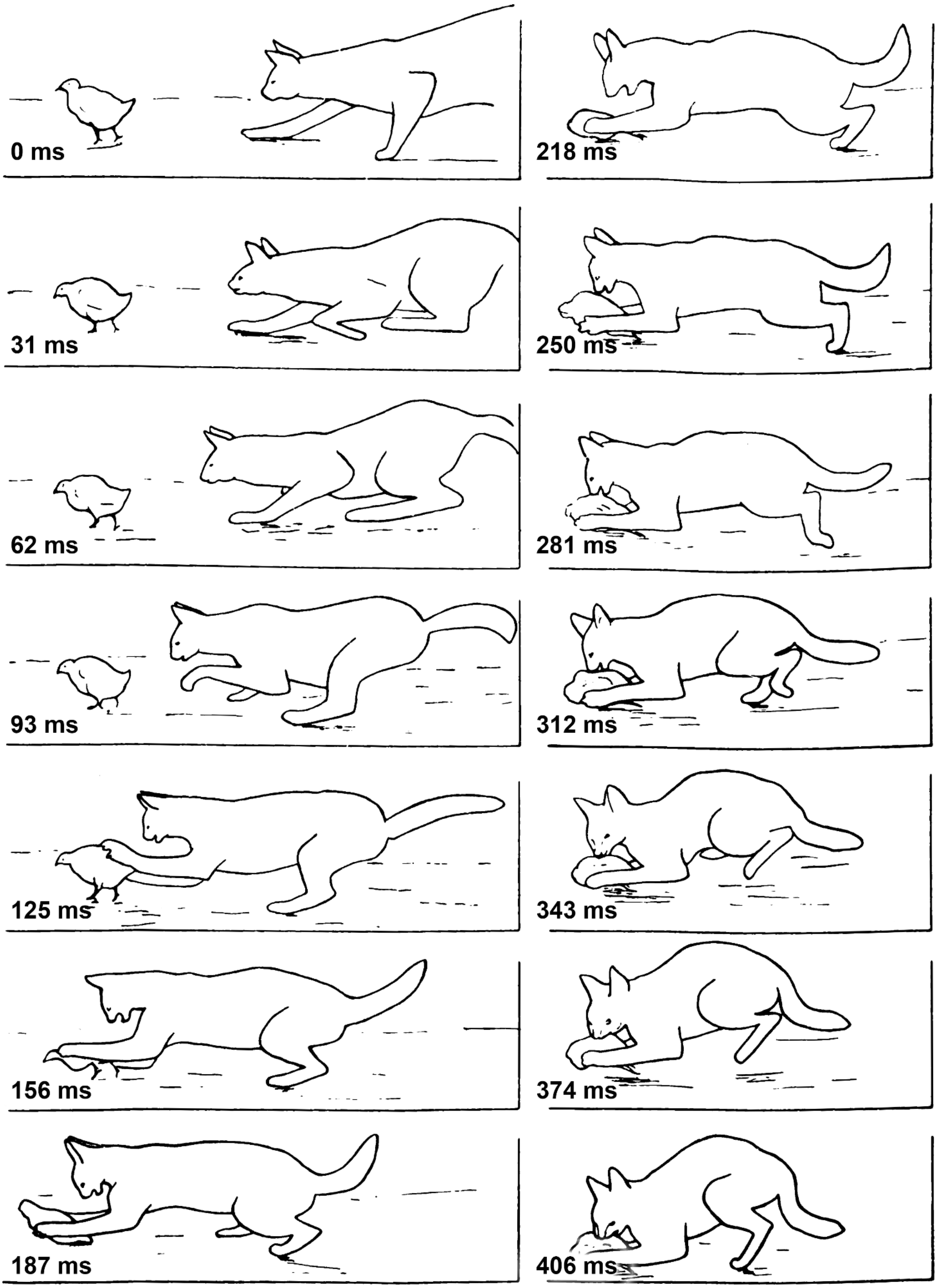


Illustration: Ultrafast death.
A female serval, a wild African cat, attacks a chick; the original 1/32-second frame timings have been rounded to whole milliseconds. These drawings are from *Cat behaviour: The predatory and social behaviour of domestic and wild cats* [36]. Studies on predator attack speed are rarely reported; the information above, based on filmed attack frames, is a rare exception. It highlights how predators can capture prey with astonishing "snap" speed after a stealthy approach. The widespread failure to appreciate predator attacks' instantaneousness has caused a parallel lack of recognition of predator-safe habitats' critical role in human evolution. The key challenge nearly all nonhuman animals face is "anytime" unpredictable rapid attacks springing out from nowhere.

2. PREDATOR FEAR, ATTENTION EXTRACTION AND SCLERA SELECTION

> *Act 1: Predators' indirect impact on prey equals their direct kills, eliminating them through stress illnesses and limited feeding. Predator calls halve songbird populations by reducing parent foraging. Critically, predator stress impairs social learning and cultural evolution.*
>
> *Act 2: Primates evolved neural machinery extracting attention from observed body actions.*
>
> *Act 3: Only humans have contrasting black and white eyes that broadcast split-second line-of-sight visible from a distance, enabling rapid shared attention.*
>
> *Act 4: Two obstacles must be overcome before white sclera emerges: (i) Bullseye Removal Of White Sclera (BROWS)—predators target conspicuous eyes, weeding them out when they arise, and (ii) Valley Of Darwinian Impossibility (VODI)—coloured sclera and white sclera offer mutually exclusive predator protection methods and suffers the "booting impasse" that paradoxically white sclera needs to exist already before it is advantageous.*
>
> *Act 5: When australopiths overcame BROWS and VODI, contrasted eyes aided split-second team coordination, making predators shun, not hunt them, unlocking previously wheel-clamped capacities for aligning cognition, shared intention and joint action, setting the stage for cumulative culture and the human story.*

Act 1: A "horror story"—Predator fear "murdered" cultural evolution

The first act introduces a recently uncovered "Edgar Allan Poe-like" situation about predators' impact.

> From the 1940s to as least as late as 2010, predators were commonly viewed as little more than scavengers, killing the very young, old, sick, or injured, the so-called 'doomed surplus'. [37]

But in a dramatic science turnaround, new research now shows that predator

> non-lethal effects may be larger than lethal effects in determining the behaviour, condition, density and distribution of animals. [28]

Ironically, animals' precautions against predators can be as lethal and debilitating as direct attacks. For instance, limiting foraging to avoid predators may inadvertently cause starvation and malnutrition-related death [28].

Critically, these indirect predator effects can "sabotage" animals' ability to sustain culture.

SCENE I: THE TRAGEDY OF THE SONGBIRDS

To illustrate predators' impact, consider songbirds whose fear responses can be experimentally induced by recorded predator calls.

> Frightened parents provisioned their young 26% less frequently with the result that 20% fewer of their offspring survived to fledging (leaving the nest). This reduction in offspring survival coupled with fewer eggs laid and more hatching failure meant that frightened parents produced nearly 40% fewer offspring over the breeding season. … Combining results from this experiment with that on early-stage care, we project that fear itself is powerful enough to reduce late-stage survival by 24%, and cumulatively reduce the number of young reaching independence by more than half, 53%. [38]
>
> predator playback parents producing 53% fewer recruits to the adult breeding population. Fear itself was consequently projected to halve the population size in just 5 years, or just 4 years when the evidence of a transgenerational impact was additionally considered … Our results not only demonstrate that fear itself can significantly impact prey population growth rates … that fear may constitute a very considerable part of the total impact of predators. [37]

However, this is just the tip of the iceberg. Fear of predators, by restricting nourishment for the young, can cause nutritional stress, impairing brain development, social learning, and cultural transmission.

> swamp sparrows subjected to nutritional stressors early in development, exhibited poorer copying fidelity of model songs as adults when compared with ad libitum controls In addition, the volumes of two song-control regions, HVC and RA (robust nucleus of the arcopallium), were significantly smaller in the food stressed birds. … Stressed starlings also sang less frequently, performed shorter song bouts and generally delayed singing behaviour compared with controls, when assessed the following year. Spencer et al. found that nutritional stressors significantly reduced zebra finch nestling growth rates, and resulted in adult song that was significantly shorter and contained fewer syllables compared with the control condition. Furthermore, HVC volume for the food-stressed finches was selectively reduced compared with the overall brain volume and other nuclei. [39]

Stress from predators could alter the syntax of bird songs, much like stress from being raised in large groups does.

> birds from large broods (i.e., of poor early condition) in comparison to birds from small broods copied syntactical dependencies of song elements from the song motif of their tutor less accurately and had less consistent sound duration between song motifs.[40]

Furthermore, the impact of fear extends due to

> enduring neurobiological and behavioral effects … in wild animals that mirror those diagnostic of post-traumatic stress (PTSD) in humans. [22]

Another study concluded

> PTSD is not unnatural, and that long-lasting effects of predator-induced fear, with likely effects on fecundity and survival, are the norm in nature. [41]

A recent study discovered that a brief, five-minute stress event in mice, simulating fear from a predator, had lasting effects not only on the parents but also on their yet-to-be-conceived offspring and was even “unexpectedly persistent and produced similar behavioral phenotypes in the F2 offspring” [42].

This stress from fear, similar to that caused by nutritional restriction, can hinder social learning, including that needed for foraging skills. This limitation reduces the future generations’ ability, independent of predator fear, to provide nourishment for their young

> juvenile zebra finches that were fed the avian stress hormone corticosterone (CORT) during the nestling phase later formed less exclusive (or more random) social bonds in a colony setting (free-flying aviaries containing six to seven families) relative to their control-treated siblings. In particular, CORT-treated juveniles spent less time foraging with their parents. When presented with a novel foraging task, we next found that while control juveniles tended to copy their parents’ behaviour to solve the task, their CORT-treated siblings exclusively copied unrelated adults. [40]
>
> CORT-treated juveniles copied their father’s song less accurately as compared to control juveniles. We hypothesized that this could be due to having weaker social foraging associations with their fathers, and found that sons that spent less time foraging with their fathers produced less similar songs. [40]

Once begun, predator-induced stress creates a self-perpetuating cycle, undermining cultural transmission of effective foraging and extending culture-suppressing stress across generations.

SCENE II: ESCAPE FROM PREDATOR FEAR ON JICARON ISLAND

These examples concern songbirds, but camera trap studies of predator-free Jicaron Island capuchin monkeys in Coiba National Park suggest a direct primate link to tool use traditions and human evolution. Unlike nearby mainland monkeys facing predators like tayras, ocelots, jaguarundis, and coyotes, these island monkeys often move in large ground groups, and “females carrying infants were frequently photographed on the ground at the island sites, but never at the mainland sites” [43]. Pertinent to cultural transmission, these islands have

> the only population of gracile capuchins (e.g., *Cebus* rather than *Sapajus*) documented to use stone tools. Capuchins on the island of Jicaron habitually use hammerstones and anvils to crack open a variety of foods they acquire on the ground, including seeds of *Terminalia catappa*, crabs, and bivalves. It is possible that the availability of abundant terrestrial food resources (or the lack of sufficient food in the trees) helps explain why capuchins on these islands spend so much time on the ground. It is also possible that spending more time on the ground as a consequence of a release from predation pressure may have potentiated the innovation of the tool-use tradition in this population of capuchins, thereby opening up a new terrestrial foraging niche. Terrestriality has been linked to the innovation of tool-use traditions, but cracking nuts with hammerstones is a loud and conspicuous activity that requires significant attention. Thus, it may only arise where antipredator vigilance can be reduced because predation risk is low. [43]

Research indicates capuchin monkeys using stone tools have richer fat, carbohydrate and energy diets [44]. If australopiths constructed predator-safe habitats, this would have enhanced their capacity for sustaining accumulative culture. It’s been asked: “Why culture is common, but cultural evolution is rare”? [45,46] The answer is predator fear wheel-clamps culture’s evolutionary potential.

The plot thickens.

Act 2: The Hidden Wealth of the Primate family: MENA

Act 2’s backstory began over 63 million years ago when primates developed neural circuitry to discern others’ hidden priorities shaping their actions—their “attention” [47]. The subcortex and cortex machinery executing this is named MENA (***M***achinery ***E***xtracting ***N***eural ***A***ttention). Evidence exists for MENA in lemurs [48], which dates its origin before the strepsirrhine-haplorrhine divergence 63 million years ago. Similar predator prediction mechanisms may exist in other animals (see **Box: MENA in nonprimates**).

Box: MENA in nonprimates.

While discussed here only for primates, MENA processes could be more evolutionarily widespread and also relevant to predators. Various mammals like dolphins [49], horses [50] and wolves [51], and some birds like emus, rheas and tinamous [52], understand others' perspectives, suggesting "visual perspective taking, with accompanying representations of gazes' referentiality, evolved earlier in dinosaurs" [52]. Both prey and predator behaviour involve perceiving attention and eyes. For instance, whether herring gulls "steal food" depends on human gaze direction [53]. Many animals like lizards [54] and chickens [55,56] are startled by eyes, and evolution frequently selects predator-startling "eye spots" to aid prey survival [57]. While not exhaustively discussed here, future work will examine eye detection more broadly.

Evolutionarily, MENA is a "biological Cinderella": it has a potential for higher things but is constrained by the "stepmother" coloured sclera forced on her by wicked predation that impoverishes her ability to detect rapidly shifting eyes and find her hidden nature. Eyes powerfully indicate attention through line-of-sight changes. However, for observable changes at a distance, eyes must be conspicuous with high sclera-iris/pupil-skin contrast (see **Box: Rapid Eye Movement Perception**).

Box: Rapid Eye Movement Perception.

Whether nonhuman primates perceive rapid eye movements in coloured sclera is untested. Crucially, detection relates to ≈250 ms line-of-sight changes rather than static gaze. The issue is temporal "myopia": the ability or inability to discern ≈200-250 ms rapid changes.

Beyond later discussed psychophysics, neurological evidence deserves attention. Macaque studies investigate gaze in conspecifics at 57 cm [58], 62 cm [59], and 100 cm [60]. Ethological observations suggest hominids maintain ≤30 cm distance during social interactions, indicating "myopia" for detecting eye movements from further afar.

(1) Juichi Yamagiwa, in his seminal research paper on gorilla staring, "Functional analysis of social staring behavior in an all-male group of mountain gorillas" [61], sets this distance at 30 cm: "Social staring was defined as one individual looking into another's face for at least 5 sec from a distance of less than 30 cm. It was not accompanied by distinct facial expressions, but simply involved each individual facing the other in close proximity without any contact (Fig. 1)" (Fig. 1 depicts two such gorillas.)

(2) In *The mountain gorilla: Ecology and behavior*, George Schaller [62] notes (p. 116) that gorillas stare "one foot apart": "Suddenly VII Dominant rises and walks rapidly toward the male of group XI. They stare at each other, their faces but one foot apart, for 20 to 30 seconds. Then VII Dominant returns to his seat. This is repeated two more times. The males stand quadrupedally as they stare at each other."

(3) In *Chimpanzees of the Budongo Forest* [63], Vernon Reynolds posits that chimpanzees also stare from 30 cm (p. 70): "Muga was seen sitting down with two other adult males, Magosi on one side and Maani on the other. A subadult male Andy sat behind him. Magosi was eating the fruit and Muga was staring at his face from a distance of 30 cm".

How should we interpret this extreme primate eye gaze proximity? It seems too close for anything other than a mutual eye-on-eye "grooming" through monitoring each other's pupil movements. If so, it suggests further distances do not allow attentive eye monitoring, supporting a ≈30 cm limit on detecting quick coloured sclera eye movements between hominids.

Act 3: A hero emerges that one day will liberate turns MENA into MENSA

Eyes with high-contrast white sclera not only make detecting changes in an individual's immediate area easier, as with low-contrast coloured sclera, but also enable perception from 10+ meter distances (see **Box: Human Line-of-Sight Detection Distance**). This reach allows diverse joint attention tasks. Critically, this identifies the limitation on MENA's (***M***echanism ***E***xtracting ***N***eural ***A***ttention) attention-sharing capacity as not neural processing but an external one—poor detectable "ORE" (***O***rientation, ***R***eaction, ***E***xpression) information quality in coloured sclera eyes (see **Box: What is ORE?**). Only visible white sclera line-of-sight can overcome these constraints, transforming MENA into MEN***S***A (Machinery Extracting Neural ***Shared*** Attention). While the primary conspicuity enhancer, white sclera is not the sole factor (see **Box: Additional Line-of-Sight Visibility Factors**). However, white sclera is only possible in predator-safe habitats; otherwise, white sclera individuals get selectively eliminated, leaving only coloured sclera individuals.

Box: Human Line-of-Sight Detection Distance.

Research shows human gaze direction precision can be as accurate as 1 minute of arc [64] or even 0.71 minutes [65]. (1° equals 60' minutes). This acuity enables discerning if someone 5 meters away looks at your nose bridge versus your face's edge. Gibson and Pick [64] concluded, "The ability to read the eyes seems to be as good as the ability to read the fine print on an acuity chart". Other studies [66] have established an "effective viewing distance" that ranges from 1 meter to 32 meters. In these studies, researchers used video screen presentations featuring photographs of individuals looking at "targets placed either side of the camera lens". They found that sensitivity to gaze deviation remained consistent within what they termed "the critical distance." Observing a face for 1 second, movements as subtle as 0.88° could be detected from about 15 meters. For a 20 ms glimpse (2 screen refreshes), the smallest detectable eye movement increased to 1.38°, reducing the critical distance to about 8 meters [66]. These findings align with the observation that different faces, viewed for half a second, can be distinguished even when their angular size is only 12 minutes of an arc degree (equal to a fifth of 1°)—comparable to discerning a 145 mm wide face from 42 meters away. This level of discrimination remains relatively constant, even for very brief views: at 19 ms, the size expands only to 19 minutes of an arc, equivalent to viewing a face from 26 meters [67]. This research focused on high-reflectance, light skin-toned faces did not explore if line-of-sight is equally or more observable in dark-skinned faces, which seems likely given their greater gaze direction contrast (discussed later).

The last act reveals the dramatic plot twist of the white sclera shift that "magically" transformed MENA into MENSA. The twist reveals white sclera granted humans, like a fairytale godmother, the capacity for team coordination, ending predator threats that have since primates originated weeded out white sclera.

Box: What is ORE?

"ORE" was chosen to echo the mining connotations of "extract" in MENA (Mechanisms *Extract*ing Neural Attention) regarding the information it takes in by observing others. Later, I realized ORE is also an acronym for the three main body sources of such information (***O***rientation, ***R***eaction, ***E***xpression).

Attention directs external body part **orientation**, including eyes, head, ears, nostrils, limbs and fingers. Although I focus on eye orientation as an attention indicator, other sources also contribute to the brain's attention extraction. **Reactions** like startling or repositioning in response to stimuli offer information on how events and behaviours relate to an animal's experience. A quick eye shift to a noise reveals the brain deems it significant. **Expression** relates to subtle motor kinematics (hesitations, pacing, mirroring, exaggerations) and kinetics (force, energy, momentum). All three can co-occur, like line-of-sight darting with a surprised eyebrow expression to a sound. Though not discussed here, non-eye orientation, reaction and expression (head, body, hands, fingers, facial muscles) become crucial in MENA/MENSA neuroscience and social interbrain coupling development.

ORE information can come from nonvisual senses, like sound and touch. Multiple sources also allow complementary cue refinement. For example, lip-pointing [68] indicates a side direction to which an accompanying gaze direction adds precision. ORE broadcasting can be incidental or deictic (intentional demonstration).

Attention is an internal neural process, while orientation is its visible result. However, not all attention manifests externally (covert attention), nor does orientation necessarily indicate attention, as in amblyopia/strabismus or absent-minded gazes.

A key ORE aspect is creating interbrain “batting,” allowing attention-cue “tennis” exchanges among individuals—crucial for human development. Another is supporting deictic communication, to be expanded upon when discussing MENSA neuroscience.

ORE not only extracts attention—it adds depth and complexity to social interactions, cognitive development, and knowledge acquisition. As a result, it is a cornerstone in neuroscience, ethology, psychology, and most human social sciences.

Box: Additional Line-of-Sight Visibility Factors.

Besides white sclera, other facial features also improve human gaze direction conspicuity:

(1) The human eye slit is proportionally larger and more elongated than in other primates [10]. For example, when looking straight ahead, the human sclera is three times the size of that in orangutans (*Pongo pygmaeus*) [69].

(2) The human eye socket’s outer edge (the temporal orbital margin) is positioned further back [70,71], significantly expanding the temporal visual field. Even a “minor 8.4° anatomical difference results in a large (2.5-fold) difference in maximum temporal visual field eccentricity” [71]. This rear position also allows observers to determine the pupil’s position, and thus its line-of-sight, from a wider angle.

(3) Modern anatomical humans (*H. sapiens sapiens*) have control over eyebrow movement, a muscle expression missing in other hominids [65] and seemingly also in extinct *Homo* species like *H. neanderthalensis* [72]. Gaze and facial expression integrate within 300 ms [73], enhancing ORE sharing through surprise cues in MENSA, potentially explaining the survival and advancement of the contemporary of *H. sapiens sapiens* over extinct species.

(4) Human facial skin is unusually smooth due to well-developed buccal fat pads [74] and the underlying tissues of the superficial musculoaponeurotic system (SMAS) [75]. This layer of connective tissue between the skin and deep fascia encloses the mimetic facial muscles responsible for expression [75]. This smooth yet flexible skin allows subtle facial expressions and may also modify the eye’s visibility during eye movements, such as closing or squinting the eyelids. Additionally, eye appearance can change due to emotional tears—humans are unique in crying as an expression of inner feelings [76]. Complementing these effects, human skin is slightly reflective due to facial sweating, highlighting facial contours.

(5) Bipedalism positions the eyes for easier observation and stabilises their movements within a more “fixed” head frame [77].

(6) Evidence also suggests white sclera enhances visibility in low-light conditions [250,251]. Line-of-sight conspicuity depends on various factors, including eye and facial (and information derived from body and head direction—such as the Wollaston effect [78]). Also important are lighting conditions (shadow light contrast), luminosity (twilight, full moon, full daylight), and visual processing (scotopic, mesopic, or photopic) factors. Both coloured and white sclera eyes in hominids are reflective and can show sky, sun and other light source glints.

Act 4: The Curse of VODI (Valley Of Darwinian Impossibility)

Before the final act, Act 4 explains why earlier primates could not tap white sclera’s informational broadcasting riches. Two adversaries had to be overcome first.

The first is “Bodyguard” BROWS or ***B***ullseye ***R***emoval ***O***f ***W***hite ***S***clera. Predators identify the most vulnerable prey for meals. Once selected, they quickly locate the neck for efficient kills. White sclera, especially with visible defensive teeth, creates a ‘triangular’ bullseye ⁂ instantly locating for the predator neck position. This liability makes white sclera individuals either preferred targets or ensures quick dispatch when attacked, favouring coloured sclera survival.

But “Bodyguard” BROWS is just the first white sclera block. Another is “Lord” VODI of the ***V***alley ***O***f ***D***arwinian ***I***mpossibility. VODI prevents white sclera from offering any initial advantages, even if it gets pass BROWS, through enabling team coordination that could end predation.

VODI puts up multiple “you shall not pass” either/or fitness barriers that can’t be easily crossed. Coloured sclera aids individual fitness by concealing eyes from predators. In contrast, white sclera—

(i) offers a group-level advantage, not an individual one, and

(ii) effective predator mobbing is not passive but conditional on learning preexisting traditions.

Critically, mobbing to halt predation also needs:

(iii) a social behaviour policy preventing predators from consuming group members' remains. This policy is crucial because it stops predators from associating the scent of the prey species with eating, an important predation risk factor discussed later.

If these conditions aren't met, white sclera does not aid in stopping attacks.

In summary,

- coloured sclera eyes offer a *passive* protective advantage to *individuals*;
- while white sclera advantages depend on *active* learning and benefits the *group*.

Moreover, for white sclera to be advantageous,

- a complex set of preexisting conditions must be in place, creating an evolutionary chicken-and-egg problem.

Because they confer opposing fitness advantages, coloured and white sclera are mutually exclusive and undermine each other's evolutionary selection. The "Valley of Darwinian Impossibility" (VODI) encapsulates the antithetical nature of this opposition, which adds to BROWS's blockage of white sclera emergence. This discussion only scratches the surface of a complex yet unexplored evolutionary phenomenon; a more detailed analysis will follow, as with other introduced topics.

Due to VODI and coloured sclera, primates can only extract low-resolution temporal and spatial information from orientation, reaction, and expression (ORE) when observing each other's eye movements (see **Box: Head and eye movement "ORE"**). In contrast, white sclera allows MENA to extract high-resolution attention information, turning it into MENSA that could unlock primates' latent capacity for team coordination. This process then would create the predator-free conditions needed to develop existing neural capacities with social learning and cumulative culture. What makes us human, I propose, already lay deep in the primate brain—hidden and unexpressed, awaiting white sclera broadcasting liberation.

Box: Head and eye movement "ORE".

The sclera covers 1 and 2 cm² versus the body's 16,000–18,000 cm². Pupils vary 1-8 mm; the average iris diameter is 12 mm [79]. Interestingly, the pupil is slightly nasal-shifted, a detail noted by animators, as seen in films like Pixar's *Elemental* (2023). This shift affects gaze direction perception as this is based on the pupil centre, not the iris [80].

Human eyes shift ≈10° in 50-60 ms [81], roughly a fist's width at arm's length. Such gazes occur up to five times per second, as in reading. Fixations can be as brief as 100 ms [81]. Viewers can extract information from eye movements: given a 3s video clip with at least 6 fixations on locations viewed in a picture, they can identify manipulated scanpaths and distinguish the scanpaths of different people [82]. Part of the posterior superior temporal sulcus (pSTS), the "gaze-following patch" is specialized in both humans and nonhuman primates for extracting information from such observed eye movements [83,84].

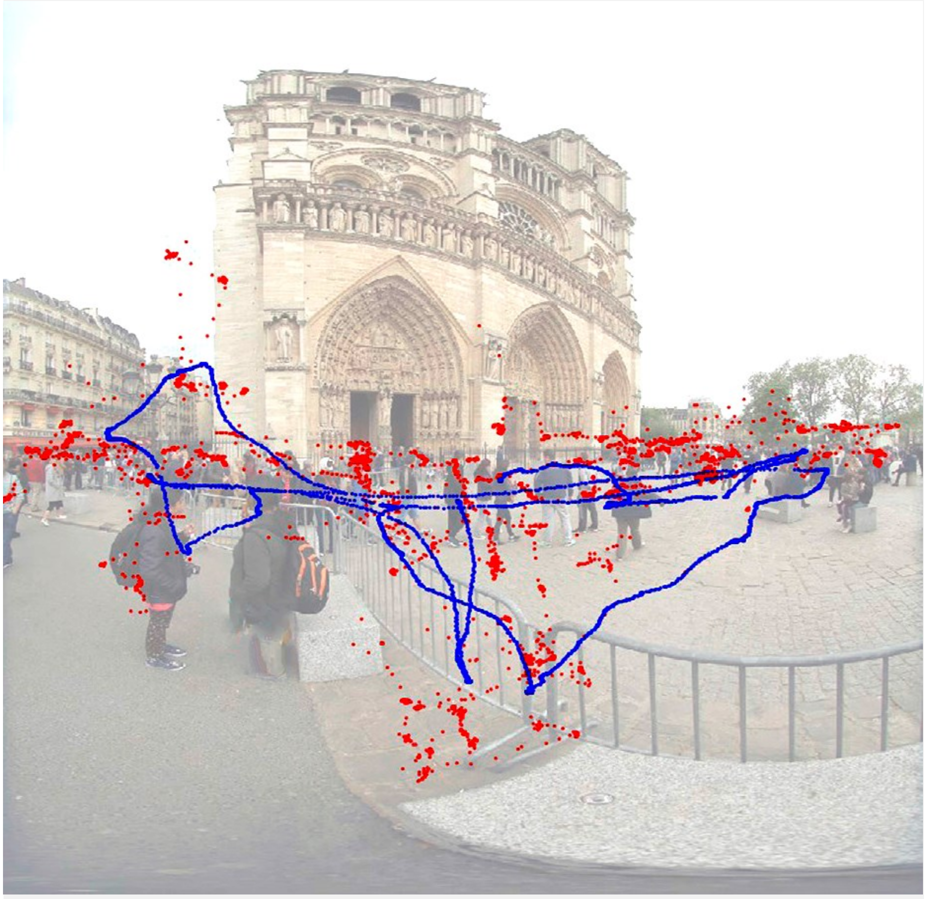
Research shows eye movements, especially with white sclera, offer more precise temporal and spatial attention extraction information than heads. Studies on ophthalmoplegia patients with paralyzed eyes indicate small eye shifts, like reading, can be substituted by heads [85]. However, large head movements are slower, less frequent, and tend to drift [86]. This X makes kinetic sense, given the head's substantial inertia compared to the eye, which merely rotates in its socket. With simultaneous head and eye movements, research shows heads move less, slower, and exhibit drift [87,88]. As a result, heads provide inferior ORE for attention extraction from behaviour-event associations than eyes.

Chimpanzee studies corroborate heads provide less informative movement than less visible eyes.

> Glances, for example, are highly incongruent with head movement and remain so regardless of activity state. In contrast, fixations are rarely accompanied by head movement. During scans, the eyes provide information that head movement does not in approximately half of all cases [89].

Alex Mearing and colleagues have further observed

> the degree to which nonhuman primates can respond to conspecific 'glance' cues, i.e., movements of the eyes independently of the head rather than 'gaze' cues, i.e., movements of the head is unclear. Experimental evidence that nonhuman primates can interpret referential information from glance cues is sparse, though studies are few and have examined only several species to our knowledge. By contrast, several phylogenetically diverse species of nonhuman primates are reported to be able to follow head direction. [90]



An image from [87] shows the discrepancy between a person’s nearly continuous head (blue) and scattered eye (red) movements over 40 seconds of passive virtual reality viewing.

The research noted in **Box: Head and eye movement “ORE”** was not done specifically to examine ORE quality. However, it suggests different ORE information from heads versus eyes is available for attention extraction. This preliminary work paves the way for targeted studies quantifying white versus coloured sclera differences. Such research is empirically feasible. For example, cosmetic contact lenses used to alter eye appearance for cosplay or cinematic purposes could be employed. (Scleral lenses differ from regular vision-correcting and medical “scleral contact lenses.” In the USA and other countries, a prescription from an optometrist is required for them.) Such lenses, together with skin-tone makeup, would enable researchers to directly study the effects of coloured sclera eyes compared to white sclera ones for extracting and using attention information from ORE in situations ranging from psychophysics to team coordination.

What “saviour” could help primate evolution bypass BROWS and VODI, allowing MENA to unleash its buried potential and become MENSA, thus enabling teamwork to end predator attacks and free its MENSA potential? Act 5 reveals all.

Act 5: Primates’ hero—white sclera liberates the primate family’s hidden cognitive/cultural “wealth”

The story’s dramatic turn comes in the final act with white sclera, revealing the primate family’s untapped neurocognitive “wealth.” Australopiths found a way to “overcome” VODI, enabling rapid tennis-like 10+ meter line-of-sight exchanges—previously impossible for primate brains. Like magic, these conspicuous eyes turned MENA into MENSA (Machinery Extracting Neural Shared Attention). What had been only latent attention-sharing potential for tens of millions of years became a lived experience. This pivotal change enabled coordinated teamwork against predators, finally breaking "the curse of VODI" and unleashing the primate family's buried neurocognitive riches.

Critically, MENSA enables cognitive alignment, shared intentionality, and split-second coordination through joined exchanged attention between individuals (see **Box: MENSA’s cognitions**). These cognitions replaced ineffective mobbing with effective team predator action, enabling predator-safe habitat niche construction. Here, the play’s story, in its unrevealing of a Schopenhauer-like capacity in humans to detect what no other primate cannot see, connects

Goodall’s observations on white sclera with Louis Leakey’s experience of the *Homo* Predator Anomaly.

Box: MENSA’s cognitions.

MENSA enables three interbrain couplings: cognitive alignment, shared intentionality, and split-second coordination. Generally, cognitive alignment deals with perception, shared intentionality with goals, and split-second coordination with synchronizing physical actions. Cognitive alignment is “singing from the same sheet,” shared intentionality is “being in the same boat,” and split-second coordination is like running together in a three-legged race.

Chess analogies: Cognitive alignment is like multiple people observing the same board, shared intentionality is them collaboratively controlling same-colour pieces, and split-second coordination is jointly lifting pieces in unison, with each person using just one finger tip.

Cognitive alignment is more than snapshot perception. A chess novice and grandmaster may see the same board, but only the grandmaster foresees several moves ahead. Alignment means seeing the same possibilities, limits and opportunities. It’s like everyone identifying the same unmarked paths on a shared map. Shared intentionality is like driving without GPS by alternating driver/navigator roles, so needing to effectively share contributions.

Split-second coordination occurs when multiple individuals synchronise mortise-and-tenon-joint like their body movements (including vocalization ones), aligning their spatial positions, temporal timings (kinematics), energy, force, and momentum (kinetics) to create a unified single action or effect.

In neurological terms, cognitive alignment involves connecting sensory processing across multiple brains. Shared intentionality expands this to include pooling emotions and rewards, while split-second coordination generates sensorimotor unification. This interconnectedness enables human brains to coordinate not just like self-coordination of eye, hand and leg body parts—but to organize their different bodies as elements of a single acting entity. Within-brain communication of timing coordination, kinematics and kinetics is complex, as movement disorders show. Similarly, multiple brains must communicate such information to integrate together as a superbody or team.

Various sociocognitive phenomena highlight interbrain coupling’s importance in human life, examined in a separate work originally intended for this article. It investigates how this foundational concept supports ideas like intentionality, communication, relevance (as defined by Sperber and Wilson [91]), and “mind reading” or “theory of mind.”

The white sclera and team coordination duo emerges as the “hero”, enabling the MENSA transformation that liberated early *Homo* from fear-dominated lives. This freedom ignited an ongoing cognitive revolution by increasing faithful social learning and cultural transmission, previously wheel-clamped by precautions against predators. The cognitive leap led to the emergence of a new primate genus within the primate family Hominidae: Australopiths with white sclera awoke to discover that they were the first members of *Homo*.

Crucially, the potential for a MENA-to-MENSA shift has existed since MENA originated in primates 63 million years ago. The original mechanism required no internal changes, only an external white sclera enhancement of available ORE information. The groundbreaking *Homo* genus emergence was thus not genetic innovation but a pre-existing internal capacity exaptively unlocked by white sclera.

3: THREE RESEARCH OPENINGS AND ANTIRACISM

> *Three approaches can quantitatively test the proposal.*
>
> *First, psychophysics can measure eye movement detection contrast, with lower eye contrast requiring longer durations and larger visible areas (Bloch's and Ricco's laws). This science enables modelling contrasted vs noncontrasted eyes' impact on predator targeting and line-of-sight broadcasting.*
>
> *Second, 250-millisecond neuroscience explains why nonhumans reserve the initial quarter second of neural experience for predator vigilance reactivity and why repurposing it for shared coordination happens when predation ceases.*
>
> *Third, sub-second onsets and offsets display an unfakeable "polygraph"-like turn-taking honesty signal triggering human cooperativity.*
>
> *Dark skin may have facilitated early Homo emergence by enhancing line-of-sight, making it integral to human evolution. All our Palaeolithic ancestors were Black; did their Blackness also make us human?*

Three hard science research rooms

I've used a five-act drama structure to outline this proposal's key interrelated concepts. While we can't time-travel to confirm details like *Australopithecus* eye colour or chaotic mobbing, the theory identifies empirical reasons that they, in fact, existed.

The proposal enables quantitative assessment. I've mentioned traits like vigilance and quarter-second durations as they are quantitatively researchable. Current methods let us investigate human origins by focusing scientifically on these brief moments. This exploration is like visiting research "mansion" "rooms".

Let's enter these "hard science research rooms".

PSYCHOPHYSICS AND SUB-SECOND TEMPORAL BIOLOGY

One research "mansion" wing contains psychophysics and "quick" biology rooms related to quarter-second information processing durations.

Current ideas about coloured and white sclera often overlook psychophysics' crucial role in understanding contrast and detection time. The evolutionary importance of the colour contrast in white sclera was initially recognized in the signalling eye hypothesis proposed by Hiromi Kobayashi and Shiro Kohshima [92–94]. Their work suggested that the low contrast of coloured sclera in nonhuman hominids camouflages the eyes, albeit not in the ways discussed here. They note that high-contrast white sclera makes eyes more visible, aiding in "gaze signalling." Fumihiro Kano expanded this to include situations "where multiple individuals communicate with one another in a large group, of which members are distributed over space" [95]. Michael Tomasello's cooperative eye hypothesis also argues white sclera visibility is key for joint attention and social cooperation [96,97].. This proposal differs in that other theories propose coloured sclera camouflage and white sclera social signalling had independent functions, whereas this proposal does not view them as independent: the shared defence against predators enabled by such signalling directly made coloured sclera camouflage redundant. In other words, not only are two different functions linked to coloured and white sclera, but they are antithetical, making white sclera originate from predator survival in two ways. It enables ending predation (through team "shunning" defence), which eliminates the need for eye camouflage from coloured sclera that previously protected against predators.

Another difference is that these authors provide only qualitative sclera contrast insights, lacking the quantitative analysis psychophysics provides for utility modelling.

Psychophysical methods, for example, offer the scientific means to quantitatively measure the temporal and spatial resolution to observers of eye movements with contrasting white and coloured sclera. These measurements are essential for modelling line-of-sight and "bullseye" detection and opportunities with experimentally determined detection angle, distance and millisecond parameters.

Specifically, Bloch's and Ricco's Laws help quantify the detection of eye movements within sub-second durations (see **Box: Bloch's and Ricco's Laws**). Furthermore, there is a substantial body of neuroscience literature, too extensive to cite here, that, while not directly referring to this psychophysics, employs stimuli of opposing high and low contrasts. This neuroscience finds contrast to have temporal effects on the brain's stimulus processing consistent with Bloch's law. For instance, according to a randomly selected paper, the response time in the superior colliculus neurons to small 0.51° disks with 100% contrast is 55 milliseconds, while the same stimuli at 5% contrast take 90 milliseconds; their responses are also a tenth weaker, as indicated in Figure 3, top row “A” [98]. Stimulus contrast is a potent factor influencing neuron response in non-psychophysics research.

Bloch’s Law is also relevant to evidence accumulation and decision-making. Huk, Katz and Yates observe: “The computational neuroscience of evidence accumulation starts with Bloch’s Law … [but] Despite its historical significance, Bloch’s Law is rarely applied to modern decision-making tasks” [99]. Potential research connections are being missed. Scientific brains need knocking together.

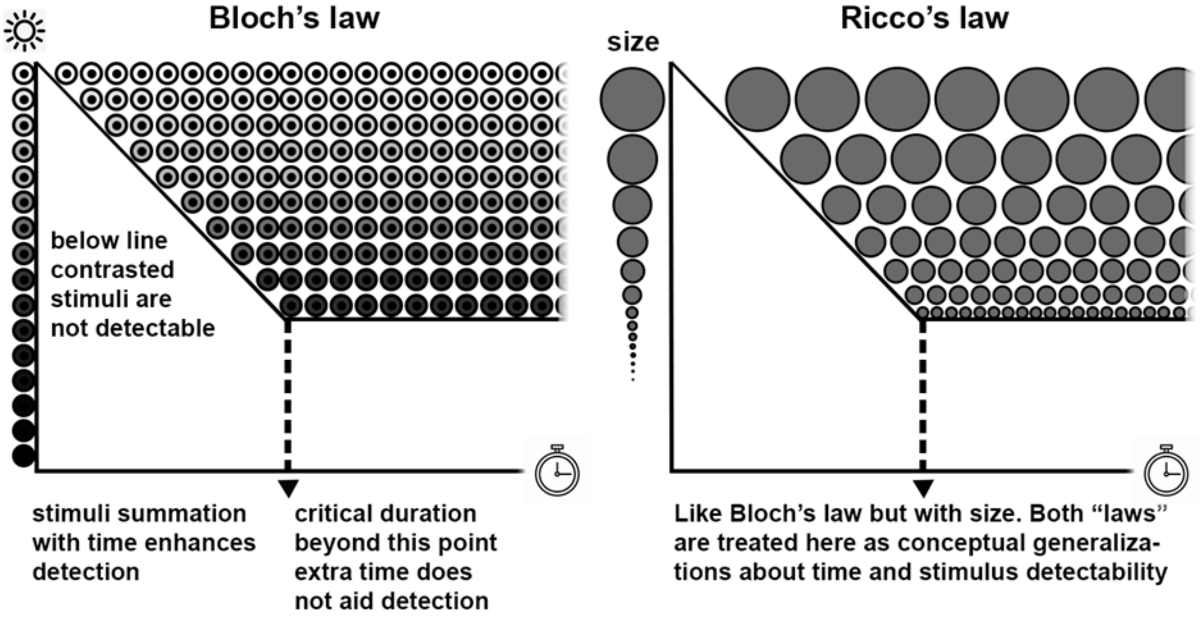
Box: Bloch’s and Ricco’s Laws

In 1885, Adolphe-Moïse Bloch found that below a certain duration, “the [visible] light is markedly in inverse proportion to its duration. This is to say that, in order to obtain the cessation of visual sensation, doubling the intensity of the light requires halving its duration” [100]. Due to temporal summation, sufficient photons must accumulate to exceed a detection threshold. This threshold can be reached quickly with abundant photons but needs a longer duration with fewer photons. However, a critical duration exists beyond which more photons do not improve detection. Therefore, contrast stops affecting detection beyond this critical duration (see illustration below).

Ricco’s law is related to Bloch’s law, which states that the threshold is met within a certain area, known as the critical diameter when the luminous energy accumulates to a constant value. To put it another way, if the luminance is halved, the area of the stimulus must be doubled to reach the same threshold. For lines separated by 0.083 degrees, or 12 cycles per degree, the critical duration amounts to 215 milliseconds [101]. Ricco’s law is not confined to areas defined by luminosity; it also applies to areas defined by the absence of light, such as dark holes [102]. Since the apparent size of an image on the retina is inversely related to its distance, Ricco’s law explains why distant, low-contrast images, which produce smaller retinal images, are more difficult to detect.

Bloch’s law applies to non-luminosity perceptions. Colour change critical durations for pure luminosity 480, 527, 580 and 600 nm pulses are 56, 68, 62 and 64 ms, but for chromic pulses, they are 250, 250, 160 and 110 ms [103]. Similar auditory processing effects occur, with ~50 ms delays differentiating rare 20% versus prevalent 80% tones by lower volume [[104,105]. Bloch’s law is seen in insects [106].

It also impacts higher visual processing. Identifying triads of zeros and ones has a critical duration ranging from 200 to 350 ms [107], while the recognising Landolt rings (an “O” with a small gap of varying position) requires a duration of 400 ms [108]. These extended durations may be linked to non-retinal processing. For example, studies on cats reveal that “some visual cortical cells integrate more slowly than expected on the basis of the known integration times in the retina. The evidence for this … Firstly, both the amplitude and the latency of the response peaks of the cortical cells increase progressively when stimulus duration is prolonged up to 320 msec. Secondly, some cortical cells show constant responses (at least in terms of maximum firing rate) to constant products of stimulus intensity and duration for flashes lasting 200 msec or more. Thirdly, the persistence of cortical responses can be quite large (over 300 msec) [109]. Ricco’s law, too, plays a role in advanced cognition, especially regarding searching. Visual searches are bound by the retinal image size of the entity being sought [110].



While exceptions exist, Bloch’s and Ricco’s laws identify duration limits determining detection resolution for stimuli like the rapidly changing eye movements needed to determine quickly changing line-of-sight directionality.

Bloch’s and Ricco’s laws make cooperative eye theories experimentally testable regarding conspicuously contrasting eyes—assessing predator targeting and the use of conspecific line-of-sight information. An eye moving rapidly with little scleral pigment contrast may be visible at close range but not from farther away, restricting neural attention extraction.

Reading illustrates contrast’s cognitive impact through identification time for small, distant, quick stimuli. Words function as images fixated on for 200-250 ms in rapid succession. Text contrast varies—faint copies or faxes—and font sizes can range from tiny 4-point, normal 8-point, to large 12-point. New fixations require adequate current word image processing for identification. Despite stable reading speed with contrast changes, extremely small fonts significantly slow reading. For instance, in full contrast, two readers read 0.25° letters at 300 words per minute. But at 10% contrast, one could not read at all, and the other read at 25% at their original rate [111]. Even a 22% contrast reduction increases fixation time by 51 ms [112]. A similar phenomenon may apply to sclera contrast in which the issue is not image identification time but the minimum duration to identify gaze direction change from altered canthal sclera/iris/pupil appearance.

Psychophysics is critical for modelling both line-of-sight detectability and a predator’s decision-making before and during an attack. A predator stalking or ambushing from a distance must identify the most suitable prey based on the likelihood of a successful attack. A key factor for the predator is the ability in an attack to instantly identify the prey’s vulnerable body parts, such as eyes and throat, especially when the prey’s body struggles quickly and aggressively to stop itself from being clawed or bitten to death. Psychophysics, therefore, aids in modelling the aid given by white sclera for predators in victim selection and then in the execution of rapid killing strikes.

Not only do stimuli with lower contrast undergo slower processing, but neuroscience also suggests that this slower processing modifies the brain’s ability to handle such stimuli. A complex temporal “alchemy” exists between the speed of input processing and its contrast.

In addition to psychophysics, cosmetic scleral lenses offer another avenue for quantitatively exploring sclera theories, as proposed by Kobayashi, Kohshima, Kano, and Tomasello. Commonly used in film and cosplay, these lenses enable research into white and coloured sclera roles in ecologically relevant tasks and settings. For example, they allow the study of whether and how white sclera enhances rapid coordination in pitch-and-catch or five-a-side football. Do white sclera individuals show superior abilities to coloured sclera? The evolution of coloured /white sclera is very amenable to scientific investigation once the research potential and need are recognized.

≤250 MS INITIAL “HERE AND NOW” TIME SKIMMING NEUROSCIENCE

In another wing of our hypothetical imagined mansion, we find rooms devoted to brain research and ultrafast reactivity. A quarter-second sliding window is critical in neuroscience (see **Illustration: 250 ms sliding window**). This continually skim-captures sensory input, enabling near-instant multisensory integration and reactions if unexpectedly attacked.

This continuous capture creates not the conscious “now” but the “now” for unexpected predator detection and instant survival response. Multisensory integration makes the brain perceive differently timed events as simultaneous. For instance, visual and auditory events are perceived as synchronous within 225 ms [113]. A similar perceived time exists for audiovisual lip sync—unnoticed up to 80 ms delays, they still remain unified (tolerated rather than distracting) when video leads audio by no more than 240 ms or audio leads video by 160 ms [114].

Subcortical processes mainly govern this quarter-second sliding window of survival-focused neuroprocessing. Following this initial survival skim, more leisurely theta oscillation-aided cortical processes take over. While still split-second, they follow after this initial 250 ms survival input skim and so do not interfere and compromise their processing. They, however, can top-down context “tune” such ultrafast processing with priors about circumstances. Hence, these processes are crucial for survival as they prepare an animal to adapt to specific places and situations, enabling it to always make the most effective ultrafast survival detections and reactions. The key insight is that a 250 ms sliding window continually integrates sensory input for immediate survival reactions, which are enabled mainly by subcortical processes.

Theta oscillation-enabled cortical processes follow this initial survival skim. They enable the brain to multithread cognition (see the theta oscillation in the **Illustration: 250 ms sliding window duration**). These processes enable memory retrieval, encoding, and complex interactions across multiple brain regions. Theta activity was “present at movement onset and modulated by saccades. Many neurons were phase-locked to theta, with few showing phase precession” [115]. Importantly, “eye movements strongly modulated neural activity in all regions” [115]. Complementary, V1 and V2 visual cortex areas rhythmically sample saccade input three to four times a second [116].

The Red Queen Effect selects both prey and predator brains that can make ultrafast “quick and dirty” survival decisions. Since this requires only the “rough and ready” integration of multisensory information, this gets done pre-reflectively within a quarter second. This focus requires that they exclusively “occupy” this initial skim moment so they are not compromised by survival nonurgent cognitions.

However, this changes in a predator-safe habitat. With no threat, there is no advantage for the initial perception skim to enable ultrafast detection and reaction—these are unneeded. Not only can other processes use the skim time, but neural circuits previously handling survival data can be reallocated to non-survival functions, enhancing them.

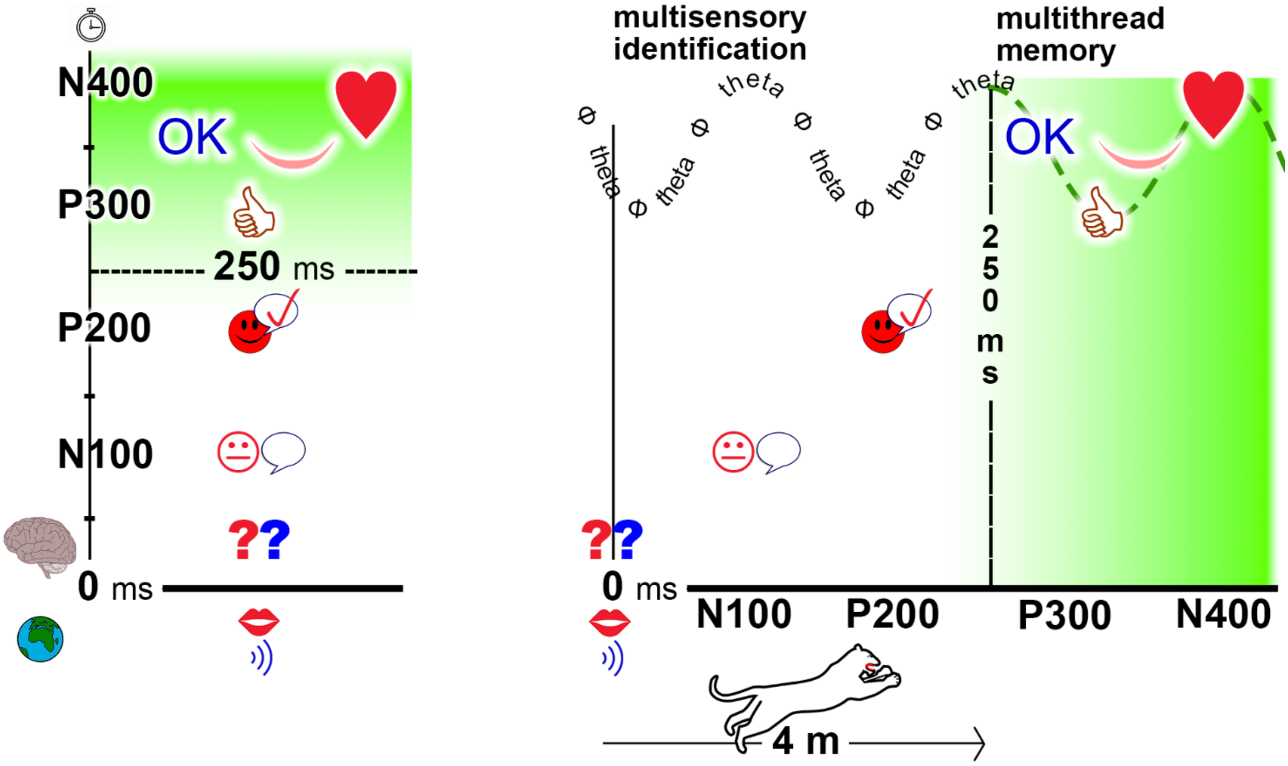


Illustration: 250 ms sliding window.

The brain takes time to process sensory input into conscious “now”. An event with visual and auditory inputs undergoes processing stages: input, multisensory integration, identification, and then division into different parallel occurring information processing streams. A second illustration timewise compares these to a predator ambush/stalk launch, aligned with theta “multithread” oscillation phases. Critically, prey initially reserve a quarter-second exclusively for survival vigilance, with other cognition coming afterwards. In predator-safe environments, this quarter-second can be redeployed for other functions requiring ultrafast “skim processing” like those involving white sclera line-of-sight and turn-taking. Freeing these initial stages could foundationally innovate human cognition. Evoked potential peak times vary by task and individual brain, associated broadly with sensory processing (N100), feature detection/attention (P200), memory/novelty (P300), and semantic integration (N400). P300’s complex theta oscillation relationship will be reviewed later.

Nonhumans' survival skimming time can be repurposed in humans to aid in detecting 250ms ORE events. This adaptation facilitates transforming MENA into MENSA by extracting white sclera line-of-sight. Further, skimming's contextual tuning can shift from preparing ultrafast predator detection/reactions to enabling equally quick social turn-taking detection/responses. Quarter-second changes in line-of-sight can then information process attention in other brains for context-tailored turn-taking replies.

Bloch’s law and psychophysics allow modelling of the resolution at which different ORE sources (white vs coloured sclera) might provide key information to the brain in this quarter-second skim (predator targeting vs team coordination). Predator-safe areas release existing ultrafast detection/reactions from predator focus to social turn-taking. Normally, profound brain function change requires brain evolution, but here, it can happen without it through high-quality white sclera ORE and freedom from predator fear.

SPLIT-SECOND TURN-TAKING AND SHARED INTENTIONALITY

Tomasello's shared intentionality ideas open a third research room suite [11–16]. The pivotal paper is "Fast Response Times Signal Social Connection in Conversation" by Emma Templeton, Luke Chang, Elizabeth Reynolds and Thalia Wheatley, published in PNAS in 2022 [117]. This research builds upon earlier studies concerning the speed and universality of conversational turn-taking [118].

> Turn taking is a human universal that develops early … Months before words are uttered, infants engage in a communicative back and forth that helps establish a bond with their caregivers. Within this ecological niche, language develops, adding the exchange of semantic meaning. In a remarkable feat of coordination, turn taking minimizes the time that one speaker stops and the other begins without sacrificing understanding. The modal conversational response time is extremely short, around 200 m—three times faster than the average speed with which people can name an object and too rapid to rely on deliberative conscious control. Conversational response time is also extremely consistent across cultures and languages ….
>
> Conversation is an incredible feat of coordination. We must pass the conversational baton within a split second and, as with professional athletes, a few milliseconds can make a striking difference. Here, we show that how quickly people pass this conversational baton is a robust marker of how connected they feel. Across two studies of unstructured, natural conversation, we found that faster response times were associated with increased social connection in conversations—both between strangers and friends. Reduced response times likely reinforce feelings of connection.…
>
> Response times in everyday conversation are … simply too fast to be under conscious control and thus cannot be faked. This brevity is a feat of coordination that provides a natural, "honest" heuristic about how well the conversation is going. Moreover, by virtue of being a feature of conversation itself rather than requiring post hoc self-report and by virtue of being a signal readily accessible to outside observers.[117]

Response times … simply too fast to be under conscious control and thus cannot be faked … readily accessible to outside observers. Human hypercooperation origins challenge understanding. Uniquely among hominids, humans practise hypercooperation, allowing non-relatives to care for infants [119]. In contrast, alloparenting has risks in nonhumans, including infanticide and neglect. Game theory provides strategic payoff explanations, but another is the "polygraph-like" ability to detect deceit's neurocomputation slight delays. Indeed, a modified Ultimatum game revealed motor "kinematic codes" for fairness in actions like reaching, grasping and lifting [120]. Humans can thus gauge trustworthiness by observing caregiver turn-taking timing/fluidity with infants, sensitive to calculation delays that might reflect unsafe caregiving (see Box: **Turn-taking in nonhuman hominids**).

Box: Turn-taking in nonhuman hominids.

According to the Lear Principle, "nothing comes from nothing" (Shakespeare, *King Lear*, Act I, Scene I.).

Rapid turn-taking originated in nonhuman primates, evident in captive bonobo mother-infant pairs "engaged in participation frameworks and cooperative adjacency pair-like sequences and communicated at a speed remarkably similar to the timing of ordinary human conversation" [121]. Vocal turn-taking can also be quick—260 ms in Japanese macaques [122]. Wild mother-infant bonobos/chimpanzees incorporate gaze into signals when near recipients: "Bonobos consistently addressed the recipient via gaze before signal initiation and used so-called overlapping responses, chimpanzees engaged in more extended negotiations, involving frequent response waiting and gestural sequences" [123]. (White sclera in nonhuman primates infants [7] may aid this.)

However, nonhuman turn-taking differs from that of humans in key aspects. Bonobo gaze exchange is limited to short "arm's length" distances (fig. 2) [123]. Turn-taking behaviour in bonobos appears to be confined to mother-infant pairs [121]. Nonhuman turn-taking lacks creative responses; it builds upon previous interactions but results in habitual social reactions. Their turn-taking does not feature what might be described as attentional "tennis", where responses alter, enlarge and develop each other. Unlike humans, who engage in a mutually enriching cognitive journey during turn-taking, nonhumans engage in repetitive style exchanges. Put another way, humans, but not nonhumans, take an interactional journey together and enrich each other as they neurocognitively take turns.

Motivational and cooperative dispositions also differ. Tomasello and his team found that while children take turns, chimpanzees predominantly opt for a monopolisation strategy. In tasks involving a resource that only one of a pair could use at any given time, Tomasello and his team report: "children in this study showed turn-taking is in line with recent work showing that young children's reciprocal behaviour develops in middle childhood. In contrast to the children's turn-taking, we found that chimpanzees mostly opted for a monopolization strategy” [124].

Also, nonhuman primates cannot coordinate recursively. As Tomasello clarifies,

> … in joint attention, I know that I am watching the video and that you are watching the video, but I also know that you are aware of my video watching (and me watching your video watching) also. That is what makes it joint: we both know recursively that we both know we are watching the video. Subjects came into a room in which a human was watching a video, and the subject watched the video for a while also. What differed between conditions was whether the human turned and looked at the subject just as the video came on. If they did, one could argue that the subject knew not only that the partner was attending to the video but also was attending to her attention to the video. But this ‘knowing look’ of the partner had no effect on the chimpanzees; they subsequently chose to be equally distant from the partner whether he did or did not look to them as the video started (in the control condition, he looked to the subject at a later moment after the video was off but before the dependent variable was measured). This was in contrast with human children who chose to be closer to the partner if he had looked to them at the key moment as the video began: the key for them was truly shared attention [125].

This research suggests nonhuman primates exhibit basic turn-taking, but humans cognitively transformed these rudiments developmentally and interindividually. This transformation provides an intercoupling runway, enabling cognition alignment, shared intentionality and split-second coordination to interactively elevate human social interaction into a mutual conversational “flight”.

Other facial sources of ultrafast information

Central to human turn-taking are visual cues from the human face, including not just line-of-sight but attendant eyebrow movements.

> Speakers’ gazing practices often demonstrate explicitly to coparticipants that an initiating action is being directed to a particular party, thus selecting that party to speak next. This shows the gazed-at participant that he or she is the intended recipient, and it shows the participants not gazed at that they are not the intended recipient. For this method to work, then, an intended recipient must see the gaze—and others may also need to see it to grasp that someone (else) has been selected.[126]
>
> If a current speaker wants to select a co-participant as next speaker, it is gaze during the final stretch of talk in a turn-constructional unit, i.e., when approaching a possible transition space, that turns an addressed co-participant into a selected next speaker (other next-speaker selection techniques being absent). [127]

An illustration below highlights turn-taking eye signals (200 ms before/after): eyebrow frowns/raises, unilateral raises, eye-widening, squints, blinks, shifts, wrinkles, pressed lips, mouth corners down and smiles [128]. Novel human features like white sclera (eye-widening, squints, blinks, shifts), mobile eyebrows (frowns, moves) and possibly lip reddening (pressed lips, smiles) enhance these. Manual gestures accompany them within similar timeframes [129].

Reflexive peripheral gaze orientation can occur in under 105 ms, although the cueing effect disappears within a second [130]. Constant human upright posture makes these eye signals visible, with gesturing hands further aiding turn-taking. *Homo* ORE offers much to human turn-taking.

Extracting others’ eye information alters profoundly individual visual perception, understanding and experience:

> people implicitly treat other people’s eyes as though they emanated a weak force, gently “pushing” on objects in the external world. We propose that this implicit, fluid-flow model of other people’s gaze may help keep track of visual attention in a complex social environment. … It is well-known that, during the course of evolution, it is not uncommon that ancient biological mechanisms are reused in a different role, a phenomenon called “exaptation”. We speculate that the visual motion system may have been used during the evolution of social brain mechanisms for tracking the attention of others. It may have simply proved adaptive to coopt the brain’s motion system to keep track of sources and targets of visual attention. It is as if the brain draws a quick visual sketch with moving arrows to help keep track of who is attending to what. [131]

The conclusions of Colin Palmer and Colin Clifford support this research:

> If we look at gaze directed at a moving object, the perceived depth and movement of it gets influenced by their eye tracking. This effect is so powerful that the focus we see in another’s gaze as shown by their head rotation, eye deviation, and binocular vergence can override what we see. Thus an illusion can be induced in which the ‘‘veridical’’ movement of an object in terms of its size does not change (it moves with no change of depth cues in a straight line perpendicular to the observer’s view) But gets experienced in a compelling way as move in an elliptical trajectory nearer and further away more consistent with the seen gaze. [132]

Two phenomena highlight visible sclera ORE’s primary importance for MENSA-related cognition.

- Children born blind, lacking access to this visible ORE, initially have a high autism prevalence with MENSA impairments [133,134]. These disappear later, presumably as language compensates for lost social attention interaction.

- Preschoolers link existence with eye engagement—63% believe they become invisible with closed eyes, and 56% think an experimenter would become invisible if she closed hers [135]. One researcher concluded, “it is not the person’s body, [that needs] to be visible to another, the two people must make eye contact” [136]. For them, eyes offer such potent interactional ORE that it overrides physical reality.

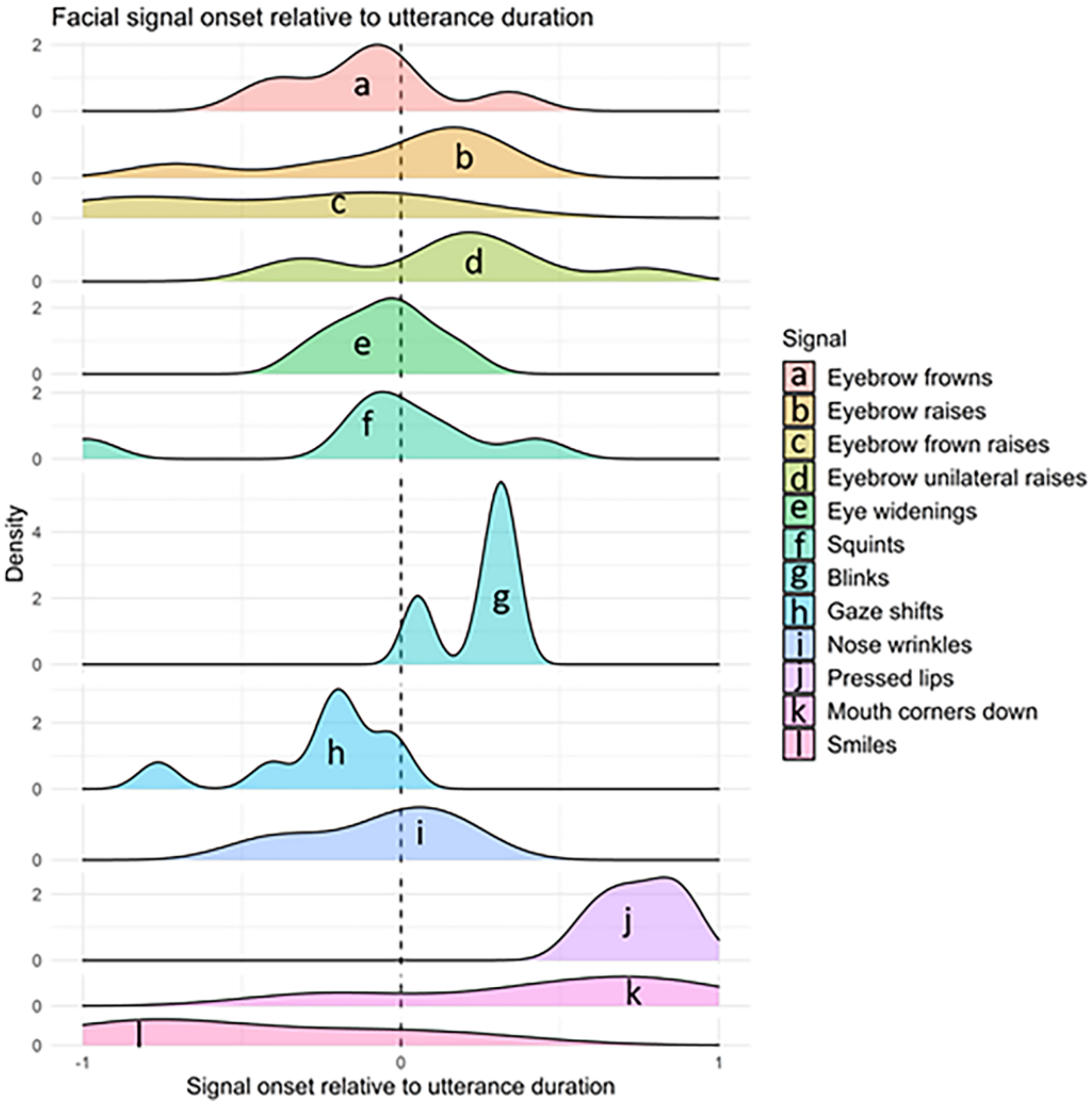


Illustration on facial clues in turn-taking.

From “Turn-taking in human face-to-face interaction is multimodal gaze direction, and manual gestures aid the coordination of turn transitions” [129], it shows the facial cue richness, particularly eye-related, in verbal turn-taking onset. Negative values indicate pre-utterance facial signals. “Only facial signals that started or ended between a time window of 200 ms before the onset of the question transcriptions and 200 ms after the offset of the question transcriptions were annotated (until their begin or end, which could be outside of the 200 ms time window)” [129]. Actual durations are given in their Table 2. For example, gaze shifts had a median duration of 960 ms, 40 ms (minimum) 8480 ms (maximum); eyebrow raises 720 ms (median), 40 ms (min), and 20120 ms (max).

Presenting the argument: problems and narrative strategy

The above overview describes an epic ethological/neurobiological jigsaw that intricately fits together interrelated human-origin pieces.

- White sclera upgrades MENA’s ORE quality, facilitating MENSA-level cognitions for reciprocal attention and exchanging turn-taking.
- A pivot exists between negative better-safe-than-sorry predator fear adaptations and positive social learning/cultural transmission cascades once fear is eliminated.

Additional elements will be elaborated upon in subsequent sections.

- *Homo* evolved heightened sensitivity to predators on life history, along with increased savannah vulnerability.
- The most credible explanation of *Homo*’s survival despite their vulnerability is that unexpected predator attacks no longer mattered.
- Before language, early *Homo* coordination relied on detecting rapid white sclera line-of-sight changes.
- Team coordination allowed *Homo* to proactively prevent attacks via a “don’t kill, win respect” strategy that achieved safety through predator shunning.
- In predator-safe habitats, white sclera was no longer eliminated by BROWS. With ultrafast predator detection/reaction unneeded, neurocognitive functions were repurposed to further enhance coordination.
- Once established, teams offered additional benefits in foraging, social bonding like dance/song, and complex cultural relationships.

In summary, exaptive changes combined with novel scientific concepts explain how a bipedal “chimp” became a distinctly un-chimpanzee-like human primate.

At a higher level, this transfiguration occurred through two niche construction chronicles. White-scleral *Australopithecus* niche constructed predator-safe habitats in which—due to effective team mobbing—predators shunned them. This development allowed these now *Homo* hominins to take the primate evolution rulebook and cross out: “Thou Art an Ape that Shalt Fear Unprovoked Attack”.

However, this niche construction was just the beginning. Previously, better-safe-than-sorry adaptations had wheel-clamped hominid social learning potential; predator stress also impaired health and nutrition, further limiting cognitive development. Now, with cognition liberated from these detriments, cultural niche construction could shift into overdrive. This new cultural capacity altered the very nature of hominid biology and what it meant to be a primate.

Explaining this intricate, unexplored multiaspect scientific landscape of our origins is challenging. The devil is in a maze of details. But writing is linear—sentences, paragraphs, and sections requiring their nuances and the logic of their connections to be untangled into a straightforward narrative. Themes must be discussed from different angles, detail levels, and a helter-skelter of back-and-forth topic switching. The introductory five-act play and three-suite mansion metaphors attempt to bring order to the "blooming, buzzing confusion" of facts and observations.

To break the fourth wall, my current health situation further complicates this. At 65, I risk sudden cognitive impairment from haematological issues. I am hastily compiling the relevant science into a coherent account to preserve these research ideas before a thrombotic event consigns them to an inaccessible file or discarded hard drive. Completing this requires sharper mental acuity than normal—"hyperundementedness"—to invent a word. Echoing Voltaire’s “The perfect is the enemy of the good,” this may result in some disjointed or repetitive sections that more time could have smoothed out. I hope this text serves as a foundation and resource for others to build on theoretically and empirically.

Instead of appendices/notes for supplementary information, I use boxes. Before the predation impact section, a key box addresses an unspoken racial bias impeding human origins research.

Dark-toned skin, racism, and humanity’s origins

Box: Dark-toned skin, racism and humanity’s origins.

Detecting where someone is looking depends on seeing the two canthal triangles—medial and lateral—on either side of the central iris/pupil. Triangle conspicuity depends on the contrast between the surrounding skin, white sclera and central iris/pupil separating the triangles. This contrast visibility is key for two gaze detection methods: (i) judging relative triangle brightness and (ii) using geometry to locate the pupil [137–140] (see **Figure: Canthal conspicuity and line-of-sight**).

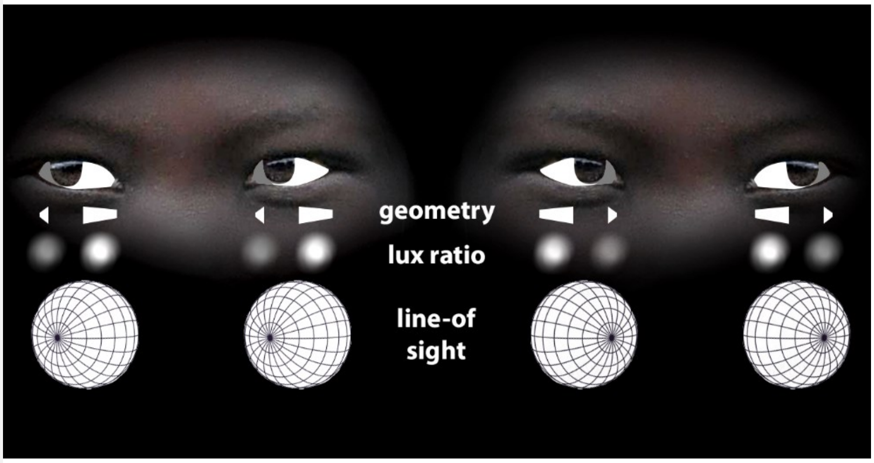


Figure: Canthal conspicuity and Line-of-sight.

Two techniques can calculate line-of-sight: one uses geometry and the canthal triangles' dimensions, and the other uses the luminance (lux) ratio between them. The latter matters most at a distance and develops in children before the geometric method [135]. It is also simpler computationally [136]. Dark-toned skin could improve gaze detection by making the canthal triangles more contrast conspicuous.

Gaze detection depends on sclera/iris/pupil contrast. Greater contrast enables more accurate line-of-sight change detection—angle, distance and speed (up to 4-5 times per second). This contrast effect raises questions about it affecting line-of-sight detection.

(1) In palaeoanthropology, it is accepted that humans evolved with dark, low-reflectance skin rather than light, high-reflectance skin. The latter is more common among today's culturally, technologically and economically dominant Global North. Skin tone is usually excluded from human evolution discussions as it is considered incidental. The tacit assumption is human evolution would have progressed similarly with either tone—in the larger picture, it's evolutionarily unimportant. Given the canthal triangle conspicuity's gaze detection role, this assumption needs re-evaluating.

(2) Currently, science privileges whiteness by treating it as an unmarked default rather than a specific attribute. To explain this marked-unmarked concept, consider scissors: right-handed scissors are unmarked. In contrast, left-handed ones are marked—specifically denoted as "left-handed scissors" (right-handed ones are simply referred to as "scissors", making them linguistically unmarked). The concept can be applied cognitively: illusory faces (pareidolia) seen in inanimate objects are biased to be male (the unmarked default) rather than female [141]. In science and elsewhere, whiteness is the default, unmarked skin tone [36]. One manifestation is white people being seen as more divine and leadership-worthy, even by non-whites [142]. Ugandan children develop pro-white bias between ages 5-12, favouring white peers [143].

(3) From a scientific standpoint, if we examined humans neutrally (like an extraterrestrial biologist), the default would be dark skin. Factually, humans had dark skin throughout our genus' history, including today's *H. sapiens sapiens*. Biologically, white skin is a recent variation like left-handed scissors. Treating light skin as default risks overlooking Goodall's observation that white sclera may confer greater "signaling" benefits to a "dark-skinned individual"

(4) This bias exists in gaze detection research, which considers skin contrast for nonhumans like canids [144], dolphins [49], and chimpanzees [145] but not humans [146]. Human studies only examine sclera/iris/pupil contrast, ignoring surrounding skin. This oversight precludes investigating whether dark skin could be a critical causal human evolution factor.

(5) In humans, skin reflectance ranges 20-70% [147] and iris 15-65% [148] (low is dark, high is light). For gaze detection, the highest contrast comes from a dark skin-white sclera-dark iris ratio of ~20:100:15 rather than a light skin-pale iris ratio of 70:100:65.

(6) Humans evolved with dark skin, originating in high-UV equatorial Africa. Two key factors produced this pigmentation: UV protection and lack of fur. UV degrades folate, the essential B12 vitamin, so skin pigment shields it. Unlike other hominids, *Homo* lacks fur, an adaptation for clearing running's heat generation (*Homo* seems to be the first running hominin [149–151]). This cooling not only requires skin air circulation, which fur would hinder but increased subsurface blood flow, exposing circulating folate to UV, necessitating even stronger UV-protective pigmentation. Further, heat clearance has been suggested to enable humans to be active in the heat on the open savannah [152] to take advantage of opportunities created by other animals being less active—a time, however, of greatest UV exposure and, therefore heightened need for UV protection through darker skin pigmentation.

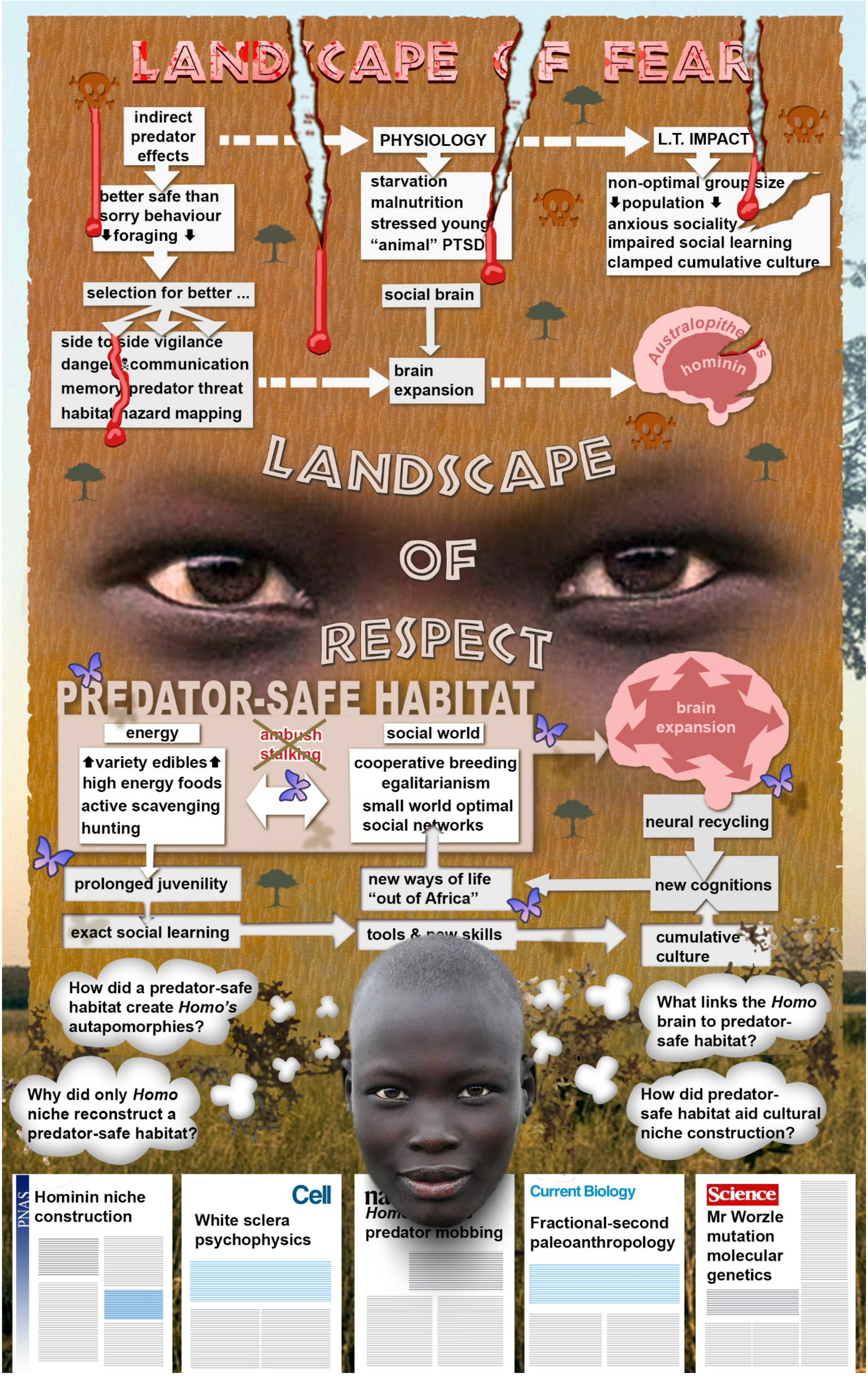
A third complex factor is contemporary African skin pigmentation variability.

> Skin pigmentation is highly variable within Africa. Populations such as the San from southern Africa are almost as lightly pigmented as Asians, while the East African Nilo-Saharan populations are the most darkly pigmented in the world. Most alleles associated with light and dark pigmentation in our dataset are estimated to have originated prior to the origin of modern humans -300 ky ago. … These observations are consistent with the hypothesis that darker pigmentation is a derived trait that originated in the genus *Homo* within the past -2 million years after human ancestors lost most of their protective body hair, though these ancestral hominins may have been moderately, rather than darkly, pigmented. Moreover, it appears that both light and dark pigmentation has continued to evolve over hominid history. [153]

Dark irises correlate with dark skin and would have been selected in hunter-gatherers, as their survival critically depends on natural eye acuity, unlike contemporary people. Light irises admit "intraocular straylight", slightly compromising sharpness [154–156]. (Some research tentatively suggests brown "non-Caucasian" (the researcher's words) irises may be superior [154,156].). Light skin genes emerged in some *H. neanderthalensis* [157]; light skin in *H. sapiens sapiens, however,* "owes its origin to migrants from Near East and western Asia" [158]. Europeans acquired light skin more recently, as "the classic light phenotype of Europeans became frequent only within the past 5000 years" [159]. On a 12-hour clock of humanity, white Europeans only appeared in the human story at two minutes to midnight. Considering our two million-year dark skin history, evaluating its gaze detection role in our evolution merits consideration.

(7) A 20:100:15 dark skin-white sclera-dark iris contrast likely enables, as Goodall noted, better distance and split-second gaze broadcasting/detection than a 70:100:65 light skin one. As discussed later, early white sclera replacement of coloured would face challenges, suggesting the quality of canthal triangle conspicuity may have been critical to early line-of-sight detection. The lighter European contrast may have been thus insufficient to confer an evolutionary advantage, especially before language, to early line-of-sight signalling—with that critical opportunity requiring dark-toned skin. If correct, this implies dark skin may have been integral to *Homo* and our *H. sapiens sapiens* origins and our advanced cognition.

Reevaluating the unmarked light skin assumption in human origins research challenges the "Scala Naturae" privilege once accorded to Europeans. Our darkly pigmented ancestors' skin may have been critically integral to our split-second coordination and team intelligence, even making humanity's very existence possible. Not only were all our Palaeolithic ancestors Black, but their Blackness made us human.



LANDSCAPE OF FEAR

indirect predator effects

better safe than sorry behaviour
⬇foraging ⬇

selection for better ...

side to side vigilance
danger☠communication
memory predator threat
habitat hazard mapping

PHYSIOLOGY

starvation
malnutrition
stressed young
"animal" PTSD

social brain

brain expansion

L.T. IMPACT

non-optimal group size
⬇population ⬇
anxious sociality
impaired social learning
clamped cumulative culture

LANDSCAPE OF RESPECT

PREDATOR-SAFE HABITAT

energy

⬆variety edibles⬆
high energy foods
active scavenging
hunting

~~ambush stalking~~

social world

cooperative breeding
egalitarianism
small world optimal social networks

brain expansion

neural recycling

new cognitions

cumulative culture

prolonged juvenility

exact social learning

new ways of life
"out of Africa"

tools & new skills

How did a predator-safe habitat create *Homo's* autapomorphies?

What links the *Homo* brain to predator-safe habitat?

Why did only *Homo* niche reconstruct a predator-safe habitat?

How did predator-safe habitat aid cultural niche construction?

Hominin niche construction

White sclera psychophysics

Hom
predator mobbing

Fractional-second paleoanthropology

Mr Worzle mutation molecular genetics

4: DARWIN’S ROAD NOT TAKEN: CULTURE AND COGNITION SANS PREDATORS

> *Predators are evolution’s No. 1 shaper—their threat creates chronic vigilance and caution, restricting cognitive and cultural potential. Animal defence rarely fully wards off predators, so animals inhabit a landscape of fear. Primates, especially, are impacted by predator harvesting due to slow reproduction. However, their intelligence allows better adaptive evasion, creating a gap between current abilities and predator-free potential. Humans arose when white-eyed australopiths constructed predator-safe habitats and ended attacks, unlocking previously wheel-clamped cultural and cognitive potentials to accumulate social and technological complexity. Understanding human origins requires examining predator fear versus predator-free phenotypes and how effective predator defence transforms social learning, unleashing cultural evolution.*

Predators are Evolution’s No. 1 razor.

> Steven Lima and Lawrence Dill
>
> During any given day, an animal may fail to obtain a meal and go hungry, or it may fail to obtain matings and thus realize no reproductive success, but in the long term, the day’s shortcomings may have minimal influence on lifetime fitness. Few failures, however, are as unforgiving as the failure to avoid a predator: being killed greatly decreases future fitness. [26]
>
> Andrew Parker
>
> The first rule of animal survival is to stay alive. The other rules, such as feeding and breeding, are academic if this first rule is not followed. … For a prey species, staying alive first means keeping off the dinner plate and then eating becomes important. [160]
>
> Heini Hediger
>
> “Hunger and Love” take only the second place. The satisfaction of hunger and sexual appetite can be postponed; not so escape from a dangerous enemy, and all animals, even the biggest and fiercest, have enemies. As far as the higher animals are concerned, escape must thus at any rate be considered as the most important behaviour biologically. The primary duty of the individual, to ensure its own existence, and thus the preservation of its kind, lies in being prepared to escape. By far the chief occupation of the free wild animal, therefore, is constant watchfulness; eternal alertness for the purpose of avoiding enemies. p.39 [161]

Darwin’s sharpest razor is predation; the rest is pocket change.

The niche of fear

Due to predators, animals exist in both a physical realm and a cognitive landscape of fear with constant on-edge vigilance. Safety can change ultrafast if a predator suddenly ambushes or stalks. Persistent surprise attack threats require continual watchfulness. Predators make everywhere potentially unsafe. Goodall witnessed this perpetual attention to surroundings with the “unusually vigilant” Mr Worzle, whose “gaze darted back and forth.” For this chimpanzee, Gombe was a landscape of fear. (For a discussion of the landscape of fear and its implications, see **Box: The Landscape of fear**.) The role of predator-induced fear has been largely overlooked in theories of human evolution, a major omission that has, I “fear”, limited our understanding of human origins.

Box: The Landscape of fear.

> … as animals move about the physical landscape they are constantly adjusting their behavior in response to changing levels of predation risk. We can envision, then, that prey individuals live in a second landscape, one with differing levels of risk or fear of predation: a “landscape of fear.” The topographic “hills” and “valleys” of this landscape represent the differing base levels of predation risk [21]

John W. Laundré, Lucina Hernández, and Kelly B. Altendorf, in 2001, with the above paragraph, coined the term “landscape of fear” [21]. They elaborated that: “animals, in their effort to reduce their vulnerability to predation … [will increase] their levels of vigilance … adjust their time allocation, spending more time in areas with lower predation risk, the new-found valleys of the landscape of fear. … [as they] seek out these valleys … Such changes could include temporal and spatial shifts in habitat use, e.g., avoiding higher risk areas” [21]. Initially applied to Yellowstone National Park wolves and deer, this concept has extended to various species and habitats, including oceans [162].

The “landscape of fear” concept bridges ecology and cognition. Animals inhabit not only a physical but also a cognitive world constructed through anticipations and behaviours. This neural mapping details predation risks, impacting ecology through altered herbivore foraging creating plant ignored/overgrazed areas. The internal world of fear has external world effects.

Predator fear creates onerous detriments

Beyond direct killings, predator-induced fear changes prey behaviour, causing additional indirect fatalities beyond direct predation. For instance, fear may limit or alter foraging and food intake [14,17–19] or increase disease transmission risks through crowding [28,29,163]. As noted, moulting greylag geese cease feeding and take flight for ~19 minutes every ~75 minutes, with 40% of reactions seemingly unprovoked [27]. Grasshopper mortality remains constant with predatory spiders, whether their chelicerae are operational or glued together [29]. Songbirds frightened by predator playbacks can "halve the population size in just 5 years or just 4 years when the evidence of a transgenerational impact was additionally considered" [37]. Darwin's razor, sharpened by fear, cuts deeply into life's struggle, resulting in further detrimental cuts.

Parallel to fear detriments, predator threat elimination can cascade positively. White sharks' unexplained disappearance in False Bay, South Africa, dramatically changed their Cape fur seal prey, reducing stress metabolites fourfold versus shark-inhabited regions [164]. Seals formed offshore raft groups, likely reflecting increased sea-feeding confidence. Brain size may increase, too—Trinidadian killifish have larger brains in predator-free upstream versus downstream ponds [165]. Predator-fenced woylies (a gerbil-like marsupial) developed lower body mass and leg length over ten years, "suggesting selection against size" [166]. As noted, predator-free island capuchins spend more time on the ground and make tools, unlike their mainland counterparts [43].

Better-safe-than-sorry changes, lost chances and altered phenotypes

Predator fear behaviour changes can be roughly categorised as either accommodations or adaptations.

Accommodations are negative omitted/excluded behaviours. Adaptations are positive predator-dependent behaviours. Accommodations tend to involve costs, adaptations lost opportunities. For instance, moulting geese ceasing foraging and retreating is accommodation with a lost food cost. Chimpanzees building tree nests despite ground suitability is an adaptation, changing but not impairing behaviour—they might sleep on the ground without predators—but this change is a loss of opportunity for evolution to modify and change. Indeed, the shift to sleeping on the ground has been suggested by two "cognitive archaeologists" to enhance problem-solving, learning, and memory consolidation in *Homo* sleep [167]. This change in how hominids live could thus have ramifications on what evolution can select.

Both accommodations and adaptations are passive predator responses, reducing vulnerability rather than confronting the predator to stop predation. This passivity contrasts with mobbing. Accommodations and adaptations are important as they have detrimental physiological impacts and evolutionary phenotypic consequences.

Detriments refer to observable dysfunctions like malnutrition and stunted maturity, as seen by their opposite in well-fed, healthy, mature captive animals under veterinary care. Identifying phenotypic alterations without predation is more difficult, requiring hypothetical counterfactuals. Island and captive animals provide insights, especially intelligent species like hominids—captive chimpanzees and bonobos display abilities unseen in their ever-vigilant wild counterparts.

These conceptual distinctions are crucial for understanding how predators impact evolutionary fitness, particularly the situation in which predator attacks end. They elucidate the predator role, or absence, as a social learning/sustaining cultural evolution change factor. The detriments of accommodations by impairing animals also impair their capacity to learn and sustain traditions. Accommodations also subtly block the range of variation in which differences in learning and culture might occur and thus develop.

A critical theoretical issue is whether situations might arise in which culturally transmitted knowledge equips an animal species with the skills and traditions to prevent predator attacks. In such cases, the perpetuation of this learned tradition would be autocatalytic, continuously recreating the predator-free conditions necessary for its perpetuation.

Another critical theoretical issue is the animal brain's reservation of an initial 250 ms sliding vigilance window for detecting predators. Optimizing the brain regarding such watchfulness compromises an animal's undivided attention to other activities and thus could limit its ability to engage in exact social learning. Conversely, in a predator-safe habitat, such circuits become redundant and, therefore, available for redeployment to other tasks, including those that support team coordination as well as social learning. The issue is discussed later—the point is that predators cast a long shadow behaviourally and neurocognitively over an animal's potential to become different through transmitted culture.

Understanding both physiological detriment and phenotypic change is essential for modelling a species and its evolutionary trajectory. A species in a landscape of fear has suboptimal health, poor juvenile survival, and limited reproduction—unlike the species without predator fear, which has optimal health, better juvenile survival, and less restricted reproduction. Critically, this difference provides different opportunities for innovations to be selected by evolution.

This distinction between an animal in fear versus safety can be articulated using the "roads not taken" concept. Here, an animal has two phenotypes: (i) living in fear, making overly cautious accommodations and adaptations, and (ii) feeling secure, able to fully live and learn, expressing its potential through complex behaviours from social learning and culture. The first phenotype includes detriments and overcautious changes that stop the animal from manifesting its full potential—the one expressed in the second.

Animal proactive defence and its limitations

Animals take proactive predator protection actions. For instance, Brandt's voles in Inner Mongolian steppe grasslands reduce avian predation by shrikes through "ecosystem engineering", which involves cutting down bunchgrass to minimise their predation visits [168].

Many animals directly confront predators through mobbing to ward them off. One study of baboons reported eleven cases of them attacking leopards, four of which resulted in successful kills [169]. Despite this violent retaliation, leopards prey on baboons in all fifteen studied areas [169].

Again, in the Taï forest, chimpanzees:

> If they find the leopard or happen to encounter one by chance, they very aggressively and noisily chase it away. During the study period, Tai chimpanzees were seen to chase leopards away 9 times and to rush the rescue alarm-calling chimpanzees 11 times (twice we saw leopard footprints at the site and twice we heard the growl of the fleeing leopard).
>
> … chimpanzees [were] around another large fallen tree under which the leopard was trapped in a deep and narrow hole. The leopard roared without interruption for the rest of the observation, barking loudly whenever it tried to strike the chimpanzees with its paw. For the next 42 minutes, they settled around the entrance, some grooming, others just sitting or even laying on the ground near the hole entrance. Now and then, females with youngsters neared the entrance and look advantage of the rare opportunity to have a close and safe look at a leopard. Some regularly threatened the animal. Seven times different Chimpanzees were seen to take a piece of a fallen branch and use it as a club, repeatedly trying to hit or stab the leopard in its hole (average, of 4.44 strikes per instance), each time the leopard barked in response and jumped forward out of it shelter to hit the hand of the chimpanzee holding the club seemingly unsuccessfully. But before it could try to escape from the hole the noisy reaction of the group, with a minimum of 3 adults rushing toward sit, forced it back to its refuge. The small entrance hole (about 70 cm at its highest point and narrowing down towards the leopard) prevented the chimpanzees from taking effective action and at 14.32 hrs i.e. 2 hours 22 minutes after the first sighting, they left the site, the leopard silently leaving the hole 11 minutes later. [5]

And the reward for Taï forest chimpanzee violence? As noted in the introduction, "on average an individual will be attacked by a leopard once in 3 years and 4 months and will be killed within 18 years" [5]. The ineffectiveness of their mobbing is discussed in a later section.

The evolutionary implications of effective predator defence

What if an intelligent species developed 100% effective mobbing, niche constructing predator-safe habitats despite living amongst predators that now shunned them? "Cocooned" within its habitat of safety, such an animal could express its previously predator fear "wheel clamped" untapped evolutionary potential—its "road not taken" phenotype.

This evolutionary shift could transform the species, detaching its phenotype from natural constraints to differ fundamentally from its original form—like humans who initially evolved as palaeolithic savannah-dwelling bipedal primates but now lead lives profoundly different from these of their immediate-return hunter-gatherer ancestors.

Predator fear elimination would positively cascade changes:

- Without needing vigilance, previously constrained potentials could be unlocked as better-safe-than-sorry precautionary changes stop with the ending of predator fear.
- As mentioned for songbirds, they would more efficiently forage, better support immaturity and enhance social learning.
- Critically, their lives and brains would no longer be shaped by constant preparedness for brief unpredictable life/death moments determining whether or not they live and pass on their genes. Without predator fear, their attention would be undivided, improving learning and the role of culture in shaping them.

Predator-safe habitat niche construction could be particularly relevant to understanding human evolution (see Box: **Niche construction of predator-safe habitats**). Unlike other animals, humans are rarely surprise attacked by predators as they are shunned. While provoked attacks may occur, such as when humans encroach upon a mother with young or corner a predator, these attacks usually have preceding vocal warnings and unfold more slowly than the instant unexpectedness of ambush or stalking attacks. Humans are not preyed upon for food; instead, predators actively avoid humans. One puma study found that out of 172 approaches to pumas (median distance 20 m), only in 16 instances did the animal “exhibited threat behavior (e.g., hissed, growled, approached, charged)”. Mostly, they left the area (114), watched without leaving (37), or “showed no detectable response” (5). Of the 16 that were threatened, 14 were females with cubs [170]. Attacks in a predator-safe habitat, while not without risk, would not involve being hunted for food.

Box: Niche construction of predator-safe habitats.

> Niche construction is the process whereby organisms actively modify their own and each other’s evolutionary niches. Examples include the building of nests, burrows, mounds, and other artifacts by animals; the alteration of physical and chemical conditions; the creation of shade, influencing wind speed; and the alteration of nutrient cycling by plants. [171]

These constructive processes might also entail an animal altering its niche to stop predation threats. However, upon conducting keyword searches on Google Scholar, I found no connections between the concept of the “landscape of fear” and that of “niche construction”. One reason for this disconnect is that ecologists coined the term “landscape of fear” to investigate the impact of predator-induced fear through animal behaviour on the environment rather than its impact on the animals themselves. In contrast, evolutionary theorists employ the concept of niche construction to explore non-genetic inheritance. Another reason is that the landscape of fear, as a niche, appears to be static and immutable in terms of actions that prey could undertake. As prey typically react by fleeing or fighting back when attacked, they are not commonly viewed as proactive in altering their risk of being hunted. However, prey can modify their likelihood of being hunted by mobbing predators, thus altering their threat niche. Except for humans, such alterations never achieve the 100% shunning effectiveness required for a predator-safe habitat.

The concept of a predator-safe habitat in terms of niche construction is also negative—it focuses on what does not occur but could—which could lead to criticisms of it being non-constructive. Nevertheless, Odling-Smee, in his original definition of niche construction, included the possibility of negative changes. In his 1988 paper “Niche-constructing phenotypes”, he explicitly clarified the term “construction” by adding “the proviso that it also implicitly refers to its negative aspect, niche destruction” [172]. Did *Homo* niche deconstruct its landscape of fear?

Constructing predator-safe habitats could profoundly impact human neurocognition by freeing brains from constant split-second predator detection/reaction needs. This shift could associate with human interbrain coupling advancements like turn-taking, developing cognitive alignment, shared intentionality and split-second coordination—skills necessary for effective predator mobbing, enabling predator-safe habitats. Reduced predator fear thus leads to neurocognitive developments, further securing fear-free living in a self-perpetuating manner.

Recognizing predator-safe niche construction’s theoretical significance could revolutionize paleoanthropology. The landscape of fear incapacitates primate behaviour and evolution. Primates, especially intelligent hominids, possess vast, untapped “roads not taken” potential suppressed in landscapes of fear. Humanity may only exist because innovative *Australopithecus* unlocked this constrained potential for novel genetic and cultural evolution.

Predator fear and the primate “road not taken” phenotype

Examining hominids reveals powerful predator avoidance influences on their lives [173–177], with them developing complex strategies minimizing predation risks affecting sleep [30], foraging and eating habits [178], and social structure [5,179]. This predator-driven intelligence and adaptation can be attributed to the particularly severe impact predator harvesting has on slow-to-reproduce primates—low fecundity and long maturation cause high sensitivity even to low predation (see **Box: Life History, population equilibrium, and predator harvesting**). Even if primates make up only a small part of a predator’s diet, such predator “harvesting” strongly favours the development of greater intelligence in primates so they can better avoid and counter predator attacks.

Box: Life History, population equilibrium, and predator harvesting

Life history concerns the relationships between factors such as the number of offspring, their size and sex ratio, timing of reproduction, age at maturity, overall size, and lifespan. Such factors exist in a balancing relationship with predator-caused mortality. This adjusting relationship is a kind of “hydraulic challenge” or equilibrium based on Le Châtelier’s principle in which life history factors counteract in response to changes in predation mortality. These adaptations may include increased reproduction rates to offset predator losses, greater investment in anti-predation measures, and larger group sizes for enhanced detection and defence. Critically, when animals have low reproductive rates, long periods of maturation, and significant investment in their offspring, they become highly sensitive to even low levels of predation. This heightened sensitivity is independent of the animal’s value as a food source for predators; the animal merely needs to have a small population size and be hunted occasionally. One way primates have adapted to this sensitivity is by significantly increasing the sophistication of their anti-predator better-safe-than-sorry adaptations.

Life history factors let us retrospectively assess an animal’s sensitivity to predation and so whether they had effective or not strategies for reducing losses to predators. For instance, if a species in the fossil record exhibits notably low reproductive rates, prolonged periods of reproduction, and increased investment in offspring, one can infer that it also developed highly effective means of limiting predation. Early *Homo* species, I suggest, not only show such sensitivity but intensified it by adapting to life in the savannah and abandoning adaptations, such as tree-nest building, that had protected their *Australopithecus* ancestors. They also lost physical features like longer arms and larger jaws, which provided some means of defence against attackers. I argue elsewhere that endurance running comes with a Faustian Bargain trade-off: it makes *Homo* species more vulnerable to predator attacks due to their easily punctured but exertion-heat removing skin.

Therefore, it can be inferred that the emergence of *Homo* is closely tied to the ability to construct niches that mitigate the risk of predation—a terrestrial example of the anthropic principle. If such niche construction had not occurred, *Homo* would have faced early extinction, leaving no humans to ponder their origins two million years later.

Despite their vulnerability to predators due to life history, primates display advanced intelligence. This intellect allows compensatory adaptive, flexible behaviour, making them more effective than other animals at limiting predation. (Arboreal life, of course, developed to minimise ground predator exposure.) However, while these adaptations improve survival, they also paradoxically and profoundly widen the gap between primates’ expressed and untapped potential cognitive abilities that could emerge in predator-safe niches.

This cognitive gap is not just theoretical for primates; many in captivity exhibit new cognitive skills. For example, Kanzi, the predator-free bonobo, developed language absent in his “landscape of fear” counterparts [180].

> [Kanzi] displayed an understanding of the possessive structure, adjectival modifiers, anaphoric pronouns and clausal modifiers. This comprehension has been documented under conditions that require syntactical processing. [181].
>
> [These abilities are shown under a handicap as he and other symbols using apes] employ a symbol board instead of their natural vocalizations, their productive utterances are much shorter and simpler than the English syntactical constructions they comprehend. Nonetheless their productions follow grammatical rules that reflect English word order. … Their comprehension skill extends to the conversational level and includes understanding of narrative dialogue. [181]

One study on the potential of chimpanzees and bonobos raised with interactions similar to human children found that they

> proved to be quite capable of acquiring human-like cognitive abilities in many domains. Perhaps the most interesting area of comparison is the three tasks involving communication (Comprehension, Production and Attention State) …. In these three tasks, the apes showed no significant differences from the human children in the first two measures and actually outperformed the children on the third measure. Clearly these apes were sensitive to the highly communicative culture in which they were reared and gleaned the necessary knowledge from their early experiences to develop highly sophisticated communicative capacities. Similar observations of the facilitative effect of enculturation on social learning have been reported in studies of imitation. [182]

Similarly, studies on captive chimpanzees and bonobos show they can learn through demonstration, an unobserved wild teaching method [183]. As discussed later regarding shared intentionality origins, social games like peek-a-boo do not occur in the wild but feature in some captive apes’ lives—Washoe even learned the ASL “peek-a-boo” sign [184].

This evidence implies predator fear inhibits potentials in the wild that could otherwise prompt revolutionary cultural developments if animals escaped their landscape of fear and its phenotype wheel clamp.

One theoretical consideration is the extent to which observed behaviour in current wild primates reflects their behavioural repertoire when living in a landscape of fear, as opposed to now, when many live in environments where predators have been eliminated. What we observe in the “wild” may be modern, not ancestorial, animal behaviour.

In conclusion, scientists studying primate evolution examine animals with untapped potential due to ineffective predation measures. Kanzi potentially reveals the tip of cognitive abilities enabled two million years ago upon achieving predator freedom.

Homo predator-safe niche construction: Theoretical consequences

I propose *Homo* diverged from *Australopithecus* approximately two million years ago when a group discovered how to get predators to shun rather than attack them. This precipitated a revolutionary shift from a landscape of fear to a predator-safe habitat. If songbirds learn more songs without predator fear, australopith social learning might also be amplified in a predator-safe niche. This niche construction change could, therefore, trigger a domino sequence of cumulative culture, faithful social learning, hypercooperation, larger brains, and Lower Palaeolithic technology in a niche construction cascade, each exponentially developing the other (see my "Human neuromaturation, juvenile extreme energy liability, and adult cognition/cooperation" [185]).

Thus, *Australopithecus*, now *Homo*, could redefine animal potential and boldly venture where no species had gone before. This transformation led to innovations like Einstein's relativity, nation-states, the Anthropocene, language, and Hamlet's self-aware "to be or not to be" soliloquy (see introductory graphic abstract). Everything we are today, including the reader pondering how to take these ideas further, resulted from this dual niche construction cascade.

This niche construction genesis could explain human distinctiveness despite biological similarities to other species. We are, after all, the only species aware we are aware and find ourselves "puzzlingly different". Would a chimp seek to read this work?

5. HUMANS: EASILY KILLED BUT SPURNED AS FOOD

> *Humans, compared to other savannah species, are more vulnerable yet paradoxically ignored for predator attacks as food. Erect posture, lack of natural weapons and easily punctured skin make humans easy prey, yet predators like lions and leopards shun even defenceless sleeping humans. If attacks happen at all, they occur defensively in panic or as fallback scarce prey food. Solving this vulnerability-immunity paradox is key for human origins science.*
>
> *Behind this paradox is an antipredator conflict dilemma—coloured sclera camouflages eyes from predators but hinders team coordination, while white sclera enables coordinated defence but aids predator attacks on individuals. As these strategies are mutually exclusive, an evolutionary XOR fork exists. Diverse factors accompany and reinforce this impasse. However, once initiated, white sclera's group defence makes its selection self-sustaining, unlocking predator-fear wheel-clamped cognitive potentials for social learning and cumulative culture. Evolution innovates blindly based only on prior events, unable to foresee future creative possibilities.*

Vulnerability to predators

> We evolved the ability to survive, day and night, on the ground in the absence of trees, despite being surrounded by large predators. We are the only primate to do so. How does a day-active ape, with a weak musculature and regressed climbing abilities, with poor to mediocre night vision, incapable of hard biting, disarmed and harmless, a fat and historically tasty morsel for predators, survive on the ground with many night-active predators? And survive night after night for decades, despite menstruation, births, the crying of babies, snoring, or the scent of wounds acquired accidentally in the course of daily activity? And predators do zero in on wounds! How did we evolve long hours of deep sleep? And what does one do when meeting predators during daylight where there are no trees to climb? What did we do to survive and thrive, that hundreds of primate species failed to achieve in millions of years, in so gigantic a continent as Africa? Moreover, there were more than twice as many large predator species in African then as there are today. Finding ways to reliably escape large predators on the ground, night and day, was thus the crucial first step in human evolution. Valerius Geist [186]

Valerius Geist, here, highlights *Homo*'s predator paradox. As animals, humans evolved defenceless against predators yet venturing into risky predator environments. Though rarely discussed by paleoanthropologists, Darwin noted it in *The Descent of Man* [187]. He described humans as:

> one of the most helpless and defenceless creatures in the world … defenceless … weak creature … slight corporeal strength … little speed … want of natural weapons.

Darwin suggested that these vulnerabilities were

> counterbalanced, firstly by his intellectual powers, … and secondly by his social qualities which lead him to give aid to his fellow-men and to receive it in return.[187]

In addition to intellectual capabilities, he also included the ability to create "weapons, tools, &c". He then raises our core question: how did the "early progenitors of man" survive "dangerous beasts" given they "lost their brute-like powers", becoming more "helpless and defenceless" than their more advanced descendants (he mistakenly calls them "savages")? His solution was a special "warm continent" or "large island" where "they would not have been exposed to any special danger".

> No country in the world abounds in a greater degree with dangerous beasts than Southern Africa; no country presents more fearful physical hardships than the Arctic regions; yet one of the puniest races, namely, the Bushmen, maintain themselves in Southern Africa, as do the dwarfed Esquimaux in the Arctic regions. The early progenitors of man were, no doubt, inferior in intellect, and probably in social disposition, to the lowest existing savages; but it is quite conceivable that they might have existed, or even flourished, if, whilst they gradually lost their brute-like powers, such as climbing trees, &c., they at the same time advanced in intellect. But granting that the progenitors of man were far more helpless and defenceless than any existing savages, if they had inhabited some warm continent or large island, such as Australia or New Guinea, or Borneo (the latter island being now tenanted by the orang), they would not have been exposed to any special danger. [187]

I propose it was not "some inhabited some warm continent or large island" but constructing predator-safe habitats by getting predators to shun them.

Human comparatively defenceless

In his 1980 paper, "How might Early Hominids have Defended Themselves Against Large Predators and Food Competitors", Adriaan Kortlandt provided the most comprehensive review of *Homo* vulnerability [188], noting "present-day paleoanthropologists" rarely mention this issue. The only serious awareness is Joseph Jordania [189–192], an ethnomusicologist who observes: "Virtually no scholar of human evolution has ever discussed seriously how our distant ancestors survived the threat of predators after they descended from the relatively safe environment of tree branches to the dangerous ground" [191]. But apart from him, over forty years later, paleoanthropologists still ignore the question.

There are several reasons why humans and *Homo* are "easy prey".

- Unlike savannah animals such as giraffes and buffaloes with hides and fur over 1 cm thick resisting lion bites [4], human skin readily pieces, lacking this while having
  - (i) "a hypodermal fatty layer (panniculus adiposus) which is considerably thicker than that found in other primates, or mammals for that matter" [193],
  - (ii) no "panniculus carnosus" [193] (a layer of muscle under the skin enabling its twitching), and
  - (iii) a liability to bleed as "no other animal [like it has] skin so abundantly vascularized, not even in the great apes" [193]. As for why humans have such abundantly vascularized skin, see **Box: Endurance running and *Homo*'s integument Faustian Bargain**.
- Humans leave an easily trackable scent trail from sweating and upright walking that predators can follow [194]. Additionally, humans, like other hominids, lack the uricase enzyme [195]. This deficit makes humans mammals that excrete nitrogen as urea, CH_4N_2O, rather than allantoin, $C_4H_6N_4O_3$ [196]. (Oddly, Dalmatian dogs also lack uricase—see the discussion comments to [2].) This distinctive molecular scent difference helps predators track humans.
- Humans have only half the strength of other hominids like chimpanzees [197] and lack natural weapons like horns, claws, and sharp teeth. For example, baboon upper canines self-sharpen to enable bone biting [198]. Even cat tongues have rough, large papillae spines roughened with keratin that "enable the cat to scrape every piece of meat off a bone" and aid in the "laceration of meat" [199].
- Constant postural adjustments are required for humans to maintain an upright posture by aligning the centre of gravity through the head to the heels. While aiding bipedalism, this also makes humans easy to knock down, disadvantaging defence or escape. Moreover, humans risk minor injuries like ankle sprains that temporarily limit mobility. Studies show 73% of athletes have recurrent ankle sprains, with "significant disability" in 59% of cases [200]. Such vulnerability to minor injury is not seen in other hominids. For instance, handicapped yet successful chimpanzees were observed by Jane Goodall at Gombe (reviewed later) [3].
- Hunter-gatherer women have 24-28% body fat; men have 9-18% [201]. In contrast, female and male bonobos have 3.6% and 0.005% fat, respectively [202]. Human newborns start with 15% body fat [203], rising to 26-33% by five months [204]. Fat contains about twice the energy of protein—37 kJ/g versus 17 kJ/g. Some predators, like bears, require fat, unable to live solely on lean protein [205]. (Likewise, humans suffer "protein hunger" without fat [200].) Prey choice involves factors like protein-to-fat ratios [206]. Therefore, humans' high-fat composition could make them attractive prey for predators. (Note that the limit on protein intake might be related to the lack mentioned above of uricase: human physiology has a limit on clearing the nitrogen released from protein of 55 mg urea N/h per kg body weight $^{0.75}$; see [207].)

A picture of Jambo, a chimpanzee at Twycross Zoo primate centre with alopecia causing hair loss, shows the lack of subcutaneous fat in nonhuman hominids. Compared to humans, it reveals their greater muscular development (from Wikipedia).

- Early *Homo* faced three times today's carnivorous predators [208]. (Valerius Geist underestimated.) This decline coincided with rising *Homo* brain size [209].
- *Homo* lost skeletal climbing adaptations [210], indicating abandonment of the safe tree refuge. Trees are scarce in the savannah. And as Kortlandt notes, existing ones:

> often consist predominantly of very thorny *Acacia* and *Commiphora* species. In emergency situations, e.g. if one suddenly came across a large sabretooth cat, a group of hyaenas, a bad-tempered rhino, an aggressive elephant, a monstrous pig, or a giant baboon, it would often be impossible to quickly climb one of these thorny trees. (Some *Acacia* and *Commiphora* thorns can puncture a Landrover tyre!). [188]

Worse, those that are climbable will not necessarily offer safety as leopards and lions often go up them.

> Lions readily jump or clamber into acacia and Kigelia trees and there lie on the broad horizontal branches. They are not adept climbers, and their descent appears clumsy as they slide head-first in a shower of bark down the trunk and finally leap to the ground. I observed lions climb one meter or higher into trees on 127 occasions, a total which indicates the climbing only of vertical trunks, not fallen trees. Eighty percent of the animals ascended to a height of 2 to 5 m and none went higher than 7 m. … Females in particular sometimes ascended trees briefly and there looked around as if scanning for prey. [4]

Note, while acacia trees have thorns (which, like porcupine quills, lions and leopards fear), their broad branches are thornless.

Box: Endurance running and *Homo's* integument Faustian Bargain.

Homo struck a Faustian Paleolithic bargain with evolution. In exchange for bodies capable of sustained, heat-generating exercise by accepting skin vulnerable even to a predator's slightest scratch. This deal stripped us of other hominids' protective fur, making us the "naked ape". The "small print" of this agreement retains hair follicles, but the hairs are fine and barely visible except on the head and some post-puberty areas. Beneath the surface, other changes gave us a highly vascularized, fat-padded skin that easily bleeds and offers little resistance to cuts and punctures.

The term "integument" better describes than "skin", the anatomy protecting our bodies, as it includes the dermis, epidermis, and the presence or absence of fur and structures determining external penetrability.

The highly vascularized nature of human skin supports its cooling function. Blood carries heat generated by muscle activity to the skin's surface, removed by sweat evaporation. This cooling system is essential for endurance activities like running, which massively raises the body's waste heat generation.

Running at 4.8 m/s causes an 18-fold increase in total energy expenditure compared to rest [211]. Converting energy from fuel sources like glucose into force is only ~20-25% efficient; the remaining ~75-80% becomes waste heat. Without effective cooling, this surplus heat could be fatal.

For example, during a 42 km marathon, a runner burns ~4,600 kilojoules (kJ), of which 3,450-3,680 kJ becomes waste heat. If not dissipated, this heat could raise body temperature from 37°C to 51-52°C. 40°C body temperature is life-threatening, and 43°C can kill.

Our furlessness allows air circulation next to the highly vascularized skin, dissipating muscular waste heat through sweat evaporation. Under "normothermic conditions," subcutaneous blood flow is 0.3 L/min, just 5% of cardiac output. However, under "tolerable levels of heat stress," this intensifies 24-fold to 8 L/min and 60% of cardiac output [212]. (Note: due in part to cardiac output increases but also redirection from gut and kidneys.)

While running, people can sweat 0.83 to 1.2 litres per hour [213], evaporating 1,880-2,710 kJ of heat. Higher rates occur; one study found that the average American Football NFL lineman lost 2.285 L/hr ± 0.52, with one individual losing 3.284 L/hr—nearly 6 pints [214].

This skin adaptation prevents heat exhaustion, which stops most other savannah animals from prolonged intense exertion. Equines like zebras also sweat but through different sweat glands aided by a wetting protein, latherin. This wetting agent enables sweat to pass through their coat fur [215,216]. (Latherin causes foaming when wet horse coats are rubbed.)

Endurance running is not the only benefit—cooling also helps walking at midday when external heat makes other animals seek shade or stop activity [152]. Being able to stay cool when others must rest allowed *Homo* a novel opportunity to exploit food resources others could not on the savannah.

However, this heat adaptation comes at the cost of making humans vulnerable to predators. Even minor contact from claws or jaws easily pierce the skin, risking infection (a real danger before antibiotics).

As a result, no human can "wrestle" a carnivore without severe mauling unless it is disabled. This Palaeolithic Faustian Bargain, thus, made us not just naked but defenceless—a double disadvantage since 24-fold increased skin blood circulation during any energy-intensive fight-or-flight would cause any predator injury to bleed like hell.

Humans are slow, unlike predators and most savannah animals

The relatively slow speed of humans makes them particularly vulnerable to would-be predators. Animals might need to run for their lives on detecting an attack, and a predator's success often depends on stopping that by catching them by surprise. A leopard or lion covers 17 metres in just one second [4], and a chimpanzee 12.5 metres in "rough terrain" [188]. (For different animal speeds, see **Box: Human running speed** .)

Box: Human running speed

Savannah animals are fast; a cheetah covers 30.5 m/s, a giraffe or zebra ~17 m/s, and a hippopotamus 15.5 m/s [217,218]. In contrast, humans are much slower. Even Usain Bolt averages only 10.44 m/s in a 100-meter sprint. During the crucial first 10 meters for escaping predators, 100-meter sprinters, however, are only half as fast, reaching their top speed at around 50-60 meters [219]. (Human running speed depends on elastic energy built up in initial sprint steps [220].) Moreover, sprinting on a track is an upper limit, enhanced by modern training and surfaces. For example, Thomas Burke won the first Olympic 100-metre sprint in 1896 at only 8.34 m/s. Ordinary people are slower, with 9-15 year olds averaging 5-6.5 m/s in a 50-meter sprint (Table 4 in [221]).

These speeds occur on smooth artificial surfaces, while the savannah has tripping hazards. Falling is a particular risk for humans, who uniquely run upright (questions exist about whether *Australopithecus* ran comparably to *Homo* [222–225]). Even when not running, humans are prone to falls; about half of 20-year-olds can expect to fall over 16 weeks due to tripping or slipping [226]. A 0.6 meter fall can break the radius bone when landing on an outstretched hand (Colles fracture) [227]. Therefore, rough terrain running will be slower than on tracks, requiring constant attention to avoid tripping.

Interestingly, humans can strike faster than they can run. A middleweight boxer can hit at 11.9 m/s, some at 13.4 m/s [228]. Karate punch speed varies from 6.1-14.2 m/s depending on punch type [229]. One woman's forward reverse punch clocked 25.1 m/s (Table 1 in [229]. A badminton racquet can smash at 94 m/s [230].

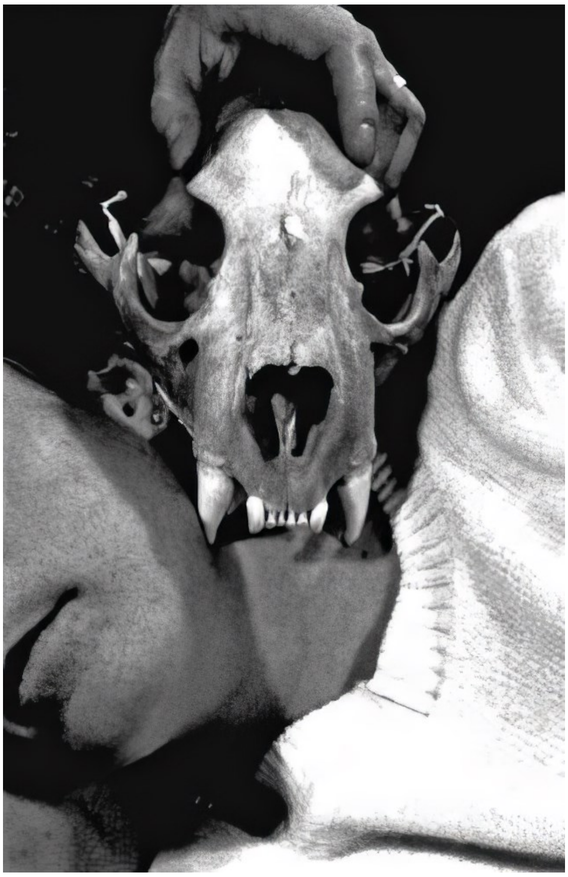
Survival depends on the brain's rapid ability to detect and respond to the onset of predator attacks [231]. This quickness extends to swiftly reacting to sudden changes in predator behaviour, as many prey animals watch distant predators while foraging. Consequently, even a 250 ms or less delay, too brief for awareness, can mean the difference between life or death—either the predator catches its prey or misses, allowing it a narrow escape. (For group members, ultrafast detection and reaction can also promote survival through the “outrun your fellow hikers rather than the chasing bear” principle. However, here it is about “out-quickly reacting”. Herds may share vigilance and signal threats, but faster responses still matter.)

The need for quick threat detection has crucial implications for understanding evolution’s constraints, including human evolution. While a hominid may live around one billion seconds or 32 years [8], its reproductive success could depend on its brain’s ability to detect and respond in unpredictable moments under 250 milliseconds. Natural selection has “designed” the brain to prioritize these brief yet crucial survival moments over all other cognitive functions, even though they are tiny drops in the “ocean” of a potentially decades-long lifetime. Later, I will elaborate on how understanding this unpredictable, split-second threat and its removal unlocked key innovations in human neurocognition.

BROWS (Bullseye Removal Of White Sclera) and sclera masking

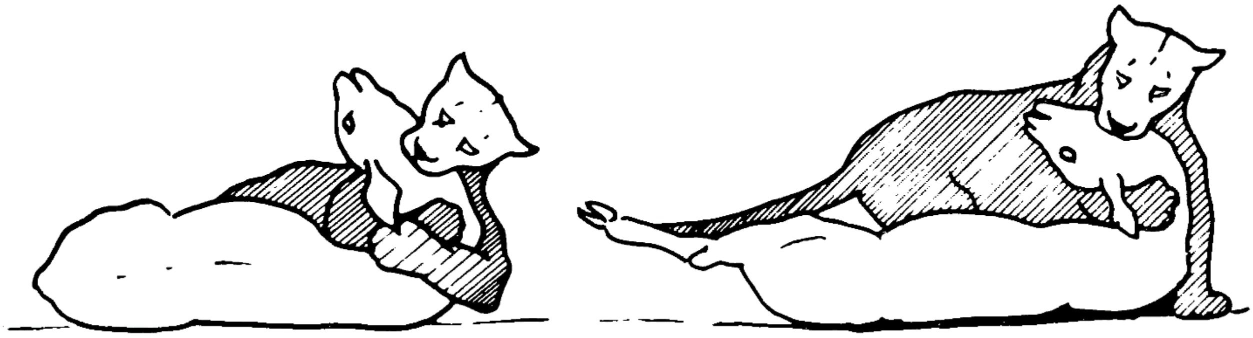
The introduction notes humans don’t camouflage their noticeable eyes with coloured sclera. “Camouflage” comes from the French “camoufler,” meaning “to veil, disguise”. This origin relates to “camouflet,” meaning “smoke blown in one’s face,” from the Italian “camuffare,” meaning “to muffle the head”. This etymology makes it fitting to discuss coloured sclera as head camouflage aimed not at invisibility but at muffling eye conspicuity.

Coloured sclera muffles prey eye visibility, which otherwise helps predators target strikes. This visual hindrance benefits prey at two key stages: first, when the predator chooses a victim, and second, in the crucial moments of dodging the predator’s claws and jaws. Predators usually target the neck, carotid arteries, and windpipe, making conspicuous eyes and exposed teeth a focal asterism ⁂ “bullseye” for locating them. It acts as a reverse bullseye; predators, except leopards, typically aim to strike the head opposite the eyes. Aiming at this also prevents prey from seeing the attacker during its despatch and defending with its teeth (see photograph).



A photograph of a jaw clamped over the nape from “Fatal big cat attacks”, *American Journal of Forensic Medicine and Pathology* [232].

Primates with white sclera effectively display a “target me” cue for predators by offering a visual guide on where to strike. This targeting risk aligns with the term “bullseye” (according to Wiktionary https://en.wiktionary.org/wiki/bullseye [accessed April 28, 2023]), which “may have originated from the practice of English archers shooting an arrow through the eye socket of a bull’s skull to demonstrate skill”.



A leopard kills a goat from [36]. Related text notes, “[of the goat] …bitten it in the throat, crossed his forepaws over its nape, and is pulling its throat thus to his breast, while simultaneously pressing its head away with his fangs [left]. He holds it like this for a seemingly endless time (though on estimate it cannot have been more than 30-40 secs). The goat trampes a little and is breathing heavily. It really does look like strangulation.”

The biological reasoning is:

(1) Conspicuous eyes in prey function as “bullseyes”, aiding predators in directing their teeth and claws. This visual support helps predators locate the neck.

(2) The throat is the most vulnerable area in prey. Injury here can rapidly cause death by crushing the windpipe, severing the carotid arteries, or breaking the cervical spine.

(3) Predators typically attack the throat from behind, clamping their jaws on the nape. To position effectively, they must quickly spot the head’s front to find the back behind it on their prey. Attacking from behind also potentially snaps the spine.

> Lions prefer to bite the throat and use their muscled forelimbs to hold onto prey, bringing it to the ground. With small prey, lions bite the nape, often breaking the spinal cord, piercing the windpipe, or severing the jugular vein or the common carotid artery. … The method of tiger attacks is very similar to that of a lion. [232]

In contrast, leopards attack from the front (see drawings below).

(3) Blinded individuals struggle when escaping or defending. Knowing eye location also assists—as prey violently fights for life, this lets a predator attack from outside the victim’s field of vision.

(4) This targeting occurs in two phases:

- First, when selecting a victim in stalking or ambushing, predators often have the choice of multiple individuals for a successful strike. Since surprise is key, they usually have just one chance. Therefore, they must pick the one they are most likely to kill.
- Then, during the attack, lightning-fast, precise actions are vital. As prey tries escaping, the predator must execute ultra-rapid, accurate bites and claw strikes to immobilize and kill it.

In conclusion, predators targeting individuals with conspicuous white sclera have an increased chance of executing a fatal, successful attack.

Some further points on how prey affects predator decision-making

Several points warrant discussion concerning the non-aid of coloured sclera to predators.

“Muffling” obscures details predators use to choose prey. This information critically shapes predator decision-making. If a predator has multiple hominids to pick from, it must select the easiest to kill, given the low success odds (see **Box: Most hunting attempts by predators fail)** and injury risk (see **Box: Injury risk in prey and predators**). For stalking or ambushing predators with just one surprise attack opportunity, the stakes are even higher. Therefore, pigmented sclera doesn’t conceal eyes so much as reduce the visibility of what influences the predator’s target choice. Any feature limiting visibility, like coloured sclera, will be strongly favoured, while those that don’t, like white sclera, will get picked and thus weeded out.

This protection parallels “outrun your hikers rather than the chasing bear.” Here, the goal is to “out-muffle” or offer less information, making you a target than other group members. This reduced visibility compared to others especially matters when predators are most active, like at dusk and night.

Box: Most hunting attempts by predators fail.

I insert the failure percentages after the authors success ones.

> Stalking by single lions, driving, and ambushing are equally successful (17-19%) [81-83%], but running by single lions shows a low return (8%) [92%]. When two or more lions hunt together, their success is 30% [70%]. [4] … [Of leopards] attempts only end in kills in 5% [95%] of hunts in the Serengeti, 16% [84%] of hunts in Kruger and 38% [62%] of hunts in Kaudom. [233]
>
> Once a lion has launched itself into the final rush, its chance of catching a reedbuck or topi is 13 to 14% [86-87%], a gazelle, zebra, or wildebeest 26 to 32% [68-74%], and a warthog 47% [53%]. [4]

Predators ignore many potential targets if they judge the odds of a successful meal to be low, and this factor combined with the risk of injury. Prey animals are aware of this.

> Lions in turn recognize their limitations and seldom indulge in futile rushes. On one occasion zebra cautiously approached two male lions on a kill to within 23 m. … Giraffe and buffalo may watch lions pad past them a mere 20 to 30 m away. One night a hippopotamus ambled past two male lions 25 m away as if they did not exist. On another occasion four lionesses rested beneath a bush as a browsing rhinoceros approached; when it was within 7 m the lions retreated 6 m and watched without eliciting a response. [4]

Predators pass up many targets when success seems unlikely, factoring in injury risks.

> Predators are pragmatists in that they pursue the most vulnerable animals, the young and the weak, when presented with a choice. For example, 57% of 190 Thomson’s gazelles killed by cheetah were subadults, as were 70% of 120 wild dog kills. Of 33 adult moose killed by wolves, 39% had some disability. Selection for weak prey is not surprising when one considers the low rate of hunting success of even the most efficient predators. Wild dogs captured all of the Thomson’s gazelle fawns they pursued, but only 38% of the older animals. [234]

I suggest camouflage often hides traits that might encourage targeting specific individuals. While coloured sclera doesn’t conceal hominids, it obscures conspicuous eyes. If present, this could cause predators to pick others—like white sclera individuals. Thereby, nonpigmented—white sclera—eyes get weeded out.

Box: Injury risk in prey and predators.

Nonhuman hominins survive and thrive despite severe injuries. For instance, Jane Goodall observed crippled yet socially and reproductively successful chimpanzees at Gombe. Jane Goodall [3] notes:

> in 1966 there was a severe outbreak of a paralytic disease, probably poliomyelitis. Six individuals died or disappeared during the epidemic, and six others were afflicted and survived as cripples.

She further, however, comments:

> Those who survived adapted well to their various disabilities.

For example, Faben:

> Despite his paralyzed right arm, Faben learned to perform spectacular bipedal charging displays; when Figan displayed at rival males, Faben almost always joined in to help his brother. Indeed, it was Faben who helped Figan to attain alpha position.

And Melissa:

> Melissa was one of the polio victims. Afflicted in the neck and shoulders, for a while she was unable to use her arms for walking and had to travel bipedally. Eventually she regained the use of her arms, but she still cannot raise her chin properly or turn her head. All the same, she is a very high-ranking female.

In 2020, Sting was reported: “a bonobo individual that survived for prolonged time without teeth, without the help of other individuals and without access to domesticated food sources” [235].

In contrast, predators rely on extreme agility for successful hunting. Injuries sustained when attacking prey can impair them.

> Large carnivores may actually be quite fragile. In the absence of any assistance from a social group, a large carnivore may face death if it suffers even a moderate injury that temporarily reduces its capacity to hunt. A swollen paw or a sprained muscle may render a cheetah incapable of capturing its prey—starvation may be imminent. [236]

When they attack their prey, they often get injured.

> Careless and inexperienced lions may be crippled or killed by the horns or hooves of the prey. One lioness with a smashed jaw in the Ngorongoro Crater and a male with a similar injury in the Serengeti possibly were kicked by zebra. I found a lioness dead with a broken leg and one alive with a horn wound in her side, both no doubt the result of a mishap while hunting. Sable, roan, kudu, and buffalo have all been known to gore lions. Beyers’ photographs of a lioness attacking and in turn being attacked by buffalo illustrate how a slight misjudgment could well end fatally for the cat. Mangani found a lion killed by buffalo, and I came across the old skeletons of a male lion and a bull buffalo side by side. Goddard observed a subadult male attacking an adult rhinoceros: “He bit her just above the hock, attempted to hang on, and clawed her thigh. The female wheeled around with incredible speed and gored him twice in the centre of the ribs, using the anterior horn with quick stabbing thrusts. The lion rolled over, completely winded. The rhinoceros then gored the lion once in the centre of the neck, followed by another thrust through the base of the mandible, killing him instantly.” [4]
>
> An adult female cheetah … died as a consequence of capturing a common duiker … [she was] found to be seriously injured (bleeding profusely). The habituated cheetah tried to move with difficulty but remained at the site. …A professional tracker (Master tracker Pokkie Bernadie) was called in to reconstruct the sequence of events from spoor, and discovered a freshly killed, adult female common duiker, with bite marks on the throat characteristic of cheetah kills, approximately 50 m away from where the cheetah was found … the cheetah had a cut to the abdomen that had penetrated the femoral artery. This cut was consistent with a hoof slash as this duiker was hornless … Despite veterinary treatment, the cheetah died during the night, due a combination of a loss of blood and peritonitis.[237]

As one review titled “Dangerous prey and daring predators” summarized:

> Carnivores also appear to be injured frequently by their prey. High rates of fractured canines were recorded for many species of carnivores. These included 5.4% of lions (*Panthera leo*), 9.2% of tigers (*Panthera tigris*), 9.8% of leopards (*Panthera pardus*), 9.6% of spotted hyenas (*Crocuta crocuta*), 9.8% of grey wolves (*Canis lupus*), 17.3% of stoats (*Mustela erminea*) and 12% of weasels (*Mustela frenata*). Since carnivores drive their canines into moving and struggling prey, the observed breakage rates are likely to be due to injuries sustained during hunting. While these data provide compelling evidence that injuries during hunting are common in carnivores, they are certainly underestimates. No data are available for the proportion of individuals injured or killed by prey through injuries to soft tissues or other parts of the body. Such injuries, however, are known to occur. For example, … African wild dogs may incur deep cuts, broken teeth and injured limbs. [238]

Outside eyes, prey appearance may have otherwise evolved to avoid preferential predator picking. For example, primate rump similarity to a face viewed from a distance could confuse predators about front versus back—critical for a lethal neck strike [166]. The lack of a protruding nose structure in nonhuman hominids, including *Australopithecus* [239], could also disorient predators trying to differentiate an animal’s front from its back in certain visual circumstances. These traits may have, like coloured sclera, been selected in a “least-likely-to-be-picked” winnowing of prey by predators.

Limited research exists on factors governing predator prey selection and attack decisions. One "obvious" idea is that predators attack when prey stops looking at them. However, the only citation is anecdotal comments, not scientific literature, about a YouTube video of a lion behind glass "running and attacking" a boy when he turns away (https://www.youtube.com/watch?v=QeB0Wn_vw0M). One empirical study found herring gull selectivity when snatching food depends on the target's gaze direction [53]. Studying predator cognition during actual attacks is challenging—encounters are rarely observed, and predators cannot be directly examined. However, lab experiments with domestic cats and biomimetic "prey" robots with different sclera contrast eye characteristics could help elucidate the impact of eye traits on targeting.

Alongside the "bullseye" factor, other camouflage-related effects may disadvantage conspicuous white sclera eyes (see **Box: Other predator issues disadvantaging white sclera).**

Box: Other predator issues disadvantaging white sclera.

Rapid "I-have-yet-to-see-you" scanning.

Potential prey constantly scan for predators. As Goodall observed of Mr Worzle, "his gaze darted back and forth from side to side. In fact, such scanning is quite normal (unless the individual is very relaxed or concentrating on some task), but the white sclerotics drew attention to the movement" [3]. Critically, this eye movement only happens before detecting a threat. Once identified, behaviour changes—fleeing to a safe location or freezing while staring fixedly at the predator. In the latter, remaining still is key. The predator may be unaware of the animal, and any movement could reveal its location. Also, monitoring to identify unknown threats becomes unnecessary. Instead, maintaining a vigilant, focused watch on the predator helps the prey determine whether it has been spotted.

This benefits coloured sclera as their lack of contrast masks the detectability of rapid eye shifts from predator observers. Coloured sclera induces "short-sightedness" in observers about quick movements. In contrast, white sclera, contrasting the iris and pupil, reveals to those distant the eyes scanning motions. This visible rapid scanning inadvertently broadcasts to a predator that prey is unaware of its presence and still checking for threat. Coloured sclera prevents predators from acquiring this "I have not seen you yet" information revealed by white sclera.

Distinctiveness.

Predator hunting decisions are limited, as they do not receive a comprehensive "J-12" education on optimally effective strategies. Evolution imparts only limited innate biases in prey targeting between generations, supplemented by information from mothers, conspecifics, and hunting experiences of hunting success and failure.

Identifying vulnerable prey like sick, pregnant, or young-caring individuals is crucial for hunting success. However, evolution cannot provide precise vulnerability identification details. Instead, inheritance passes nonspecific general distinguishing traits like smell (wounds), size and appearance. Individual learning builds on such biases. A key general nonspecific shared attribute of the vulnerable (e.g., injured, ill, pregnant, or old) is distinctiveness from healthier individuals. I conjecture this "difference" vulnerability marker selects for attacking individuals who stand out to predators for unrelated reasons. Consequently, prey must minimize visual uniqueness detectable by their predators, lest they target them. One distinctive trait risking standing out is white sclera eyes if conspecifics have coloured ones.

Memorability.

Predators may make multiple attacks over hours on prey. Targeting specific individuals can be advantageous, as predators gain familiarity with their evasion tactics, and they might accumulate weakening injuries. Individual distinctiveness makes it easier to remember previously attacked victims. Therefore, prey benefits from being as unremarkable as possible, lest they be recognized. This safety requires minimizing features that could individualize them in a predator's memory. Avoiding conspicuously unusual eyes like white sclera when conspecifics have coloured ones would thus aid survival by reducing distinctiveness.

Homo shunning-immunity from predators

Alongside *Homo*'s vulnerability, humans uniquely seem immune to predator attacks, reversing the usual predator-prey fear dynamic to make would-be predators wary of their would-be human prey. I propose understanding this vulnerability yet behavioural shunning-immunity paradox is key to unravelling *Homo* origins.

As noted, five Serengeti lions sniffed but ignored Louis Leakey and his colleague. Though not formally studied, lions avoid attacking sleeping humans despite them offering easy meals.

Louis Leakey described a 1931 incident:

> In 1931 I had two students in my first camp at Olduvai, and a lion came, sniffed at them as they lay in their cots, and walked through their tent. He was a hungry lion, but he did not touch them. [2]

He also had an encounter with a leopard while in bed that did make an attack:

> [Louis Leakey in his tent] was laid up with malaria when he became aware that a strange animal had entered the darkened enclosure. As he was too weak to call for help, he watched, frozen with fear, as a leopard came toward him. At the last moment it sprang, tore a pet baboon from his side and crashed away into the night. [240]

This also happened to an assistant to his wife:

> Mary [Leakey] woke in the night to the sound of eight leopards coughing and snorting outside her grass hut. They could smell the Dalmatians inside and padded back and forth, trying to find a way in. Once a leopard did succeed in breaking into the hut of Mary's assistant, Michael Tippet, and carried off his pet baby wildebeest.[241]

In 1955, Elizabeth Marshall Thomas reported lions strolling among sleeping campers:

> three lions walked among us as we slept, sniffed us, and watched us with their yellow eyes, although we didn't know until morning when we found their tracks. [242]

Kortlandt noted,

> many people who slept in the open air woke up without having been eaten and found carnivore tracks around their beds. [51]

While it may be common for Africans to sleep as lions visit and sniff around, I found no non-European accounts. Such incidents might be too routine to note or report. But Louis Leakey recounts a dramatic event with an African named Ndekei.

> We camped at the end of the season beside a rather dirty little water hole called Len Lemoru, between Loliondo and Olduvai, and an incident occurred there that clearly showed the lions' inquisitive nature. After an early supper we lay down next to the trucks to sleep. One of the men. Ndekei, had been running a temperature and feeling rather shivery, he decided to curl up in his blanket by the supper fire, some 20 yards from the rest of us. During the night I woke up to hear handclapping and a man calling "Shoo! Shoo! Shoo!" "What's the matter?" I asked loudly. Ndekei replied, in a voice muffled by the blanket, that he had driven off some animal that had come and sniffed at his head—a jackal, he thought. I jumped up and switched on the spotlight of my lorry. There by the water, just 25 yards away, stood seven magnificent lions!
>
> I warned everyone to keep quite still, and stood by with a rifle in case anything happened. As I expected, the lions finished their drink and after about 20 minutes moved on out of sight. By that time most of the party had gone to sleep again. Ndekei, I must say, had been a bit surprised. Had he panicked and tried to run, the lions would almost certainly have struck him down. page 51 [243]

Building thorny acacia bomas also implies predators generally disregard humans, with structures protecting cattle, not people [244]. This selective defence argues predators rarely view humans as prey, focusing on livestock instead. When targeted, humans seem a "fallback food" eaten only when options are limited (discussed below).

The general predator disinterest in humans is puzzling, given a human body could provide a substantial meal. For example, lions need six kilograms of fresh meat daily [245] and "can eat 18 to 30 kg of meat in one meal" [4]. The average adult male has ~30 kilograms of skeletal muscle [246,247]. So, assuming Leakey and his colleague were of average build, the five lions could each have had around 12 kilograms of meat—enough for two days. This "ready meal" lay on the ground, "plate" ready. However, Louis Leakey and his African colleague "kept very quiet", and the lions walked gently into the night. Darwin's razor remained sheathed from consumable human flesh. This eating avoidance is an ethological anomaly needing explanation (for an alternative viewpoint, see **Box: Man the hunted?**).

It's not that predators never ambush or stalk humans—they might when injured or starving. But generally, they pose far less threat to humans than to other hominids. Had five predators found Mr Worzle asleep on the ground, it's likely Jane Goodall would have discovered him the next day, just a bloody stain and scattered bones.

Box: Man the hunted?

"Just another item on the menu", argues Donna Hart and Robert Sussman in their book *Man the hunted: primates, predators, and human evolution* [248].

As they make explicit, their central argument, articulated in chapter two's title, "Debunking 'man the hunter'", aims to challenge the notion humans evolved as predators. They imply humans cannot have been hunters if humans were prey. But tell that to any mid-sized predator that restricts hunting to avoid being hunted by larger ones, and they will give you a little chuckle. Even large predators get killed by other large predators of their own and different species. Had a predator species reviewed their book, they would write: “Profs Hart and Sussman, come spend a day with us”.

But Hart and Sussman make specific arguments that *Homo* was hunted as prey, which need to be addressed. They identify predation on human remains at Zhoukoudian (Beijing, China) and Dmanisi (93 km southwest of Tbilisi, Georgia).

Zhoukoudian: Based on Boaz and Ciochon [249], they argue, “The extinct giant hyena Pachycrocuta [brevirostris] preyed on hominids in the area, and then brought pieces of their prey home to the cave. There they chewed up the facial skeleton to obtain marrow and broke open the skull vault to get at the fatty brain tissue. Mystery solved”. However, Boaz and colleagues were less conclusive: “Our hypothesis explaining this observation is that the remains were transported into the cave by hunting and scavenging activities of large mammalian carnivores, and then subjected to significant pre-depositional modification, probably primarily by hyaenids” [249]. The evidence is only that “that 67% of the hominid sample shows bite marks or other modifications ascribed to large mammalian carnivores, particularly the large Pleistocene cave hyena, *Pachycrocuta brevirostris*” [249] This interpretation leaves room for the hyenas scavenging already deceased humans. Moreover, a cranial cast re-examination has questioned the hyena scavenging theory: “Exocranial locations of these trauma marks are consistent with patterns of skull damage known to result from violent interpersonal combat” [250].

Dmanisi: “One of the few crystal-clear things that can be stated about Dmanisi is that—whomever they might be—the wandering hominids were preyed on by many large carnivores.” However, the evidence only indicates consumption, not necessarily hunting. There is no “crystal-clear” evidence of “predation by many large carnivores” rather than scavenging. They counter the scavenging argument by noting hyenas are more likely to hunt than thought previously. Yet all predators scavenge when possible, as a taphonomic analysis of *Australopithecus* at Sterkfontein suggests, linking their remains to scavenging brown hyenas [251].

Adrian Treves and Paul Palmqvist [252,253] might also be cited in objection. However, their primary focus is whether *Homo* competed with predators via confrontational scavenging, not providing specific evidence of predation on *Homo*.

One could argue scavenging contradicts my later claim that humans retrieve their dead from predators. However, that is a separate issue concerned with how predators learn to associate scent for tracking from that of living prey. All *Homo* that ever lived at some point died. Palaeolithic humans lacked crematoriums, and paleoanthropology finds suggest no burials and spontaneous dematerialization does not happen. *Something* must have happened to dead palaeolithic *Homo* bodies. Louis Leakey offers a solution consistent with the need to retrieve predator-taken bodies:

> nearly all African tribes threw out their dead to be eaten by hyenas, at least this group of carrion feeders was fond of human flesh. But we discovered that normally hyenas will not touch it until it is putrid. They prefer to wait some 36 to 40 hours after a person has died and been thrown out before eating the decaying flesh. By this time its smell has changed very considerably and is perhaps no longer recognizable as human. [2]

Supporting this, predators start hunting humans after epidemics when normal body disposal leaves them fresh smelling of the living.

> Leopards, unlike tigers, are to a certain extent scavengers and become man-eaters by acquiring a taste for human flesh when unrestricted slaughter of game has deprived them of their natural food. … when disease in epidemic form sweeps through the hills and the inhabitants die faster than they can be disposed of, a very simple rite … is performed in the village and the body is then carried to the edge of the hill and cast into the valley below.
>
> A leopard, in an area in which his natural food is scarce, finding these bodies very soon acquires a taste for human flesh, and when the disease dies down and normal conditions are established, he very naturally, on finding his food supply cut off, takes to killing human beings.
>
> Of the two man-eating leopards of Kumaon, which between them killed five hundred and twenty-five human beings, one followed on the heels of a very severe outbreak of cholera, while the other followed the mysterious disease which swept through India in 1918 and was called ‘war fever’. [254]

In summary, while humans may have been consumed, it was not necessarily as prey, and likely only postmortem when scent had “changed very considerably” and no longer risked predators linking the corpse’s smell to the living. This postmortem scavenging when scent is “no longer recognizable as human” is the likely source of human remains at Dmanisi and similar sites. Therefore, while humans may have been eaten, it was not necessarily because they were hunted.

Contemporary human-predator relationship: respect, not fear

Unlike other animals, humans defend themselves from predators with induced avoidance, not fear reflexes. We respect predators' space, avoiding surprise encounters or triggering chase instincts, especially near offspring. Human predator survival centres on mindfulness, not reaction speed; mutual respect, not ultrafast reactions.

This safety stems from predators proactively fearing and shunning humans. (The reason will be discussed later; we currently focus on staying safe around animals that already seek to evade humans.)

Wilderness guidebooks [255] advise:

- Never get between a mother and her cubs;
- Go in small groups, not alone;
- Avoid going out at night;

If you meet a predator (it depends on the species), usually:

- Stop, stand upright, don't run;
- Face the animal, talk calmly, slowly back away, and leave an escape route.
- Try to appear larger—wave your arms, raise your jacket over your head, and stay higher than the animal.

Predators remain risky, with 88 people in Nepal's Chitwan National Park killed by tigers from 1979-2006 [256]. One review concluded that "worldwide, large carnivores have killed at least 150 people a year on average throughout the 20th century" [257]. However, context is crucial: hippos and crocodiles each kill 500-1,000 annually (a common internet "fact" but I cannot find a specific research source). Just one snake, the saw-scaled viper, causes 5,000 deaths yearly [258], with all snakes (due to only a small minority of 200 out of 3,500 species) causing between 20,000 and 94,000 snakebite fatalities each year [252]. This potentially is an underestimate, as a Mozambique household survey found "increase snakebite incidence levels tenfold and the number of deaths by 30-fold" [259]. Most of these deaths, apart from crocodiles (and a few non-venomous deaths caused by pythons), are not because humans are "considered food to eat".

When and Why Predators Attack Humans

Attacks usually occur when humans unwittingly enter an animal's "critical distance" [20], triggering panic, not hunger. This risk applies to predators like big cats and non-predators like rhinos and elephants. Most animals, predator or not, however, flee when encountered. For example, at night in Laetoli, Tanzania, Mary Leakey wandered out of the camp and nearly stepped on a lioness. Louis recounts:

> I heard two sounds—a sharp cry from Mary and a low feline growl!… In a flash I saw two figures running fast in opposite directions—Mary towards me and the lioness up a grassy slope. The lioness was every bit as frightened… as Mary was. [ellipsis … in original] [241]

George Schaller, in his book *Serengeti Lion,* notes:

> lions usually flee as soon as they perceive a person away from a car. On the dozen or so occasions when I met lions while hiking either alone or with another person, they bolted at distances of 30 or more meters. [4]

Radio-collars show wolves and bears actively avoid humans—wolves keeping 1,200 meters away when approached in calm, quiet conditions [260], and brown bears moving 114 meters (active) or 69 meters (resting) away [261]. Despite collar locations, bears evaded detection by researchers 85% of the time, suggesting that bears are very adept at avoiding discovery.

Human safety depends on being shun-feared by predators. Survival then requires keen observation and listening to prevent accidentally encountering one and triggering panic. Care is also needed to ensure easy escape routes. People should also avoid provoking "triggers". For example, Leakey and his African colleague lying motionless on the ground prevented the sudden movements that might have triggered an attack. Respect for predators replaces fear of them.

Falling prone is particularly risky, as shown in the Las Vegas entertainer Roy Horn's mauling on stage by his white tiger Mantacore. On the October 3, 2003, night when Roy Horn was attacked by Montacore, he initially retained some control over the wayward tiger, but he tripped over Montacore's leg and fell on the stage floor. The vulnerability of this prone position triggered Mantacore to attack Roy's neck. Incidentally, it highlights bipedalism risks—losing balance when attacked by a predator can quickly change one's position from vertical to horizontal, the worst position to make a defence.

While big cats like lions and tigers occasionally attack and kill humans, these are outliers—when the animal has difficulty hunting usual prey due to dental/cranial disease [262,263]. For instance, studies in Nepal found “56% of tigers that were examined had physical deformities” [256]. Attacks also occur when suitable prey is scarce or extinct [262,264], with humans not a normal food source but, out of necessity, a fallback one.

Healthy predators like pumas—mountain lions or cougars—usually avoid places where humans live. They travel 29% less daily and limit their territory by 68% to avoid human areas [265]. This avoidance targets humans specifically, not dogs that may also be present—pumas abandon kills if humans approach but not dogs [266]. During COVID-19 stay-at-home orders, 50% less human movement in California’s Bay Area led to a noticeable change in mountain lion behaviour, such that their “aversion to the urban edge disappeared” [267]. Advice [255], like “Make noise to avoid surprising a cougar” or wearing a bear bell, exploits predators wanting to avoid humans.

Though rare, unprovoked predator attacks on humans happen, justifying their human fear. Rather than live-and-let-live, humans collectively find and kill any predator responsible, stopping any learned “scent-eat” associations that might encourage stalking or ambushing future humans. Consequently, predators that attack or kill humans are hunted down and euthanized.

Given these considerations, the odds of a human being attacked by a large carnivore are extremely low. According to a study in the *Human Ecology Review,* “the risk of a large carnivore attacking a human is relatively low in comparison to other natural threats, such as being struck by lightning” [268].

Evolutionary Paradox: Vulnerability and Immunity

However, a paradox exists in human evolution. Despite becoming more vulnerable to predators in terms of life history sensitivity, humans have put themselves at greater risk by venturing into environments with big game that support large numbers of predators and, thus, where attacks are more likely. Also, an adult human’s flesh can sustain a lion for five days. So why aren’t humans targeted by predators when we’re such easy, nutritious prey?

Only Valerius Geist, Adriaan Kortland and Joseph Jordania have highlighted the core importance of this problem. Jordania sums it up:

> the long and intense pressure from African predators, particularly modern-day big cats and their ancestors, was the crucial evolutionary factor that shaped how we look and behave in the present day.[191]

To grasp the paradox of predator vulnerability yet shun-immunity is to understand human origins. The best explanation is *Homo* found a way to stop predators seeking them for food by getting themselves shunned. *Homo* are *Australopithecus* that took the *Origin of Species* Bible and crossed out: “Thou Art an Ape Who Shall Fear Unprovoked Attack.”

The Valley of Darwinian Impossibility (VODI) and the XOR fork of Eye Conspicuity

In evolutionary terms, nonhuman hominid (coloured sclera camouflage) and human (white sclera signalling to get shunning) anti-predator strategies are mutually exclusive. You either get camouflage from coloured sclera but lose group coordination’s ability to create shunning, or you get white sclera enabling shunning inducing teamwork but conspicuous eyes that aid predator targeting. Darwinianly, one or other advantages, not both—the exclusive Boolean XOR fitness fork.

Several factors initially lockout white sclera selection:

- White sclera benefits groups since predators shun the scent of whole communities. But coloured sclera advantages like camouflage help individuals. If some predators avoid while others don’t, coloured sclera individuals could get both group and individual benefits, causing a free rider problem.
- Scent-based shunning aids nearby rival groups with coloured sclera sharing the species scent, not just the community creating it. This creates an aid-your-competitor quandary.
- White sclera benefits others seeing your line-of-sight even if they have coloured sclera. The benefit, however, can be asymmetrical. Advantaging the line-of-sight seen by the observer does not itself always benefit the conspicuous white sclera broadcaster. White sclera only gets selected, however, if it advantages the white sclera individual. In mixed, competitive groups, visible attention can, therefore, disadvantage white sclera individuals. Those with coloured sclera, for example, can see white sclera’s attention toward desired resources like bananas without revealing

their own interests [269], creating an asymmetry Machiavellian advantage snag.

- Early predators were diverse; some extinct, like sabre-toothed cats, and some still existing today, like spotted hyenas. This complexity creates issues in early anti-predator team coordination evolution. Some predators may shun humans due to group mobbing, while others still ambush and stalk. In mixed groups, coloured sclera individuals could benefit from the shunning yet retain camouflage against those remaining ambushers and stalkers. This creates a stag-hunt predicament.
- Isolated white sclera individuals may have lower reproductive success since visible gaze could seem strange and unattractive to mates. But once white sclera is the norm, coloured sclera individuals might be reproductively disadvantaged instead. This creates a mating lockout dilemma (and once white sclera sustains reproductive isolation it also creates rapid speciation).
- For coordination to advantage groups, cultural evolution to develop effective anti-predator strategies will be necessary. Intimidation tactics must strike a balance, intimidating predators without making them feel so desperate they attack back. Mastering this might need knowledge and know-how traditions filtered by cultural evolution and passed down through generations. Mobbing success would also depend on policies preventing predators from associating your primate scent with edibility (discussed elsewhere). So white sclera advantages might take generations to fully emerge, creating a wrong-end-of-the-cultural-evolution-learning-curve constraint.

Mathematical induction and evolution

Alongside these problems is a chicken-and-egg impasse. Paradoxically, white sclera's advantages require it to already exist to emerge. How do those initial conditions for its appearance arise? Not needing coloured sclera depends on living where predators don't ambush or stalk, weeding out white eyes. Yet that avoidance stems from team mobbing and the split-second coordination white sclera enables. Team success requires being raised by individuals already skilled in team interactions to develop coordinating competence. But how did those team-skilled individuals emerge to provide that team-joining upbringing?

A parallel exists here to mathematical induction, an inference method that French mathematician Henri Poincaré termed “raisonnement par récurrence” (reasoning by recurrence) [270]. In mathematical induction, one proves a base case ($n = 0$) and shows if a statement holds for $n = k$, it also holds for $n = k + 1$. I argue a similar inductive process occurred in human evolution. The link between white sclera and team mobbing shows the “recurrence” but doesn’t explain the initial conditions setting off the chain. It only shows that if the right circumstances existed, they would self-repeat. We know this self-sustaining situation exists since predators shun modern humans. Understanding the starting point differs from understanding the nature of the continuation once begun.

While *Homo* origins initially seem a self-defeating puzzle, it divides into two scientific challenges: (1) understanding sustaining a self-perpetuating cycle and (2) identifying its rare starting events. Speculating on these initial conditions is not difficult. Various factors such as caves, islands, caterpillar secretions (as reported by Christophe and Hedwige Boesch at Taï Forest [6]), and other unknown triggers lost to history could have set the stage for the advantages of conspicuous gaze and team coordination. Once ignited in one location, this chain reaction expands and becomes self-sustaining, like a fire that, once kindled, spreads out across a landscape in an expanding inferno.

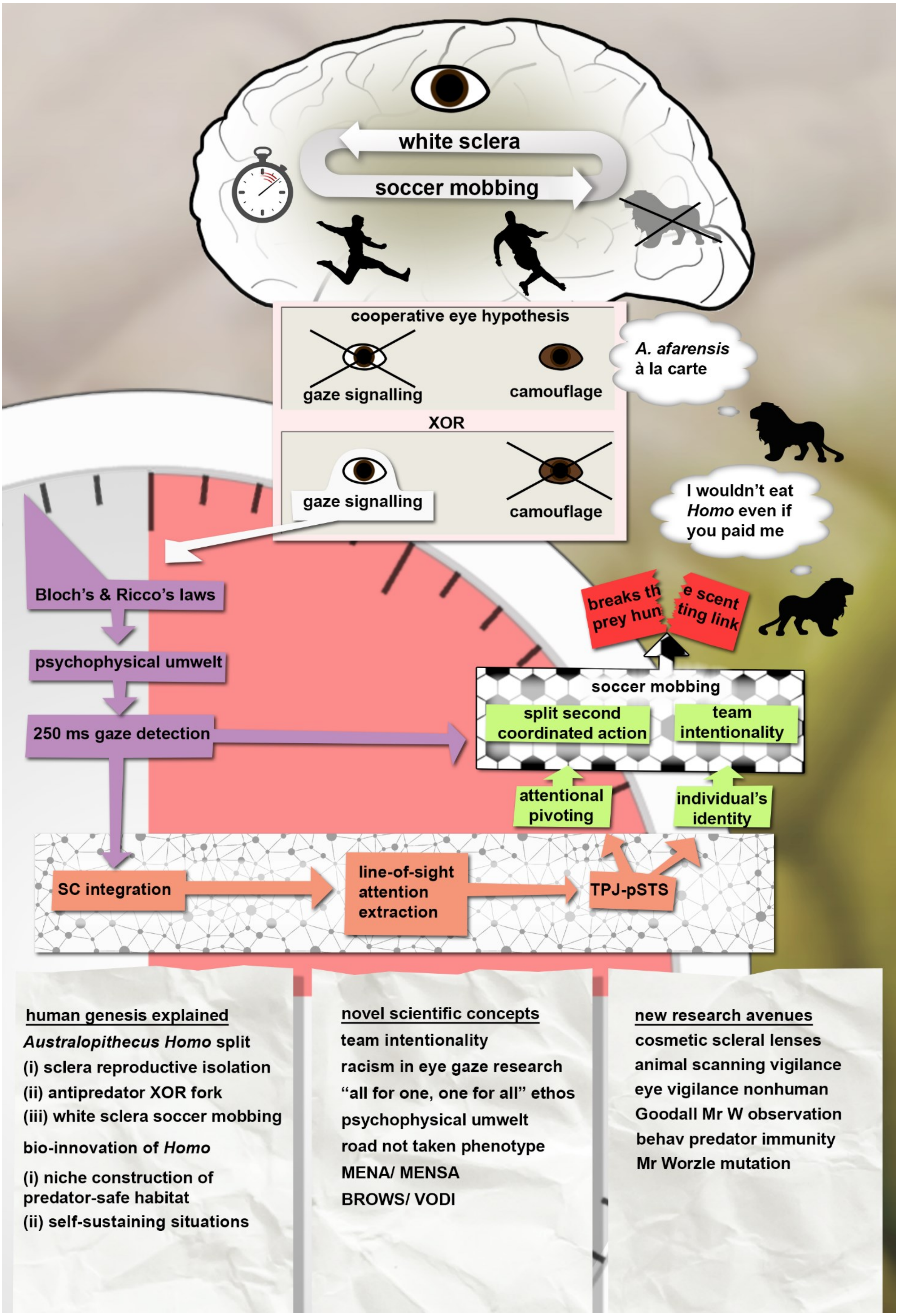
Since we all have white sclera, there must have been an initial “spark” igniting this self-sustaining cycle of team coordination in *Homo*, even if that spark is now lost in the mists of time.

The XOR fork in human evolution suggests that a high threshold had to be met for white sclera to become a self-sustaining evolutionary adaptation. In its early stages, team coordination would be difficult given the complexity of initiating the new antipredator defence. One factor aiding crossing the threshold of its achievement could be the easier line-of-sight detection in dark-skinned individuals. This suggestion raises the possibility that the emergence of *Homo* might have only happened as palaeolithic humans had dark-toned skin and dark-iris facial ratio of 20:100:15, and it could not have occurred if our palaeolithic ancestors had the more recent “two minutes to midnight” one of light-tone skin and light-iris ratio nearer 70:100:65.

Evolution’s blindness

Evolution does not anticipate the paths it might take; its road is what has been—rearview mirror nucleotide “engineering”. As noted above, hominid intelligence is limited in how it gets expressed due to better-safe-than-sorry adaptations. White sclera, however, could unlock latent primate potentials that could be explored, exploited and expanded, leading to a range of biological novelties if only evolution could look ahead. For instance, the freedom to move without regard to predators could lead to better acquisition of high-energy foods. Similarly, social learning among hominids could accumulate, much like song transmission among birds, when free of predator fear. The team mobbing enabled by white sclera could thus aid the evolution of energy-intensive organs like larger brains, support the costly extended maturation needed for development and the more complex skill acquisition created by accumulative cultural learning—the key factors that shaped our species.

However, evolution cannot see beyond fitness valleys in its adaptive landscapes to imagine what gainful or constructive future consequences might exist in those unexplored places. Evolution blindly operates solely on past events, unable to envision or explore what might be—even radical revolutions just a single codon mutation away. It is an unthinking inventor. Studying it examines that DNA non-intelligence and its valleys of innovation impossibility blocking innovation. This is what made "Lord" Vodi intent on preventing coloured-eyed australopiths from becoming white-eyed, lest it unleash trapped primate brain potentials that could transfigure them into humanity.



human genesis explained

***Australopithecus Homo* split**

(i) sclera reproductive isolation

(ii) antipredator XOR fork

(iii) white sclera soccer mobbing

bio-innovation of *Homo*

(i) niche construction of predator-safe habitat

(ii) self-sustaining situations

novel scientific concepts

- **team intentionality**
- **racism in eye gaze research**
- **"all for one, one for all" ethos**
- **psychophysical umwelt**
- **road not taken phenotype**
- **MENA/ MENSA**
- **BROWS/ VODI**

new research avenues

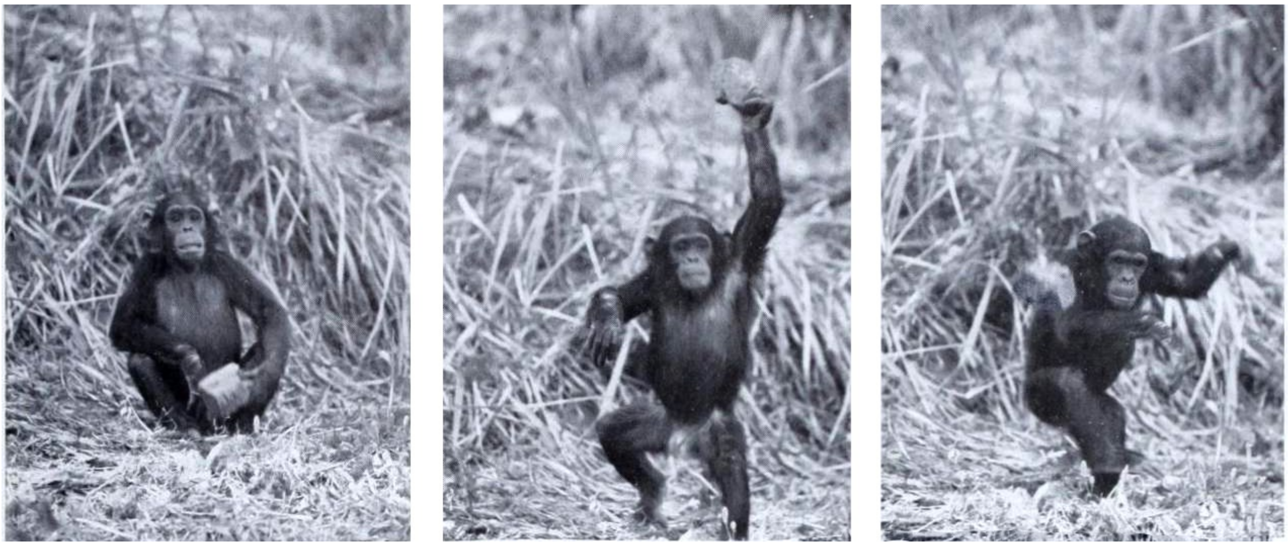
- **cosmetic scleral lenses**
- **animal scanning vigilance**
- **eye vigilance nonhuman**
- **Goodall Mr W observation**
- **behav predator immunity**
- **Mr Worzle mutation**

Illustration displaying connections between coloured and white sclera and temporal neural processing of gaze and predation. Eye-related interpersonal cognitions involve cognitive alignment, shared and team purpose, and split-second coordination.

6. AUSTRALOPITH OLD WINE, HOMO NEW BOTTLE: STICKS, STONES AND SONGS

> *Historical indigenous thrower accounts suggest overlooked human adeptness in combining throwing with unpredictable dodging.*
>
> *Humans vocally imitate diverse sounds—words, melodies and animal calls. Vocal coordination precisely aligns outbreaths and vocal tract articulations into different 8-12 per second sounds. Moreover, such coordination can also precisely align with body actions (dance, drumming, instruments) and chorally with others.*
>
> *Kortlandt proposed acacia thorns enabled "porcupine" predator defence, avoiding paw damage. Supporting this possibility, acacia phytoliths are found on Acheulean handaxes.*
>
> *Brains internally split-second coordinate actions between body parts; humans also externally coordinate groups. A two-way street exists between individual body and collective coordination—precise throwing benefits from games training eye-hand timing.*

Armed—safe-at-a-distance throwing



The three pictures are of Flint (b. 1964 d. 1972) at Gombe, throwing a rock at a camera [3].

Teams need to do more than threaten predators; they must be able to inflict nonfatal injuries that give predators unpleasant and unforgettable experiences. Throwing offers a means to "sting" predators from a safe distance.

Nonhuman hominids can throw objects, but accuracy is lacking. Goodall observed:

> One male, Humphrey, on two separate occasions threw more than twenty rocks in the general direction of another male … Sniff of the Kahama community threw at least thirteen rocks into a ravine where males of the unhabituated Kalande community were displaying. … Aimed throwing may be overhand or underhand: larger missiles are more often thrown underhand, and sometimes launched with both hands. Chimpanzees have good aim, but the missiles often fall short of their targets. …During the 1977-1982 period at Gombe, 412 instances of aimed throwing were observed, sometimes involving more than one missile.
>
> Flint in 1968 was observed throwing thirty times: 60 percent of these missiles were hurled at humans. And Frodo in 1981 threw 74 percent of his eighty-nine missiles at humans. I found ten reports of Humphrey throwing in 1974 and six times the objective was a human. Although he threw fewer missiles, he selected larger rocks than the youngsters and threw much harder—and with better aim.
>
> The Bossou chimpanzees also threw at human observers. They picked branches and threw them, mostly underhand, from the trees above. The adult males showed good control and threw large missiles up to 120 centimeters long and 3.2 kilograms in weight. Sometimes the humans were hit, and the incidents "actually represented severe attacks for the authors. [2]

Adriaan Kortlandt summarises the evidence of throwing missiles by primates at predators:

> Baboons which were cornered have been reported to scoop up and throw sand and gravel at humans and at a crocodile in their way. This could injure the eyes of the opponent. In intimidation displays, both baboons and macaques (particularly ♂♂) have been reported to throw or knock down stones from cliffs and slopes in the general direction of humans and donkeys on a mountain road. Such behaviour was frequently mentioned in the older literature, but it has become very rare in our time, apparently due to the spread of firearms. New World monkeys (particularly the larger species among them) sometimes fling down fruit and break off dead branches in the trees above human

> observers, in areas where they are neither hunted by guns nor habituated to regular observation. The occurrence of this behaviour seems to depend on the balance of curiosity, aggression and fear. Similar behaviour occurs extremely rarely among the Old World monkeys, but according to three reports it has been observed in response to leopards and leopard-patterned cloth. Some orang-utans dislodge large dead branches above humans. Among gibbons, chimpanzees and gorillas the same behaviour also occurs, though quite rarely. However, it was elicited several times in succession by placing a stuffed leopard under the trees. Similar behaviour was performed when a chimpanzee was feeding in a tree top and discovered a living leopard 49 m away. When chimpanzees and gorillas are encountered on the ground they occasionally throw objects in the general direction of the observer, and chimpanzees do the same in hostile encounters with baboons. The frequency and motivation of such behaviour were much higher when forest-dwelling chimpanzees were confronted with an animated stuffed leopard in a clearing, but their aim was still quite bad and no hit was achieved. [188]

The fact that hominids throw stones at intruders, including potential predators, raises a question: Why is not their aim more accurate? One idea was suggested by Charles Darwin

> the hands and arms could hardly have become perfect enough to have manufactured weapons, or to have hurled stones and spears with a true aim, as long as they were habitually used for locomotion and for supporting the whole weight of the body, or as long as they were especially well adapted, as previously remarked, for climbing trees. Such rough treatment would also have blunted the sense of touch, on which their delicate use largely depends. p. 141 [187]

Accurate throwing

The importance of accurate throwing in human evolution gets dismissed because thrown stones cannot kill large animals:

> …the projectile ranges for killing large game are typically between 5 and 40m, with the majority between 10—20m. This is as true for Nunamiut caribou hunters with high-caliber rifles as it is for the Ju/’hoansi with poisoned arrows. From this range, hunters pick a restricted anatomical target on an individual animal, which varies according to the strategic goal of the shot. This anatomical target presents a small window, never a radius of more than 20 cm. … hand-thrown projectiles are not effective for this goal, which necessitates more complex technology, such as spear throwers, bows, and the like. Could a skilled hominid routinely hit with a lethal force this small target window with a hand axe? Highly doubtful.…
>
> Actualistic research offers no link between the archaeological patterning associated with handaxes and the inference that they were lethal projectiles. [271]

The idea still has its supporters, such as William Calvin, who proposed throwing played a role in projectile predation [272,273] or “killer Frisbee hunting” [273]. One advantage is that it “reduces the chance of injury to the hunter, keeps one out of range of horn and hoof” [273]. However, throwing success requires initial pinpoint accuracy since the first throw will cause the prey animal to fly or run outside the aim’s distance. One factor easily overlooked is that while our human integument is not particularly well padded and protective that of other large animals is—they evolved to survive carnivore attempts to bite and claw them. This toughness is also true of predators (see **Box: The Human ability to instantly kill predators is recent**). A lethal hit needs the concentrated force provided by an arrow or spear tip, otherwise, it only bruises.

This limitation does not apply if the goal—as with team mobbing—is specifically not to kill predators—a dead predator will be quickly replaced in a self-defeating way by another that takes over its territory. Instead, the objective is to change behaviour by inflicting memorable and unpleasant experiences, thus asserting dominance over them and receiving respect. Throwing objects from a safe distance allows such intimidation. For example, a pebble striking a predator’s nozzle may only result in a bruise, but its “string” will cause the animal to retreat, teaching it to keep its distance in future from the stone-throwing hominids.

That stones were used by early *Homo* is suggested by the finding of caches of what palaeoanthropologists call “manuports”: stones deliberately taken from one place and left in another:

> stones were found in ‘‘caches’’ which represent small samples of stopping points in a highly dynamic system of flow/transport of rocks across the landscape—in and out of the sites excavated. In the oldest layer, FLK NN3, are 22 unbroken rocks that were collected by hominids some 1·8 mya. Although the range of mass chosen is from 158–695 g, when grouped around units of 100 g, there can be seen a marked preference for rocks around 400 g—the mean is 408 g and the mode 416 g.[274]

Hand grenades have a weight-optimized for throwing distance while remaining accurate range of 230–670 g. Young men selecting among stones of various mass for maximum impact initially pick one of 480 g [274]. A 500 g rock has the same impact energy as a 32-revolver bullet [274]. This weight is more than that of baseballs (142-149 g) and cricket balls (156-163 g men; 140-151 g women)—but the aim throwing in these sports is not impact but hitting within a strike zone or at wickets (while not being intercepted by the other side’s batter). Such caches must have had a role. If not to kill, then what? I suggest to intimidate—like a lion's roar—they do not kill but demonstrate a power that is best shunned.

Box: The human ability to instantly kill predators is recent.

Before the development of modern firearms that can create body cavities, humans did not have the means to quickly dispatch large, threatening animals. Arrows tipped with poison are slow-acting, requiring hours to take effect; long spears must be multiple and organized with traps or corrals. Firearms from before the mid-nineteenth century, such as muskets, are slow to reload and, unless they strike a vital organ, are likely to make a large predator even more dangerous [275]. Historical accounts record that multiple shots could be needed to kill a large predator, even with highly skilled marksmanship.

> Captain Clark of the famous Lewis and Clark expedition used a flintlock rifle on grizzly bears. His largest bear received five balls through the lungs and five balls in other parts of the body, and took 25 minutes to die after this wounding. Tales such as this are legion. A projectile through the brain or the spinal cord will anchor a grizzly, but not a body wound inflicted by lance, arrow, knife, or small-bore, low velocity rifles. [275].

Nor were earlier weapons:

> Killing a bear safely with weapons tipped with stone or bone points is a very difficult task. The first technical problem is that flint and obsidian points on arrows or spears shatter when they hit a bone, while bone points are likely to chip and also fail to penetrate. Stone points do cut very well through soft tissues, as good as iron points or better, but if the projectile is aimed at the heart, it is not at all certain to reach it. From the front, the heart and lungs of a large mammal are so well protected that a projectile would strike bone 90 per cent of the time; from the side, it is still some 50 per cent or so protected. Half the spears thrown will not penetrate to their mark—if such is the heart. [275].
>
> If arrows or throwing-spears are the prime weapons, then even if one does penetrate the animal's chest, the narrow wound channel of such a weapon is not likely to disable a bear, nor kill it quickly. In fact, grizzly bears wounded with narrow cavalry lances remain long capable of sustained attack and die very slowly. Coronado's soldiers lanced a grizzly, pushing the shaft to half its length into a bear. This bear still caught the rider's horse, and while mauling it was run through with a second lance, after which it was apparently lassoed and finally dispatched. A similar incident, in which three Mexicans lanced a grizzly, was reported by Lieutenant Z. M. Pike in 1808; two of the Mexicans were killed by the grizzly and the third was wounded. [275].

Therefore, the option to quickly kill a predator before it could retaliate did not exist until the mid-nineteenth century.

Without modern killing technologies, earlier weapons—such as slings, spear-throwers, boomerangs, killing sticks, and bolas—could only debilitate an animal, requiring hours of waiting for a safe opportunity to finish it off. To do that the specific weapon was less important than the team's ability to coordinate its use from a safe distance.

Unlike attempts to kill, which require precise throws, throwing to cause distress does not need pinpoint accuracy, as it can create a distressing "rain" of projectiles that keep startling it by their unpredictability. Throwing to kill is usually only a one-off opportunity—once the throw is made, the animal will run quickly out of range. Therefore, near-misses in attempts to kill are failures. However, when throwing to cause distress, the purpose is to make the animal run; near-misses that alarm so an animal sprints off startled and distressed but without serious harm are a success. It is, therefore, a feature, not a bug—if a "missed" aim anguishes an animal without causing it life-threatening injury. You do not want to kill predators; you want them to live and shun you. One form of throwing aims to injure, while the other plans to get avoidance.

Rather than killing predators, as other hominids seek to do, the smart thing is to "educate" them through unpredictable disorientating actions that humans "rule" the savannah and, therefore, are a species to stay clear of. A well-coordinated team can throw from different places, making the projectiles unpredictable and keeping the predator constantly unsure of what will happen next. The goal is to create a confusing, unpleasant ordeal for the predator, teaching it to avoid, not approach, the mobbing species in the future. The neurology behind this aversion will be explained in a subsequent section.

Throwing can kill

Throwing, it is worth noting, can be lethal; protective gear is worn for a reason by modern baseball players and cricketers:

> A good baseball pitcher or cricket bowler can throw a ball ≥ 140 km/hr (90 mph). Since 1862, over 100 baseball batters have died after being hit in the head, over 90 batters have died after being hit elsewhere on the body (usually the chest), and over 10 base runners have died after being hit by thrown baseballs (approximately 145 g). Moreover, several cricket players have died after being struck by thrown cricket balls (about 160 gram).[276]

More crucial than killing, however, is the distance at which projectiles can be thrown. Although the average person can throw up to 20 meters without training, specialized athletes can achieve 100 meters or more distances, according to internet sources and historical accounts.

> In 1868 a team of Australian aboriginal cricketers toured England. Their skills need not surprise us, but they are worth noting: cricket balls (225 g) are recorded as being thrown 105 and 130 m, and frequently between 88 and 102 m. Wisden (Cricket Book of Records) notes a throw of 129 m in 1884 on Durham Sands. [277]

Even if humans can't kill a large animal with a single stone throw, they can incapacitate it, allowing for a kill once the animal is down. Stoning doesn't have to be lethal to be effective.

> a Tanzanian camp attendant … surprised a zebra. Picking up a stone, he threw it with such force at the skull that the zebra fell to its knees kicking. … the incident … took place at a distance of 30-40 m, and the stone was estimated to be of a fist's size. … three men were then able to dispatch it with a knife. [277]

Critics of throwing focus on accuracy (needed for killing), but distance is more relevant. Predators might make aggressive charges if their throwing mobbers are near them. An adult lion can jump 12 feet into the air leaping forward 36 feet. Even though animals can sprint faster, humans can out-distance a predator that turns "nasty" after receiving a hit on their snout, given a head start due to their greater running endurance. For instance, a lion sprinting at 17 m/s would catch up to a human running at 8 m/s if nearby but throwing from an 80 m distance only at 151 meters. However, by that point, the lion would begin to slow down due to heat exhaustion, while the human would continue at their fast pace. With a throwing range of 20 meters for the average person and up to 80 meters or more for those who have trained, humans can stone nuisance "bully" predators so they back away intimidated and learn avoidance rather than kill or injure them.

Throwing while agile dodging is the critical human skill

Reports of humans using stones against animals are rare, but there are accounts from the 18th and 19th centuries by Westerners of the throwing skills of supposedly less "civilized" people. These accounts suggest that humans when trained from a young age, possess remarkable abilities to throw while also moving quickly.

> But the most surprising strokes of the Hottentot dexterity are seen in their throwing of a stone. They hit a mark with a stone to a miracle of exactness, though the mark be a hundred paces distant, and no bigger than a half-penny. … I still expected, after repeated successes, that the stone would err: but I expected in vain: still went the stone right to the mark… You would imagine the stone was destined not to err, or that you was destined to see it. … But a Hottentot's unerring hand in this exercise is not the only wonder of the scene. You would be equally struck, perhaps, with the manner in which he takes his aim. He stands not still, with a lift-up arm, an a steady staring eye upon the mark, as we do; but is in continual motion skipping from one side to another; suddenly stopping; suddenly rising; now behind on this side now on that: his eyes, hands and feet are in the most bewildered action, and you would think he was playing the fool, and minding nothing less than his aim, when on a sudden, away of the stone, with a fury, right to the heart of the mark, as if some invisible power had directed it. [Hottentot is a historical term for non-Bantu- indigenous South Africans; orthography modified to modern usage] pp. 243-243, Peter Kolb (also known as Kolben), 1731, [278]

> … as a thrower of missiles in general the Australian stands without a rival he has a singular faculty of throwing stones. … Many a time, before the characters of the natives was known, has armed solider been killed by a totally unarmed Australian. The man has fired at the native, who by dodging about, has prevented the enemy from taking a correct aim, and then has been simply cut to pieces by a shower of stones, picked up hurled with a force and precision that must seen to be believed. … To fling one stone with perfect precision is not so easy a matter as it seems, but the Australian will hurl one after the other with such rapidity that they seem to be poured from some machine; and as he throws them he leaps from side to side, so as to make the missiles converge from different directions upon the unfortunate object of his aim. In order to attain the wonder skill which they possess in avoiding as well, as in throw … it is necessary that they should be in constant practice from childhood. page 729, John George Wood, 1870, [279]

> … the modern Syrians still preserve their old dexterity: I have often heard the tale, and have no reason to doubt its truth, of a brown bear (*Ursus syriacus*) being killed in the Libanus by a blow between the eyes. When the Arab Bedawin are on the raid and do not wish to use their matchlocks, they attack at night, and "rain stones" upon the victim. The latter vainly discharges his ammunition against the shadows flitting ghost-like among the rocks; and, when his fire is drawn, the murderers rush in and finish their work. The use of the stone amongst the wild tribes of Asia, Africa, and America is almost universal. In Europe, the practice is confined to schoolboys; but the wild Irish, by beginning early, become adepts in it when adults. As a rule, the shepherd is everywhere a skilful stone-thrower. pp. 17-18, Sir Richard Francis Burton, 1884, [280]

There's no anatomical reason why early *Homo* could not have had similar agility to dodge about while quickly throwing with targeted accuracy. Interestingly, while throwing is a component of sports like javelin, shot put, and discus, the aspect of doing so while dodge running is absent. Basketball comes closest—as does, in a way, adroit moving about a tennis court to return balls with a racket. Humans are not only precise throwers but throw accurately while unpredictably changing positions—the above quotes identify it as a human athletic skill that could be a sport. This skilled agility could, and perhaps should, be an Olympic event.

Throwing as a skill might have compensated for jaws and claws. Darwin thought so:

> but as they gradually acquired the habit of using stones, clubs, or other weapons, for fighting with their enemies, they would have used their jaws and teeth less and less. [187]

These practised projectile skills make humans unique as the only large species that can offensively harm from a distance without risking counterattack. Mammals like camels, alpacas, llamas, and non-mammals such as cobras and some birds can spit, but these animals do so defensively. Apart from small spiders that shoot venom-laced silk threads and archerfish that squirt water drops at insects, humans are unique in being aggressors while safe from afar, a violent capacity dating perhaps back two million years, long before modern weaponry.

Origins of accurate throwing

> Throwing is one of the few physical skills at which we surpass all other primates. Compared to other primates we are poor climbers, poor jumpers, clumsy runners, and poor sprinters. With training, we can excel at endurance running, but it takes humans about twice as much energy to run a given distance than it does another mammal of equal body mass. In terms of strength, we compare very poorly with the great apes. [281]

The anatomy of the human shoulder may facilitate throwing [282,283], and as Darwin notes, bipedality might play a role. But I propose that it is mainly a byproduct of split-second coordination and team practice.

Pitch and catch is a game all human children play. It is social, promotes shared attention, bonds and is fun. In contrast, when nonhuman hominids throw objects, it is done as part of dominance displays or acts of aggression. Catch coordination as a game has a profound consequence: it fills childhood with throwing practice. From an early age, the thrower learns to time the release of their hand precisely, aiming the projectile so that the catcher can coordinate their movements to grab it in a catch. The receiver, in turn, improves their own throwing skills by observing and anticipatorily “mirroring” the thrower’s movements. Because the game is enjoyable, considerable time gets spent perfecting throwing skills. The result is a proficiency that does not arise—even if it is anatomically possible—in nonhuman apes.

An unexplored yet intriguing subject is the role of white sclera in enhancing the visibility of others’ throwing. This eye trait aids the observing catcher’s brain to determine precisely where, when, and how to intercept a throw. By closely observing the direction, release timing, and kinetics of a throw, individuals, moreover, can improve their own throwing skills through mirror neuron reconstruction of how they coordinate their movements. This observation raises important and researchable questions about the evolutionary role of white sclera. For example, is it easier to catch a throw from someone with white sclera than from someone with coloured sclera? Could nonhuman hominids like chimpanzees improve their throwing and catching skills if they interacted with partners with white sclera instead of coloured ones?

Choral intimidation

> … the ability to mimic low loud sounds [which correlate with large body size], together with imitation of the rhythms, tonal variations, and range of sounds specific to each predator species, would parasitize each predator species’ tendency to withdraw from dangerous conspecifics. A group of early *Homo* individuals roaring in unison, choosing their sound specifically to fit predator and situation, would be overwhelming in signaling stimuli that frightened predators. There could be no evolutionary defense by predators against these sound-mimicking hominids. Any predator who ignored the danger signals emitted by the hominids would probably not be deterred by similar signals from conspecifics. This would greatly increase the predator’s chances of attacking conspecifics and being wounded with the certain loss of reproductive fitness. Any species of predators that shifts its vocal threat signals would only experience that hominids mimic its new vocal threat signals. However, once we grant even a crude ability to mimic sounds, it is but a tiny step to signal the appearance of a predator by imitating its voice. Valerius Geist [284]

Human vocalisation stands out for its ability to make a wide diversity of rapidly changing articulations, creating distinctive sounds in a continuous sequential stream. Unlike birds, which vocalise on individual breaths (except for rapid 30 Hz trills), humans can articulate dozens of sounds at up to 10 per second upon a single breath. Moreover, humans can precisely synchronise these vocalisations with others in a chorus or with their own actions, such as playing musical instruments, clapping, or dancing. Ventriloquists exemplify this by suppressing visible speech movements while timing them to match those of their puppets. No other animal vocalisation, even lyrebirds, has comparable coordination, whether in singing together or synchronizing it with an instrument or their body actions.

Box: Humans possess unique and exquisite vocal abilities.

Human vocalisation is a unique and biologically remarkable skill: unlike other hominids, humans lack laryngeal sacs, setting their vocalisation apart from them. Uniquely, it depends on the thoracic stabilization during vocalization out-breaths of constant pulmonary pressure below the vocal cords, enabling a diverse range of sounds to be generated in sequence during a single exhalation. This form of vocalisation is neurocognitively innovative and aligns with other unique human coordinative abilities, such as dexterity and hyperbipedality, and is due to the expanded human brain, particularly its cerebellum. These innovations are all critically linked to the cerebellum's ability to motor stabilise a framework, within which the motor system can create further complex, agile and skilled movements.

Hyperbipedality refers to the human ability to maintain bipedalism despite massive upper-body and foot perpetuation and manoeuvring challenges. This vertical stability is achieved through rapid postural adjustments against forces that could otherwise topple erect posture by irrecoverably shifting the centre of gravity outside its footing base [285,286]. Human bipedality is far more than merely walking or standing on two feet. It is robustly perpetuation resilient against internal and external disruptions and challenges. This is human unique.

In dexterity, coordination stabilisation occurs when impactful movements of the right hand stabilise the left hand. This phenomenon is evident paleoanthropologically, where a core is held in the non-dominant hand while being knapped with a stone in the dominant hand [287].

In vocalisation, stabilisation is achieved through a consistent pulmonary pressure, "thoracic respiration", maintained throughout our outbreath, regardless of what we say or sing. This constant pressure enables our vocal cords and vocal tract to engage in various exquisitely gymnastic coordinated articulations, each lasting between 140-300 ms, that sound the same whether executed early or late in the outbreath. Check out the International Phonetic Alphabet for the diversity of such vocal track gymnastics.

Beyond ordinary speech, human vocal dexterity extends to phonation without the glottis, as seen in alaryngeal speech or "Donald Duck talk". Humans can also manipulate their breath to produce sound through musical instruments like trumpets, oboes, and flutes. They can use unconventional vocal techniques such as Tuvan overtone throat singing or Silbo Gomero, the Canary whistling speech. This vocal adaptability arises not from our anatomy but from our brain's unparalleled ability to coordinate its vocal apparatus.

An intriguing conjecture raised later is that the capacity for int*ra*body coordination parallels the interbody coordination done in teams. That singing, dexterity, and hyperbipedality involve the body as a kind of team or that the split-second coordination done between team members overlaps in its timed synchronization with that of body parts when working together in vocalization, manual activities and upright actions.

Human vocalization is built on imitation

A critical novelty of human vocalisation is the effortless ability to reproduce the pronunciation of overheard words. For instance, upon hearing an unfamiliar word like a stranger's surname, we can instantly use its pronunciation in our next spoken sentence. "May I introduce myself? I'm John Skoyles." "Hello, Dr. Skoyles." When wearing headphones, we can immediately shadow aloud the spoken words we hear. This ability is so commonplace that its extraordinary nature and critical role in the very existence of language go unrecognised [288].

Impersonators entertain by skilfully mimicking well-known voices, and humans can even vocally replicate the sounds of drums and other percussive instruments [289]. Some even can imitate animal calls—while mimicking animal vocalisations may not have a role in modern human life, it is invaluable for hunters. For instance, it is used by the Mbendjele hunter-gatherers in northern Congo-Brazzaville.

> Men fake animal calls to lure animals to them. Most men competently fake many key animal sounds. I remember watching a group of men passing time deceiving a mother hen by so perfectly mimicking the chirping of her chicks that the she would constantly attack them—to laughter and a gentle shove. Most young men are capable mimics of bay duikers and blue duikers, both very abundant game and popular food. Faking the duikers' call ''come frolic with me'' brings them to within a few meters of the hunter. The confused animal can return again and again, unable to understand why he is not meeting another duiker. Monkeys are drawn out of the canopy into range of crossbows or shotguns by faking the sound of a fallen infant or the call of a monkey eagle. Faking a crocodile's mating call while standing waist deep in sludgy dark water and as return calls gradually get closer requires courage. The crocodile is lured onto a small island in the marsh where prepared liana ropes are used to trap its jaws shut, before binding its limbs. Calling pigs is done when pigs are already close by and involves mimicking

> eating sounds so as to attract greedy animals close enough to be speared. p245 [290]

Hunters often resort to mimicry to coordinate their actions, especially when other sounds would alert their prey:

> Sign language and fake birdcalls are crucial at this stage since all must know where the others are in order to prevent accidents when the action starts. During the wait and subsequent encirclement men only communicate in these ways. Each local group has its own characteristic bird or animal call that men habitually fake. In this way they coordinate their movements without the prey being aware. p244 [290]

Interestingly, while not imitative, chimpanzees emit distinctive bark vocalisations to facilitate cooperative hunts [291].

Mimicry is also made in hunting stories.

> Mbendjele pay careful attention to the sounds of the forest and take pride in mimicking them precisely when recounting their day or chatting. When describing an encounter with a forest animal great attention is paid to the acoustic features of the event—lexical descriptions may be dropped for meticulous mimicry of the sounds of the encounter, from the thrashing of trees, to the calls or hoots of the animal that tell their forest-educated listeners all they need to know. There is a common vocabulary of characteristic sounds that are regularly incorporated into accounts and stories. I call these characteristic sounds of encounters with animals ‘‘sound signatures’’. This is not onomatopoeia. The word for gorilla is onomatopoeic—’’ebobo.’’ This sounds rather like the beautiful ‘‘bobobobobo’’ call gorillas make to know where group members are. However, the sound signatures used most often to represent gorillas are their warning barks—meaning ‘‘I passed near to a male gorilla.’’ Or the characteristic furious retching roar followed by the sound of thrashing bushes that means ‘‘I was charged by a silverback.’’ These represent the typical sounds of an encounter with male gorillas. Juveniles and females are rarely encountered since they tend to flee from people. Hearing these sound signatures while listening to people’s accounts of their experiences both reminds and educates listeners. Younger listeners’ attention is drawn to key warning sounds, and all are reminded of the actions behind the sounds, and what to do or not to do in response. p238 [290]

Other species also engage in vocal mimicry. For example, Amazonian cat predators imitate primate sounds during hunts [292], and blue jays mimic the calls of raptors [293]. Moreover, some birds imitate other animals. Bower birds imitate “the calls of the Australian Raven *Corvus coronoides* and of *D. novaeguineae*, which are predators of eggs and young birds” [294]. Lyrebirds can mimic the sounds of mixed-species flocks mobbing a predator, including “two individuals calling at the same time … calling from different distances … [and] the wing beats of small birds performing short flights” [295]. These have been heard during courtship and copulation but not as yet in defence [295]—an event that would be challenging, due to its rarity and nature, if it occurred, to scientifically observe.

Effectiveness of choral vocalization

Elizabeth Marshall Thomas has proposed that hunter-gatherers’ trance chants may serve a protective purpose.

> animals who gather in groups to vocalize do so because they want their distant rivals to know that they are many. It must be daunting to lions, for instance, or wolves, or howler monkeys to hear large groups of their own kind vocalizing in the distance. We won’t go there, they tell themselves.
>
> I then wondered if the Ju/wa trance dances once had a similar function. Very few things made loud noises in the Kalahari, where even the wind is quiet. Not counting overhead thunder, lions were the loudest, and ostriches roared almost as loudly as lions, so the sound of a trance dance was probably the third loudest noise to be heard. The sharp sound of women clapping seemed to carry almost as far as the sound of the large West African gonglike talking drums, and the singing was pitched at about the same frequency as a scream—a sound intended for long-distance travel—so, in the dry, cool air and utter silence of the African veld at night, a group of people holding a trance dance could be heard for many miles. If a lion can be heard at twenty miles, the sound of a trance dance might travel almost that distance. So it is not completely impossible that at one time, such cooperative sound making served the same purpose as that of other creatures, a notice to others far away that a large group was present in a certain place—present, vigorous, and very much united. pp. 271-272 [296]

Edward H. Hagen has proposed [297,298] the “credible coalition quality signaling hypothesis”, which argues cooperative humans used synchronized singing in

> signaling detection and defensive capabilities to external threats, be they predators or conspecifics, so as to deter their attacks. … increasingly cooperative hominins evolved increasingly synchronized visual and auditory displays to warn fellow group members of specific deadly threats and recruit defenders, to credibly signal predators or hominin attackers that they had been detected and would be met with a highly coordinated defensive response, and to signal competing intra- or interspecific groups that the territory was occupied and well-defended by a highly cooperative group. [297]

Can group sound change animal behaviour by affecting perceptions of group size and aggressiveness? The impact of football chants, often called the “12th player”, on referee judgment suggests they can. The home team usually has more supporters in home games, and their louder chants can bias referee assessments. “If football supporters voice that a player was fouled in the penalty box, the referee might misinterpret the biased opinion of the supporters as signals that the player was actually fouled” [299]. Research on games without spectators during the COVID-19 pandemic supports this evaluation bias.

> the standout effect of playing behind closed doors was the significantly decreased severity of punishments for the away team, mainly through the reduced number of yellow cards awarded. This suggests that the referee is normally affected by the social pressure of a predominantly home-team-supporting crowd, punishing the away team’s players more severely. [300]

This phenomenon shows that vocalisations can impact group assessments, raising the question of whether such vocal bias could assist human intimidation of predators by aiding the impression that humans were supersized and capable of violent aggression.

Predators are susceptible to auditory biases when evaluating the risk of attacking a group of hominids, especially if hominid choruses respond with loud, mimicked dominance calls. Exploiting through a deceptive bias without it being discovered as false for two million years may seem implausible. Still, biology is full of examples of animals evolving to use fake warning signals successfully. These include Batesian mimicry, in which nonpoisonous animals mimic toxic one’s warning signals. Males of many species deepen their vocalizations to potential rivals, falsely suggesting they are larger than they are. Nature is the story of evolutionary trickery that plays successfully on innate biases repeatedly without losing its effect. And, of course, choral singers have other cards up their sleeves if their bluff is called, like throwing projectiles at curious predators checking the reality behind the intimidating hullabaloo.

The vocal capabilities of *Australopithecus* remain unknown. Some argue that these abilities evolved with *Homo* [301]. Even if *Australopithecus* lacked advanced vocal skills, they could still make intimidating sounds, as shown by the loud drumming of chimpanzees.

> [Chimpanzees can] drum on the buttress roots of trees, generating low-frequency sounds that can reach distances of over 1 km. Buttress drumming is produced in bouts of beats and is often accompanied by pant hoots, the species-typical long-distance vocalization. … We found individual differences in drumming bouts produced by seven male chimpanzees during travel events as well as in their timing within the pant hoot, and discriminated specific patterns of beats for some chimpanzees. … Together these findings suggest that chimpanzees may be able to choose to encode identity within individual drumming ‘signatures’.[302]
>
> [They can also “drum” by throwing] stones against particular trees, generating a loud noise (“Azng”), often accompanied by pant-hoot vocalisation … The chimpanzees can either ‘hurl’ the stones against the tree, ‘toss’ the stones into a hollow tree cavity and/or between its buttress roots, or ‘bang’ the stones repeatedly while holding the stone in their hands, Occasionally, chimpanzees have been observed drumming the tree with their hands or feet … The stones used … can be as heavy as 3-7 kg (even stones of 17 kg are reported) …[this is done in] an almost ritual manner, such as staring at the tree, swaying back and forward, pant-hoot vocalisation (an accelerating and increasingly louder u:hu:-sound, until a loud scream; up to and including the throwing of a stone.[303]

Drumming can intimidate by mimicking predators’ dominance calls. There even exists a drum known as the “lion’s roar”, which sounds like a lion’s roar (see Wikipedia’s article on “Lion’s roar (instrument)”).

Another sound making would be foot stamping and clamping. Bipedality not only enables this, but when it is hyperpedality and so capable of being done with vigorous upper body movements, it can be synchronically done with other body movements, vocalizations and chorally in dance with others. The Greek word *choros,* from which the English word chorus derived, originally referred to a group dancing in unison.

Kortlandt thorn branch weaponry

Hominids possess the potential to create and use naturally occurring, razor-sharp weapons, as noted by Adriaan Kortlandt:

> under certain conditions, a shield of densely grown thorns carried in the hands and turned towards the predator would probably suffice to protect an early hominid. No carnivore can move as quickly around a man as the man himself can turn his body. Should several predators attack, two or three men standing back-to-back would be able to fend off the assailants. [188]

Kortlandt observed that thorn branches make effective weapons because thorns distress predators much like porcupine quills. As noted, predators can not risk injuries that impair hunting. Even minor paw injuries cripple their ability to eat, as their delicate touch is needed to quietly and stealthy creep up on prey. (Why else would cats have retractable claws if not to avoid interrupting the soft quietness of their paw treads until claws are needed?)

The sensitivity of a lion's paw is legendary, as in the tale of Androcles and the lion. In this story, the runaway slave, Androcles, takes shelter in a cave and saves a starving lion by removing a thorn from its paw. While the story may be apocryphal, Kortlandt, with the help of George Adamson (of *Born Free*—two Oscars, 1967—fame), found evidence supporting that lions dread thorns. They did this by putting meat under thorn branches and observing lions.

> The most striking phenomenon was their obvious fear of hurting the pads of their paws on the spines. They could easily have swept away the thorn branches, or lifted them up, with just one gentle movement of a paw, but they were much too afraid to do so. [He then added] A thorn in a lion's paw can indeed be a great handicap … Normally, however, lions themselves manage to pull thorns out by means of their teeth (George Adamson, personal communication) [188].

Kortlandt notes the potential of thorn branches as weapons.

> There were many varieties of thorn bushes and trees whose branches could be converted into the most horrible hand weapons one could imagine. The so-called "wait-a-bit" trees were densely set with sharp thorns, either recurved or straight, which grew from the branches and twigs in a backward direction, or in pairs, one forward and one backward pointing. … Furthermore there were the "hook-and-stick" species (e.g. *Acacia tortilis*, *A. retinens* and *A. mellifera subsp. detinenr*) which had both straight spines and recurved thorns that pushed the spines into the flesh. Still others, like *Acacia nilotica* and most *Commiphora*, had extremely long spines that could penetrate deeply into the eyes or perforate the abdominal wall. All these thorns and spines were needle-sharp. Some species could be used as a beating weapon, others as a stabbing weapon, like Neptune's trident, and still others could be flung towards the enemy in order to catch him and stick to him. Furthermore there was the whistling thorn tree (*Acacia drepanolobium*) which often grows very dense saucer-shaped crowns that could be used as a shield. A bite of this "shield" by a carnivore would provide a painful mouthful because the spines grow in V-shaped pairs that loosen very easily and consequently might find their way into the gut.
>
> A practical problem could have been the requirement for sharp-edged stone tools with which to cut off branches. However, I found that, with some dexterity, the branches of some species could be torn off at bifurcation points. Dying and dead branches were often brittle enough to be broken off with bare hands, but were still tough enough to be used as weapons. Moreover, dead branches with the thorns still intact were on the ground in abundance in many places. The main tool-making activity which was required was the careful breaking off, using the fingers, of sufficient thorns to get a hand-hold. This would not present a problem to any creature with an ape's intelligence. [188]

Kortlandt observed in tests with savanna-dwelling chimpanzees and an "animated stuffed leopard" and estimated from 16 mm cinecamera film that

> apes used sticks up to 2 m long and 4 cm thick as clubs to attack the same dummy. They inflicted heavy blows with hitting speeds up to at least 70 km/h, probably much higher, possibly even 150 km/h, i.e. sufficient to cause serious injury. [188]

It should be noted lions and leopards can go up acacia trees, but the thorns are at the ends of their twigs, not on the trunks and main branches they climb.

Nonhuman hominids can, therefore, use branches as weapons against carnivores. That is halfway to using thorn branches to end predation by creating predator shunning. Why did it remain only a potential, not an expressed capacity? This "dog that did not bark in the night" is a key question in palaeoanthropology.

Scientific status of Kortlandt's thorn branch theory

With one exception, Kortlandt's work gets ignored by paleoanthropologists and human origin theorists. Despite his arguing for further research, this has yet to happen. That one exception is a theoretical observation about the "construction of protective thorny enclosures similar to 'bomas' used today in East Africa to protect livestock" that it raises as a "hypothesis" and which, like Kortlandt suggests the need for research and that "the presence of Acacia phytoliths … [and] tools associated with them show evidence of Acacia cutting" [304].

It might seem overly speculative to suggest that early *Homo* used thorn branches, especially since no direct evidence exists. However, given their availability, the question arises: why wouldn't they have been exploited? Were they too sharp to handle, or did early *Homo* simply never imagine the branches they found on the ground might be useful? Science risks falling into the streetlight effect/ the drunkard's search mistake—the bias of looking for answers where it's easiest to look—rather than where answers are most likely to be found. What survives from the past is what palaeoanthropology finds, not what prehistorically existed. Fossils are imperfect time capsules, only revealing what was physically able to persist buried for millennia, like knapped stone tools. An entire palaeolithic world that vanished existed alongside these relics, just as critical to their lives as what endures to be excavated.

Suppose we knew nothing about contemporary Africa, but an alien had visited 2 million years ago and showed us pictures taken then of early *Homo* living among trees bearing razor blades and long sharp needles. Wouldn't we infer that our ancestors likely exploited these blades and needles rather than ignore them and their possibilities? Why should our inferences differ when we learn of them not from aliens that visited early *Homo* but from the thorn plants that grow today on the African savannah?

But we require neither aliens nor knowledge of present Africa. When Mary Leakey discovered the famous 3.7 mya *Australopithecus* footprints at Laetoli, she also found fossilized "twigs with thorns": "Organic materials replaced by calcite are widespread at the base of the Footprint Tuff. Lagomorph (?) dung and twigs are the most common calcified materials, Acacia leaves and twigs with thorns have been noted." [305]. (Lagomorphs refer to rabbits and hares.) These fossils suggest that hominids were walking through scattered thorns. Indeed, research on Acheulean stone handaxes finds traces of *Acacia* sp. phytoliths [306], suggesting they were used for woodwork. But for what purpose? The authors propose making "rudimentary spears", overlooking Kortlandt's idea that the acacias were cut to exploit predators' fear of thorns. Perhaps early *Homo* woodworkers had the imagination of these later *Homo* investigators and just used them for "rudimentary spears". But I conjecture if we went back in time and visited them, they would have waived their thorn branch weapons and given a big high five to Kortlandt.

A block of seeds and twigs embedded in tuff collected by Mary Leakey. Taken with slight modification from [307]

Body coordination and team coordination

Team coordination links actions by different people into a larger action. The brain also similarly links the actions of its own body's elements and limbs. Indeed, many actions we consider simple actually comprise multiple parts—some done consciously, others done unawares that lend stability. For example:

- When we speak or sing, we not only rapidly articulate vocal tract movements but also, in coordination, adjust the diaphragm and other chest muscle pressure below the vocal cords so air pressure stays constant from breath start to end.
- Walking requires leg movements coordinated with anticipatory postural adjustments across the whole body to maintain upright balance. Even standing still needs such adjustments to counteract breathing's effects on the centre of gravity [308].
- Knapping a stone requires aiming with the dominant hand while the non-dominant hand grips and counteracts in coordination with the hammer strike's force, ensuring the stone does not move but directs the blow's energy into it.

I will not go further into such coordination as I have reviewed the issues elsewhere: "Respiratory, postural and spatial-kinetic motor stabilisation, internal models, top-down timed motor coordination and expanded cerebellar-cerebral circuitry" [265].

I propose an interaction exists between the coordination of body parts that is similar to that coordination done between individuals. The difference is that brains internally coordinate their parts using timing information communicated through its white matter connections, while pre-linguistic humans had to externally coordinate timing information through line-of-sight gaze and exchanged attention.

- First, even without specific evidence, it is not implausible the process might overlap. Most motor actions at a high level are not effector specific: how we sign our signature with a pen held in our hands is similar to when we draw it with our finger in the air or with a pen between our toes.
- Second, and this is important for understanding evolution, team coordination can feed down onto improved body coordination. The simplest example would be the coordination needed to throw accurately. The best development is constant practice from childhood in pitch and catch games. These involve coordination between two individuals.

I have detailed how team games aid individuals in fine-tuning their body coordination to target projectiles. But the body-to-team principle can also apply to vocalization, where we shadow with our own vocalizations those of another, more experienced individual. By mirroring their sound articulation, we tutor our less skilled competence by scaffolding on their mastery. Imitation is not only the sincerest form of flattery but the royal road to picking up motor expertise.

Another group-individual interaction is that team coordination often weaves together skilled individual performances synchronously. Group dancing requires not just individuals moving together but also those movements integrating into a complex whole. Choral singing needs timing similar vocals yet also combining diverse vocal parts into complex musical unities like polyphony, harmony and counterpoint.

Core to the ability of teams to stop predators from attacking humans is drawing on the highly different skills of its members. Humans show at the ordinary individual level very different abilities to throw, sing, and drum. Some are gifted singers, others tone-deaf. To take drumming as an example, a tiny few are highly skilled due to a professional level, while most people lack any skill. Teams exploit the different abilities of its members to maximize what it can do together as a whole.

One skill I mention—thorn branches—may not seem like a skill, but more an accomplishment. But a marked difference exists between waving an ordinary branch and a spiky, razor-sharp one. Coordination skill in group defence use of them is needed to avoid injuries to self and others. Several individuals fencing off a predator like Greek phalanx soldiers require coordination to avoid slashing themselves while troubling their opponent.

In summary, nonhuman hominids neared possessing many skills that, if coordinated, could effectively intimidate predators. Imagine throwing, singing, drumming and thorn weapons combined, aided by white sclera and line-of-sight, in split-second coordinated mobbing. Predators would learn to keep away. This new anti-predator strategy causing predator shunning, I propose, birthed *Homo*. The science behind how split-second coordination leads to this new strategy now needs to be explored.

7. THE SOCCER HYPOTHESIS

> *Playing football (soccer) offers human evolution insights as it combines split-second team coordination and endurance running in no-body contact contests against opponents, mirroring human predator contests where skin contact vulnerability forced humans to show superior prowess solely by their coordination.*
>
> *Endurance running with head starts allowed escaping faster predators. Like early bipedalism, football requires agile foot control.*
>
> *Football tests prolonged shared split-second problem-solving team coordination. This proficiency requires training, improvement drive, planning, self-discipline, and mutual teammate concern. Humans gain split-second coordination as it is fun—critical for survival practice. Competitiveness and rivalry now fuel human teamwork. Further, coordinated problem-solving gets attentionally mirrored in spectators. Football's global popularity arises from the shared human pleasure in split-second teamwork coordination that initially arose to win from predators shunning.*

Sans time machines

Since time machines don't exist, we cannot travel back two million years to directly observe how nonhuman australopiths and the first *Homo* species, aided by white sclera, mobbed predators. Without time portals, we do palaeoanthropology.

I propose australopiths (like modern hominids) made disorganized, emotional predator attacks, while early *Homo* used shared attention and split-second team coordination to impress and intimidate predators. Understanding what happened would benefit from a modern human team activity by which we can bring into relief australopiths' lack of group control against opponents compared to humans' planned, tactical flexibility and cool-headedness from using coordination to show opponents one's superiority over them. I suggest soccer football.

This game not only requires teamwork against opponents but shares multiple similarities with the problem faced by Palaeolithic humans—broadcasting to opponents through the quality of your coordination—that you are to be respected and not "messed-about-with" while—and this is critical—doing that while avoiding direct physical attack.

I focus on soccer football as it is universally familiar in its key details. However, what applies to this game also extends to other no-contact team sports like basketball, volleyball, and field hockey (but not ice hockey [309]). I call it soccer football rather than just plain "football" since another team game of that name exists in North America, gridiron football (which covers American and Canadian football) see **Box: Soccer football vs American football**.

Unlike contact sports (American football, rugby, Australian rules football), soccer football teams win through split-second coordination, never physical combat. I propose *Homo* mobbing similarly challenged opponents using coordination instead of muscle and fights. In both, split-second coordination substitutes for body-on-body combat. In soccer football, teams win by being more than the sum of their 11 players through superior ball control. If, instead, they make physical contact and obstruction, it leads to free kicks for the opposing team, cutting down the offending side's ability to win.

Box: Soccer football vs American football.

Two games go by the moniker "football." Outside North America, "football" refers to what Americans call soccer (also known as association football). However, in North America, football means American or Canadian football (for simplicity, I will refer to both as American football). These two types of football differ fundamentally. Despite its name, American football involves mostly hand or body contact. NCAA Football Rules state, "A legal kick is a punt, drop kick or place kick … Kicking the ball in any other manner is illegal". It is not a control of a ball by the foot game. A better name might be "run-hold-throw ball." Critically, American football, unlike soccer football, is a collusion contact game—bone-on-bone-slam-wrestle-thud ball.

Another key difference is intelligence location. In American football, coaches and quarterbacks dictate plays, directing players. Each roughly four-second play amounts to only 11 minutes of actual play across over three hours [310]. In football, two 11-player teams must improvise and coordinate for two 45-minute halves without off-field guidance. Critically, during these 45 minutes, both teams must constantly adapt to unpredictable ball movements and opponent actions. Success requires the 11 players to split-second instantly coordinate decisions about ball control.

The term "soccer" derives from shortening "[as]soc[iation]" and adding to indicate agency an "-er" suffix, like "bake/baker" or "teach/teacher." While "association" traditionally refers to football clubs, it aptly describes the on-field coordination agency critical to the sport. This term highlights its team coordination essence. (In addition, it was the term I used in the 1970s at school, while it also conveniently separates “football” from its namesake played in North America.)

My analysis focuses on two main categories: physiological factors unrelated to teamwork—like the lack of physical contact and endurance running’s role—and those derived from or linked to teamwork.

Soccer and human unique physiology: Contact vulnerability

The genius of soccer football lies in integrating three key features into one game:

(i) our vulnerability to physical assault, represented by the no-contact rules;

(ii) our ability to offset this vulnerability through endurance running and skilled bipedalism; and

(iii) what I contend is human survival against predators’ cornerstone—the capacity to demonstrate superior control via split-second team coordination.

In soccer, control is a team’s ability to net the ball, an easily observed and recorded outcome—that once on boards was chalked as goal counts and so literally “scored”.

This emphasis on non-contact is one key reason I distinguish soccer from contact sports like American football. In soccer, the only permissible player-to-player contact is through the ball itself. Any limited body contact occurring aims solely at facilitating ball control. For example, executing a tackle without some incidental “shoulder-to-shoulder” contact is difficult—rules exist, and referees decide when such contact becomes foul play.

The International Football Association Board (IFAB) Laws of the Game are “the same for all football throughout the world, from the FIFA World Cup through to a game between young children in a remote village”. Law 12, which focuses on Fouls and Misconduct, sets the standard for fair and unfair play.

1. A direct free kick is awarded if a player commits any of the following offences against an opponent in a manner considered by the referee to be careless, reckless or using excessive force:

   ● charges

   ● jumps at

   ● kicks or attempts to kick

   ● pushes

   ● strikes or attempts to strike (including head-butt)

   ● tackles or challenges

   ● trips or attempts to trip

   And so on for another 14 pages.

These rules banning collisions and physical attacks creates the game of “the game” by making its success dependent—and only dependent—on team-coordinated ball control.

I propose this ban on physical contact against opponents parallels the Palaeolithic situation where humans could not directly skin-to-fur confront predators but had to rely instead—and only on—their ability to team coordinate. Attacks, jumps, kicks, pushes, strikes and tackles against savannah hunting animals were suicidal, given their thick hides, formidable claws, biting-sharp teeth, and superior strength. Due to the earlier noted Faustian Bargain, human skin is easily grazed and punctured. Humans could always be “aced” by a predator’s contact swipe. Paleoanthropologists have yet to find remains of accident and emergency services, ambulances or antibiotics on the Palaeolithic savannah. If humans were to defeat their “eating enemy” adversaries, like in soccer, they had to avoid body contact—their survival depended entirely on—and only on—like in soccer football—their skill for split-second coordinated teamwork.

Soccer and human unique physiology: Endurance running

Endurance running is another crucial soccer aspect. Excluding the goalkeeper, players cover nearly 11 km in a 90-minute game [311]. This speed equates to about two meters per second, including standing still and walking. They don’t strike each other, but their feet constantly hit the ground.

While we often focus on human intelligence, we shouldn’t overlook our bodies’ evolutionary specialty in our endurance running capacity. The *Homo* genus may not be the fastest savannah sprinters, but it specializes in long-distance endurance running [149–151]. This ability is part of a trade-off I call the Palaeolithic Faustian Bargain: we can run long distances without overheating because our skin—naked and highly vascularized—is easily punctured. Endurance should join “sapiens”—wise—in our scientific name—*Homo* ***patientia*** sapiens. This endurance can offset our lack of speed. For instance, while you can't outrun a lion, given a sufficient head start, you can in a long chase. Lions aren't built to dissipate their muscle-generated heat during prolonged activity. They can sprint short distances, but longer runs would dangerously raise their body temperature, impairing their speed. In contrast, human marathon runners may hit a "wall", but this is a muscle fuel, not a heat dissipation issue.

Human bodies have an almost unique heat dissipation advantage thanks to our sweating ability and lack of fur. Due to sweat and nakedness, human bodies do not face the physiological heat limit that constrains most other animals [152]. (The main exception are horses whose sweat contains a special wetting protein, latherin, aiding its coat surface passage [216].) Evaporation heat enables our bodies to rid themselves of exertion heat—even at the hottest times of the day [152]. When running, people lose between 0.83 and 1.2 litres per hour [213]. This adaptation allows kilometre after kilometre long-distance running without overheating, an uncommon animal capability. For marathons (42 km), the fastest speeds reach 5.8 m/s (the average marathoner is about 2.6 m/s). Humans can run even longer—for instance, Aleksandr Sorokin ran 100 km in just over 6 hours at 4.55 m/s.

Endurance running offered *Homo* subsistence advantages in several potential forms.

- One is persistence hunting [312]. Exhausted animals are pursued and then caught. While modern hunter-gatherers do this, its human evolution relevance is questioned as "it might have been too energetically expensive and low-yield for the benefits to have outweighed the costs" [224].
- However, endurance running has other advantages. Once vulture-alerted to dead carrion, the ability—even in the hottest times—to reach it before other animals (all predators scavenge when possible) is needed [224]. Given the distance, travelling quickly at a fast but steady endurance pace is more important than sprinting speed.
- Another is the ability to travel over large territories searching for infrequent, unpredictable animal (injuries, sickness, age, pregnancies) and plant (rarely fruiting trees) resources. Here, steady, fast speed will increase the scouting range, as will the midday travel ability [152] with energy efficiency (territory patrolling takes a quarter of the energy of some predators [313]).
- A further possibility to persistence hunting is Geist-stalking [284,314], where such running locates animals then ultrastealthily approaches until stunning them with a hand-held stone or projectile-caused falling, allowing further stunning and killing with more blows.
- By enabling *Homo* to venture out during the peak heat times of the day [146] when other animals are shade resting or uninterested in activity, it opens up a new world of opportunities to exploit as a specialist—much like the nocturnal (night) or crepuscular (twilight) niches (but presently unnamed).
- Passive scavenging can merge into confrontational scavenging depending on recentness or carnivore needed engagement to be persuaded from their kill. Confrontational scavenging occurs in modern hunter-gatherers [315].
- Another possibility is "carnivorous" predation like that done by other predators [316–318].

Currently, agnosticism is required about early *Homo*'s subsistence mix. Given the last two would competitively pit *Homo* against its potential predators, I suggest they occurred late in human evolution—only they—and not the others—would have made *Homo* a direct predator rival. Being a nonfood competitor to its would-be predator was critical, I conjecture, to early *Homo*'s survival.

Moreover, endurance running, combined with a head start, offers another advantage. Normally, a faster predator can catch prey as both similarly heat-exhaust. However, slower but sustained speed offsets initial speed superiority, given an initial separation. This situation allows a slower but steady runner to outdistance a faster starter. For example, a lion sprinting at 17 m/s a few meters from a human sprinting at 8 m/s will quickly catch them. But if the human is 80 m away, by the time the lion has reached the human's 80 m point, they've run further away. They gradually converge and meet at 151 m. But that assumes the lion sustains their initial 17 m/s running speed. But the lion will slow due to heat exhaustion, allowing the slower but more enduring human to escape.

However, unless seeking to kill you as prey or a rival, the lion will stop before 151 m, satisfied at having "chased you off" its territory. George Schaller notes that lions running after intruders are not seeking to catch them:

> When a lion pursues a stranger it usually maintains a certain distance, at least 10 m, adjusting its speed to that of the intruder. [4]

In short, lions seek to chase individuals to drive them away rather than pursuing them over long distances. They would be more interested in seeing you dash than catching you.

Soccer football isn’t just about endurance running but also skilled bipedalism. Players cover long distances with precise football foot control. This foot skill requires balance proficiency mirroring evolutionary savannah uneven terrain navigation demands. In both contexts, the brain must think ahead to place feet correctly, whether avoiding tripping or executing a skilful dribble, kick or pass.

Moreover, the brain must act intelligently against an opponent; fleeing and abandoning a companion to a predator is foolish. It's smarter to run, diverting the predator's focus, especially if they can't easily catch you. On the pitch, combining agility and intelligence is critical. A kicked ball moves faster than players, requiring instant coordination. Effective play needs physical dribbling, passing, kicking precision and synchronizing these skills with predicted teammate movements. Players must anticipate current and future teammate positions for optimal coordination, especially during pass exchanges. While individual talents matter, their impact amplifies when integrated with the team's joint intelligence. Only this synergy ensures superior team ball manoeuvring and control.

Team coordination

We are the only team species.

Teamwork requires more than individuals sharing a goal; it needs seamless split-second integration of each member's actions into a unified whole. This principle applies to many human activities. Conversation relies on coordinated turn-taking, enabling informative, enjoyable communication. A child and caretaker playing peek-a-boo must synchronize actions for the suspenseful, "surprising" game to work. Musicians exemplify this by coordinating instruments and vocals to create harmonious, rhythmic, melodic music.

This split-second coordination distinguishes teams from mere aggregates of individuals. In aggregate, each member acts independently, without adjusting their actions to fit together like a mortise and tenon joint. Nonhuman hominids are aware of each other’s actions during mobbing but don’t strategically align their efforts. This disunity results in collective behaviour less than the sum of its parts. Teams may be made of separated individuals, but from the outside, their different movements appear as if made by one thinking, anticipating and “dexterous” agent.

Nor is team coordination simple group synchronization. Animals like geese in “V” formation show unified behaviour driven by basic reflexes rather than intelligent, diverse action coordination. Startling murmurations and fish shoals “dodge” predators with collective “actions” that seem organized but actually stem from automatic brain reflexes to adjacent others.

Discussing “team,” it’s important to note a key British and American English difference regarding collective noun verb agreement. In British English, collective nouns like “team” take either singular “is” or plural “are” verbs, as in “The team is playing well” or “The team are trying their hardest.” In contrast, American English strictly uses singular “is” verbs with collectives, like “The team is trying their hardest.” This distinction isn’t just grammatical; it reflects profoundly different team conceptions. Here, a team is both a singular entity and a collective of individuals—able to function as both singular and plural, coordinating actions to operate as a unified whole while comprised of individuals—"is” and “are”.

What humans do—and other animals do not—is execute detailed tactics in dynamic, challenging contexts rapidly and precisely as a “whole” that achieves a shared desired outcome. Soccer football may best exemplify our capacity for teams, but spontaneous split-second coordination in “the sum is larger than parts” interactions is widespread and fundamental throughout all human lives. Consider the art of conversation—it has a specific purpose: facilitating communication. Participants in a conversation take turns, each adding their own contributions to the unfolding dialogue. These contributions are not isolated; they are coordinated in time and build upon what has already been communicated, thereby evolving the shared discussion that people make as a “conversational team” together. Similarly, when a child and a caretaker engage in a game of peek-a-boo, they share a mutual objective: to provide cognitively enriching entertainment. Their coordinated actions—alternately hiding and revealing—are not just the game's purpose but the means to enjoy it. This coordinated play is a learning “runway” for acquiring coordination skills. Developing teamwork skills, like developing language skills, relies on participatory learning—picking up the unwritten rules and patterns of coordination by observing and interacting with experienced team members.

Connecting these diverse coordination activities is cognitive alignment—playing from the same hymnbook, shared intentionality—seeking a common outcome in which all participate and split-second coordination—mortise and tenon joining the timing of actions into a larger “joint” one. Different individuals do them by detecting each other’s attention and making it a common framework in which they participate either as a common perception, common aim or common act. The hypothesis set out earlier was *Homo* could share such attention because white sclera created conspicuous line-of-sight. This new external information turned existing MENA into MENSA with shared attention they exchanged, leading to human cognitive alignment and shared intentionality. Critically, line-of-sight enables split-second team coordination.

I distinguish between coordination, collaboration, and cooperation. Coordination involves fitting actions “mortise and tenon”-like together into a cohesive, unified kinematic/kinetic behavioural whole. Collaboration involves individuals outside the direct action who give support, like managers, coaches, and teachers, because their observation makes them vicarious “participates” in this “mortise and tenon” joining that can spot mistakes and help improve “fitting” skills. Cooperation refers to the support that aids the team’s ability to coordinate successfully. Examples include providing transport, food, resources, funding and appreciation, such as the “roar” of the crowd after a team scores a goal.

One could expand on teams—and further on the role of rules, leadership, performing set pieces, scores and texts (as when coordinating to bring existing dance movements, musical compositions or scripts to “life”) and myriad other ways by which humans develop team coordination in complex social, entertainment and aesthetic creations. Music might even be an internal world created out of coordinated note entities—themes, melodies, chord harmonies, key changes—working together like individuals, creating a whole that is more than their individual parts. But since these issues touch on most of human psychology—social, developmental and neurocognitive—and a large chunk of the humanities and possibly music theory—I leave exploring them for another occasion.

Soccer Teams and the need for coordination

Football soccer teams present team qualities in pure form. The game’s aim—to score goals—depends entirely on the ability of 11 players to split-second coordinate their actions. The immediate objective may be to get a ball in the other side’s net, but doing that by the Laws of the Game forces competing teams to do that solely by controlling the ball without touching their opponents. Critically, unlike American football, where play-calling comes from the sidelines and plays on the field last only four seconds, the players’ intelligence in soccer is continuously created on the field by those 11 players that mostly (with limited replacements) remain the same. For an hour and a half of play, the game challenges the team to integrate its individual skills into cohesive, single-minded play. The number of goals scored is a straightforward, easily counted measure of a team’s superiority in constantly doing that split-second coordination.

That control is tough. A soccer ball can reach speeds of up to 27 meters per second—6.74 metres in 250 milliseconds. Though slower when dribbled, a kicked ball outpaces players over distance, as evident during games. Moreover, as both teams compete, the ball’s rapid, unpredictable movements make its control impossible by one player. Effective play demands that teammates coordinate their actions in real-time, making split-second decisions for passes, tackles, and positioning. Even the team captain has limited influence; success rests on each of the eleven players’ ability to instantly sync what they do with each other.

That requires the team to think spontaneously together, coordinating as one, not parts, as they continually run, dribble, and pass to score. This coordination needs constant observation of each other, opponents, and the shifting ball. They then individually extemporize using the experience of their and opponent sides as part of a larger entity exploiting and responding to split-second opportunities and challenges.

Aggressive physical contact would shift the focus from such teamwork, which is why the Laws of the Game forbid it. At its core, soccer tests team coordination, the ability to make the team whole exceed its players’ parts.

Soccer’s coordination need echoes Palaeolithic humans’ savannah survival challenges. Faced with quick predators, individuals had no chance—their fragile teeth, easily punctured skin, weak nails and claws made body confrontation suicidal. However, a coordinated team could outwit even speedy, strong predators by manoeuvring as a unified tactical entity. As we’ll see, demonstrating control itself powerfully alters predator behaviour, showing you are more than a feeble, furless biped. Coordination made us savannah “superapes”.

Other aspects of team coordination

Field coordination is the tip of an iceberg. Team coordination for two halves of 45 minutes is not spontaneous—it is the product of hours and days of prematch work. Before a match, the captain and coach will discuss the team's strategy. The players will have practised regularly in friendly matches and skill-focused five-a-side games. After each match, they analyse their performance and discuss how to play better. Spontaneity and coordination on the field rely on constant off-the-field learning.

Humans constantly invent ways to enjoy coordinating together. The activity itself is a reward irrespective of its utility. That is essential since teams that must life-or-death coordinate must first have done much let's-do-fun-coordination together. The evolution of a capacity for team coordination requires a brain's pleasure in coordination. We are the only species that seek to practise team coordination. We like split-second coordinating. It animates us when we meet. We like learning to time better. We do not so much have a team instinct as a team practice one.

I argue that this drive to practice and improve arises from the pleasure of bouncing between each other shared attention. Without this reward in synchronizing attention, nonhuman animals have little incentive to practice coordination. But for humans, sharing attention is joy itself, giving rise to a unique enthusiasm to join teams. Unlike other animals, we don't harbour hatred toward our team opponents; instead, we feel intense rivalry and competitiveness driven by pride and a desire to prove our "unequalled" abilities. Soccer football rival teams shake hands before matches, and most team games afterwards—basketball, American football, rugby and many solo ones such as tennis. Soccer was once an exception to post-game handshaking, but it is increasingly now done. It is often explained by honouring "fair play", but I suggest it is deeper—about contesting opponents to show respect, not hatred. Indeed, the competitions of the original Olympic games in ancient Greece were done as part of celebrations to honour the Gods. This emotional underpinning is distinct from the "hassen auf" hatred the Nobel Prize-winning ethologist Konrad Lorenz described. A shared skill rivalry focus and the satisfaction of well-coordinated interactions fuel our competitive drive.

Teams, survival and value

While football and Maasai olamayio lion hunting may seem worlds apart, Joseph Lemasolai Lekuton has drawn parallels between the sport and his Maasai experience of olamayio lion hunting.

> the goalkeeper for the other team had become a lion to me. The soccer field had become the plains of northern Kenya, the great savanna. I was focused on the lion, and the lion was again looking at me right in the eye. I knew this was my chance. This time I was not going to turn back, to run away. I was thinking, 'What can I do? How can I score a goal?' I was in a trance—an initiated warrior. I had spent so much time preparing to be a man. All the warrior songs were ringing in my ears. And I did it! In 20 minutes I scored two goals. [319]

Although olamayio isn't predator mobbing [319,320], it is a team effort, even though a single individual typically makes the kill. For the surviving lions, it is an encounter that teaches them to respect and shun humans. The team olamayio coordination explains why the five lions left Leakey and his colleague unharmed. Maasai engage in team-based lion hunts after lions attack Maasai cattle. I suggest the lions' memories of such olamayio hunts were recalled when they encountered the two men beside the broken-down car. As they sniffed Leakey and his African colleague on the ground, the lions might have glanced at the broken-down car and wondered if it hid a third human that might organize an olamayio-like hunt against them. Thus, they had a strong incentive not to attack the two men and go gently into the night.

It's crucial to distinguish the stakes in soccer versus Paleolithic predator mobbing. In sports, stakes exist within the game: rewards, accolades, victories, and championship glory. As such, they are like Monopoly play money. This in-game reward can gain real value—often considerably—outside the game but arises solely from following rules and referee decisions. Winning reality exists in the shared game reality—agreeing on playing to its "laws" and acknowledging results. Match-fixing "wins", for example, once uncovered are worthless. In contrast, predator mobbing stakes were existential—life and death—making coordination not an opportunity for a game but a prerequisite for survival.

Bill Shankly, Liverpool FC's manager, observed after retirement (in a 1975 radio interview with the former British Prime Minister, Harold Wilson): "Some people believe football is a matter of life and death, I am very disappointed with that attitude. I can assure you it is much, much more important than that". These words have been widely quoted and faulted. However, the fact that they are widely quoted touches that football, though "only" a game, gets taken intensely seriously as if league position was actually about survival of life and death. I suggest this reflects that soccer football originated in what was once key to survival—the Palaeolithic team's assertion of control to earn respect-dominance shunning from opponent predators. The game turns deadly serious palaeolithic contest into a friendly rivalry. (Shankly's words, it should be noted, are taken out of context: he was making jocular hyperbole to observe that football should never, in fact, be that important. Immediately before these widely quoted words, others go unreported: "I put all my heart and soul into it to the extent that my family suffered. I regret that very much" [321].)

I conjecture that soccer's popularity among contemporary humans, both as a game and a spectator sport, stems from it tapping into its key overlap with what makes humans so biologically unique as an animal—our ability to enthusiastically engage in and play practice—split-second team coordination, particularly combined with endurance skilled and intelligent running. Such coordination originally arose to win respect from predator opponents in the palaeolithic; today, it gets focused in a game that challenges team coordination by players on two sides as entertainment.

Soccer football, in short, showcases, best of all our activities, our unique ability to work together with split-second coordination—no wonder it is known as—Beau Jeu and Joga bonito—the beautiful game. It mirrors the beauty of our uniqueness as animals.

8. THE HUMAN SIDE OF THE STORY

> *Prey use an "exterminate, bloody nose" strategy against predators. Chimpanzees confront leopards, and baboons kill them. However, primate mobbing involves uncoordinated individual actions, which only partially succeeds as predator hunting resists extinction. Hominids were on the verge of an alternative "don't kill, win respect" mobbing strategy that sidesteps extinction resistance by replacing violence with intimidation to win dominance that gets them shunned. Chimpanzees already brandish sticks at leopards and use territorial patrol threats to prevent fights. Their status displays involve drumming, throwing and vocal challenges. Split-second coordination could integrate such activities into a new, effective anti-predator strategy.*
>
> *In parallel, predators display-threaten rival predators as they do their own kind—lions intimidate hyenas like other lions, leading to "armed truces". "Don't kill, win respect" allowed Homo to get "armed truce" predator shunning through calculated, controlled displays of coordination strength. This strategy further requires group solidarity to recover bodies, preventing predators from tasting human flesh and associating Homo with edible prey. The "all for one, one for all" ethos arising initially for defence could then extend to collaborative foraging and cooperative breeding.*

Prologue

> Darwin
>
> … an eagle seized a young Cercopithecus, which, by clinging to a branch, was not at once carried off; it cried loudly for assistance, upon which the other members of the troop, with much uproar, rushed to the rescue, surrounded the eagle and pulled out so many feathers, that he no longer thought of his prey, but only how to escape. This eagle assuredly would never again attack a single monkey of a troop. [322]
>
> Konrad Lorenz
>
> Social animals in particular take every possible chance to attack the "eating enemy" that threatens their safety. This process is called "mobbing". Crows or other birds 'mob' a cat or any other nocturnal predator, if they catch sight of it by day. The survival value of this attack on the eating enemy is self-evident. Even if the attacker is small and defenceless, he may do his enemy considerable harm. All animals which hunt singly have a chance of success only if they take their prey by surprise. If a fox is followed through the wood by a loudly screaming jay, or a sparrowhawk is pursued by a flock of warning wagtails, his hunting is spoiled for the time being. Many birds will mob an owl if they find one in the day time, and drive it so far away that it will hunt somewhere else the next night. [20]

Diverse prey proactively attack their predators, including:

- bluegill fish [323],
- jackdaws [324],
- giant otters [325],
- meerkats [326],
- monkeys [327],
- baboons [328],
- chimpanzees [329]
- bonobos [330]

Chimpanzees have been documented to vocally confront a leopard and take its kill [331]. Mobbing, in nonhominid primates, furthermore, might be culturally transmitted—at least in the case of langurs' reactions to snakes [332].

Nonhuman hominids engage in chaotic, pell-mell *hassen auf* mobbing. That is hate-fuelled individual initiatives done without group planning. It is an "exterminate, bloody nose" strategy described by Darwin and Lorenz above. These prey animals either kill or injure their predators to stave off future attacks. The strategy works by predator elimination or creating memories of pain and fear in them that deter.

Homo replaced this with planned, cool-headed team intimidation, "mobbing". The strategy here is "don't kill, win respect." Predators defer to their *Homo* mobbers—teams get predators to assess them not as puny bipeds but as a dominant animal to be shunned. *Homo* treats its would-be predators not as "eating enemies" but as opponents to be "educated and "persuaded" into keeping out of its way by its greater sum-of-its-individual-parts intimidation displays. It is not about deterrence but deference—creating avoidance respect.

The problem is establishing that such a strategy exists, and it occurred two million years ago due to conspicuous white sclera line-of-sight enabled split-second team coordination. How does that split-second team coordination change what *Homo* brings to the stopping predation problem that is not already done by australopiths and other hominids? What is it about predators and how they interact with other (nonprey) animals—conspecifics and intraguild predator species—that makes this new split-second coordination ability of hominids cause them—but not other hominids—to switch from hunting *Homo* to shunning them?

This question breaks down into two related parts: the *Homo* side of the story (this section) and the predator's side (the next). Competences (the *Homo* side of the story) need to match into opportunities upon which, by interaction, they may have unique effects (the predator's side). The two sections, *Homo* and predator orientated, detail them.

To some degree, the competence and the opportunities they exploit, however, cannot be separated. What is important about the new competencies is their effect on predators, and why predators get changed reflects what *Homo* had the unique ability to do to them. Some duplication, therefore, may exist between these two sections. Moreover, many phenomena need to be covered, requiring that issues are treated from different but related overlapping perspectives.

Critically, my concern here is not just explaining what happened but doing so in a scientifically testable, explorable, refinable way—despite occurring two million years ago. The conjecture aims to get scientists to see familiar issues in new ways and unfamiliar ones as if long known. After the previous section, for example, I hope readers never see a soccer football game the same again, likewise later with entropy and animal submission. Or with the habenula and my "Devil's Inverted Golden Rule"—likely new to readers—which I hope will feel somehow already familiar. My aim is that the reader, despite the speculative nature of this prehistory, can approach it as concrete science.

Nonhuman mobbing

To appreciate how *Homo* altered existing hominid mobbing, we must examine that found in extant chimpanzees and bonobos.

Such mobbing is an aggregate of individual violent ape initiatives.

On July 17th, 2020, at 6:10 am, 19 adult bonobos set off in three feeding groups after a "night-nest party". At 7:40, party #1 found a leopard 10 m up a Dialum tree in an old bonobo nest. Party #2, hearing their calls, ran to join them. From 8:05 to 10:25, the following took place.

> Jack, an adult male, climbs the leopard's *Dialium* tree … An unidentified individual climbs the tree and approaches to 5–7 m from the nest. At this point the leopard jumps from the nest and chases the approaching bonobo away. … Bonobos continue shaking branches, hitting trunks, and screaming at the leopard. … The leopard roars and moves towards any bonobo that approaches to within 5 m. Emil, Jack and Flora are most active in harassing the leopard from near this distance. … Whenever the leopard leaves the nest and roars to try to displace the arboreal harassers, terrestrial bonobos respond by jumping back into trees and joining in the chorus of screams and barks.
>
> Jack moves nearer, and displaces the leopard, which roars and moves towards Jack before jumping to a higher spot. … Flora continues harassing the leopard, until it jumps and chases her away. In response, bonobos again climb nearby trees, scream and shake branches. This time the leopard retreats to the *Dialium*'s tree highest point … Flora again approaches the leopard to within 4–5 m, hitting her support-branch with her feet and hands, and flailing an arm towards the leopard. The leopard shows its teeth in a clear threat. …The leopard was not seen or heard again. [330]

Mobbing hominids can further torture and kill their "eating enemy", as was done to a leopard cub on October 3 1984, by chimpanzees after chancing on one in Mahale Mountains National Park, Tanzania:

> 10:06 Kagimimi lunges into the cave and emerges, holding a leopard cub (40 cm body length) in his hand; Lubulungu is with him in the cave at this point. Kagimimi drags the cub for 3 m, then, Ntologi, Kalindimya and Lubulungu join him in a huddle round. The cub cries several times. Ntologi drags the cub from the huddle. The cub cries. Ntologi drags the cub across on the ground. Wanaguma (old female, probably Ntologi's mother) grabs it from him, swings it and drops it. Others, near and watching, all bark. 10.11 Ntologi rolls the cub over and pokes its belly with his fingers. Lukaja returns to the cave mouth. Toshibo (juvenile male) and Jilba (juvenile male) approach. Lubulungu bites the cub on its right shoulder, but does not chew. Lubulungu and Ntologi return to the cave mouth. Toshibo grabs the cub, climbs 1 m up a woody vine and drops it.
>
> [This mauling of the cub carries on for nearly half an hour.]
>
> 10.28-10.35: Kalindimya sniffs the cub, then grooms its ear, poking his index finger in its ear; he holds up the cub as if it were an infant chimpanzee, grooming around its eyes and face with his lips. The cub was dead by this time. [329]

Despite such aggressive violence, chimpanzees and bonobos live in landscapes of fear. They cannot sleep on the ground and risk, like Louis Leakey and his African colleague—calmly letting five lions sniff their faces—and live "to tell the tale".

Where do nonhuman hominids go wrong? What did the first do *Homo* differently that got predators to 100% stop surprise attacking them? How did team coordination enable hominid proactive anti-predator mobbing to achieve what was not achieved before?

We lack time machines, but I suggest an example of what *Homo* did exists in the display made by a lioness that visited Elizabeth Marshall Thomas and 20 others in the Kalahari Desert:

> One night when we and the Ju/'hoansi were sitting around our campfires, this lioness walked out of the woods. She was by far the biggest lioness I had ever seen, and she had come to tell us something, so she began to walk up and down beside our campsites, roaring so loudly that we couldn't hear ourselves think, and no wonder—a lion's roar can be heard five miles away and this lioness was almost beside us. At least 20 of us were sitting by our campfires, but there was nothing we could do except not move. I glanced at my watch for some reason and when at last she stopped roaring and stood still, I looked at it again. Perhaps my brain had been influenced by sheer terror, but she seemed to have roared for at least 30 minutes. She looked down at us humans too terrified to move. She seemed satisfied. I think she didn't know that we didn't speak lion. She turned as if her mission was accomplished and walked off among the trees. [333]

The lioness was a single individual and not a team. But ignore that. Instead, compare and contrast her interaction with the would-be opponents with the above account of nonhuman mobbing. She did not hurt Elizabeth Marshall Thomas or the other 20 people at that campfire. She was not violent, angry or combative. Instead, she put what no English word exactly expresses—but the nearest is a "boundary". She impressed her would-be opponents that she was number one—their superior—an individual not to be messed about with. She could see she had asserted her supremacy: "We didn't move or blink or even breathe conspicuously".

Critically, unlike most cases of mobbing by prey of their predators, she sought out those whose behaviour she wanted to change and visited them. She was proactive, not reactive. She was engaging, I suggest, in a "don't kill, win respect" display. Predators do that to other predators. Predators can murderously kill food rivals, both conspecifics and sympatric (same locale) predator species (reviewed later). But to that lioness, the 20 people around that campfire were not her food competitors. It was enough for her to make them know by a roaring display that showed if she wanted, she could do a "mean bit of violence".

Fundamental to her display is that it was about mutual respect—even if it was one-sided. She did not touch Elizabeth Marshall Thomas or the other 20 other people—though she could have quickly slain a few. And that was her message: "I could kill you, but I am not going to". She is asking for respect and giving it—albeit on her "I am the unchallenged tops around here" terms. It was a *quid pro quo*: I exchange leaving you alone for you keeping out my affairs. Respect me as superior—accept subjugation and that you—listen to my roars—are *my* inferior, and I will respect you, providing you deferentially shun-avoid me. End of message.

And lions keep their word—the Ju/'hoansi among whom she lived were left bar one exception alone, who might not have unfortunately been recognized by the attacking lion as human. Elizabeth Marshall Thomas comments:

> My brother made a study of causes of death among the San, involving about a hundred people over about a hundred years. He found one person killed by a lion—a paraplegic girl who dragged herself along the ground with her hands. [333]

I suggest early *Homo* went out as teams—perhaps the whole band, mothers and infants included—and performed what that lioness did to resting predators. Song, dance, drumming, perhaps with a few stone throws to startle them and tell them by their show to keep their distance. Loud, synchronized, confident, bold as brass, borrowing the predators' own dominance calls but imitated with the volume and rigour only a coordinating chorus can make with added stamping, clamping and banging—a ritualized palaeolithic haka that commanded their opponent's respect. Established a boundary. Asserted subjugation that requires deferent hiding and being scant—shunning—while *Homo* went about its business. And then the message made, the performance ended, no predator harmed, and they left. End of mission.

Due to *Homo*'s intimidating display, its would-be predator opponents knew that *Homo*, not they, on the savannah, were the ones in control. Except in one particular circumstance (when a predator has tasted blood), the predators were also safe—the aim—like the lioness, was not to injure but to command.

The problem that *Homo* faced in doing this was that, unlike that lioness, they were puny, easily killed primates. The lioness impressed them with deafening roars, but she could back up its volume with a muscular, strong body, razor-sharp claws, and a jaw lined with piercing canines and tearing incisors. *Homo*'s body has nothing to compare. They could substitute to some degree with knapped rocks and thorn branches. But that was not enough since, unlike the lioness, its integument covering offered no protection—there is even an English word for the results of that animal attack vulnerability—to be “mauled”. *Homo* had to hide that defencelessness while making its multiheaded, loud, split-second coordinated shows of primate strength equal or surpass the roars and howls of their opponent’s carnivore power.

Nonhuman hominids on the edge of something new

Jane Goodall has reported the early stages of chimpanzee mobbing behaviour that extends dominance intimidation displays made between themselves to their predators.

> A few encounters between chimpanzees and large predators (lions and leopards) have been observed at both Gombe and Mahale: the chimpanzees sometimes brandished branches, hurled rocks and sticks, and performed intimidation displays. When confronted by a stuffed leopard (in field experiments performed by Adriaan Kortlandt and his colleagues), the chimpanzees displayed aggressively. [3]

Goodall’s observation suggests that nonhuman hominids are on the verge of applying the intimidation displays they use for social ranking among themselves to their would-be eating enemies. Such behaviours, indeed, when rival hominid communities encounter each other, have been shown to replace physical fights intended to kill or injure.

> When the number of males in the two parties appears to be similar, members of both sides usually engage in vigorous displays with much drumming and throwing, interspersed with pant-hoots, roar pant-hooting, and waa-barks. After a wild outburst the participants stand or sit in silence, apparently waiting to see if the other party will reciprocate. If it does, another outburst ensues. Vocal challenges of this sort are common and usually end with one or both parties withdrawing, noisily, to the core areas of their respective home ranges. [3]

Reciprocally, predators treat species that are predation food-hunting rivals in the same way they treat their same species competitors, as noted by George Schaller:

> When a lion chased a leopard or hyena, for example, it used the vocalizations and facial expressions typical of intraspecific aggressive encounters, in strong contrast to its silent and inexpressive behavior when hunting prey. Thus, behavior which among nonhuman primates is largely used between conspecifics is among carnivores frequently directed at other members of the [Carnivora] order. [234]

Just like chimpanzees during territorial patrols, displays against intraguild opponents (i.e., other predator species) can involve both intimidation displays and violent attacks, even leading to murderous killing.

George Schaller provides details.

> In general, predators tend to be intolerant of each other, even to the extent of killing without provocation-and not just at kills. However, a clear distinction must be made between hunting behavior and aggression, between predators killing each other for food and for other reasons. Leopards commonly catch small carnivores such as jackals and servals and eat them as any other prey. On the other hand, lions may pursue hyena, leopard, and cheetah, using not the inexpressive facial features of a hunt but the bared teeth and vocalizations typical of intraspecific strife; they treat other predators as they would other lions. In this context it is of interest to note that man, too, is usually attacked like another predator rather than like a prey item. Such interspecific intolerance is particularly striking in lions and leopards and less so in hyenas and wild dogs. Indeed these last two species have an armed truce which usually remains in effect while they are not at kills, except when dogs have pups, even to the extent of both species resting side by side in the same mud hole. The various predators seem to view each other as competitors. [4]

Here is an opportunity for *Homo* to extend displays and establish with savannah predators what Schaller calls here an “armed truce”. Crucially, this is possible because they need not compete for food—*Homo*’s diet, consisting of persistence and other nongame animal hunting and plant gathering, wouldn’t overlap with that of potential predators. Using split-second team coordination, *Homo* could enhance the intimidation displays previously used ineffectively by earlier hominids. Now coordinated with choral singing, synchronized clamping/ground stamping, drumming, stone-throwing, and thorn weapons, they would advertise to predators that *Homo*, more than they, was the savannah’s most ferocious, aggressive, and supersized “beast”. This intimidation would get *Homo* judged by its predators as the primate equivalent of a lion, leopard, hyena or wild dog that they dare not risk “messing about with”. Split-second team coordinating *Homo* could thus take intimidation displays hominids already do to each other (and occasionally predators) to gain safety from predators by winning from them “don’t poke the bear” respect “armed truce” type shunning “tolerance”.

The unacknowledged trauma of predator attacks on primates

Anger and hatred of frustration might seem unsuitably subjective to describe animal behaviour, but animals have rage emotions. Research can induce them by frustration. Rats starved of food for 24 hours bite separated plates with intense anger (after 48 hours, they are too weak to show biting rage) [334].

From the perspective of hominids, predators are not neutral “predators” as described in biology journals and textbooks but ruthless murderers aiming to sink their teeth into them and their kin, eat them, howling in raw agony, Hannibal Lecter-style, warm and alive. One of the most fundamental but difficult-to-grasp facts about primate life is that slasher-horror movies—*Friday 13th*, *The Texas Chainsaw Massacre*, *A Nightmare on Elm Street*—are not popcorn fiction for them but lived reality. Their home is a landscape of fear filled with lurking butcherers that plot to eat them, no anaesthetic. No wonder they rage with *hassen auf*.

The neutral language of scientific discourse often obscures predatory attacks’ emotional and psychological impact.

> On 18 September 1987 at 10.43, we heard very load screams … Falstaff was covered with 16 bleeding wounds on his left arm, near his right ear, on his upper right thigh, and on the right side of his back. His right eye was missed by 1 cm. The wound on the back was the biggest, bleeding during the first 2 hours. … Falstaff was attended by several chimpanzees with special care and intensity … Snoopy, a young adult male and also a very keen hunter like Falstaff, was caring for his wounds, licking the blood off the wound and the fur and removing any piece of dirt near or in the wounds. Falstaff positioned himself so as to present a wound to Snoopy who would then lick it carefully. … Perla, a newly transferred female, was even more attentive and she remained with Falstaff for almost the entire 3 hours and 15 minutes he was resting. Snoopy groomed him for 35 minutes and tended his wounds for 60 minutes, Perla groomed him for 30 minutes and cared for his wounds for 85 minutes. Other chimpanzees, like Macho, Ulysse, Chanel, and Xérés, were grooming him regularly and tended his wounds as well. He was constantly groomed. … On the 19 September, Falstaff was still within the group 1.5 km south of the leopard attack, and he was given regular care by the adult members of the party. Brutus and Darwin licked his wounds and groomed him for 122 minutes. … By this time, we knew he was there before we saw him because of his strong smell. All wounds were looking much better, except for the one under his right arm from which a whitish fluid was running. … During the next 2 weeks, Falstaff was seen in the group only for 3 days. All wounds had healed except for the one under his arm. On the 4 November, we saw him for the last time. [6]
>
> I [Christophe Boesch] walked carefully in the direction of the calls to find Salomé, the second-ranking female of the group, lying on the ground and her son, Sartre, some 10 metres up in a tree, alarm calling while looking both at her and around about him. I got closer and realized that Salomé’s chest had been broken opened by a single bite of a leopard. With one bite, the leopard had broken her ribs and punctured her lungs, so that she died immediately from a pneumothorax. Salomé was a fully grown female, some 150 centimetres tall and weighing 38 kilograms. I waited half hidden near her body and 45 minutes later a female leopard approached her, but vanished on seeing me. Female leopards are about half the size of the males, but she still killed an adult chimpanzee with a single bite! [335]

Suppose you were Snoopy, Perla, and one of the other chimpanzees who showed Falstaff tender, loving care—or Sartre, the shocked orphan, screaming as he saw his mother slashed open alive. What would you feel about your local leopards if you were them? I propose the same “anger-like emotions” exhibited by starving rats—violently venting on their biting plate—except, in this case, against your neighbourhood eat-me-and-my-friends-alive butcherers.

However, this intense "hassen auf" emotional response presents a paradox. While such strong emotions may seem to drive effective mobbing that deters predators, the opposite is true. The impulsivity and rage of "hassen auf" are counterproductive, unlike calculated, coordinated mobbing strategies that organize intimidating yet non-harmful displays to end predatory threat. In other words, the very emotions galvanizing primates into action may prevent the organized, level-headed actions that could let them escape their slash-horror world of carnivore Hannibal Lecters.

Teamwork, thus, is not just about split-second coordination but also—even under extreme testing—patience and shared emotional control. Soccer success is more than skilled ball passing—it requires refraining from violence, however warranted towards opponents. A team that gets penalty kicks awarded against it or has players sent off cuts greatly its chances of moving up leagues and winning games.

The potential exists: nonhuman hominids like chimpanzees can occasionally restrain their emotions. Jane Goodall has reported instances where chimpanzee groups on patrol maintain disciplined silence, suggesting a capacity for controlled behaviour when in a group.

> A patrol is typified by cautious, silent travel during which the members of the party tend to move in a compact group. … Perhaps the most striking aspect of patrolling behavior is the silence of those taking part. They avoid treading on dry leaves and rustling the vegetation. On one occasion vocal silence was maintained for more than three hours. [3]

However, the restraint required is more than the absence of behaviours but the capacity for cool-headed teamwork confrontation. Nonhuman hominids, to develop the actions for such coordination, must develop the shared attention and split-second attention that characterizes human teams. This change would enable them to work together in an active, disciplined team with a common cool-headed purpose.

No hassen auf (hatred)

Konrad Lorenz discussed mobbing and emotionality in his book *On Aggression* [20]. However, the book's English translation deviates critically from the German original by omitting his references to *hassen auf*. This old German hunting phrase refers to how birds chase their predators, meaning "to hate after" or "to put a hate on". As Kenneth Westhues comments [336], "*Hassen auf* emphasizes the depth of antipathy with which the attack is made. This sense is an important connotation that the English word 'mobbing' lacks since it is sometimes used, at least in English, to describe the friendly milling of a crowd around a celebrity". The above accounts of hominid mobbing show chimpanzees and bonobos expressing this *hassen auf*, "to put a hate on".

However, I retain the word "mobbing" for the proposed *Homo* engagement with predators, though it is opposite in some ways to the "friendly milling of a crowd" of nonhuman mobbing. (I cannot think of a more appropriate alternative.)

Lorenz makes the key point that predators are not angry when they attack: "the lion, in the dramatic moment before he springs, is in no way angry. … [but] The opposite process, the 'counter-offensive' of the prey against the predator, is more nearly related to genuine aggression" [20]. Kortlandt makes similar observations about lions: "When stalking and running at a prey, lions neither bare their teeth nor growl. (Many museum exhibits of stuffed lions are highly misleading in this respect.) Instead, they have a highly attentive expression without revealing any specific emotion, like a poker player" [188]. The lion attacks calculatedly—teams, likewise, I suggest, work in a "poker player" manner calculatedly together. Indeed, it isn't easy to coordinate as a team unless everyone is cold-headed—coordination requires shared giving up of individual emotional motivation to a shared calculated end.

This cool-headedness allows a different engagement with predators—not to kill them, but to win their respect. Humans end predation by asserting dominance over animals—making them think we primates have the savannah "trump cards". Team split-second coordination lets us act as a greater entity than its individual parts. But as a card hand, it is a bit of a poker bluff that never gets played, never to be called—nearly all large savannah animals can easily kill humans if they get close and maul. But smartly done (choose your opportunities wisely), human coordination can get them to "fold" before team *Homo* intimidation displays and never learn how physically defenceless we are as animals.

Mobbing and calculation

Louis Leakey provides evidence for the cool heads needed for Palaeolithic team approaches to predators. The *New York Times* reported that he reminisced a year before his death [337] (he also mentioned the incident earlier [338]) about how he and his son, Richard, went

> leaping about and flailing away with bleached animal bones up to hyenas next to their zebra kill and even got to take away a bit of the Zebra.

However,

> they were furious and after 10 minutes, I signaled to my son, "Get out. It's not safe any longer". [337]

This incident shows

(1) it is possible to approach and pester predators to the degree that they get "furious" and

(2) the importance of teamwork if this is to be done safely: "I signaled to my son, 'Get out.'"

Effective team coordination in confronting predators requires a balance. The group must act in unison, avoiding chaotic or impulsive actions and in controlled order, also when retreat signalled, avoiding, as the French put it, "à la débandade". The key is not to instil fear but to command respect. This situation is a Goldilocks scenario: too little confrontation, and the predator remains unimpressed; too much, and it may retaliate dangerously. Team coordination is critical to hitting the sweet point of getting the balance right if an error is made, getting everyone out of danger.

The impulsiveness of "hassen auf" is incompatible with such calculated intimidation and, therefore, the team coordination display of control needed for effective team mobbing. Impromptu violent outbursts can put the team in danger and, therefore, must never occur. Taunting predators must be done intelligently, not recklessly, such that they never feel trapped, triggering against the mobbers a violent charging retort—lions can jump 12 feet high and leap 36 feet. The team members must always maintain “cool heads”, so if a signal is given the predator looks dangerous, they immediately leave.

All for one, one for all team ethos

Team mobbing, I propose to halt predation must, without exception, retrieve all bodies, least a predator acquires a taste for their flesh. No team member can thus be left behind or forgotten; they must be treated as still part of the team, even in death. Teams thus work emotionally, as well as cognitively together, as a unified entity, with each team member equal to the whole. This idea is embodied in a renowned phrase—*Unus pro omnibus, omnes pro uno*—the motto of Switzerland, and also as *Tous pour un, un pour tous*—between Athos, Porthos and Aramis in Alexandre Dumas’s *Les Trois Mousquetaires* (*The Three Musketeers*). In English: *All for one, and one for all*.

I suggest teams stop predators from eating group members by creating an all-for-one, one-for-all ethos among themselves. This shared mutuality of concern exists even if they dislike each other. (Many teams succeed despite tensions, such as before its break-up, the noted vocal quartet with mixed instruments of John, Paul, George and Ringo.) This all-for-one, one-for-all ethos is not out of liking each other. Rather, it is a fundamental layer of mutual dependence required for working together as one.

This team ethos manifests in the importance humans place on recovering or honouring the deceased if recovery is impossible *in absentia*. A team's unity involves not just coordinated action but also shared emotion, ensuring those physically "missing" remain part of the "team".

Philosophers ignore the moral profundity of this enduring connection that absent people have in our lives even after death. Yet, despite this neglect, we deeply experience their continuity. Soldiers, for example, report that their lost comrades remain friends:

> If I talk about him, I talk about him as if he is alive. He died when I was twenty years old and he was twenty-two but he grew old with me, I mean I am now sixty-six and he is sixty-eight, that’s how I see him, he is a part of me so he grows old with me … I feel that he is alive with me … [Guy]
>
> He is with me in happy times, in sad times … I talk to him, tell him about those times, about my inner thoughts and feelings. And I consult with him about things, like should I take that job or not … I see us together, as if he is alive. [Amir]
>
> I go to the cemetery to be with him. I feel like I have to … next to his grave it feels more real than in other places because he is there and I’m right next to him. When I go there, I allow myself to fall apart, to cry and to really talk to him … [Gad] [339]

The military places a high priority on the safe return of every mission member. The emotional urgency of rescuing those left behind is intense and propels plots in books and films, such as *Rambo: II* and Andy Weir’s *The Martian*. The repatriation of prisoners of war (POWs) and accounting for those missing in action (MIA) was a major issue in the United States after the Vietnam War. In 2011, with 79% public approval, Israel exchanged 1,027 prisoners to return one kidnapped soldier, Gilad Shalit.

Moreover, the memory of those who have died in war is a cornerstone on which national identity rests. This homage is commemorated through annual remembrance days, solemn monuments, and well-kept military cemeteries dedicated to the “fallen”. These individuals are not forgotten; two of the most significant speeches on democracy and its values—Pericles’ *Funeral Oration* and Lincoln’s *Gettysburg Address*—were delivered before the remains of the war dead, honouring them by explaining for what they had made the ultimate sacrifice.

In contrast, nonhuman animals have a markedly different response following a predator mobbing when one of their own kind is caught and killed. Consider this description in a paper titled, *“Risky business? Lethal attack by a Jaguar sheds light on the costs of predator mobbing for Capuchins*”. Six adult males remained near a jaguar after the rest of the group had left. Five of the six then departed, leaving one individual.

> we could still hear the capuchin that had remained alone near the jaguar making alarm calls. We heard sudden movements, the alarm calls stopped, and ca. 30 s later we heard two weak vocalizations, similar to a moan, after which there was only silence. We encountered the rest of the group ca. 100 m from the place where the mobbing had occurred. The capuchins were very quiet, but had returned to their normal activities and were foraging for insects. … LK has not been seen since this event. [340]

Could the five capuchins have returned to help LK? While capuchins occasionally rescue each other from predators [341], in this particular case, it seems unlikely that they could have saved LK while he was still alive. However, they might have been able to retrieve his body, a less challenging task, thereby stopping the jaguar from consuming capuchin flesh. Given that LK’s body was never found, this presumably is what happened. Failing to retrieve the body not only allowed the jaguar to have a positive—not a negative—reinforcement learning from its capuchin encounter but also risked passing on the taste for their flesh and the meal association of their scent to other predators, including offspring.

Therefore, the phrase "All for one, and one for all" is more than a clever saying; it encapsulates the survival principle that losing even one life jeopardizes the whole group. No one can separate their interests from those of everyone else; as Benjamin Franklin said: “We must all hang together, or, most assuredly, we shall all hang separately.” The word “individual” comes from the Latin *indīviduus*, which means “undivided, indivisible, inseparable.” If members prioritise their own interests over the group’s and do not act all-for-one, one-for-all, they risk a predator associating the group’s scent with a huntable meal. Such an association could result in the end of safety for everyone and anyone’s life suddenly ending in a butchered-alive attack.

Breaking the smell-eat link—recovering taken bodies

Displays need, therefore, to coexist with another group action—getting respect for the group’s own scent. Each member has the group’s smell—and if eaten, could teach a predator they might be a possible meal.

Standing erect, unlike nonhuman hominids that knuckle-walk, we do not sniff the ground. As a result, we overlook the crucial role of olfaction for other species. Even when human hunters track their prey, they mainly rely on visual cues. Predators on the savannah, however, define their prey initially by scent, sensing them not as individual animals but as bundles of energy marked by a species’ aroma. They pursue, and then vision takes over as they select victims and attack. At the last moment, as carnivores sink their teeth into flesh, they are then blind as they shield their eyes from blood squirts with their “third eyelid” nictitating membranes.

OPPORTUNITY TO BREAK THE APPETITE BEHIND THE SMELL-EAT LINK

The potential to disrupt this smell-eat link exists because even appetites that might seem wired in our “genes”, like the link between thirst and seeking water, are initially learned. This unexpected scientific finding is in the title of a paper: “Evidence that Appetitive Responses for Dehydration and Food-Deprivation are Learned”.

> Weaning age rats do not seek water when dehydrated by a salt load. This lack of appetitive behavior is in contrast to the precocious ingestive responses shown to dehydration when fluids are infused directly into their mouths. Indeed, dehydration produces increased intake of orally infused solutions in dehydrated rat pups as young as 2 days of age without an accompanying increase in seeking behavior. Thus, early in development dehydrated rats do not seek water, but do vigorously consume water that is immediately available at their mouth. It is not until after 3 weeks of age that rats actively seek water and drink when dehydrated. Recent experiments provide an understanding of rats’ late-emerging appetitive responses, at the same time renewing support for a 90-year-old proposal that, in contrast to the consummatory responses, the appetitive components of behavior are learned, or acquired. Without the paired experience of dehydration and drinking, rats appear unaware of the significance of dehydration and its internal and peripheral signals. That is, they do not express searching out water and drinking. With specific experience, however, rats acquire the water-seeking behavior that leads to drinking. [342]

The key phrase here is “the appetitive components of behavior are learned, or acquired”. The paper’s author, Mark Changizi, attributes this idea to Wallace Craig. In 1918, he proposed the learning process involved.

> An appetite is accompanied by a certain readiness to act. When most fully predetermined, this has the form of a chain reflex. But in the case of most supposedly innate chain reflexes, the reactions of the beginning or middle part of the series are not innate, or not completely innate, but must be learned by trial. The end action of the series, the consummatory action, is always innate. [343]

I propose that a predator’s hunting strategy is similarly rooted in a learned appetitive pairing between the scent of its prey and the act of consuming its flesh. The key to unlocking a predator-safe environment lies in severing that appetitive link.

Another factor exists: appetitive links are initially inhibited by neophobia—wariness of unfamiliar foods and associated odours [344]—which further increases dependence on active learning.

> Within days of leaving the lair, [cheetah] cubs were introduced to solid food. On these first occasions, cubs approached and sniffed the carcass gingerly but then backed away. Cubs returned to the carcass when they heard their mothers churr, and after roughly three exposures, lost their fear and sat next to it or played nearby.[33]

This aversion to the unfamiliar is reversed through individual learning experiences, communal food sharing, or observing the eating of others. Most notably, young predators acquire the connection between scent, edibility, and hunting from their mothers [345].

> First, the mother brings dead prey to her young and eats it in front of them. She then brings live prey for them to play with and kill, and only intervenes to stop the prey escaping or to alert her kittens to the presence of the prey if they have lost interest. Finally, she allows her kittens to follow her on hunts, where they are allowed to kill prey themselves. Lions and other big cats differ from smaller species in that prey are not generally brought to the young, because the prey are too large to be carried long distances, and so young big cats may only observe the killing of prey for the first time when accompanying their mothers.[346]
>
> Some female cats promote the learning of skills connected with hunting in their young by creating situations where these can be practiced. Cheetah, for example, may bring a gazelle fawn to their young and release it, and a tigress may pull down a buffalo and then let her cubs kill it. Such behavior was extremely rare in lions; only one female was seen to carry a living gazelle fawn to her cubs. However, young lions have the opportunity to learn stalking techniques and killing methods by observing adults. They trail along on hunts when only a few months old, and on one occasion, when a lioness captured a zebra in a streambed, 13 cubs lined up along the bank and watched her strangle it. That house cats are able to learn a task rapidly by observing another animal perform it has been repeatedly shown in laboratory experiments. Thus cubs may have learned the hunting techniques before they have had much experience. Errors in the actual performance are not critical to the survival of cubs, for their association with adults continues until they are at least 2½ years old, longer than for any other cat. [4]
>
> Lions attacked the baboons during eight of these encounters. One adult male and one adult female were killed and six attacks were unsuccessful. All attacks were by a lioness with two large cubs (3/4 size) who joined the hunt on at least two occasions. [347]

This maternal instruction informs them about which animals are viable prey, as evidenced by their mothers' successful hunts. The critical importance of this becomes apparent if young predators begin to hunt without earlier maternal guidance:

> captive-bred adult male cheetahs were released into two different private nature reserves in the eastern Transvaal Lowveld of South Africa. Their only previous experience of killing prey was that of a single captive Barbary sheep, *Ammotragus lervia*, although they were fed on dead impala, *Aepyceros melampus*, which was the natural prey in the release areas. However, once released they turned their attention to the calves of giraffes, *Giraffa camelopardalis*, which they hunted cooperatively in pairs; one animal would hook the calf's rump with its dewclaw, while the other would jump onto its shoulders, bringing it to the ground. In this way the cheetahs achieved a hunting success of 41.7% (n=12) for giraffes compared with 9.3% (n=97) for impala, which would have been expected to be their natural prey. Therefore, these cheetah did not recognise their natural prey and were incompetent at hunting it. Although giraffe calves were hunted very successfully, the cheetahs risked increased injury from hunting large prey (individuals were injured trying to hunt an African buffalo, *Syncerus caffer*, a zebra, *Equus quagga*, and a wildebeest, *Connochaetes taurinus*). …
>
> It would appear that mother cheetahs provide essential opportunities for their cubs to know which prey to hunt. For example, Caro (1994) noted that when following their mothers, cheetah cubs would often become distracted by inappropriate prey (including giraffe calves in 10% of inappropriate 'hunts' at 8.5 months or older), but as they grew older their attention became focused on the correct prey, owing to the intervention of their mothers. [346]

Adult predators can learn about potential prey not just from their mothers but other adults. Instances where large cats have killed humans but showed no signs of craniodental disease [263] suggest that these predators learned to consume human flesh by sharing kills with afflicted partners. For instance, "Eyewitness reports of the attacks suggest that one lion was initially responsible for the bulk of the depredations while the other waited in the bush; later attacks involved both lions" [262].

Therefore, a pivotal aspect of early *Homo*'s escaping from the landscape of fear was stopping predators from becoming "educated" to associate human scent with a potential meal, particularly to prevent mothers from passing such knowledge on to cubs.

One consequence is the critical importance of the noted need for groups to maintain discipline and retreat together when given a signal, lest a member gets captured and endangers all by allowing predators to associate their scent with food.

KILLING IS RESERVED ONLY FOR THOSE WHO TASTE BLOOD

While it's unlikely that early *Homo* could kill attacking predators, they could still pursue and retrieve freshly killed human bodies. Two factors make this possible. First, "In the drier environment of the savanna, dead bodies last much longer: leopards routinely keep their quarries for days before eating them" [6]. Second, predators often surrender their kills when faced with attackers, as shown in kleptoparasitism—food theft. This circumstance suggests that even if a predator managed to catch an individual, a team of *Homo* could potentially follow, pester the predator, and retrieve the body, engaging in what could be described as "a game of psychological warfare"—as noted in the following observation:

> On one occasion, six hyenas stood within a meter of a male lion which had taken a

> wildebeest from them; another time, after a subadult male had scavenged a wildebeest, eight hyenas tugged at one end of the carcass while he tried to eat at the other. Instead of attacking, he departed with a growl. … I was often surprised that a few lions were able to take a kill with impunity from many hyenas. For example, one subadult male took a carcass from 17 hyenas, and 2 lionesses appropriated one from 31 hyenas. A communal attack by the hyenas could easily have driven these lions off, and this indeed happens occasionally … Seventeen percent of the kills were abandoned after the lions had eaten a portion of the carcass; 39% of the carcasses were consumed by the lions themselves, usually after others joined those already present; the remaining 44% were taken over by hyenas before the lions were finished with them. Usually hyenas gathered around the kill, circling it, whooping, drawing closer then retreating, playing, it seemed, *a game of psychological warfare*, [my italics] until the lions became uneasy and departed. On three occasions they drove lions off forcefully. [4]

Preventing this scent-food-hunt association is vital. A species not appearing on a predator's olfactory "menu" remains unhunted. This lack of association can self-perpetuate; even if an animal is edible and can be hunted, the opportunity to make this connection, if it rarely arises, might remain unlearned—as the animal must first have hunted it to establish that association.

Therefore, breaking the association between scent and edibility is as important as intimidating mobbing. Nonhuman animals' mobbing tactics, even if they produce trauma in predators, fail to prevent these predators from associating their scent with eating and hunting. As such, these mobbing efforts can, at best, only be partially successful. Effective team mobbing must prevent them from forming this eat-hunt olfactory link.

Gaining respect from predators would usually avoid killing them. Humans would be advantaged to keep local predators that have already learned to avoid them alive rather than have them replaced by new, "untutored" ones from outside.

However, a different course of action would be necessary if a predator tasted blood.

Reflecting this, modern humans recognize the link between predator attacks on humans and human flesh being eaten. In most countries, national park policy is to hunt and euthanize predators responsible for human fatalities. A similar policy in the Palaeolithic would have been critical for survival to prevent predator assaults on hominids. This practice is necessary because predators might eat hominids and teach other adults and their young that they are suitable prey, leading to further attacks.

Theoretical importance of coordination against predators for human cooperation

Of theoretical importance, I suggest, is that the cooperation needed for successful mobbing is critically different from that required for group hunting, confrontation scavenging [348,349] or other forms of "obligate collaborative foraging" [115,291,292]. In mobbing, the cooperative effort is not focused on obtaining food but ensuring no one is food. Non-cooperation harms may persist for decades if predators gain a taste for the group's flesh, a negative payback that endangers every individual. This situation is a mirror inverse of the stag hunt in game theory, which relates to the rewards of cooperation (procuring food) rather than the penalties of non-cooperation (becoming food). Furthermore, the outcome is not a short-term cooperation benefit (an extra meal) but a long-term one (a habitat free of predator threat). Since predation binds their fates, everyone loses (gets put at risk of predation) if one individual suffers (gets eaten by a predator). This payback situation makes it a more likely origin of team coordination than other shared activities that have been proposed, such as collaborative foraging.

Moreover, as noted previously, an extra factor exists: the quickness of split-second turn-taking coordination creates the "honesty" signal [119] needed for the continued unself-centred existence of *all-for-one, one-for-all*. The very act of "moving our muscles rhythmically and giving voice" in coordination may itself also "consolidate group solidarity"— William McNeill's well-known keeping time together theory of group bonding [350].

Also, teams win by not linking success too strongly to individual accomplishments—the player who scores a goal does so only due to every member's prior teamwork. The team wins or loses as a whole, and its members do not exist apart from what they achieve as a team. Though there may be a player of the match, the overall play of the match and which team wins is what matters. Again, this supports *all-for-one, one-for-all*—an individual's success is inseparable from those with whom they split-second coordinate.

Importantly, this coordinating *all-for-one, one-for-all* teamwork need not end with mobbing; once established, it can extend to other forms of group collaboration, such as hunting, communal foraging, and cooperative breeding. However, the genesis of this cooperation starts, I suggest, not in these activities but in the uniqueness of the *all-for-one, one-for-all* paybacks that first arose with the predator coordinating mobbing necessary for niche constructing a predator-safe habitat.

9: THE PREDATOR SIDE OF THE STORY

> *A complementary predator perspective explains how coordinated teams stopped attacks. The "exterminate, bloody nose" strategy deters by making hunting hazardous and costly. The "don't kill, win respect" strategy instead elicits deference by making the mobber dominant. It wins submissive-shunning by displaying superior coordinated "superorganism" power. Split-second coordination enables this through haka-type prowess displays of "theatre violence". These prompt predator retreats and future avoidance by power assertion, not hurting or killing. Critical is predators perceiving* Homo *as fellow "predators". Factors promoting submission include low-cost alternate prey, judging* Homo*, a nonrival predator, and deference shunning becoming an intergenerational tradition.*
>
> *Dominance display gets shunning-submission by exploiting neurology adapted for within-species ranking by control superiority assessment. Detecting differential control involves the "Devil's Inverted Golden Rule" of causal perception—discerning what "you can do onto others that they cannot do onto you". This "rule" underlies vertebrate status contests, dominance and submission and predator "armed truce" shunning. The proposal's neurological components are researchable.*

Introduction

Why should intimidation display that does not kill or injure be effective in stopping predation when killing and violence fail? Why is less, more? We need to enter the perspective of predator calculations.

The "exterminate, bloody nose" strategy works by altering the cost-benefit assessments in predators' prey "business plans". When effective, its violent nature prompts predators to hunt elsewhere or target easier prey. However, this strategy is ineffective because predator hunting is reinforced on an intermittent schedule—a type of learning resistant to extinction.

The "don't kill, win respect" strategy exploits the "armed truce" tolerance between predator species. It also takes advantage of a critical difference in predators' decision-making process when targeting prey for food versus eliminating food competitors. Both situations involve a cost-benefit calculation, weighing the likelihood of success and risks of attack against the potential gains—either securing a meal or removing a rival. However, killing for food typically relies on surprise, while eliminating competitors does the opposite—it begins with advertisement—visual and auditory displays of intimidation, escalating only if ineffective to actual physical attacks. This initial display stage allows rivals to judge whether engaging in combat is worth the risk, persuading them to go elsewhere to hunt. It is an opening by which *Homo* could get predators to shun, not hunt, it.

Core concepts

This section is more theoretical than the others—the questions it asks have not been previously raised. Though there already is a field called neuroethology, it combines neuroscience and ethology in a novel way to a different end. It is grounded on three ideas.

The Devil's Inverted Golden Rule theory: Successful brains detect their ability to control the behaviour of others without being reciprocally controlled in return—their capacity to "do onto others as they cannot do onto you". In other words, brains recognize the control imbalance they can exert over other agents—the extent to which they can assert agency over them without reciprocal agency against them.

The Habenula's Role in Dominance-Submission and Tolerance-Intolerance: The behavioural inhibitions between animals, as studied by ethologists and animal behaviourists, arise from core neurological processes centred on the brain's habenula nuclei. The habenula is crucial for detecting the Devil's Inverted Golden Rule Devil's Inverted Golden Rule, status contest defeat [351,352] and enforcing regulatory inhibition, such as submissiveness or shunning. (Other areas, such as the amygdala and orbital frontal cortex, build on what it provides as an information processing "chassis" for them.)

Entropy Contests Analysis: Entropy contest information theory measures the information "surprise" by which animals decide winners and losers in status opponent challenges. This information underlies the Devil's Inverted Golden Rule, which the habenula detects. (Entropy contests were initially developed to analyse the information determining winning and losing in soccer [353–356].)

These concepts provide a scientific foundation for the "don't kill, win respect" strategy by which Palaeolithic humans constructed predator-safe habitats.

SIX CONJECTURES

I make six strong conjectures:

- **Two Mobbing Strategies**: There are two types of mobbing strategies—one employed by nonhuman animals, I call “exterminate, bloody nose,” and another unique to *Homo* made possible by team coordination, I term “don’t kill, win respect.”
- **Detecting Causality**: Recognising the causal relationship between oneself and others is a crucial function that has evolved in the vertebrate brain. This function asks, “What can I do to others that they cannot do to me?”—the “Devil’s Inverted Golden Rule.” This causal detection is associated with the habenula, a brain region that emerged with the first vertebrate brains around 500 million years ago. This function is exploited in the “don’t kill, win respect” strategy by *Homo*.
- **Submission and Dominance**: Relationships of submission and dominance are near universal among vertebrate conspecifics. This phenomenon arises because vertebrate brains, regulated by the habenula, evolved to control the behaviour of others without being reciprocally controlled. Detecting “Devil’s Inverted Golden Rule” in relationships, I propose, creates shunning between intraguild predators.
- **Submission and the Habenula**: Submission occurs when the habenula identifies that other individuals can exert control over one’s ability to achieve goals while lacking the reciprocal ability. This recognition typically occurs during contest confrontations when the balance of control is established. Importantly, these status contests begin with a “mock” advertisement display at a distance of the potential to exert control without, in return, being controlled. This assessment can also be made vicariously by observing interactions between third parties, leading to social ranking—even fish are capable of this [357].
- **Active State of Submission**: Submission is an active behavioural state in which the brain modulates actions to prevent dominant individuals from perceiving challenges to their winner status. This loser status is usually manifested by (i) shunning dominant individuals and (ii) granting them unchallenged access to resources like food and territory, and in the case of conspecifics, also mating opportunities. This behaviour underpins predator “armed truces”.
- **Exploiting Submission**: Because the brain actively generates a state of submission linked to the detection of superior control in another, this allows split-second coordinated human teams to exploit their ability for unified action to advertise such superiority. By confronting predators not as “puny savannah apes” but as a unified, choral singing, dancing, foot-stamping, clapping, drumming, multiheaded “hydra”, humans advertise themselves as “supercombatants”. Key to this credibility is that predators have little to lose by deferring to, avoiding humans, and so never learning how easily they can be mauled. What appears to be fire is best treated as fire unless a compelling reason motivates a check on whether it might only be an illusion. Utilising split-second team coordination and leveraging the habenula’s detection of the Devil’s Inverted Golden Rule makes the “don’t kill, win respect” strategy effective. An avoidant predator poses no risk of surprise attacks or stalking, thereby creating for *Homo* a predator-safe habitat.

These claims are evidence-based

Table: Exterminat, Bloody Nose and Don’t Kill, Win Respect contrasted.

	EXTERMINATE, BLOODY NOSE	DON’T KILL, WIN RESPECT
done by	nonhuman animals	*Homo*
basic mechanism	deterrence	deference
inhibits predators by	costs that affect the decision to hunt	exploits the need to shun individuals assessed to be dominant
behavioural change	elimination (death) fear move elsewhere shift to easier, alternative prey	cordon sanitaire respect modus vivendi coexistence mutualism (possible)
behavioural change factor	recalculation on suitability to hunt	submission inhibition (avoidance)

driving emotion	*hassen auf* rage-aggression	cool-headedness confident assertion
expresses	cathartic hatred	haka respect ritual live and let live modus vivendi
organization	chaotic, pell-mell aggregate of solo actions	team “soccer” coordinated preplanned, strategic, tactical practised/learnt
related behaviour	pursuing prey patrolling against rival conspecific groups	dominance intimidation displays
skills	disabling/ dispatching prey injuring/killing conspecific rivals	choral dominance-call singing drumming/dancing stamping/clamping throwing weapons
occasion	reactive to local predator presence	proactive visitation (akin to nonhominid boundary patrolling)
core targeted predator brain area	PAG (periaqueductal gray survival emergency responses)	Habenula (anti-reward)
Enduring emotion	fear	respect
Eco-lebenswelt (animal life-world)	landscape of fear	predator-safe habitat
limitation	Interval schedule reinforcement stops extinction	Need to avoid overlapping food competition creditability

Requirements for ‘Don’t kill, win respect’ strategy

The strategy “don’t kill, win respect” can, as a process, be scientifically investigated as it has researchable constraints and opportunities.

Displays of intimidation have the constraint that they must lead predators to reclassify *Homo* not as prey but as another predator, notably not one competing for the same food. This situation creates an opening as predators assess the risks and benefits before attacking either prey or other predators. Moreover, the decision to attack another predator critically is informed by displays used for assessing dominance, similar but interspecies-wise to how animals evaluate rivals within their own kind. This pre-attack assessment as a nonrival predator thus creates the opportunity in which *Homo* could sidestep its integument vulnerability and still get a 100% shunning provided it meet two criteria in the sense organs of predators:

(i) be judged as a fellow “predator” species, and

(ii) be judged as a “predator” species that also posed no food competition and, therefore, could be tolerated.

These are discussed in detail below in how predators assess whether to tolerate or not other species predators.

The key lies in split-second team coordination, which enables *Homo* to advertise the impression of being a powerfully aggressive do-not-mess-with-us savannah primate. For example, choral vocalization produces a sound volume akin to a much larger animal. Synchronized dance movements appear, from a distance, as the actions of a single, hydra-like supercreature. This display of intimidating prowess solves *Homo*’s problem; physically, it is only a puny primate, vulnerable to a mauling if a predator was to claw and jaw attack. However, predators avoid attacking creatures they assess as having more fighting capacity than themselves, especially if the “predator” is not competing for their food, hence not challenging their survival. The details of this will be explained later.

By getting predators to take *Homo* to be another predator—but one that does not compete with them and one with the power to attack—they credit *Homo* with an “honorary predator” status. It does not matter whether *Homo* is a carnivorous predator like them (as some have suggested) or largely living off plant matter (as others have suggested); the actual subsistence of early *Homo* is a different topic. The critical issue is that the would-be predators of *Homo* take it to be another hunting attack-capable predator. That leads them to avoid making carnivore-body-on-naked-hominin-body contact—a mauling contact *Homo* cannot survive given its integument weakness.

Lack of contact helps link the ferocity of its intimidation display to the individuals in it. Though the predator might not be able to smell the mobbing entity from a distance, that odour will linger where it was displaying, and later, the predator will sniff and link their scent to their display fierceness. A *totum pro parte* ("the whole for a part") transference then occurs through that shared group and individual scent, leading predators to treat individual *Homo* with the apprehension they reserve for the larger, display-threatening *Homo* team.

DISPLAY WITH BACKUP

The use of team coordination as a substitute for the claws and jaws that *Homo* lacks invites one criticism—it suggests an element of false advertising. As Kortlandt points out:

> Given evolutionary time, carnivores should certainly have been able to learn that human hullaballoo not backed up by weapons is as harmless as lightning and thunder in the clouds. I do not know of any intimidation behaviour by higher vertebrates that is not supported by some form of last-resort fighting. [188]

For this reason, Kortlandt argues *Homo* used thorn-branch weapons, combining throwing to compensate for its lack of body strength, claws, and strong jaws. While these aid its defence, predators may also overestimate *Homo*'s capabilities due to cognitive limitations. For instance, predators fail to test that animals are dead rather than feigning death, thus losing easy meals. In one study, 60%—or 29 out of 50—ducks caught by a red fox survived by playing dead.

> Initial death feints lasted from 20 sec to 14 min. … Death-feigning birds appeared alert and often took advantage of escape opportunities. Twenty-nine [of fifty] birds survived initial capture and handling by the foxes. [358]

The fact that predators don't spot the "playing dead" trick has led to the repeated reinvention of this bluff in fish, amphibians, reptiles, mammals, crustaceans, and insects, not just adults but also damselfly larvae [359]. This example of consistently successful biological deceit raises the question: to what extent would predators check *Homo*'s intimidating display of "lightning and thunder"? If they don't do "a reality check" on the easy meals of animals playing dead, why expect they would physically check a "predator" species that advertises a strong capacity for violence, particularly one not competing for their food? The risk of physically testing its actual capabilities behind this show by fur-on-skin combat would not be worth "the candle". After all, from a distance, team *Homo* appears to a predator as a multiheaded "monster" capable of great violence. Nothing in the evolution of carnivorous species has prepared them for a species like *Homo* that can split-second coordinate different individuals to vocally (through chorus) and behaviourally (through foot stamping, arm waving, clamping, body jumping dance) turn themselves into a single, intimidating superhydra primate behemoth.

Moreover, if the "false" advertising of such displays were in the poker sense "called", *Homo* had backup to replace the jaws and claws they lacked. The show is not all bluff. As Kortlandt observed, thorn branches can deter predators from getting in mauling distance, given the sensitivity of their paws to sharp objects—the porcupine defence. Additionally, humans could use targeted stone-throwing to make predators back off. While these throws might not be lethal, they could still cause injury, making predators unlikely out of mere curiosity to risk testing what lies behind their intimidation, "lightning and thunder".

GETTING JUDGED AS A "PREDATOR"

One requirement is to get predators to categorize *Homo* as a primate predator. Olfaction would aid this judgment. Predators and their excreta smell of blood, and this olfaction critically marks out an animal as a meat killer. Predators are highly sensitive to the smell of blood, specifically to trans-4,5-epoxy-(E)-2-decenal, an evolutionarily conserved chemosensory blood signal to which they are sensitive and attracted [360,361] (wounded animals are easily caught). Their olfactory senses are hyperacute. Dogs, for example, can distinguish between the metabolic states of ill and healthy people, identify specific diseases [362], recognize individual predators (tigers) from their scat [363] and follow with 77.5% accuracy scent trails left by people earlier in busy urban centres two days latter [364]. It is thus more than creditable that predators can identify the diets of different species and detect those that eat meat.

Hominids like chimpanzees hunt small mammals and monkeys [3,35]. Early *Homo*, it has been argued, were carnivorous [316–318]. *Homo* show adaptations (the Palaeolithic Faustian Bargain) for endurance running. One utility could be to catch prey by exploiting their vulnerability to heat exhaustion in persistence hunting [312]. Thus, *Homo*, if not competing directly with savannah predators, would smell to them, due to this and other forms of hunting, as another "predator" meat-eating species.

This predator status would still be the case even though *Homo*'s diet was mainly fruits, tubes and other plant matter. Further, *Homo,* through culture, could give itself an extra source of blood scent—as they lacked fur, early *Homo* could smear blood directly onto their skin, an option to "stench" of blood not so easily done by fur-covered hominids like chimpanzees in which it would glue hair into unhygienic mats. *Homo* is known to have cosmetically used red ochre as early as 250,000 BP [365]. Unlike ochre, however, blood is readily available and needs no preparation—just a tradition of self-adornment. Carnivores commonly rub themselves with the scents of other species [366], so this behaviour is not particular to humans. Animal skins for clothing or bedding would inadvertently transfer the smell of blood and other prey odours. This contact is plausible, given early *Homo* lacked its own pelt of fur insulation, animal skins provide warmth, and nighttime temperatures drop to around 10°C (50°F) and lived in the East African Rift mountains in Africa's Ethiopian Highlands [367] where they drop even lower. Frosts occur in Kenya, damaging crops [368].

A crucial factor in establishing that you are a "predator" is that your aggression is proactive—intrudes uninvited on opponents—rather than reactive to them. This proactiveness is because while prey animals can defend themselves as furiously as predators, this is reactive. What marks a predator as a predator is that their attack abilities are go out offensive. Their *modus operandi* is to go out, ambush or stalk, then attack chosen victims. "Professionally", their aggression is to hunt, search, sneak up, and kill proactively. To convince another predator that it, too, is a "predator", an animal must confidently demonstrate its "search-you-out" potential for aggression. Such animals are not ones you want to get on the wrong side of—if they judge you as a threat, they might surprise attack when you are off guard.

Therefore, early *Homo* can present to would-be predators two key pieces of information:

(i) That they are predators by emitting a blood odour and engaging in aggressive, demonstrative visiting proactive displays;

(ii) but at the same time, they were not in direct food competition, as evidenced by not being seen or smelt near their would-be predator kills.

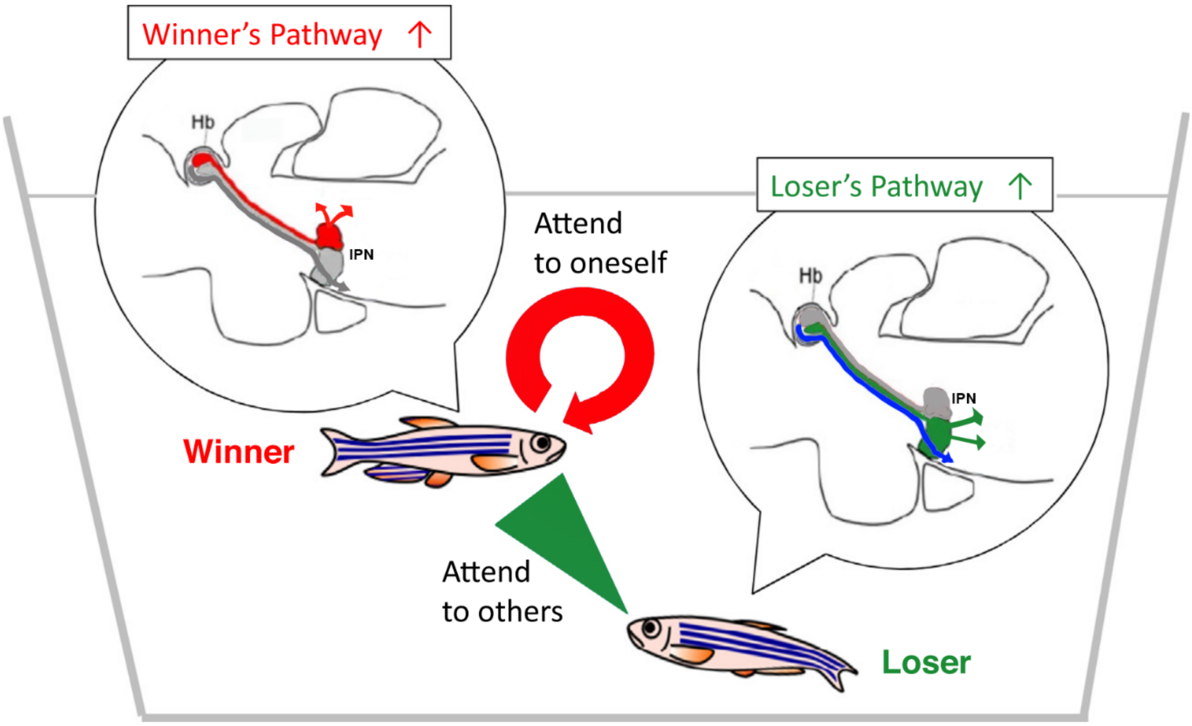


Illustration of habenula dominance submission circuitry.

The mobbing strategy that prevents *Homo* from being attacked by predators is rooted in the vertebrate brain's existence of winner's and loser's pathways (the fish brain circuitry is shown). When an animal wins a display contest, the winner's pathway activates while the loser's pathway deactivates, and vice versa. The loser's pathway allows a team-coordinating hominid to engage in intimidation displays that activate them as having, in the predator's brain, the "winner" status. The diagram illustrates that losers become submissive by shifting their attention to shun winners, who focus on their own needs while ensuring losers don't infringe on their "entitlements". The winner's pathway (red) originates in one habenula nucleus (Hb) and projects to the interpeduncular nucleus (IPN), which then projects onto other parts of the brain. The loser's pathway (green) activates another habenula nucleus (shown in blue) that projects elsewhere in the brain, creating submissive avoidance (swim to the bottom of the tank, fold dorsal and ventral fins). These pathways likely date back to the Cambrian Era, the origin of the vertebrate brain. The diagram (with modification) is from "Habenula as the experience-dependent controlling switchboard of behaviour and attention in social conflict and learning” [352].

Ethology, intimidation displays and avoidance submission

EXTERMINATE, BLOODY NOSE VS. DON’T KILL, WIN RESPECT

Intimidation mobbing aimed at getting submissive avoidance from predators offers two key advantages over the nonhuman “exterminate, bloody nose” mobbing strategy, which seeks to kill or injure: (i) cultivating a safe local buffer of predator population and (ii) 100% shunning effectiveness.

Cultivating a Safe Local Buffer Predator Population: Killing or injuring predators leads to their replacement by less predictable, unfamiliar predators from outside. The “don’t kill, win respect” strategy fosters and maintains a local predator population that acts as a buffer, keeping out such predators. Having experienced dominance displays, the local population learns to respect and avoid *Homo*. These local predators may even pass this respect to their offspring, culturally propagating a self-sustaining cycle of *Homo* shunning into future generations.

100% Effectiveness: This advantage creates an effectiveness such that ultrafast 250 ms vigilance for surprise ambush and stalking attacks can be dropped. Exterminating and injuring predators inhibits predators through pain and suffering, making predation more dangerous and costly. However, hunting is already risky, where multiple factors, including the possibility of injury, are factored in by the predator before initiating an attack (see **Box: Predator Business Plans**). The “exterminate and bloody nose” mobbing aims to recalibrate predator calculations by demonstrating that they can inflict harm, thereby “persuading” predators to seek alternative prey. One problem limiting this strategy is that hunting is shaped by intermittent schedule reinforcement reward [369]. Most hunts fail, but when they unpredictably succeed, the rewards are large, reinforcing the intermittent success against a constant background of hunting failures. This type of frequent frustration but unpredictable high-reward reinforcement creates associations resistant to punishment [369], limiting the effectiveness of nonhuman mobbing. Significantly, this approach doesn’t remove the mobbing species from the predator’s list of potential prey; it merely adjusts the predator’s cost-benefit calculations. The mobbers remain hunted, albeit with a revised risk assessment.

Box: Predator business plans.

To a predator, a prey species is revenue (food), while hunting them involves a bunch of cost, risk, and probability calculations akin to a business plan. On one side of the equation is the energy and nutrient reward of hunting a particular prey species; on the other side are the counterbalancing expenses, uncertainties, and dangers. Even simple predators like nematode worms, with only around 300 neurons, evaluate which prey to attack [370].

These factors include:

- What are the odds of success?
- What is the likelihood of sustaining injuries that could impair future hunting?
- What is the risk of becoming prey to other predators while hunting, an especially important concern for <20kg “mesopredators”?
- What are the opportunity costs of targeting this particular species instead of another or even opting for alternative food sources like scavenging or kleptoparasitic theft?
- After a successful kill, is there a risk of having the prey stolen (the other side of kleptoparasitism)?
- Does initiating an attack compromise the ability to launch future attacks in the near term (for example, the element of surprise in an ambush or after stalking can only be used once; an attack might alert nearby wildlife, thereby warning other potential prey)?

I leave out the energy costs of making attacks, as these are minimal. Research with GPS and accelerometer collars for leopards found only a 63 to 304 kJ increase in the two minutes surrounding the kill. In comparison (a measure that reflects the energy they obtain from each kill), the energy used between them is 52,015 kJ—a 171- to 825-fold difference [313].

Predators have limited lifetime opportunities to fine-tune their hunting business plans for each prey species. Constantly changing circumstances make determining the ideal cost-benefit trade-offs challenging, rendering their decision-making always a work in progress.

Reliance on learning and binary decision-making [371] implies that if predators never pursue certain types of prey, they won’t discover that such prey might be huntable and, therefore, won’t include them in their business plans. Consequently, predators tend to stick to hunting the prey already included in their existing business plans while avoiding unfamiliar species they have not yet learned to consider (further research on this is noted below).

The “exterminate, bloody nose” mobbing strategy seeks to adjust the predator’s business plan calculations. It aims to make predators view the mobbing prey as too high-cost to hunt profitably, thus encouraging them to opt for alternative prey. Importantly, while this strategy modifies the predator’s calculations, it doesn’t remove the mobbing prey from the predator’s business plans.

In contrast, the “don’t kill, win respect” strategy aims to inhibit the learning that might otherwise include the prey in the predator’s business plans. This strategy is feasible because intimidation displays tap into specialized brain circuitry, specifically in the habenula, which detects “control or be controlled” between individuals that underlie dominance-submissive relationships and how they are established by contests (see **Box: Submission is an active behaviour**).

Achieving this “no hunt” status is credible, as predators often exclude certain species from hunting (discussed later). Additionally, an “armed truce” shunning exists for species that predators categorise as fellow nonrival guild predators. The tactic employed by *Homo* is to use submission-shunning avoidance to ensure that it not only gains but also maintains its place on that “no hunt” exclusion list.

The submissiveness that results from shunning is self-reinforcing. Because the predator actively avoids contact (see **Box: Submissiveness is an active behaviour**), it never learns that the animal to which it is submissive might be easy prey. Humans are vulnerable due to their easily punctured skin, lack of fur, and weak nails—they need to stop predation through what can be achieved as split-second coordinated teams. For example, in chorused vocalisation, the collective singing of many individuals creates one bigger individual “volume” sounding voice. Neurologically created in the predator’s habenula, this submission avoidance creates the opportunity to be safe as it prevents *Homo* from being viewed as prey and, provided there is no direct food competition, results in them being ignored and skirted around.

Box: Submissiveness is active

Submissiveness acts as “behavioural camouflage” that minimises attacks. In this context, “behavioural camouflage” refers to concealing behaviours to avoid detection, typically by refraining from actions when they could be observed. This concealment usually takes the form of the submissive individual keeping clear—shunning— of those who might be provoked to attack them.

Critically, submissiveness is strategic acting, not actual helplessness. The submissive animal plays docile to avoid inviting attacks. If a conspecific, this lets it wait until it can replace the dominant. This active, not-triggering behaviour also gives itself the option, when not observed, to act differently and sneakily take food or mates. The smarter the behavioural play-acting, the more it can covertly subvert its apparent I-do-not-threaten you “passiveness”.

The presence of the habenula and its role in creating submissiveness offered early *Homo* a window of opportunity for this predator-avoidance strategy two million years ago. Exploiting the predator’s habenula to make them shunning submissive, I propose, is the neurological foundation for the niche construction of predator-safe habitat.

WHY DON’T KILL, WIN RESPECT STRATEGY WORKS

The don’t kill, win respect strategy is a case of “less is more”.

This strategy addresses two flaws in the “exterminate, bloody nose” strategy.

- First, predators already anticipate that their prey will fight back fiercely and might inflict serious harm—they, after all, will be fighting for their lives—attacking an animal with hooves, horns, and teeth is never risk-free. This “exterminate, bloody nose” mobbing cannot alter that background expectation; it merely moves the “dial” in hunting calculations.
- Second, deterrence does not break the scent-eat-hunt link. Ending this link is crucial. The don’t kill, win respect strategy by exploiting the deference of predators to intimidation corrects both these shortcomings.

In contrast, advertising superior control lets *Homo* win dominance confrontations. As previously explained, pre-fight assessments usually decide these contests before physical contact. These evaluations consider not just size and strength but also the superior coordination skills shown in displays that would make one the likely winner in an actual fight. Teams would exploit such assessments to get submission without the confrontation escalating to direct bodily contact. This requirement is critical given the Palaeolithic Faustian endurance-running-naked-radiator Bargain, which makes *Homo* skin highly susceptible to even minor injuries from predators.

Further, from a predator’s perspective, teams are perceived as a multiheaded “hydra.” Individual members, coordinated together, are assessed as a single “superorganism” greater than the sum of its individual *Homo* parts. Instead of seeing a dozen 43 kg hominids [372] facing them 40 m or 80 m distant on the savannah, the predator sees and hears a 516 kg shape-shifting multiheaded savannah goliath. Through split-second coordination, teams can create the illusion of a powerful, confrontational entity considerably larger than their predator opponents despite being composed of individuals. For instance, a single individual mimicking a predator's roars, howls, growls and other dominance-asserting calls is much less impactful than a dozen or more individuals chorusing that sound together, aided by synchronized drumming/stamping/clamping.

In addition, predators have little to gain from winning such “contests,” unlike confrontations with conspecifics and directly competing predator species. In the latter cases, rights to mating, food, and territory are at stake. When it comes to intimidating humans, the only loss for the predator is the opportunity to hunt one among many potential prey species. As I will show later, the circuitry in the habenula makes this a doable option, provided it is done as a coordinated team.

AVOIDANCE IS LOW COST

A key factor determining dominance-submission relationships is minimizing energy costs.

> Dominance captures behavioural patterns found in social hierarchies that arise from agonistic interactions in which some individuals coercively exploit their control over costs and benefits to extract deference from others, often through aggression, threats and/or intimidation.[373]

Avoidance of costly encounters with dominants is a key part of submissiveness. For example, in rhesus monkeys:

> Peaceful coexistence in rhesus society depends in large part on the behavior of subordinates. Their avoidance behavior minimizes the chances of casual conflicts with the dominants … In rhesus macaques, approaching a dominant, even for appeasement purposes, is risky, and subordinates just don’t want to take the chance. [374]

Given the low stakes for predators, they would opt for the lowest-risk choice and back off submissively when faced with a superior mobbing group. Escalating the situation offers no advantage. Therefore, the best choice for the predator is to move elsewhere and avoid the intimidating group upon encountering their scent. These primates are only marginally important to the predator’s diet and are not worth confronting.

Predators also can shun-avoid *Homo* submissively and keep their own ranking dominance submission hierarchy amongst their conspecies rivals. Lions don’t care about being the top beast on the savannah. They and other predators' only concerns are mating conspecifics and those other species that compete for the game animals they hunt.

Shunning *Homo* is not even a big dietary loss. Baboons (a terrestrial primate) and leopards illustrate how little primates matter: “Even in areas where baboons are abundant, their contribution to leopard diet seldom exceeds 5%” [375]. If leopards ceased hunting baboons, the actual dietary loss would be much smaller than that 5%. Leopards could offset this 5% loss by hunting alternative prey instead of baboons.

Leopards have this option as they hunt 111 species [376]. Other predators also have diverse diets: tigers 32 species [377], spotted hyaenas 30 [378], lions 42 [379], wild dogs 45 [380], and cheetahs 58 [381]. Critically, the study of predator diets also finds species exclusions:

> Although spotted hyaenas only significantly avoid buffalo, plains zebra and giraffe, lion and leopard significantly avoid 11 prey species, cheetah avoid 16 species and wild dog significantly avoid 16 prey species. [378]

This lack of “menu sacrifice” might be called the “no skin off my big cat’s nose” factor, suggesting that avoiding early *Homo* would not have been high stakes for would-be carnivores. Since predators already exclude many potential prey from their diets, adding one more wouldn’t much affect them.

INTOLERANCE VS TOLERANCE COST-BENEFIT BALANCE

Schaller’s idea of an “armed truce” tolerance arises as predators are “weaponized” for attack and defence. A predator must consider whether eliminating a food competitor has benefits that outweigh the risks of even a minor injury that might impair their future hunting and, thus, ability to eat. The risk is substantial: attempting to kill another predator is inherently dangerous, given that they have evolved the claws, jaws, strength and agility to quickly and violently subdue fighting-for-their-lives prey. Their victims can return what they get in a fight. Worse, if they survive (and most predator attacks fail), they might hunt their attacker, waiting for the opportunity when they can least defend themselves. Attacking a specialized “killer” risks a hornet’s nest of problems—if the gains and stakes are low, best demonstrate you’re a better fighter with a show and avoid combat.

One factor tipping the balance towards such armed truce tolerance is that an individual removing a food rival shares any gained benefit with nearby rival predators that also are advantaged from its killing but without incurring any of its risk or danger. Unless the competition is intense, the default decision for predators will be to threaten food competitors away, not go further and kill them—many factors side with caution.

All predators, however, compete for food to some extent. While they may specialize in certain prey—like cheetahs, known for their speed—they are opportunistic, and everyone will scavenge carrion when available. As noted earlier, despite its specialized hunting tactics and dewclaws that hock its prey [382], the cheetah has a diet comprising 58 different prey species [381]. Likewise, as noted earlier, other predators also have diverse diets: spotted hyenas eat 30 different species [378], lions 42 [379], wild dogs 45 [380], and leopards as many as 111 [376]. This overlap in prey makes them food rivals by necessity, given the broad range of their hunting. It is a question of how much, not if.

Predators can judge food competition through scent and have highly developed olfactory senses. As previously mentioned, dogs can identify individual animals [362]. Predators carry their own species' scent and that of their recent prey. Therefore, they can determine both the presence and the level of food competition with another predator using the odour linked with their "carnivory".

Size is another factor. Schaller's observation that predators like leopards hunt "jackals and servals and eat them as any other prey" is due to the small size of these animals. Carnivores are divided into two dietary categories: smaller carnivores weighing less than 20 kg, which feed on very small prey like invertebrates and small vertebrates, and larger carnivores weighing over 20 kg, which specialize in large vertebrates [383]. Jackals and servals fall under the 20 kg mark and consume foods not eaten by larger carnivores that prey on them. Therefore, due to diet-related olfactory cues, large predators won't recognize them as fellow intraguild predators. Smaller, they are not such a risk to kill. Body weight estimates for early *Homo* (50-90 kg) and *Australopithecus* (25-60 kg) [384] exceed this 20 kg threshold, and they could also complement that by dabbing themselves with the blood scent of larger prey hunted by potential predators. Consequently, their size and smell would categorise *Homo* as a fellow predator. *Homo* would need to emit just enough blood odour to be identified as a large predator but not so much as to be judged as a food competitor.

Homo would still be a food competitor, however. What one predator consumes, another cannot. This zero-sum situation is especially relevant if a predator defends a territory. Such competition can result in intraguild killing.

> intolerance between carnivores is conspicuous around kills. Any hyena that ventures too close to a feeding lion may be killed-though usually not eaten afterwards. Wilddogs, which occasionally are so tolerant of hyenas that they permit one to rest with their pack, frequently attack them around a kill. [234]
>
> Kruuk (pers. comm.) observed some 20 hyenas mob 2 lionesses one night. One escaped into a tree but the other was briefly covered by the pack before she freed herself and ascended a small tree where she sat while several hyenas tried to jump up at her. On two occasions I observed hyenas mob a lion in daytime for no obvious reason by following it in a tight pack while whooping. On another occasion, I found male No. 159 crouched in the plains while 17 hyenas stood near him, some within 30 m. When he rose, the hyenas whooped immediately and trotted toward him. Emitting a growly miaow, he lay down with his head on his forepaws. An attack seemed imminent but at that moment five lions appeared 200 m away and the hyenas dispersed.[4]
>
> Turner gave me the following excerpt from his field notes: "On 17th September, 1960, at 8 A.M., the local pride of lions was noted lying under a tree near the Seronera River with a female leopard high in the tree above them obviously very nervous… The leopard attempted to descend but was promptly chased up again. Suddenly the lions converged on a grass clump and pulled out two small leopard cubs about 6 weeks(?) old. They were immediately torn to pieces and consumed". [4]
>
> Mortality resulting from interspecific killing can be high, ranging from 43% to 68% of mortalities, as, for example, in cheetah, bobcat, spotted hyena, African wild dog, coyote, European pine marten, kit fox, or Egyptian mongoose. … Negative relationships exist between densities of cheetahs and both lions and spotted hyenas, densities of African wild dogs and both lions and spotted hyenas, and Egyptian mongooses and Spanish lynx. … In each case, interspecific killing between pairs of these species has been witnessed repeatedly. [385]
>
> In cheetahs, offspring survival is strongly affected by lion and hyena predation. Over 90% of cheetah cubs die before reaching independence, predominantly due to predation. [386]

Whether predators opt for tolerance or aggression depends on risk gain weighing. They are more likely to tolerate each other if the food competition is minimal and the risk of injury from an attack is high. Conversely, intolerance prevails if the threat to survival outweighs the risks of combat. *Homo* could earn tolerance if it could convincingly demonstrate, through intimidating displays, its potential to be aggressive, which made it appear too risky an opponent to attack given that it was a non-food competitor. Achieving this status would not be challenging for a species that primarily gathers fruits, berries, and tubers and whose hunting targets differ from its potential predators: it would easily tick the non-competitor food box.

The term "modus vivendi" in international relations captures this cost-benefit tolerance. Consider the 19th-century relationship between the United Kingdom and France. From the end of the Napoleonic Wars in 1815 until the *Entente Cordiale* in 1904, no peace treaty existed between these two geographically adjacent world powers, yet they maintained friendly, if not amicable, terms. Queen Victoria's summer holidays in the French Riviera during the 1890s even helped make Nice a major tourist resort. The UK and France concluded that, despite their colonial rivalries, the costs of war far outweighed any potential gains. This mutual noninterference was not the case with another of France's neighbours, Germany, which invaded France three times between August 4, 1870, and May 10, 1940—within less than 70 years. (The first time after the French declared war on Germany on July 19, 1870.) Ironically, in each instance, the initiator of the conflict miscalculated the cost-benefit analysis and ended up worse off. Predator "armed truce" tolerance is *modus vivendi*: getting along so you keep out of each other's way and don't get into costly no-win fights.

ASSESSMENT OF A PREDATOR

Homo, as a primate, is distinct from its savannah carnivora predators in that it lacks claws, jaws, and body strength. Compounding this vulnerability is the Palaeolithic Faustian Bargain, which traded a protective integument for a heat-radiating but weaker one for endurance running. The constraint on *Homo* is to get its ability to split-second coordinate as a team to register in predators as it being another—albeit not a food-competing—predator.

But what makes a lion treat a leopard, cheetah, wild dog, or hyena—but not a chimpanzee or baboon—as a fellow predator?

The key difference is that predators are specialized "attack machines". They assess this quality in other animals. Predation requires pursuing, wrestling, and dispatching struggling "fighting-for-life" prey. The jaw and claw tools enabling this can be reused against opponents in intra- and interspecies conflicts. Prey animals like rhinos or elephants may also fight, but only defensively. Their eating-enemy opponents must thus first put themselves in harm's way to be subject to their charge, tusk, and horn attacks. Such prey are like mobile forts that turn into battering rams in defence. In contrast, predators are designed for hunting, grabbing, killing, tracking, and pursuing escaping victims. They are like fast assault vehicles that prevent their dinner targets from fleeing. This offensive attack can also be directed against opponent rivals of their own species or food competitors. When predators categorize other animals as predators, they do so regarding this capacity for offensive go-out-and-hunt aggression. Hence, the critical importance that displays are unexpected, uninvited and proactive as this signals an offensive predator fighter rather than a defence prey reactive one. While a chimpanzee or baboon may have some limited ability to fight back, their adaptations are geared towards escape and avoidance. Their physical bodies are not evolved for getting food by killing (their predation of monkeys is an opportunistic "sidegig"), unlike those of predators, which gives such predators a killer capacity for lethal fights. Their mobbing is mainly reactive—it mainly occurs if they encounter predators, rather than proactively hunting them out—such visitation is a critical source of information to a predator that an animal is a fellow predator as only predators go out, search and attack.

Predators thus assess other animals as predators on their offensiveness—their capacity to go out, find opponents and uninvited display their fierce capacity for aggression.

ONLY SHUNNING SUBMISSION

Another factor advantaging *Homo* is its intimidation display only requires an omissive shunning-avoidance submission response from its predator "subordinates". In contrast, accepting submission among conspecifics often involves positive ritual submissive displays when they encounter each other. Darwin noted that submissive dogs, for example, "lower their bodies and crouch a little sometimes throw themselves in the ground with their bellies upwards". [322]. In red foxes, a submissive individual "crouches low, whines, beats ones tail licking the corner of the dominant's mouth" [387]. In rhesus monkeys, it is "bared-teeth display and the hindquarter presentation" [388], and in rats, it involves "tolerating hair-nibbling and whisker-trimming" [389]. Such positive submission acts let predators in a shared location keep their social dominance and submission ranking hierarchy among themselves. However, these positive actions can be skipped in the relationship between *Homo* and its would-be predators. Unlike conspecifics, they don’t socialize. Instead, *Homo* seeks from its potential predators only the shunning component of submissiveness.

EFFECTIVE INTIMIDATION ANNOYS BUT ISN’T VIOLENT

Critical to the “don’t kill, win respect” strategy and what distinguishes it from the “exterminate, blood nose” one is that the confrontation displayed to predators should make them feel intimidated but not life-threatened. This nonviolence is crucial because whatever *Homo* teams do, they must do it without risking predators reacting with retaliatory attacks. *Homo* needs to keep safe from panic violence by predators that result in blood drawing claw swiping, jaw bites or eating of their flesh. The predator cannot be allowed to learn that they are edible and, given their vulnerability, easily ambushed or stalked hunted.

In *On Aggression* [20]*,* Lorenz, however, notes that predators only attack when they feel trapped and unable to escape. Otherwise, they will ignore or retreat from those annoying them. Lorenz states, “Many animals will attack desperately when surprised by an enemy at less than a certain critical distance, whereas they would have fled if they had noticed his coming from farther away”. Intimation mobbing is about conditioning predators into fleeing. If they are terrified by intimidation rather than annoyed, they will not learn submission but escalate to violent attempts at retaliation.

APOSEMATIC WARNING

A related idea to the one proposed here is Joseph Jordania’s notion that human intimidation displays have an aposematic function [191]. Indeed, this approach is close to the one I am suggesting, though it differs in specific but critical details. In aposematic defence, an animal advertises its potential that it is not worth attacking or eating to predators. It’s about changing the calculation in a predator’s business plans. According to Jordania, humans exhibit several aposematic cues. Among the visual ones, he suggests, are bipedal tallness, body painting, masks, and body movements in perfect synchrony, “giving the impression of a much bigger super-organism”. Among the auditory cues of singing groups are loudness, precise rhythm, “attention-grabbing dissonant harmonies”, and animal call imitation. He also suggests humans have a “strong body odour”. Aposematism, I suggest, can be divided into reactive and proactive. Reactive warns predators that engage the aposematic animal when hunted for food. Proactive occurs when an animal seeks out a potential predator to communicate its warning. Most aposematic animals are of the former kind, with perhaps only some stinging insects seeking out potential predators. Jordania’s account, it seems, is of the first kind. Mine is of the second and, unlike aposematic accounts, does not concern painful aversion. The target is a predator’s deference circuits by which it adopts to a superior opponent submissive shunning.

THE DEVIL’S INVERTED GOLDEN RULE

Core to my analysis is the link between ethology and neuroscience in understanding dominance and submission among conspecifics and intolerance and tolerance among intraguild predator species. The link is provided by what I call the Devil’s Inverted Golden Rule. This “rule” regulates animal behaviour. It is antithetical to the well-known Golden Rule. Indeed, the Golden Rule may have arisen to counteract the otherwise negative social effects of the Devil’s Inverted Golden Rule on human communities.

The Devil’s Inverted Golden Rule states in a personalised form: “Do unto others what they cannot do back unto you.” This phrasing inverts the Golden Rule’s principle of “Do unto others as you would have them do unto you.” (It’s important not to confuse the Inverted form with the Negative one, which states, “You should not treat others in ways you would not want to be treated yourself.”)

The Devil’s Inverted Golden Rule describes not a cardinal moral principle but a causal neural perception—the asymmetry in causation that the vertebrate brain has been detecting in its relationships with conspecifics and other nonprey animals to regulate its behaviour towards them since its origin over 500 million years ago. It answers the question, “What can my behaviour cause in you that you cannot cause back on me?” This assessment of causality usually arises from status contests that feed into how animals' dominance submission regulates their behaviour with one another.

Michel Foucault noted a parallel relationship between control and power:

> Power … strategic games between liberties—in which some try to control the conduct of others, who in turn try to avoid allowing their conduct to be controlled. [390]

The Devil’s Inverted Golden Rule can operate vicariously and transitively. For example, if Y can control me but not vice versa, and I observe that X can control Y, then it follows that X can control me. Even fish can detect such transitive dominance-submission rankings through observation [357].

Critically, this rule leads to proxy assessments, such as displays, through which animals can learn about the extent of each other's ability to exert control against each other without the risk of injury. In dominance and submission, animals only resort to physical fighting when closely matched; a pre-match stand-off assessment usually suffices. Such assessments reduce the need for actual combat, conserving energy and reducing the risk of harm. Intraguild predators can use assessments following similar stand-off contests to adjust their behaviour to avoid direct competition.

In summary, the vertebrate brain evolved to detect control, whether it was in control or controlled by another, known from contests that escalated from initial stand-off displays. They then use the contest's outcome afterwards to regulate relationships as dominant and submissive. This causal perception between agents allows each animal to find with minimal injury its "place" in a self-regulatory, minimally violent hierarchy.

In addition to detecting winners and losers of status contests, the habenula also actively "brakes" behaviour with anti-reward (what is liked is treated as the opposite), so individuals act submissive and show themselves as "losers". Consistent with this, depression has been linked to the habenula. (Winner behaviour is generated elsewhere in the brain's reward circuitry).

Mathematically, the Devil's Inverted Golden Rule involves contest entropy and informational surprise. Each agent aims to increase regarding the other the entropy of their own behaviour toward an opponent, thereby causing it surprise, while decreasing the entropy of their opponent's behaviour toward them so they avoid being surprised. This conflict creates a mathematically analysable asymmetry where one agent's behaviour but not the other has a greater impact on their interaction's outcome.

I propose that the habenula detects the Devil's Inverted Golden Rule causality asymmetry. It is part of the brain's core information processing "chassis". The habenula dates back to the Cambrian Era half a billion years ago and the emergence of the first vertebrate brains and, thus, the first agented individuals. It is not an evolutionary "afterthought" but as much a foundation of brain function as seeking food or a mate. As a neural "chassis", its functioning gets considerably elaborated by more recent higher brain areas such as the amygdala and orbital frontal cortex.

The Inverted Gold Rule explains why the opportunity for intimidation displays exists to be effective in getting shunning from a would-be predator: predators detect in stand-off displays that *Homo* can control them but not vice versa due to the predator's habenula detecting the asymmetrical causality power of *Homo* over them. This causal perception makes them avoidant; if such avoidance had an important survival cost, they might test what is behind the mobber's display, but since "throwing in the towel" usually has no survival cost—*Homo* are only one among many species, they might hunt—they opt for the uncomplicated decision and like a submissive circumvent, shun them and get on with their own lives.

DEVIL'S INVERTED GOLDEN RULE ASSESSMENT

Displays convey information and are crucial for establishing dominance-submission contests because physical fights come with high costs. Typically, confrontations start with stand-off advertisement, and if this does not suffice, a gradual escalation of increasingly involved physical contact until one participant realizes that continuing would likely result in permanent injury or death. Life and death contests only occur when the opponents are evenly matched, and early stages of escalation fail to establish one as superior, ending in full "no-limits" fighting.

Male zebrafish, for example, go through specific phases. Initially, the first phase

> consists mainly of mutual assessment behaviors, with fish assessing each other by exhibiting display, circle, and bite behaviors to determine the other fish's relative fighting ability.

As Lorenz explains displays

> serve to "size up" the opponent, to measure the fighting potential of one rival against that of the other before damage is inflicted. A small fish may swim up to a bigger one and display broadside-on, but will collapse and flee the moment the other unfolds his unpaired fins and shows his size and colours. If the difference in size and strength between the rivals is slight, matters may proceed to tail-beating and, if still slighter, to mouthfighting. The combatants must indeed be very equally matched if the observer is to see an actual, damaging fight. [391]

Once this assessment settles who the winner is, a second stage ensues in which

> all agonistic behaviors are initiated by the winner (e.g., bite, chase, and strike), whereas the loser tries to flee and displays submission and freezing postures. At the end of

> fights, losers usually stay near the bottom or top of the tank adopting a submissive posture. [392]

Withdrawing from the contest allows individuals to live another day, avoiding injuries that could end future opportunities for making themselves the top animal.

Various methods exist for individuals to assess an opponent's potential for harm without engaging in physical combat. One approach is to observe proxies such as size, strength, and stand-off advertised of fighting skill [393]. These attributes can be assessed without physical contact. Contestants can demonstrate superior skills needed for fighting, such as manoeuvring, reacting, and anticipating through mock spurring and jockeying. By displaying these skills, contestants advertise their capabilities without the risks of direct, flesh-on-flesh combat testing.

Critical issues:

(1) The "don't kill, win respect" strategy aims not to seriously injure predators but rather to "educate" them into shunning. Serious injury refers to harm that would stop a predator from hunting and thus eating or might trigger the predator's midbrain emergency threat circuitry (in the periaqueductal gray, PAG). This educational approach creates a local population of avoidant predators who seek to preserve their territory by keeping out potentially dangerous, "untutored" outside ones.

(2) This strategy replaces physical violence with proactive team intimidation, which I suggest took the form of ritualized visitation harassment—akin to a haka-style performance.

(3) These displays serve as a group equivalent to individual mock confrontations aimed at intimidating opponents into submission without the risks of actual combat and, as such, are *coitus interruptus* ("coming together", interrupted) and don't escalate into actual physical combat. Humans cannot win skin-fur nail-claw with carnivores. Therefore, these displays are poker-bluffs played, not to be called. Predators must never find out how easily they can "ace" these primates if they get near and maul.

(4) Predators "fold" to these haka displays and retreat in a submissive avoidance, as little gain exists to escalating. Even where hunted, modern primates comprise no more than 5% of a predator's diet. Further, the losses from not hunting one species can be made up by hunting others. It is not worth the "candle" to risk possible harm and check out what is behind the hullabaloo.

(5) Once a predator has been conditioned into submission, it switches from using its sense of smell to hunt humans to using its senses to shun them.

(6) This predator-stopping strategy relies on *Homo*'s ability to coordinate as a team, which arises from white sclera making line-of-sight conspicuous and MENSA attention sharing. This predator-stopping closes the loop since for white sclera to exist, predators must no longer hunt those with them (the BROWS white sclera elimination process).

One argument for the Palaeolithic origins of this strategy is how modern humans exploit such submission when taming pets, farm animals, and animals for zoos, circuses or, such as Roy Horn's big cats, entertainment,. The ease with which we subjugate animals suggests that our Palaeolithic ancestors could have similarly, collectively, albeit under different circumstances, induced similar submission. Perhaps significantly, the two animal species we most commonly share our lives due to our ability to make them friendly and submissive, *Canis lupus familiaris* (domestic dog) and *Felis catus* (domestic cat), both are domesticated predators, *C. lupus* (wolf) and *F. silvestris* (wild cat). Darwin observed that inducing submission is a key element in the bond between pets and their owners, stating, "The feeling of affection of a dog towards his master is combined with a strong sense of submission" [322].

Why intimidation display is so effective

While would-be predators incur low costs from these contests, mobbers gain much. Not being on a predator's scent food menu (see **Box: Predator change is scent-triggering behaviour change**) is not just about being shunned rather than hunted; it fundamentally alters how these primates live. Therefore, it's worth investing time and effort for early *Homo* to go to resting predators and regularly display-intimidate them. Proactive allows them to set the best time and place to advertise their superior fighting skill. Certain locations and circumstances offer advantages for the mobbers to do this safely, both in that predators cannot easily get them and they offer predators an easy "defeat" escape route. The mobbers also can prepare for intimidation with stockpiled stones and earlier practice in throwing, choral singing, drumming, and teamwork.

Box: Predator change is scent-triggering behaviour change.

To the predator, the mobbers are not a distinct species but a bundle of energy with a unique, trackable scent. Winning respect involves altering how the predator's brain associates in its brain that scent with hunting. The scent can either trigger an urge to pursue the species for food or inhibit that urge via the habenula circuitry, prompting the predator to maintain distance instead. Vision becomes important to a hominid predator only after it decides to hunt and needs to select specific victims for a surprise attack. This scent-behaviour link is usually learned at a young age from their mothers. Based on their mother's reactions to different scents, cubs or pups pick up cues on which animals to avoid or pursue. Humans similarly learn from their caretakers about food [394]. Intimidation displays serve not only to establish this respectful shunning but also to reinforce it and transmit it to future generations. If young predators travel with their adults, it's even better, as they will learn early from their mother's negative reaction to their scent that these hominids are animals to be avoided.

"DON'T KILL, WIN RESPECT"—PALAEOLITHIC HAKA HONOURING RITUALS

Early *Homo* might not have "consciously" gone out to intimidate predators. Activities like ritual song, dance, drumming, and ceremonial stone-throwing could have been performed for reasons different to their effects on predators, such as celebrating group unity or even showing respect to savannah animals. They might have experienced it as a Palaeolithic haka to meet and "honour" predators. Their proximal motivations (group ritual celebrations) need not be connected with their distal effects (creating predator shunning). For humans, proximal motivations were ritual and bonding to define symbolically group relationships. But distal effects shaped predator behaviour so that rather than ambushing or stalking *Homo*, they got treated with avoidance respect.

RECAP—A DOABLE OPPORTUNITY

All the ingredients, therefore, I propose, exist for this alternative deference-seeking mobbing strategy, not deterrence-seeking one. *Australopithecus*, as a hominid, would already have made dominance displays. As mentioned in the previous section, they would have had, like contemporary chimpanzees, rudimentary skills like throwing and drumming, which could be refined to intimidate predators. Therefore, it wouldn't be a large leap for them to adopt a "don't kill, win respect" mobbing strategy that could end through winning respect predator attacks—but only if they could split-second coordinate—like in soccer football—as a team—the critical result of white sclera and conspicuous line-of-sight.

Why teams make intimidation effective

The key ingredient in the "don't kill, win respect" strategy is split-second team coordination.

Teams are essential for five reasons.

INTIMIDATION "TEMPERATURE" CONTROL

Only a team can intimidate predators by ensuring group behaviour is:

(i) sufficiently annoying to get a predator to back off, activating its habenula circuitry

while simultaneously,

(ii) this irritation is not so irritating that it crosses the predator's "critical distance", triggering its survival threat circuitry as a risk to its life, causing uncontrolled charges against its intimidators.

Thus, intimidation must be done while monitoring its impact on the predator's sense of endangerment—its annoyance, "temperature." The team must retreat if irritation becomes too "hot" and gets experienced as a threat to the predator's survival, triggering retaliatory running-charge attacks. Significantly, this controlled intimidation requires that no individual breaks rank and inflicts injuries to which a predator might react by running out and attacking the mobbing team. It must be done as a "cool-headed", not a pell-mell bunch of hotheads.

SAFETY PANIC "BUTTON"

A team must withdraw as a unit, with no exceptions. Occasionally, a predator may suddenly indicate that its patience has run out—perhaps because of concealed cubs—and choose to attack rather than retreat. In these situations, the mobbing group must withdraw in unison. Recall the earlier incident of Louis Leakey and his son Richard: "they were furious and after 10 minutes, I signalled to my son, 'Get out. It's not safe any longer'" [337]. Only a well-coordinated team can safely execute intimidation. All the safety gained by intimidation "goes up in smoke" if a team member is captured and eaten, and a predator learns to associate the group's scent with food.

COORDINATION = SUPERIOR CONTROL IMPRESSION

Intimidation display advertises that you, not the predators, are in the savannah driving seat. At its core, team success pivots on creating intimidating confrontations, showing, “we are in control, you are not”. A team does this by going up to would-be predators and making unpredictable actions, frustrating predators who find anticipating what is coming next impossible. The team intimidation disorients them into a “blooming, buzzing confusion”. One moment, predators are resting, minding their own business; the next, their quiet is invaded by loud choral singing, drumming sounds, and a rain of unpredictable pebbles. They growl and roar back, but nothing they do stops the display except move off. The *Homo* mobbers return to their camp having won—they, not the carnivores, are in charge of the savannah. The mobbed predators return and sniff where the mobbers had been (if they could not already detect their smell) and then keep clear in future of that intimidating scent.

Demonstrating control is critical, as *Homo*—even with weapons and throwing projectiles—is no match physically against a predator in a “claw and jaw” combat. However, a predator doesn’t need to know its physical advantage; it assesses an opponent during display by apparent size, strength, and, most importantly, an animal’s ability to exhibit control over it as an opponent. Team coordination lets *Homo* advertise to predators that it has, at least in a poker-like bluff, the upper hand. This strategy is akin to getting predators to “fold” without revealing one’s own “cards”—*Homo* mobbers may have some “high” or royal cards like throwing projectiles or thorn/stone weapons, but critically, they cannot risk being claw and jaw “aced” in a contact mauling.

POKER BLUFF “SUPERORGANISM”

Homo may not be large individually, but as a team, they can mimic loud dominance calls either chorally or with drums. They can also inflict from projectiles, , if not severe injuries, then at least painful, irritating stings.

But critically, they can create hydra-like as they team-merge seen and heard from a stand-off distance a single opponent advertising power. No longer just puny primates, teams let *Homo* transform itself, in a Peter Parker-to-Spiderman manner, into a multiheaded stamping, singing, drumming, Superape walking across the savannah. To predators, it would be a biblical (*Job* 40:15), “Behold now the savannah behemoth, which I made with thee”!

A predator’s brain may not know that a *Homo* team comprises separate individuals. After all, it witnesses an organized, coherent whole—a primate “hydra” that can “magically” transform from individual parts into an intimidating opponent. Why would it cognate otherwise? It is not as if predators watch the carnivore equivalent of wildlife documentaries explaining that *Homo* is a weak species, ingeniously tricking its would-be “eating enemies” through split-second intimidation displays whose parts coordinate as one illusionary multiheaded “monster”. *Ars longa, vita brevis*—the Latin translation of one of Hippocrates’s aphorisms—skilfulness takes time, life is short, and *iudicium difficile*—making judgment difficult. Teams can masquerade as if their coordination is one body—and predators need never know it is just a show made for them by a frail, easily injured but cunningly—the most intelligent to have ever evolved—supersmart primate.

An alternative is that predators are aware of their synchrony. William McNeil [350] emphasises the importance of keeping in time synchrony for group bonding, and according to Edward H. Hagen’s Coalitional Signaling Theory [395], perception of this can impress potential opponents; Hagen later extended this to include *Homo*’s predators [396]. Related to this is the Beau Geste hypothesis [397], whereby it is not synchrony that impresses but the diversity of its performance. Though no specific research exists, it is plausible that predators detect ill, injured, old, pregnant or other vulnerable individuals when looking at a group by detecting which fail to react synchronously with other group members. For example, pain might disrupt attention to what others are doing; likewise, the depression associated with illness disrupts their reactions. Moreover, groups in which members are ill will lack the coherence of those in which all are in the best health. Parallel to such awareness of impaired synchrony will be the opposite—the detection of exceptional coherence in groups, which team coordination can exploit to impress opponents.

MUTUALISM OPTION

Predators may enter into mutualism with *Homo*. Team mobbing aims to create a buffer of “safe” local predators, thereby excluding less reliable errant ones from outside. This goal aligns with the interests of local predators, potentially evolving into mutual cooperation to repel from their territory nonlocal rivals. Humans provide unique skills that predators lack, such as superior daytime vision and choral singing, drumming, and projectile throwing. By aiding local predators to maintain their territories, early humans would ensure the stability of a buffer population of predators and benefit them and themselves. Other forms of mutual aid might be engaged in, such as helping predators protect their kills from kleptoparasites (perhaps, taking a cut for their services rendered). Such mutualism would create an additional reason for them to be excluded as prey.

Devil's Inverted Golden Rule and contest entropy

One reason to link teams with asserting dominance is that modern humans set up team contests as games. These team competitions challenge the ability of opposing sides to control a ball, mirroring a contest to show superior control that in dominance and submission contests decides winners and losers. Soccer football exemplifies such contests, as two sides aim to demonstrate superior control through their competitive ability to manoeuvre a ball, get its possession and kick it into the other side's net. The side with the better control scores more goals, making one team, by the game's rules, the winners and the other the losers. Differences exist with the display contests done between opposing animals for dominance, but at the core, they are control contests: the ability of one opponent to onto the other what the other cannot do back in return. In football, that asymmetry of control is played out in the ability to manoeuvre a ball; in animal dominance, a proxy display that demonstrates the agility and ability to fight—if it came to it—to come out "tops" in a physical fight.

In football, control is quantified by the number of goals scored, leading to one team being designated as "winners" and the other as "losers". The less proficient team concedes respect to the victors by acknowledging their triumph. These outcomes then determine the league positions of teams, making some top and others bottom. Within the game's rules framework, this status mirrors the dominance and submission roles observed in animal ranking hierarchies. In the animal world, winning grants access to real rewards like food, territory, and mates. In football, the equivalent rewards are defined by the game's rules, such as the pride of being top-ranked or the status of cup winners. The innate drive to win confrontations with opponents by demonstrating superior control is in our brains and genes—our species' genius is to transform this into competitive play and organized entertainment.

The vocabulary of sport strongly resembles the language used to describe dominance-submission animal contests. Those who are defeated show deference to the victors and stand in the background, acknowledging the winner's high status until the next competition or season. The metaphor of "top and bottom" is apt; in the animal world, the loser often ends up below the winner physically on top of them. The term "respect" originates from the Latin 'respecto', which means to look back, look around or behind repeatedly or intently, to look or gaze about, signifying the attention typically accorded to dominant animals or league champions.

To elucidate this control aspect of games, imagine a Premier League football team competing against amateurs. The professional team will dominate ball possession, effectively relegating the amateurs, in terms of control, to "spectators". Soccer football team play also offers valuable insights into this aspect of control. Research on successful football teams finds entropy is crucial; winning teams possess greater "information" in their collective cohesiveness, such as ball-passing patterns, than losing teams [398,353–356]. For example,

> minimizing the entropy of passes may support the team's coordinated behavior but it might: (1) limit its degrees of freedom in moving the ball and surprising its opponent; and (2) expose the team to counter attacks by the competing team that may try, for instance, to block player M when it observes player A moving the ball. The price of maximizing the certainty of passes might be an expected behavior and vulnerability to the opponent's attacks. … Taking this competitive perspective into account, we may understand that, on the one hand, a successful team may strive to minimize its entropy in order to maximize communication. On the other hand, the team may strive to maximize its entropy in order to maximize its degrees of freedom and prevent from its opponent to respond to an ordered pattern of behavior. [398]

My approach differs slightly; see **Box: Contest entropy**.

In mobbing confrontations with predators, the primary goal of mobbers is to control and disorient the predator's attention. They aim to create a sense of uncertainty, ensuring that the predator constantly second-guesses the mobbers' next move. There's a delicate balance to maintain: they want to induce just enough unease in the predator without pushing it to a point where its survival instincts, particularly its PAG survival circuitry, are triggered. This unpredictability can be enhanced through coordinated team actions. For example, suppose a stone is thrown from one direction. In that case, it might be quickly followed by another unexpected event from a different direction, such as another stone or a coordinated imitation of a dominance call. Importantly, the randomness of these unpredictable actions "shadows" the predator's behaviour to more effectively torment it into feeling helpless; the mobbers actively track and seek to undercut the predator’s attempts to control the situation. Suppose the predator tries to regain mastery, for instance, through warning vocalizations. In that case, the mobbers counter this, so it feels these attempts are fruitless and even more lacking in control. The predator faces a fork in the road; one option is to escalate the situation, charge out and attempt to catch and physically attack the mobbers or escape and retreat. No big stake exists, however, worth escalation. *Homo* isn’t an important food source and not a hunting rival. Retreating, as the unexpected events stop, allows the predator to regain a sense of control.

As a result, the mobbers condition the predator(s) to associate their scent with the act of avoidance. In doing so, the mobbers have successfully shaped the predator’s behaviour, conditioning the predator(s) to learn that the mobber’s scent isn’t indicative of food but rather a signal to shun.

Box: Contest entropy.

One of the brain’s primary tasks is determining its influence on outcomes and the uncertainty tied to those outcomes. The habenula is part of the brain specialized in detecting that uncertainty. This sensing of control with another can lead to entropy contests.

Contest entropy refers to the relative ability of opponents to challenge each other by exhibiting a better ability to achieve certainty in getting desired outcomes while making opponents uncertain of their ability to reciprocate.

In contests where the objective is to outwit the opponent through surprise, each participant aims for their actions to have high entropy given the opponent’s expectations. The challenge lies in selecting an unpredictable action for them, thus maximizing its surprise when done.

Conversely, each player aims to reduce the entropy of the opponent’s strategy regarding their own expectations. This strategy involves anticipating the opponent’s moves, thereby minimising the surprise they generate. Each contestant has equal physical capabilities: the competition is their use.

The notion of contest entropy is closely related to the concept of asymmetrical causality (the Devil’s Inverted Golden Rule). Each player aims to induce changes in the opponent while minimising reciprocal effects. In terms of entropy, the goal is to increase one’s own behavioural entropy to cause surprise while reducing the opponent’s entropy to avoid being surprised. A contest is effective to the degree it reveals any asymmetry whereby one side’s actions impact the interaction more than the other’s.

Another way to look at this is in terms of information gain. Each individual seeks to acquire as much information as possible about the opponent’s future actions, thereby reducing the opponent’s surprise entropy. At the same time, the aim is to disclose minimal information about one’s future actions, thus preserving one’s action entropy and capacity to make surprises.

To illustrate this, imagine you and a competitor each have a finger on a coin placed at the centre of a table, and you are both concerned with the predictability of its movements.

- Initially, the coin moves randomly, akin to an atom undergoing Brownian motion on a two-dimensional plane. No control contest occurs if both parties’ fingers passively follow the coin’s random movements.
- If both have equal influence over the coin’s motion, its movement stops or remains uncontrolled random, as neither side can transmit information into its actions. In this scenario, both parties are entropy-wise on equal footing.
- Contest entropy emerges when there is a disparity in control, allowing one side to exhibit conditional entropy through the coin’s movements. One party can introduce information into the coin’s motion—acting as it predicts—while the other finds itself ineffectual.

This shift requires intelligence, as the disadvantaged side has to recognises that the coin’s movement is not just random and beyond its control but specifically influenced by its opponent. This problem creates the contest: the challenge is structured so that it becomes evident to the disadvantaged side that its lack of control directly results from its opponent’s actions. It’s not a matter of randomness; the contest manifests to each other, and any onlooking spectators, each side’s comparative success in gaining control.

The coin’s motion can be compared to the movement of a football. The team with superior control prevents the opposing side from exerting entropy on the ball and asserts its own control—evidenced by its greater ability to score goals. This setup constitutes a contest because the actions of either side determine the football’s movement. The football is not an animate object controlling its own movements, nor is it so light that factors other than the teams—such as the wind—determines its movements.

Football creates a good contest because the interplay between evenly matched teams introduces chaos, consistently producing scenarios that test each side's capability to gain and sustain ball possession. Moreover, the clear yet demanding goal-scoring aspect facilitates league rankings, guaranteeing that opposing teams in arranged games have comparable skills.

Argument by inferred opportunity

The argument presented is based on the idea of inference-by-opportunities/constraints. It suggests that Palaeolithic *Homo* differed from earlier *Australopithecus* in regard to having ***A*** opportunities they lacked but did not constrain them. These opportunities link to white sclera, the impact of conspicuous line-of-sight on already existing abilities to extract attention but which now allowed it to be shared. ***A*** enabled *Homo* (or white sclera australopiths that now became them) to engage in action ***B*** because opportunity ***A*** was present, and this action led to outcome ***C.*** In this context, action ***B*** is the "don't kill, win respect" approach when mobbing predators, and outcome ***C*** is the effective prevention of predator attacks by getting their shunning.

To strengthen this argument, we introduce factor ***D***. This includes the unique human traits that could now arise from outcome ***C***, such as our vulnerability to predators even though we are suitable prey and the modern-day reluctance of predators to target humans, as seen with Louis Leaky, his African colleague, and the five savannah lions. ***D*** also includes all the "road not travelled" cognitive and cultural consequences that follow when a species can socially learn and transmit culture free from predator fear.

If evidence shows that if early *Homo* had ***A*** (something without time machines we cannot know), it could adopt action ***B*** and that ***B*** consistently leads to ***C***, and ***C*** to ***D***, and given that we observe ***D*** today, then it's likely that early *Homo* adopted the strategy denoted by ***B***. The validity of this inference rests on demonstrating that action ***B*** was an available strategy given ***A*** for the earliest *Homo*, that ***B*** results in ***C***, ***C*** then gives rise to ***D***, and that ***D*** is observable.

A⇒***B*** is supported by (i) the psychophysical differences for observers between white and coloured sclera, (ii) that white sclera is only a loss-of-function mutation away from coloured sclera, (iii) but it is evolutionarily locked out, however, by BROWS weeding out of individuals with such mutations—and that if was not a problem enough, (iv) an XOR fitness fork exists between coloured/white sclera linked predator survival strategies.

B is supported by the ability of high visible line-of-sight (as a result of white sclera) to transfigure pre-existing MENA capabilities in primate brains into MENSA ones. This seeable line-of-sight, combined with MENSA, equips *Homo* brains with the capacity for aligned cognition, shared intentionality, and split-second coordination. These intercoupling cognitive abilities allow humans to work in teams, creating behaviour that is greater than the sum of its individual parts. This sequence leads, with the additional ideas of habenula function, the Devil's Inverted Golden Rule, display induced submission and predator shunning to the cessation of humans needing split-second vigilance to surprise attacks. While this presents a complex puzzle, each piece offers avenues for research, testing and empirical expansion.

C is evident in the physical characteristics of human bodies, marked by their vulnerability to predators and also the capacity that, sans predators, we have for cumulative culture and cultural evolution. This former fragility is highlighted by the Palaeolithic Faustian Bargain, which results in human skin that offers little defence against predators' sharp claws and teeth. The latter potential is shown by what happens when the stress created by predation is removed in other animals on their increased capacity for social learning and culture—the solution I offer to explain, "Why culture is common, but cultural evolution is rare" problem [45,46].

D describes our current state. Modern humans—ourselves—are biologically extraordinary in many ways, but perhaps the most bizarre is that we are the only species that has journeyed from how it initially arose to live in a completely different alien way. Reading this, you are a contemporary modern human, but in all important respects, your genes, bodies and brains could have been those of any of your ancestral palaeolithic mobile immediate return hunter-gatherers. Remarkably, they had, at times, populations of possibly only 5,000 breeding pairs [399]. But now you—one of their descendants—are one of nearly eight billion and species biomass of 287 million tonnes [400]. If we had time machines, we could adopt one of our palaeolithic ancestors, and they could become another Jane Austin or Albert Einstein. Likewise, if we took a baby Jane or Albert from their cribs and time ported back, they could grow up to be as good a palaeolithic hunter-gatherer as any at the dawn of our species. Only a few differences in skin pigmentation, immune and other genes incidental to what makes us human separate our mobile hunter-gatherer ancestors and the mobile phone high-tech citizens we are today—we are identical in the biology needed to be human. ***C*** explains why.

REFERENCES

[1] A. Schopenhauer, Die Welt als Wille und Vorstellung, 2. Aufl., Brockhaus, Leipzig, 1844. https://opacplus.bsb-muenchen.de/search?id.

[2] L.S.B. Leakey, Development of aggression as a factor in early human and pre-human evolution, in: Aggression and Defense, Neural Mechanisms and Social Patterns, University of California Press, Berkeley, 1967: pp. 1–34. https://doi.org/10.1525/9780520340190-001.

[3] J. Goodall, The Chimpanzees of Gombe: Patterns of Behaviour, Harvard University Press, Cambridge, Mass, 1990.

[4] G.B. Schaller, The Serengeti Lion: A Study of Predator-Prey Relations, University of Chicago Press, 2009.

[5] C. Boesch, The Effects of Leopard Predation on Grouping Patterns in Forest Chimpanzees, Behaviour. 117 (1991) 220–242. https://doi.org/10.1163/156853991X00544.

[6] C. Boesch, H. Boesch-Achermann, The Chimpanzees of the Taï Forest: Behavioural Ecology and Evolution, Oxford University Press, Oxford, New York, 2000.

[7] I.R. Clark, K.C. Lee, T. Poux, K.E. Langergraber, J.C. Mitani, D. Watts, J. Reed, A.A. Sandel, White sclera is present in chimpanzees and other mammals, Journal of Human Evolution. 176 (2023) 103322. https://doi.org/10.1016/j.jhevol.2022.103322.

[8] B.M. Wood, D.P. Watts, J.C. Mitani, K.E. Langergraber, Favorable ecological circumstances promote life expectancy in chimpanzees similar to that of human hunter-gatherers, Journal of Human Evolution. 105 (2017) 41–56.

[9] D. Troilo, H.C. Rowland, S.J. Judge, Visual optics and retinal cone topography in the common marmoset (Callithrix jacchus), Vision Research. 33 (1993) 1301–1310.

[10] H. Kobayashi, S. Kohshima, Unique morphology of the human eye and its adaptive meaning: comparative studies on external morphology of the primate eye, Journal of Human Evolution. 40 (2001) 419–435. https://doi.org/10.1006/jhev.2001.0468.

[11] M. Tomasello, The cultural origins of human cognition, Harvard University Press, 2009.

[12] C. O'Madagain, M. Tomasello, Shared intentionality, reason-giving and the evolution of human culture, Philosophical Transactions of the Royal Society B: Biological Sciences. 377 (2021) 20200320. https://doi.org/10.1098/rstb.2020.0320.

[13] M. Tomasello, Origins of Human Communication, MIT Press, 2010.

[14] M. Tomasello, Becoming Human: A Theory of Ontogeny, Belknap Press, Cambridge, Massachusetts, 2019.

[15] M. Tomasello, M. Carpenter, Shared intentionality, Developmental Science. 10 (2007) 121–125. https://doi.org/10.1111/j.1467-7687.2007.00573.x.

[16] M. Tomasello, I. Gonzalez-Cabrera, The Role of Ontogeny in the Evolution of Human Cooperation, Hum Nat. 28 (2017) 274–288. https://doi.org/10.1007/s12110-017-9291-1.

[17] A. Zembowicz, R.V. Mandal, P. Choopong, Melanocytic Lesions of the Conjunctiva, Archives of Pathology & Laboratory Medicine. 134 (2010) 1785–1792. https://doi.org/10.5858/2009-0522-RAR.1.

[18] N. Efron, M. Al-Dossari, N. Pritchard, In vivo confocal microscopy of the bulbar conjunctiva, Clinical & Experimental Ophthalmology. 37 (2009) 335–344. https://doi.org/10.1111/j.1442-9071.2009.02065.x.

[19] R. Singh, A. Joseph, T. Umapathy, N.L. Tint, H.S. Dua, Impression cytology of the ocular surface, British Journal of Ophthalmology. 89 (2005) 1655–1659. https://doi.org/10.1136/bjo.2005.073916.

[20] K. Lorenz, M. Latzke, E. Salzen, On Aggression, 2nd ed., Methuen, London, 1966. https://doi.org/10.4324/9781003209249.

[21] J.W. Laundré, L. Hernández, K.B. Altendorf, Wolves, elk, and bison: reestablishing the "landscape of fear" in Yellowstone National Park, U.S.A., Canadian Journal of Zoology. (2001). https://doi.org/10.1139/z01-094.

[22] L.Y. Zanette, M. Clinchy, Ecology and Neurobiology of Fear in Free-Living Wildlife, Annual Review of Ecology, Evolution, and Systematics. 51 (2020) 297–318. https://doi.org/10.1146/annurev-ecolsys-011720-124613.

[23] C. Darwin, A Naturalist's Voyage: Journal of Researches Into the Natural History and Geology of the Countries Visited During the Voyage of H.M.S. "Beagle" Round the World, Under the Command of Captain Fitz Roy, John Murray, 1897.

[24] S.L. Lima, Nonlethal Effects in the Ecology of Predator-Prey Interactions, BioScience. 48 (1998) 25–34. https://doi.org/10.2307/1313225.

[25] S.D. Peacor, E.E. Werner, The contribution of trait-mediated indirect effects to the net effects of a predator, PNAS. 98 (2001) 3904–3908. https://doi.org/10.1073/pnas.071061998.

[26] S.L. Lima, L.M. Dill, Behavioral decisions made under the risk of predation: a review and prospectus, Canadian Journal of Zoology. (2011). https://doi.org/10.1139/z90-092.

[27] J. Kahlert, Factors affecting escape behaviour in moulting Greylag Geese Anser anser, J Ornithol. 147 (2006) 569–577. https://doi.org/10.1007/s10336-006-0081-5.

[28] W. Cresswell, Non-lethal effects of predation in birds, Ibis. 150 (2008) 3–17.

https://doi.org/10.1111/j.1474-919X.2007.00793.x.

[29] O.J. Schmitz, A.P. Beckerman, K.M. O'Brien, Behaviorally Mediated Trophic Cascades: Effects of Predation Risk on Food Web Interactions, Ecology. 78 (1997) 1388–1399. https://doi.org/10.1890/0012-9658(1997)078[1388:BMTCEO]2.0.CO;2.

[30] F.A. Stewart, J.D. Pruetz, Do Chimpanzee Nests Serve an Anti-Predatory Function?, American Journal of Primatology. 75 (2013) 593–604. https://doi.org/10.1002/ajp.22138.

[31] T. Romani, S. Tranquilli, P. Roessingh, S.B. Menken, R. Mundry, M. Konarzewski, T.C. Hicks, Factors affecting nest height and ground nesting behaviour in Eastern chimpanzees (Pan troglodytes schweinfurthii) of the northern Democratic Republic of the Congo, Folia Primatologica. 1 (2023) 1–34.

[32] A.E. Patla, J.N. Vickers, How far ahead do we look when required to step on specific locations in the travel path during locomotion?, Experimental Brain Research. 148 (2003) 133–138.

[33] T. Caro, Cheetahs of the Serengeti Plains: group living in an asocial species, University of Chicago press, 1994.

[34] J.M. Rothman, D. Raubenheimer, M.A.H. Bryer, M. Takahashi, C.C. Gilbert, Nutritional contributions of insects to primate diets: Implications for primate evolution, Journal of Human Evolution. 71 (2014) 59–69. https://doi.org/10.1016/j.jhevol.2014.02.016.

[35] C. Boesch, H. Boesch, Hunting behavior of wild chimpanzees in the Taï National Park, American Journal of Physical Anthropology. 78 (1989) 547–573. https://doi.org/10.1002/ajpa.1330780410.

[36] P. Leyhausen, B.A. (Translator) Tonkin, Cat behaviour. The predatory and social behaviour of domestic and wild cats., Garland STPM Press., 1979. https://www.cabdirect.org/cabdirect/abstract/19792242528 (accessed May 15, 2023).

[37] M.C. Allen, M. Clinchy, L.Y. Zanette, Fear of predators in free-living wildlife reduces population growth over generations, PNAS. 119 (2022). https://doi.org/10.1073/pnas.2112404119.

[38] B.P. Dudeck, M. Clinchy, M.C. Allen, L.Y. Zanette, Fear affects parental care, which predicts juvenile survival and exacerbates the total cost of fear on demography, Ecology. 99 (2018) 127–135. https://doi.org/10.1002/ecy.2050.

[39] I.F. MacDonald, B. Kempster, L. Zanette, S.A. MacDougall-Shackleton, Early nutritional stress impairs development of a song-control brain region in both male and female juvenile song sparrows (Melospiza melodia) at the onset of song learning, Proceedings of the Royal Society B: Biological Sciences. 273 (2006) 2559–2564. https://doi.org/10.1098/rspb.2006.3547.

[40] N.J. Boogert, R.F. Lachlan, K.A. Spencer, C.N. Templeton, D.R. Farine, Stress hormones, social associations and song learning in zebra finches, Philosophical Transactions of the Royal Society B: Biological Sciences. 373 (2018) 20170290. https://doi.org/10.1098/rstb.2017.0290.

[41] L.Y. Zanette, E.C. Hobbs, L.E. Witterick, S.A. MacDougall-Shackleton, M. Clinchy, Predator-induced fear causes PTSD-like changes in the brains and behaviour of wild animals, Scientific Reports. 9 (2019) 11474.

[42] S. Bhattacharya, P.E. MacCallum, M. Dayma, A. McGrath-Janes, B. King, L. Dawson, F.R. Bambico, M.D. Berry, Q. Yuan, G.M. Martin, A short pre-conception bout of predation risk affects both children and grandchildren, Scientific Reports. 13 (2023) 10886.

[43] C.M. Monteza-Moreno, M.C. Crofoot, M.N. Grote, P.A. Jansen, Increased terrestriality in a Neotropical primate living on islands with reduced predation risk, Journal of Human Evolution. 143 (2020) 102768.

[44] P. Izar, L. Peternelli-dos-Santos, J.M. Rothman, D. Raubenheimer, A. Presotto, G. Gort, E.M. Visalberghi, D.M. Fragaszy, Stone tools improve diet quality in wild monkeys, Current Biology. 32 (2022) 4088–4092.

[45] R. Boyd, P.J. Richerson, Why culture is common, but cultural evolution is rare, in: Oxford University Press Inc., 1996: pp. 77–94.

[46] K.K. Denton, Y. Ram, M.W. Feldman, Conditions that favour cumulative cultural evolution, Philosophical Transactions of the Royal Society B. 378 (2023) 20210400.

[47] S. Watzl, What attention is. The priority structure account, WIREs Cognitive Science. 14 (2023) e1632. https://doi.org/10.1002/wcs.1632.

[48] A.A. Sandel, E.L. MacLean, B. Hare, Evidence from four lemur species that ringtailed lemur social cognition converges with that of haplorhine primates, Animal Behaviour. 81 (2011) 925–931. https://doi.org/10.1016/j.anbehav.2011.01.020.

[49] C.M. Johnson, C. Ruiz-Mendoza, C. Schoenbeck, Conspecific "gaze following" in bottlenose dolphins, Anim Cogn. (2022). https://doi.org/10.1007/s10071-022-01665-x.

[50] J. Wathan, K. McComb, The eyes and ears are visual indicators of attention in domestic horses, Current Biology. 24 (2014) R677–R679. https://doi.org/10.1016/j.cub.2014.06.023.

[51] M.A. Udell, N.R. Dorey, C.D. Wynne, Wolves outperform dogs in following human social cues, Animal Behaviour. 76 (2008) 1767–1773.

[52] C. Zeiträg, S.A. Reber, M. Osvath, Gaze following in Archosauria—Alligators and palaeognath birds suggest dinosaur origin of visual perspective taking, Science Advances. 9 (2023) eadf0405. https://doi.org/10.1126/sciadv.adf0405.

[53] M. Goumas, I. Burns, L.A. Kelley, N.J. Boogert, Herring gulls respond to human gaze direction, Biology Letters. 15 (2019) 20190405. https://doi.org/10.1098/rsbl.2019.0405.

[54] R. Sreekar, S. Quader, Influence of gaze and directness of approach on the escape responses of the Indian rock lizard, Psammophilus dorsalis (Gray, 1831), J Biosci. 38 (2013) 829–833. https://doi.org/10.1007/s12038-013-9378-8.

[55] G.G. Gallup, W.H. Cummings, R.F. Nash, The experimenter as an independent variable in studies of animal hypnosis in chickens (Gallus gallus), Animal Behaviour. 20 (1972) 166–169. https://doi.org/10.1016/S0003-3472(72)80187-8.

[56] G.G. Gallup, R.F. Nash, A.L. Ellison, Tonic immobility as a reaction to predation: Artificial eyes as a fear stimulus for chickens, Psychon Sci. 23 (1971) 79–80. https://doi.org/10.3758/BF03336016.

[57] D.H. Janzen, W. Hallwachs, J.M. Burns, A tropical horde of counterfeit predator eyes, Proceedings of the National Academy of Sciences. 107 (2010) 11659–11665. https://doi.org/10.1073/pnas.0912122107.

[58] D. Cui, K. Nelissen, Two-monkey fMRI setup for investigating multifaceted aspects of social cognition and behavior involving a real-live conspecific, NeuroImage. 255 (2022) 119187. https://doi.org/10.1016/j.neuroimage.2022.119187.

[59] O. Dal Monte, M. Piva, J.A. Morris, S.W.C. Chang, Live interaction distinctively shapes social gaze dynamics in rhesus macaques, Journal of Neurophysiology. 116 (2016) 1626–1643. https://doi.org/10.1152/jn.00442.2016.

[60] O.D. Monte, S. Fan, N.A. Fagan, C.-C.J. Chu, M.B. Zhou, P.T. Putnam, A.R. Nair, S.W.C. Chang, Widespread implementations of interactive social gaze neurons in the primate prefrontal-amygdala networks, Neuron. 0 (2022). https://doi.org/10.1016/j.neuron.2022.04.013.

[61] J. Yamagiwa, Functional analysis of social staring behavior in an all-male group of mountain gorillas, Primates. 33 (1992) 523–544. https://doi.org/10.1007/BF02381153.

[62] G.E. Schaller, The mountain gorilla: Ecology and behavior, Univer., Chicago Press, Oxford, England, 1963.

[63] V. Reynolds, The Chimpanzees of the Budongo Forest: Ecology, Behaviour and Conservation, OUP Oxford, 2005.

[64] J.J. Gibson, A.D. Pick, Perception of Another Person’s Looking Behavior, The American Journal of Psychology. 76 (1963) 386–394. https://doi.org/10.2307/1419779.

[65] M.G. Cline, The Perception of Where a Person Is Looking, The American Journal of Psychology. 80 (1967) 41–50. https://doi.org/10.2307/1420539.

[66] R. Watt, B. Craven, S. Quinn, A Role for Eyebrows in Regulating the Visibility of Eye Gaze Direction, Quarterly Journal of Experimental Psychology. 60 (2007) 1169–1177. https://doi.org/10.1080/17470210701396798.

[67] M. Gur, Very small faces are easily discriminated under long and short exposure times, Journal of Neurophysiology. 119 (2018) 1599–1607.

[68] N.J. Enfield, ‘Lip-pointing’: A discussion of form and function with reference to data from Laos, Gesture. 1 (2001) 185–211. https://doi.org/10.1075/gest.1.2.06enf.

[69] G. Kaplan, L.J. Rogers, Patterns of Gazing in Orangutans (Pongo pygmaeus), International Journal of Primatology. 23 (2002) 501–526. https://doi.org/10.1023/A:1014913532057.

[70] E. Denion, M. Hitier, V. Guyader, A.-E. Dugué, F. Mouriaux, Unique human orbital morphology compared with that of apes, Sci Rep. 5 (2015) 11528. https://doi.org/10.1038/srep11528.

[71] E. Denion, M. Hitier, E. Levieil, F. Mouriaux, Human rather than ape-like orbital morphology allows much greater lateral visual field expansion with eye abduction, Scientific Reports. 5 (2015) 124–37. https://doi.org/10.1038/srep12437.

[72] R.M. Godinho, P. Spikins, P. O’Higgins, Supraorbital morphology and social dynamics in human evolution, Nature Ecology & Evolution. 2 (2018) 956–961. https://doi.org/10.1038/s41559-018-0528-0.

[73] C. Breil, T. Raettig, R. Pittig, R.P. van der Wel, T. Welsh, A. Böckler, Don’t look at me like that: Integration of gaze direction and facial expression., Journal of Experimental Psychology: Human Perception and Performance. 48 (2022) 1083.

[74] J.M. Stuzin, L. Wagstrom, H.K. Kawamoto, T.J. Baker, S.A. Wolfe, The Anatomy and Clinical Applications of the Buccal Fat Pad, Plastic and Reconstructive Surgery. 85 (1990) 29–37.

[75] A.M. Burrows, C.R. Rogers-Vizena, L. Li, B. Mendelson, The Mobility of the Human Face: More than Just the Musculature, The Anatomical Record. 299 (2016) 1779–1788. https://doi.org/10.1002/ar.23451.

[76] L.M. Bylsma, A. Gračanin, A.J.J.M. Vingerhoets, The neurobiology of human crying, Clin Auton Res. 29 (2019) 63–73. https://doi.org/10.1007/s10286-018-0526-y.

[77] T.A. Stoffregen, B.G. Bardy, C.T. Bonnet, R.J. Pagulayan, Postural Stabilization of Visually Guided Eye Movements, Ecological Psychology. 18 (2006) 191–222. https://doi.org/10.1207/s15326969eco1803_3.

[78] H. Hecht, S. Siebrand, S. Thönes, Quantifying the Wollaston Illusion, Perception. 49 (2020) 588–599. https://doi.org/10.1177/0301006620915421.

[79] S. Thainimit, L.A. Alexandre, V.M.N. de Almeida, Iris surface deformation and normalization, in: 2013 13th International Symposium on Communications and Information Technologies (ISCIT), 2013: pp. 501–506. https://doi.org/10.1109/ISCIT.2013.6645910.

[80] S. Anstis, The Role of the Pupil, Corneal Reflex, and Iris in Determining the Perceived Direction of Gaze, I-Perception. 9 (2018) 2041669518765852. https://doi.org/10.1177/2041669518765852.

[81] B.R. Manor, E. Gordon, Defining the temporal threshold for ocular fixation in free-viewing visuocognitive tasks, Journal of Neuroscience Methods. 128 (2003) 85–93. https://doi.org/10.1016/S0165-0270(03)00151-1.

[82] K. Ziman, S.C. Kimmel, K.T. Farrell, M.S. Graziano, Predicting the attention of others, Proceedings of the National Academy of Sciences. 120 (2023) e2307584120.

[83] M. Breu, H. Ramezanpour, P. Dicke, P. Thier, A frontoparietal network for volitional control of gaze following, European Journal of Neuroscience. 57 (2023) 1723–1735.

[84] I. Chong, H. Ramezanpour, P. Thier, Causal manipulation of gaze-following in the macaque temporal cortex, Progress in Neurobiology. 226 (2023) 102466.

[85] I.D. Gilchrist, V. Brown, J.M. Findlay, Saccades without eye movements, Nature. 390 (1997) 130–131. https://doi.org/10.1038/36478.

[86] M.F. Land, S.M. Furneaux, I.D. Gilchrist, The Organization of Visually Mediated Actions in a Subject without Eye Movements, Neurocase. 8 (2002) 80–87. https://doi.org/10.1093/neucas/8.1.80.

[87] J. Kangas, O. Špakov, R. Raisamo, O. Koskinen, T. Järvenpää, M. Salmimaa, Head and Gaze Orientation in Hemispheric Image Viewing, Frontiers in Virtual Reality. 3 (2022). https://www.frontiersin.org/articles/10.3389/frvir.2022.822189 (accessed February 2, 2023).

[88] M.F. Land, Eye movements and the control of actions in everyday life, Progress in Retinal and Eye Research. 25 (2006) 296–324. https://doi.org/10.1016/j.preteyeres.2006.01.002.

[89] E.J. Bethell, S.-J. Vick, K.A. Bard, Measurement of eye-gaze in chimpanzees (Pan troglodytes), American Journal of Primatology. 69 (2007) 562–575. https://doi.org/10.1002/ajp.20376.

[90] A.S. Mearing, J.M. Burkart, J. Dunn, S.E. Street, K. Koops, The evolutionary drivers of primate scleral coloration, Sci Rep. 12 (2022) 14119. https://doi.org/10.1038/s41598-022-18275-9.

[91] D. Sperber, D. Wilson, Relevance: Communication and cognition, Citeseer, 1986.

[92] H. Kobayashi, S. Kohshima, Evolution of the Human Eye as a Device for Communication, in: T. Matsuzawa (Ed.), Primate Origins of Human Cognition and Behavior, Springer Japan, Tokyo, 2001: pp. 383–401. https://doi.org/10.1007/978-4-431-09423-4_19.

[93] H. Kobayashi, S. Kohshima, Unique morphology of the human eye, Nature. 387 (1997) 767–768. https://doi.org/10.1038/42842.

[94] A.S. Mearing, J.M. Burkart, J. Dunn, S.E. Street, K. Koops, The evolutionary origins of primate scleral coloration, bioRxiv. (2021) 2021.07.25.453695. https://doi.org/10.1101/2021.07.25.453695.

[95] F. Kano, Evolution of the uniformly white sclera in humans: critical updates, Trends in Cognitive Sciences. (2022). https://doi.org/10.1016/j.tics.2022.09.011.

[96] M. Tomasello, B. Hare, H. Lehmann, J. Call, Reliance on head versus eyes in the gaze following of great apes and human infants: the cooperative eye hypothesis, Journal of Human Evolution. 52 (2007) 314–320. https://doi.org/10.1016/j.jhevol.2006.10.001.

[97] W. Wolf, J. Thielhelm, M. Tomasello, Five-year-old children show cooperative preferences for faces with white sclera, Journal of Experimental Child Psychology. 225 (2023) 105532.

[98] T. Malevich, T. Zhang, M.P. Baumann, A.R. Bogadhi, Z.M. Hafed, Faster detection of “darks” than “brights” by monkey superior colliculus neurons, Journal of Neuroscience. 42 (2022) 9356–9371.

[99] A.C. Huk, L.N. Katz, J.L. Yates, Accumulation of Evidence in Decision Making, in: D. Jaeger, R. Jung (Eds.), Encyclopedia of Computational Neuroscience, Springer, New York, NY, 2013: pp. 1–4. https://doi.org/10.1007/978-1-4614-7320-6_309-2.

[100] A. Gorea, A Refresher of the Original Bloch’s Law Paper (Bloch, July 1885), I-Perception. 6 (2015) 2041669515593043. https://doi.org/10.1177/2041669515593043.

[101] G.E. Legge, Sustained and transient mechanisms in human vision: Temporal and spatial properties, Vision Research. 18 (1978) 69–81. https://doi.org/10.1016/0042-6989(78)90079-2.

[102] L.N. Thibos, A. Bradley, R. Xu, N. Lopez-Gil, Ricco’;s law and absolute threshold for foveal detection of black holes, J. Opt. Soc. Am. A, JOSAA. 36 (2019) B35–B43. https://doi.org/10.1364/JOSAA.36.000B35.

[103] D. Regan, C.W. Tyler, Temporal Summation and Its Limit for Wavelength Changes: An Analog of Bloch’s Law for Color Vision, J. Opt. Soc. Am., JOSA. 61 (1971) 1414–1421. https://doi.org/10.1364/JOSA.61.001414.

[104] D.S. Goodin, K.C. Squires, A. Starr, Variations in early and late event-related components of the auditory evoked potential with task difficulty, Electroencephalography and Clinical Neurophysiology. 55 (1983) 680–686. https://doi.org/10.1016/0013-4694(83)90278-X.

[105] J. Polich, Task difficulty, probability, and inter-stimulus interval as determinants of P300 from auditory stimuli, Electroencephalography and Clinical Neurophysiology/Evoked Potentials Section. 68 (1987) 311–320. https://doi.org/10.1016/0168-5597(87)90052-9.

[106] J.M. de Souza, D.F. Ventura, Comparative study of temporal summation and response form in

hymenopteran photoreceptors, J Comp Physiol A. 165 (1989) 237–245. https://doi.org/10.1007/bf00619198.

[107] D. Kahneman, J. Norman, The Time-Intensity Relation in Visual Perception as a Function of Observer's Task, J Exp Psychol. 68 (1964) 215–220. https://doi.org/10.1037/h0046097.

[108] W.S. Baron, G. Westheimer, Visual acuity as a function of exposure duration, J. Opt. Soc. Am., JOSA. 63 (1973) 212–219. https://doi.org/10.1364/JOSA.63.000212.

[109] J. Duysens, B. Gulyás, H. Maes, Temporal integration in cat visual cortex: A test of bloch's law, Vision Research. 31 (1991) 1517–1528. https://doi.org/10.1016/0042-6989(91)90129-S.

[110] S. Gayet, M.V. Peelen, Preparatory attention incorporates contextual expectations, Current Biology. 32 (2022) 687-692.e6. https://doi.org/10.1016/j.cub.2021.11.062.

[111] G.E. Legge, G.S. Rubin, A. Luebker, Psychophysics of reading—V. The role of contrast in normal vision, Vision Research. 27 (1987) 1165–1177. https://doi.org/10.1016/0042-6989(87)90028-9.

[112] A. Staub, Do effects of visual contrast and font difficulty on readers' eye movements interact with effects of word frequency or predictability?, Journal of Experimental Psychology: Human Perception and Performance. 46 (2020) 1235.

[113] S. Morein-Zamir, S. Soto-Faraco, A. Kingstone, Auditory capture of vision: examining temporal ventriloquism, Cognitive Brain Research. 17 (2003) 154–163. https://doi.org/10.1016/S0926-6410(03)00089-2.

[114] R. Steinmetz, Human perception of jitter and media synchronization, IEEE Journal on Selected Areas in Communications. 14 (1996) 61–72. https://doi.org/10.1109/49.481694.

[115] D. Mao, E. Avila, B. Caziot, J. Laurens, J.D. Dickman, D.E. Angelaki, Spatial modulation of hippocampal activity in freely moving macaques, Neuron. 109 (2021) 3521-3534.e6. https://doi.org/10.1016/j.neuron.2021.09.032.

[116] E. Lowet, B. Gips, M.J. Roberts, P.D. Weerd, O. Jensen, J. van der Eerden, Microsaccade-rhythmic modulation of neural synchronization and coding within and across cortical areas V1 and V2, PLOS Biology. 16 (2018) e2004132. https://doi.org/10.1371/journal.pbio.2004132.

[117] E.M. Templeton, L.J. Chang, E.A. Reynolds, M.D.C. LeBeaumont, T. Wheatley, Fast response times signal social connection in conversation, PNAS. 119 (2022). https://doi.org/10.1073/pnas.2116915119.

[118] T. Stivers, N.J. Enfield, P. Brown, C. Englert, M. Hayashi, T. Heinemann, G. Hoymann, F. Rossano, J.P. de Ruiter, K.-E. Yoon, S.C. Levinson, Universals and cultural variation in turn-taking in conversation, Proceedings of the National Academy of Sciences. 106 (2009) 10587–10592. https://doi.org/10.1073/pnas.0903616106.

[119] N. Chaudhary, A. Swanepoel, Editorial Perspective: What can we learn from hunter-gatherers about children's mental health? An evolutionary perspective, Journal of Child Psychology and Psychiatry. n/a (n.d.). https://doi.org/10.1111/jcpp.13773.

[120] G. Turri, A. Cavallo, L. Romeo, M. Pontil, A. Sanfey, S. Panzeri, C. Becchio, Decoding social decisions from movement kinematics, IScience. 25 (2022).

[121] F. Rossano, Sequence organization and timing of bonobo mother-infant interactions, Interaction Studies. 14 (2013) 160–189. https://doi.org/10.1075/is.14.2.02ros.

[122] N. Katsu, K. Yamada, K. Okanoya, M. Nakamichi, Temporal adjustment of short calls according to a partner during vocal turn-taking in Japanese macaques, Current Zoology. 65 (2019) 99–105. https://doi.org/10.1093/cz/zoy077.

[123] M. Fröhlich, P. Kuchenbuch, G. Müller, B. Fruth, T. Furuichi, R.M. Wittig, S. Pika, Unpeeling the layers of language: Bonobos and chimpanzees engage in cooperative turn-taking sequences, Sci Rep. 6 (2016) 25887. https://doi.org/10.1038/srep25887.

[124] H. Knofe, J. Engelmann, M. Tomasello, E. Herrmann, Chimpanzees monopolize and children take turns in a limited resource problem, Sci Rep. 9 (2019) 7597. https://doi.org/10.1038/s41598-019-44096-4.

[125] M. Tomasello, The coordination of attention and action in great apes and humans, Philosophical Transactions of the Royal Society B: Biological Sciences. 377 (2022) 20210093. https://doi.org/10.1098/rstb.2021.0093.

[126] G.H. Lerner, Selecting next speaker: The context-sensitive operation of a context-free organization, Language in Society. 32 (2003) 177–201.

[127] P. Auer, Gaze selects the next speaker in answers to questions pronominally addressed to more than one co-participant, Interactional Linguistics. 1 (2021) 154–182.

[128] N. Nota, J.P. Trujillo, J. Holler, Specific facial signals associate with categories of social actions conveyed through questions, PloS One. 18 (2023) e0288104.

[129] K.H. Kendrick, J. Holler, S.C. Levinson, Turn-taking in human face-to-face interaction is multimodal: gaze direction and manual gestures aid the coordination of turn transitions, Philosophical Transactions of the Royal Society B. 378 (2023) 20210473.

[130] C.K. Friesen, A. Kingstone, The eyes have it! Reflexive orienting is triggered by nonpredictive gaze, Psychonomic Bulletin & Review. 5 (1998) 490–495. https://doi.org/10.3758/BF03208827.

[131] A. Guterstam, A.I. Wilterson, D. Wachtell, M.S.A. Graziano, Other people's gaze encoded as implied motion in the human brain, PNAS. 117 (2020) 13162–13167. https://doi.org/10.1073/pnas.2003110117.

[132] C.J. Palmer, C.W.G. Clifford, Perceived Object Trajectory Is Influenced by Others' Tracking Movements, Current Biology. 27 (2017) 2169-2176.e4. https://doi.org/10.1016/j.cub.2017.06.019.

[133] R. Jure, R. Pogonza, I. Rapin, Autism Spectrum Disorders (ASD) in Blind Children: Very High Prevalence, Potentially Better Outlook, J Autism Dev Disord. 46 (2016) 749–759. https://doi.org/10.1007/s10803-015-2612-5.

[134] R.P. Hobson, A. Lee, Reversible autism among congenitally blind children? A controlled follow-up study, Journal of Child Psychology and Psychiatry. 51 (2010) 1235–1241. https://doi.org/10.1111/j.1469-7610.2010.02274.x.

[135] J.H. Flavell, S.G. Shipstead, K. Croft, What young children think you see when their eyes are closed, Cognition. 8 (1980) 369–387. https://doi.org/10.1016/0010-0277(80)90001-3.

[136] J. Russell, B. Gee, C. Bullard, Why Do Young Children Hide by Closing Their Eyes? Self-Visibility and the Developing Concept of Self, Journal of Cognition and Development. 13 (2012) 550–576. https://doi.org/10.1080/15248372.2011.594826.

[137] S.R.H. Langton, Gaze Perception and Visually Mediated Attention, in: R.B. Adams, R.B.A. Jr, N. Ambady, K. Nakayama, S. Shimojo (Eds.), The Science of Social Vision: The Science of Social Vision, OUP USA, 2011: pp. 108–132.

[138] S. Ando, Perception of Gaze Direction Based on Luminance Ratio, Perception. 33 (2004) 1173–1184. https://doi.org/10.1068/p5297.

[139] S. Ando, Luminance-Induced Shift in the Apparent Direction of Gaze, Perception. 31 (2002) 657–674. https://doi.org/10.1068/p3332.

[140] J.E. Russo, The limbus reflection method for measuring eye position, Behavior Research Methods & Instrumentation. 7 (1975) 205–208. https://doi.org/10.3758/BF03201327.

[141] S.G. Wardle, S. Paranjape, J. Taubert, C.I. Baker, Illusory faces are more likely to be perceived as male than female, Proceedings of the National Academy of Sciences. 119 (2022) e2117413119. https://doi.org/10.1073/pnas.2117413119.

[142] S.O. Roberts, K. Weisman, J.D. Lane, A. Williams, N.P. Camp, M. Wang, M. Robison, K. Sanchez, C. Griffiths, God as a White man: A psychological barrier to conceptualizing Black people and women as leadership worthy, Journal of Personality and Social Psychology. 119 (2020) 1290–1315. https://doi.org/10.1037/pspi0000233.

[143] J. Marshall, A. Gollwitzer, K. Mermin-Bunnell, T. Mandalaywala, The role of status in the early emergence of pro-White bias in rural Uganda, Developmental Science. 25 (2022) e13240. https://doi.org/10.1111/desc.13240.

[144] S. Ueda, G. Kumagai, Y. Otaki, S. Yamaguchi, S. Kohshima, A Comparison of Facial Color Pattern and Gazing Behavior in Canid Species Suggests Gaze Communication in Gray Wolves (Canis lupus), PLOS ONE. 9 (2014) e98217. https://doi.org/10.1371/journal.pone.0098217.

[145] W. Whitham, S.J. Schapiro, J. Troscianko, J.L. Yorzinski, Chimpanzee (Pan troglodytes) gaze is conspicuous at ecologically-relevant distances, Sci Rep. 12 (2022) 9249. https://doi.org/10.1038/s41598-022-13273-3.

[146] J.O. Perea-García, M.E. Kret, A. Monteiro, C. Hobaiter, Scleral pigmentation leads to conspicuous, not cryptic, eye morphology in chimpanzees, Proceedings of the National Academy of Sciences. 116 (2019) 19248–19250. https://doi.org/10.1073/pnas.1911410116.

[147] N.G. Jablonski, G. Chaplin, The evolution of human skin coloration, Journal of Human Evolution. 39 (2000) 57–106. https://doi.org/10.1006/jhev.2000.0403.

[148] J.O. Perea García, T. Grenzner, G. Hešková, P. Mitkidis, Not everything is blue or brown: Quantification of ocular coloration in psychological research beyond dichotomous categorizations, Communicative & Integrative Biology. 10 (2017) e1264545. https://doi.org/10.1080/19420889.2016.1264545.

[149] M. Hora, H. Pontzer, C.M. Wall-Scheffler, V. Sládek, Dehydration and persistence hunting in Homo erectus, Journal of Human Evolution. 138 (2020) 102682. https://doi.org/10.1016/j.jhevol.2019.102682.

[150] L. Liebenberg, Persistence Hunting by Modern Hunter-Gatherers, Current Anthropology. 47 (2006) 1017–1026. https://doi.org/10.1086/508695.

[151] D.E. Lieberman, D.A. Raichlen, H. Pontzer, D.M. Bramble, E. Cutright-Smith, The human gluteus maximus and its role in running, Journal of Experimental Biology. 209 (2006) 2143–2155. https://doi.org/10.1242/jeb.02255.

[152] G.D. Ruxton, D.M. Wilkinson, Avoidance of overheating and selection for both hair loss and bipedality in hominins, Proceedings of the National Academy of Sciences. 108 (2011) 20965–20969.

[153] N.G. Crawford, D.E. Kelly, M.E. Hansen, M.H. Beltrame, S. Fan, S.L. Bowman, E. Jewett, A. Ranciaro, S. Thompson, Y. Lo, Loci associated with skin pigmentation identified in African populations, Science. 358 (2017) eaan8433.

[154] J.K. IJspeert, P.W.T. de Waard, T.J.T.P. van den Berg, P.T.V.M. de Jong, The intraocular straylight function in 129 healthy volunteers; Dependence on angle, age and pigmentation, Vision Research. 30 (1990) 699–707. https://doi.org/10.1016/0042-6989(90)90096-4.

[155] T.J.T.P. van den Berg, J.K. Ijspeert, P.W.T. de Waard, Dependence of intraocular straylight on pigmentation and light transmission through the ocular wall, Vision Research. 31 (1991) 1361–1367. https://doi.org/10.1016/0042-6989(91)90057-C.

[156] J.E. Coppens, L. Franssen, T.J.T.P. van den Berg, Wavelength dependence of intraocular straylight, Experimental Eye Research. 82 (2006) 688–692. https://doi.org/10.1016/j.exer.2005.09.007.

[157] C. Lalueza-Fox, H. Römpler, D. Caramelli, C. Stäubert, G. Catalano, D. Hughes, N. Rohland, E. Pilli, L. Longo, S. Condemi, M. de la Rasilla, J. Fortea, A. Rosas, M. Stoneking, T. Schöneberg, J. Bertranpetit, M. Hofreiter, A Melanocortin 1 Receptor Allele Suggests Varying Pigmentation Among Neanderthals, Science. 318 (2007) 1453–1455. https://doi.org/10.1126/science.1147417.

[158] A. Hanel, C. Carlberg, Skin colour and vitamin D: An update, Experimental Dermatology. 29 (2020) 864–875.

[159] A. Hanel, C. Carlberg, Skin colour and vitamin D: An update, Experimental Dermatology. 29 (2020) 864–875. https://doi.org/10.1111/exd.14142.

[160] A. Parker, In the blink of an eye, Perseus Pub., Cambridge, Mass., 2003.

[161] H. Hediger, Studies of the psychology and behavior of captive animals in zoos and circuses., Butterworths Scientific Pub., London, 1955.

[162] S.S. Urmy, K.J. Benoit-Bird, Fear dynamically structures the ocean’s pelagic zone, Current Biology. 31 (2021) 5086-5092.e3. https://doi.org/10.1016/j.cub.2021.09.003.

[163] J.C. Walsman, M.J. Janecka, D.R. Clark, R.D. Kramp, F. Rovenolt, R. Patrick, R.S. Mohammed, M. Konczal, C.E. Cressler, J.F. Stephenson, Shoaling guppies evade predation but have deadlier parasites, Nat Ecol Evol. (2022) 1–10. https://doi.org/10.1038/s41559-022-01772-5.

[164] N. Hammerschlag, C. Fallows, M. Meÿer, S.M. Seakamela, S. Orndorff, S. Kirkman, D. Kotze, S. Creel, Loss of an apex predator in the wild induces physiological and behavioural changes in prey, Biology Letters. 18 (n.d.) 20210476. https://doi.org/10.1098/rsbl.2021.0476.

[165] M.R. Walsh, W. Broyles, S.M. Beston, S.B. Munch, Predator-driven brain size evolution in natural populations of Trinidadian killifish (Rivulus hartii), Proceedings of the Royal Society B: Biological Sciences. 283 (2016) 20161075. https://doi.org/10.1098/rspb.2016.1075.

[166] N.D. Harrison, B.L. Phillips, N.J. Mitchell, J.C. Wayne, M.A. Maxwell, C.G. Ward, A.F. Wayne, Perverse outcomes from fencing fauna: Loss of antipredator traits in a havened mammal population, Biological Conservation. 281 (2023) 110000.

[167] F. Coolidge, T. Wynn, The effects of the tree-to-ground sleep transition in the evolution of cognition in early Homo, Before Farming. (2006).

[168] Z. Zhong, G. Li, D. Sanders, D. Wang, R.D. Holt, Z. Zhang, A rodent herbivore reduces its predation risk through ecosystem engineering, Current Biology. 32 (2022) 1869-1874.e4. https://doi.org/10.1016/j.cub.2022.02.074.

[169] G. Cowlishaw, Vulnerability To Predation in Baboon Populations, Behaviour. 131 (1994) 293–304. https://doi.org/10.1163/156853994X00488.

[170] L.L. Sweanor, K.A. Logan, M.G. Hornocker, Puma responses to close approaches by researchers, Wildlife Society Bulletin. 33 (2005) 905–913. https://doi.org/10.2193/0091-7648(2005)33[905:PRTCAB]2.0.CO;2.

[171] K. Laland, B. Matthews, M.W. Feldman, An introduction to niche construction theory, Evol Ecol. 30 (2016) 191–202. https://doi.org/10.1007/s10682-016-9821-z.

[172] F.J. Odling-Smee, Niche-constructing phenotypes, in: The Role of Behavior in Evolution, The MIT Press, Cambridge, MA, US, 1988: pp. 73–132.

[173] L.A. Isbell, Predation on primates: Ecological patterns and evolutionary consequences, Evolutionary Anthropology: Issues, News, and Reviews. 3 (1994) 61–71. https://doi.org/10.1002/evan.1360030207.

[174] K. Zuberbühler, D. Jenny, Leopard predation and primate evolution, Journal of Human Evolution. 43 (2002) 873–886. https://doi.org/10.1006/jhev.2002.0605.

[175] C.M. Anderson, Predation and primate evolution, Primates. 27 (1986) 15–39. https://doi.org/10.1007/BF02382520.

[176] B.T. Coleman, R.A. Hill, Living in a landscape of fear: the impact of predation, resource availability and habitat structure on primate range use, Animal Behaviour. 88 (2014) 165–173. https://doi.org/10.1016/j.anbehav.2013.11.027.

[177] K. Zuberbühler, Predation and Primate Cognitive Evolution, in: S.L. Gursky, K.A.I. Nekaris (Eds.), Primate Anti-Predator Strategies, Springer US, Boston, MA, 2007: pp. 3–26. https://doi.org/10.1007/978-0-387-34810-0_1.

[178] S. Lindshield, B.J. Danielson, J.M. Rothman, J.D. Pruetz, Feeding in fear? How adult male western chimpanzees (Pan troglodytes verus) adjust to predation and savanna habitat pressures, American Journal of Physical Anthropology. 163 (2017) 480–496. https://doi.org/10.1002/ajpa.23221.

[179] C. Giuliano, F.A. Stewart, A.K. Piel, Chimpanzee (Pan troglodytes schweinfurthii) grouping patterns in an open and dry savanna landscape, Issa Valley, western Tanzania, Journal of Human Evolution. 163 (2022) 103137. https://doi.org/10.1016/j.jhevol.2021.103137.

[180] S. Savage-Rumbaugh, S.G. Shanker, T.J. Taylor, Apes, Language, and the Human Mind, Oxford University Press, 1998.

[181] E.S. Savage-Rumbaugh, W.M. Fields, Linguistic, Cultural and Cognitive Capacities of

Bonobos(Pan Paniscus), Culture & Psychology. 6 (2000) 131–153. https://doi.org/10.1177/1354067X0062003.

[182] J.L. Russell, H. Lyn, J.A. Schaeffer, W.D. Hopkins, The role of socio-communicative rearing environments in the development of social and physical cognition in apes, Developmental Science. 14 (2011) 1459–1470. https://doi.org/10.1111/j.1467-7687.2011.01090.x.

[183] H. Marno, C.J. Völter, B. Tinklenberg, D. Sperber, J. Call, Learning from communication versus observation in great apes, Sci Rep. 12 (2022) 2917. https://doi.org/10.1038/s41598-022-07053-2.

[184] R.A. Gardner, B.T. Gardner, A vocabulary test for chimpanzees (Pan troglodytes), Journal of Comparative Psychology. 98 (1984) 381–404. https://doi.org/10.1037/0735-7036.98.4.381.

[185] J.R. Skoyles, Human metabolic adaptations and prolonged expensive neurodevelopment: A review, Nature Precedings. (2008). https://doi.org/10.1038/npre.2008.1856.2.

[186] V. Geist, A Brief History of Human-Predator Conflicts and Potent Lessons, Proceedings of the Vertebrate Pest Conference. 27 (2016) 3–12. https://doi.org/10.5070/V427110421.

[187] C. Darwin, The Descent of Man,: And Selection in Relation to Sex, John Murray, Albemarle Street., 1888.

[188] A. Kortlandt, How might early hominids have defended themselves against large predators and food competitors?, Journal of Human Evolution. 9 (1980) 79–112. https://doi.org/10.1016/0047-2484(80)90066-4.

[189] J. JORDANIA, MUSIC, HOMOSEXUALITY, AND CANNIBALISM AS PREDATOR AVOIDANCE EVOLUTIONARY STRATEGIES IN EARLY HUMANS, Music in Human Experience: Perspectives on a Musical Species. (2022) 139.

[190] J. Jordania, Origins of rhythm and the defence strategy of human ancestors, in: Citeseer, 2008: pp. 55–66.

[191] J. Jordania, A new model of human evolution: How predators shaped human morphology and behaviour, Lambert Academic Publishing, 2017.

[192] L. Newson, P. Richerson, A Story of Us: A New Look at Human Evolution, Oxford University Press, Oxford, New York, 2021.

[193] W. Montagna, The evolution of human skin(?), Journal of Human Evolution. 14 (1985) 3–22. https://doi.org/10.1016/S0047-2484(85)80090-7.

[194] A. Best, J.M. Kamilar, The evolution of eccrine sweat glands in human and nonhuman primates, Journal of Human Evolution. 117 (2018) 33–43. https://doi.org/10.1016/j.jhevol.2017.12.003.

[195] X.W. Wu, C.C. Lee, D.M. Muzny, C.T. Caskey, Urate oxidase: primary structure and evolutionary implications., Proceedings of the National Academy of Sciences. 86 (1989) 9412–9416. https://doi.org/10.1073/pnas.86.23.9412.

[196] F. Roch-Ramel, G. Peters, Urinary Excretion of Uric Acid in Nonhuman Mammalian Species, in: W.N. Kelley, I.M. Weiner (Eds.), Uric Acid, Springer, Berlin, Heidelberg, 1978: pp. 211–255. https://doi.org/10.1007/978-3-642-66867-8_9.

[197] M.C. O'Neill, B.R. Umberger, N.B. Holowka, S.G. Larson, P.J. Reiser, Chimpanzee super strength and human skeletal muscle evolution, PNAS. 114 (2017) 7343–7348. https://doi.org/10.1073/pnas.1619071114.

[198] A. Walker, Mechanisms of honing in the male baboon canine, American Journal of Physical Anthropology. 65 (1984) 47–60. https://doi.org/10.1002/ajpa.1330650108.

[199] K. Goździewska-Harłajczuk, K. Barszcz, J. Klećkowska-Nawrot, P. Hamouzová, P. Čížek, P. Kuropka, P. Kvapil, Comparative Study of Lingual Papillae, Lingual Glands and Lyssa of the Tongue of Selected Wild Felids (Carnivora, Felidae) in Biological Aspects, Biology. 12 (2023) 516.

[200] M.S. Yeung, K.M. Chan, C.H. So, W.Y. Yuan, An epidemiological survey on ankle sprain., British Journal of Sports Medicine. 28 (1994) 112–116. https://doi.org/10.1136/bjsm.28.2.112.

[201] H. Pontzer, B.M. Wood, D.A. Raichlen, Hunter-gatherers as models in public health, Obesity Reviews. 19 (2018) 24–35. https://doi.org/10.1111/obr.12785.

[202] A.L. Zihlman, D.R. Bolter, Body composition in Pan paniscus compared with Homo sapiens has implications for changes during human evolution, Proceedings of the National Academy of Sciences. 112 (2015) 7466–7471. https://doi.org/10.1073/pnas.1505071112.

[203] C.W. Kuzawa, Adipose tissue in human infancy and childhood: An evolutionary perspective, American Journal of Physical Anthropology. 107 (1998) 177–209. https://doi.org/10.1002/(SICI)1096-8644(1998)107:27+<177::AID-AJPA7>3.0.CO;2-B.

[204] S.J. Fomon, S.E. Nelson, Body Composition of the Male and Female Reference Infants, Annual Review of Nutrition. 22 (2002) 1–17. https://doi.org/10.1146/annurev.nutr.22.111401.145049.

[205] C.T. Robbins, A.L. Christian, T.G. Vineyard, D. Thompson, K.K. Knott, T.N. Tollefson, A.L. Fidgett, T.A. Wickersham, Ursids evolved early and continuously to be low-protein macronutrient omnivores, Sci Rep. 12 (2022) 15251. https://doi.org/10.1038/s41598-022-19742-z.

[206] G.E. Machovsky-Capuska, S.C.P. Coogan, S.J. Simpson, D. Raubenheimer, Motive for Killing: What Drives Prey Choice in Wild Predators?, Ethology. 122 (2016) 703–711.

https://doi.org/10.1111/eth.12523.

[207] D. Rudman, T.J. DiFulco, J.T. Galambos, R.B. Smith, A.A. Salam, W.D. Warren, Maximal Rates of Excretion and Synthesis of Urea in Normal and Cirrhotic Subjects, J Clin Invest. 52 (1973) 2241–2249. https://doi.org/10.1172/JCI107410.

[208] A. Treves, P. Palmqvist, Reconstructing Hominin Interactions with Mammalian Carnivores (6.0–1.8 Ma), in: S.L. Gursky, K.A.I. Nekaris (Eds.), Primate Anti-Predator Strategies, Springer US, Boston, MA, 2007: pp. 355–381. https://doi.org/10.1007/978-0-387-34810-0_17.

[209] S. Faurby, D. Silvestro, L. Werdelin, A. Antonelli, Brain expansion in early hominins predicts carnivore extinctions in East Africa, Ecology Letters. 23 (2020) 537–544. https://doi.org/10.1111/ele.13451.

[210] D.J. Green, Z. Alemseged, Australopithecus afarensis Scapular Ontogeny, Function, and the Role of Climbing in Human Evolution, Science. (2012). https://doi.org/10.1126/science.1227123.

[211] B.E. Ainsworth, W.L. Haskell, M.C. Whitt, M.L. Irwin, A.M. Swartz, S.J. Strath, W.L. O Brien, D.R. Bassett, K.H. Schmitz, P.O. Emplaincourt, Compendium of physical activities: an update of activity codes and MET intensities, Medicine and Science in Sports and Exercise. 32 (2000) S498–S504.

[212] J.M. Johnson, C.T. Minson, D.L. Kellogg Jr, Cutaneous vasodilator and vasoconstrictor mechanisms in temperature regulation, Comprehensive Physiology. 4 (2011) 33–89.

[213] S.N. Cheuvront, E.M. Haymes, Thermoregulation and Marathon Running, Sports Med. 31 (2001) 743–762. https://doi.org/10.2165/00007256-200131100-00004.

[214] S.F. Godek, A.R. Bartolozzi, R. Burkholder, E. Sugarman, Football Players: A Comparison of National Football League Linemen and Backs, Journal of Athletic Training. 2008432 (n.d.) 184–189.

[215] L.J. McCutcheon, R.J. Geor, Sweating: fluid and ion losses and replacement, Veterinary Clinics of North America: Equine Practice. 14 (1998) 75–95.

[216] R.E. McDonald, R.I. Fleming, J.G. Beeley, D.L. Bovell, J.R. Lu, X. Zhao, A. Cooper, M.W. Kennedy, Latherin: a surfactant protein of horse sweat and saliva, PloS One. 4 (2009) e5726.

[217] P. Christiansen, Locomotion in terrestrial mammals: the influence of body mass, limb length and bone proportions on speed, Zoological Journal of the Linnean Society. 136 (2002) 685–714.

[218] T. Garland, The relation between maximal running speed and body mass in terrestrial mammals, Journal of Zoology. 199 (1983) 157–170. https://doi.org/10.1111/j.1469-7998.1983.tb02087.x.

[219] A. Matsuo, H. Tsuchie, T. Yanagiya, M. Sugita, N. Ae, Analysis of speed patterns in 100-m sprints, Bulletin of Studies. 5 (2009) 97–101.

[220] A. Lai, A.G. Schache, Y.-C. Lin, M.G. Pandy, Tendon elastic strain energy in the human ankle plantar-flexors and its role with increased running speed, Journal of Experimental Biology. 217 (2014) 3159–3168. https://doi.org/10.1242/jeb.100826.

[221] M.J. Catley, G.R. Tomkinson, Normative health-related fitness values for children: analysis of 85347 test results on 9–17-year-old Australians since 1985, Br J Sports Med. 47 (2013) 98–108. https://doi.org/10.1136/bjsports-2011-090218.

[222] A.K. Yegian, Y. Tucker, D.M. Bramble, D.E. Lieberman, Neuromechanical linkage between the head and forearm during running, American Journal of Physical Anthropology. 174 (2021) 752–762. https://doi.org/10.1002/ajpa.24234.

[223] A.K. Yegian, Y. Tucker, S. Gillinov, D.E. Lieberman, Shorter distal forelimbs benefit bipedal walking and running mechanics: Implications for hominin forelimb evolution, American Journal of Physical Anthropology. 175 (2021) 589–598. https://doi.org/10.1002/ajpa.24274.

[224] D.M. Bramble, D.E. Lieberman, Endurance running and the evolution of Homo, Nature. 432 (2004) 345–352. https://doi.org/10.1038/nature03052.

[225] D.E. Lieberman, D.A. Raichlen, H. Pontzer, D.M. Bramble, E. Cutright-Smith, The human gluteus maximus and its role in running, Journal of Experimental Biology. 209 (2006) 2143–2155. https://doi.org/10.1242/jeb.02255.

[226] M.J.H. Heijnen, S. Rietdyk, Falls in young adults: Perceived causes and environmental factors assessed with a daily online survey, Human Movement Science. 46 (2016) 86–95. https://doi.org/10.1016/j.humov.2015.12.007.

[227] J. Chiu, S.N. Robinovitch, Prediction of upper extremity impact forces during falls on the outstretched hand, Journal of Biomechanics. 31 (1998) 1169–1176. https://doi.org/10.1016/S0021-9290(98)00137-7.

[228] T.J. Walilko, D.C. Viano, C.A. Bir, Biomechanics of the head for Olympic boxer punches to the face, British Journal of Sports Medicine. 39 (2005) 710–719. https://doi.org/10.1136/bjsm.2004.014126.

[229] H. Chiu, T. Shiang, A new approach to evaluate karate punch techniques, ISBS - Conference Proceedings Archive. (1999) 61–64.

[230] T. Hülsdünker, D. Riedel, H. Käsbauer, D. Ruhnow, A. Mierau, Auditory Information Accelerates the Visuomotor Reaction Speed of Elite Badminton Players in Multisensory Environments, Frontiers in Human Neuroscience. 15 (2021). https://www.frontiersin.org/articles/10.3389/fnhum.2021.779343 (accessed December 7, 2022).

[231] J.A. Walker, C.K. Ghalambor, O.L. Griset, D. McKENNEY, D.N. Reznick, Do faster starts increase the probability of evading predators?, Functional Ecology. 19 (2005) 808–815. https://doi.org/10.1111/j.1365-2435.2005.01033.x.

[232] S.D. Cohle, C.W. Harlan, G. Harlan, Fatal big cat attacks., The American Journal of Forensic Medicine and Pathology. 11 (1990) 208–212.

[233] M.W. Hayward, P. Henschel, J. O'Brien, M. Hofmeyr, G. Balme, G.I.H. Kerley, Prey preferences of the leopard (Panthera pardus), Journal of Zoology. 270 (2006) 298–313. https://doi.org/10.1111/j.1469-7998.2006.00139.x.

[234] G.B. Schaller, G.R. Lowther, The Relevance of Carnivore Behavior to the Study of Early Hominids, Southwestern Journal of Anthropology. 25 (1969) 307–341. https://doi.org/10.1086/soutjanth.25.4.3629426.

[235] M. Surbeck, A toothless bonobo skull challenges the notion of alternative subsistence strategies in early Homo, Journal of Human Evolution. 147 (2020) 102871.

[236] J.S. Brown, Ecology of Fear☆, in: J.C. Choe (Ed.), Encyclopedia of Animal Behavior (Second Edition), Academic Press, Oxford, 2019: pp. 196–202. https://doi.org/10.1016/B978-0-12-809633-8.20870-4.

[237] G.I.H. Kerley, Dying for dinner : a cheetah killed by a common duiker illustrates the risk of small prey to predators, African Journal of Wildlife Research. 48 (2018) 1–3. https://doi.org/10.3957/056.048.024001.

[238] S. Mukherjee, M.R. Heithaus, Dangerous prey and daring predators: a review, Biological Reviews. 88 (2013) 550–563. https://doi.org/10.1111/brv.12014.

[239] R.M. Campbell, G. Vinas, M. Henneberg, Relationships between the hard and soft dimensions of the nose in Pan troglodytes and Homo sapiens reveal the positions of the nasal tips of Plio-Pleistocene hominids, PLOS ONE. 17 (2022) e0259329. https://doi.org/10.1371/journal.pone.0259329.

[240] A. Malatesta, R. Friedland, The White Kikuyu, Louis S. B. Leakey, McGraw Hill Book Co., NY, 1978. https://www.biblio.com/book/white-kikuyu-louis-b-leakey-malatesta/d/880416389 (accessed April 6, 2022).

[241] V. Morell, Ancestral Passions: The Leakey Family and the Quest for Humankind's Beginnings, Simon and Schuster, 2011.

[242] E.M. Thomas, The harmless people, New York : Vintage Books, 1989. http://archive.org/details/harmlesspeople0000thom_t2y3 (accessed April 6, 2022).

[243] L.S.B. Leakey, Animals of East Africa: The Wild Realm, National Geographic Society, Washington, D. C., 1969.

[244] F.J. Mkonyi, A.B. Estes, M.J. Msuha, L.L. Lichtenfeld, S.M. Durant, Fortified Bomas and Vigilant Herding are Perceived to Reduce Livestock Depredation by Large Carnivores in the Tarangire-Simanjiro Ecosystem, Tanzania, Hum Ecol. 45 (2017) 513–523. https://doi.org/10.1007/s10745-017-9923-4.

[245] B. Green, J. Anderson, T. Whateley, Water and Sodium Turnover and Estimated Food Consumption in Free-Living Lions (Panthera leo) and Spotted Hyaenas (Crocuta crocuta), Journal of Mammalogy. 65 (1984) 593–599. https://doi.org/10.2307/1380842.

[246] J. Valentin, Basic anatomical and physiological data for use in radiological protection: reference values: ICRP Publication 89, Annals of the ICRP. 32 (2002) 1–277. https://doi.org/10.1016/S0146-6453(03)00002-2.

[247] S.B. Heymsfield, B. Smith, E.A. Chung, K.L. Watts, M.C. Gonzalez, S. Yang, M. Heo, D.M. Thomas, D. Turner, A. Bosy-Westphal, M.J. Müller, Phenotypic differences between people varying in muscularity, Journal of Cachexia, Sarcopenia and Muscle. 13 (2022) 1100–1112. https://doi.org/10.1002/jcsm.12959.

[248] D. Hart, Man the hunted: Primates, predators, and human evolution, Routledge, 2018.

[249] N.T. Boaz, R.L. Ciochon, Q. Xu, J. Liu, Mapping and taphonomic analysis of the Homo erectus loci at Locality 1 Zhoukoudian, China, Journal of Human Evolution. 46 (2004) 519–549.

[250] W. Xiujie, Identification of traumatic lesions and artificial cut marks on the Zhoukoudian Homo erectus crania, Acta Anthropologica Sinica. 41 (2022) 608.

[251] M.C. Arriaza, J. Aramendi, M.Á. Maté-González, J. Yravedra, D. Stratford, The hunted or the scavenged? Australopith accumulation by brown hyenas at Sterkfontein (South Africa), Quaternary Science Reviews. 273 (2021) 107252.

[252] A. Treves, L. Naughton-Treves, Risk and opportunity for humans coexisting with large carnivores, Journal of Human Evolution. 36 (1999) 275–282.

[253] A. Treves, P. Palmqvist, Reconstructing hominin interactions with mammalian carnivores (6.0–1.8 Ma), in: Primate Anti-Predator Strategies, Springer, 2007: pp. 355–381.

[254] J. Corbett, J. Gobetti, Man-eaters of Kumaon, Oxford University Press New York, 1946.

[255] R. Johnson, Rich Johnson's guide to wilderness survival: How to Avoid Trouble and How to Live Through the Trouble You Can't Avoid, McGraw Hill Professional, 2008.

[256] B. Gurung, J.L.D. Smith, C. McDougal, J.B. Karki, A. Barlow, Factors associated with human-killing tigers in Chitwan National Park, Nepal, Biological Conservation. 141 (2008) 3069–3078. https://doi.org/10.1016/j.biocon.2008.09.013.

[257] J. Löe, E. Röskaft, Large Carnivores and Human Safety: A Review, Ambi. 33 (2004) 283–288. https://doi.org/10.1579/0044-7447-33.6.283.

[258] What are the world's deadliest animals?, BBC News. (2016). https://www.bbc.com/news/world-36320744 (accessed October 14, 2022).

[259] H. Farooq, C. Bero, Y. Guilengue, C. Elias, Y. Massingue, I. Mucopote, C. Nanvonamuquitxo, J. Marais, S. Faurby, A. Antonelli, Snakebite incidence in rural sub-Saharan Africa might be severely underestimated, Toxicon. 219 (2022) 106932. https://doi.org/10.1016/j.toxicon.2022.106932.

[260] J. Karlsson, M. Eriksson, O. Liberg, At what distance do wolves move away from an approaching human?, Can. J. Zool. 85 (2007) 1193–1197. https://doi.org/10.1139/Z07-099.

[261] G.K. Moen, O.-G. Støen, V. Sahlén, J.E. Swenson, Behaviour of Solitary Adult Scandinavian Brown Bears (Ursus arctos) when Approached by Humans on Foot, PLOS ONE. 7 (2012) e31699. https://doi.org/10.1371/journal.pone.0031699.

[262] J.D. Yeakel, B.D. Patterson, K. Fox-Dobbs, M.M. Okumura, T.E. Cerling, J.W. Moore, P.L. Koch, N.J. Dominy, Cooperation and individuality among man-eating lions, PNAS. 106 (2009) 19040–19043. https://doi.org/10.1073/pnas.0905309106.

[263] L.R.G. DeSantis, B.D. Patterson, Dietary behaviour of man-eating lions as revealed by dental microwear textures, Sci Rep. 7 (2017) 904. https://doi.org/10.1038/s41598-017-00948-5.

[264] C. Packer, D. Ikanda, B. Kissui, H. Kushnir, Lion attacks on humans in Tanzania, Nature. 436 (2005) 927–928. https://doi.org/10.1038/436927a.

[265] B.A. Nickel, J.P. Suraci, A.C. Nisi, C.C. Wilmers, Energetics and fear of humans constrain the spatial ecology of pumas, PNAS. 118 (2021). https://doi.org/10.1073/pnas.2004592118.

[266] J.P. Suraci, J.A. Smith, M. Clinchy, L.Y. Zanette, C.C. Wilmers, Humans, but not their dogs, displace pumas from their kills: An experimental approach, Sci Rep. 9 (2019) 12214. https://doi.org/10.1038/s41598-019-48742-9.

[267] C.C. Wilmers, A.C. Nisi, N. Ranc, COVID-19 suppression of human mobility releases mountain lions from a landscape of fear, Current Biology. 31 (2021) 3952-3955.e3. https://doi.org/10.1016/j.cub.2021.06.050.

[268] J.R. Kelly, T.J. Doherty, T. Gabel, W. Disbrow, Large Carnivore Attacks on Humans: The State of Knowledge, Human Ecology Review. 25 (2019) 15–34.

[269] K. Hall, M.W. Oram, M.W. Campbell, T.M. Eppley, R.W. Byrne, F.B.M. de Waal, Chimpanzee uses manipulative gaze cues to conceal and reveal information to foraging competitor, American Journal of Primatology. 79 (2017) e22622. https://doi.org/10.1002/ajp.22622.

[270] F. Cajori, Origin of the Name "Mathematical Induction.," The American Mathematical Monthly. 25 (1918) 197–201. https://doi.org/10.1080/00029890.1918.11998417.

[271] G.S. McCall, J. Whittaker, Handaxes still don't fly, Lithic Technology. 32 (2007) 195–202.

[272] W.H. Calvin, The Throwing Madonna: Essays on the Brain, William H. Calvin, 2010.

[273] W.H. Calvin, The Ascent of Mind: Ice Age Climates and the Evolution of Intelligence, Bantam Books, 1991.

[274] A. Cannell, Throwing behaviour and the mass distribution of geological hand samples, hand grenades and olduvian manuports, Journal of Archaeological Science. 29 (2002) 335–339.

[275] J. Clutton-Brock, ed., Did large predators keep humans out of North America?, in: The Walking Larder: Patterns of Domestication, Pastoralism, and Predation, Routledge, 1989: pp. 282–294.

[276] M.P. Lombardo, R.O. Deaner, Born to throw: the ecological causes that shaped the evolution of throwing in humans, The Quarterly Review of Biology. 93 (2018) 1–16.

[277] B. Isaac, Throwing and human evolution, African Archaeological Review. 5 (1987) 3–17.

[278] P. Kolb, The present state of the Cape of Good Hope: Or, A particular account of the several nations of the Hottentots: their religion, government, laws, customs, ceremonies, and opinions; their art of war, professions, language, genius, &c. Together with a short account of the Dutch settlement at the cape, W. Innys, at the west end of St. Pauls, London, 1731. https://books.google.co.uk/books?id=z6FZnl5I1dQC&printsec=frontcover#v=onepage&q=242&f=false.

[279] J.G. Wood, The Uncivilized Races of Men in All Countries of the World: Being a Comprehensive Account of Their Manners and Customs, and Their Physical, Social, Mental, Moral and Religious Characteristics, JB Burr and Company, 1870.

[280] R.F. Burton, The Book of the Sword, Chatto and Windus, London, 1884.

[281] M.P. Lombardo, R.O. Deaner, Born to throw: the ecological causes that shaped the evolution of throwing in humans, The Quarterly Review of Biology. 93 (2018) 1–16.

[282] N.T. Roach, B.G. Richmond, Clavicle length, throwing performance and the reconstruction of the Homo erectus shoulder, Journal of Human Evolution. 80 (2015) 107–113. https://doi.org/10.1016/j.jhevol.2014.09.004.

[283] N.T. Roach, M. Venkadesan, M.J. Rainbow, D.E. Lieberman, Elastic energy storage in the shoulder and the evolution of high-speed throwing in Homo, Nature. 498 (2013) 483–486. https://doi.org/10.1038/nature12267.

[284] V. Geist, Life Strategies, Human Evolution, Environmental Design: Toward a Biological Theory of Health, Springer Science & Business Media, 2013.

[285] V.S. Gurfinkel, Y.M. Kots, E.I. Paltsev, A.G. Feldman, The compensation of respiratory disturbances of the erect posture of man as an example of the organization of interarticular interaction, Models of the Structural-Functional Organization of Certain Biological Systems. (1971) 382–395.

[286] I.W. Hunter, R.E. Kearney, Respiratory components of human postural sway, Neuroscience Letters. 25 (1981) 155–159. https://doi.org/10.1016/0304-3940(81)90324-4.

[287] M.W. Marzke, N. Toth, K. Schick, S. Reece, B. Steinberg, K. Hunt, R. Linscheid, K. An, EMG study of hand muscle recruitment during hard hammer percussion manufacture of Oldowan tools, American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists. 105 (1998) 315–332.

[288] J.R. Skoyles, Speech phones are a replication code, Medical Hypotheses. 50 (1998) 167–173. https://doi.org/10.1016/S0306-9877(98)90203-1.

[289] A. Mehrabi, S. Dixon, M. Sandler, Vocal imitation of percussion sounds: On the perceptual similarity between imitations and imitated sounds, PLOS ONE. 14 (2019) e0219955. https://doi.org/10.1371/journal.pone.0219955.

[290] R. Botha, C. Knight, eds., As well as words: Congo Pygmy hunting, mimicry, and play, in: The Cradle of Language, OUP Oxford, 2009: pp. 236–256.

[291] J.G. Mine, K.E. Slocombe, E.P. Willems, I.C. Gilby, M. Yu, M.E. Thompson, M.N. Muller, R.W. Wrangham, S.W. Townsend, Z.P. Machanda, Vocal signals facilitate cooperative hunting in wild chimpanzees, Science Advances. 8 (2022) eabo5553. https://doi.org/10.1126/sciadv.abo5553.

[292] F. de O. Calleia, F. Rohe, M. Gordo, Hunting Strategy of the Margay (Leopardus wiedii) to Attract the Wild Pied Tamarin (Saguinus bicolor), Nepr. 16 (2009) 32–34. https://doi.org/10.1896/044.016.0107.

[293] J. Hailman, Context of blue jay (Cyanocitta cristata) mimicking Cooper’s Hawk (Accipiter cooperii) cackle., Florida Field Naturalist. 37 (2009) 94–95.

[294] F.N. Robinson, Vocal mimicry and the evolution of bird song, EMU. 75 (1975) 23–27. https://doi.org/10.1071/mu9750023.

[295] A.H. Dalziell, A.C. Maisey, R.D. Magrath, J.A. Welbergen, Male lyrebirds create a complex acoustic illusion of a mobbing flock during courtship and copulation, Current Biology. 31 (2021) 1970-1976.e4. https://doi.org/10.1016/j.cub.2021.02.003.

[296] E.M. Thomas, The Old Way: A Story of the First People, Picador, 2007.

[297] E.H. Hagen, The biological roots of music and dance: Extending the credible signaling hypothesis to predator deterrence, Human Nature. 33 (2022) 261–279.

[298] E.H. Hagen, G.A. Bryant, Music and dance as a coalition signaling system, Human Nature. 14 (2003) 21–51.

[299] T. Dohmen, J. Sauermann, Referee Bias, Journal of Economic Surveys. 30 (2016) 679–695. https://doi.org/10.1111/joes.12106.

[300] J.J. Reade, D. Schreyer, C. Singleton, Eliminating supportive crowds reduces referee bias, Economic Inquiry. 60 (2022) 1416–1436. https://doi.org/10.1111/ecin.13063.

[301] A.M. MacLarnon, G.P. Hewitt, The evolution of human speech: The role of enhanced breathing control, American Journal of Physical Anthropology. 109 (1999) 341–363. https://doi.org/10.1002/(SICI)1096-8644(199907)109:3<341::AID-AJPA5>3.0.CO;2-2.

[302] V. Eleuteri, M. Henderson, A. Soldati, G. Badihi, K. Zuberbühler, C. Hobaiter, The form and function of chimpanzee buttress drumming, Animal Behaviour. 192 (2022) 189–205. https://doi.org/10.1016/j.anbehav.2022.07.013.

[303] B. Buys, S. van Loon, A.D. Puijk, New observations on chimpanzee accumulative stone throwing in Boé, Guinea Bissau, Mammalia. (2022). https://doi.org/10.1515/mammalia-2021-0098.

[304] L.A. Isbell, L.R. Bidner, E.K. Van Cleave, A. Matsumoto-Oda, M.C. Crofoot, GPS-identified vulnerabilities of savannah-woodland primates to leopard predation and their implications for early hominins, Journal of Human Evolution. 118 (2018) 1–13.

[305] M.D. Leakey, Discoveries at Laetoli in northern Tanzania, Proceedings of the Geologists’ Association. 92 (1981) 81–86. https://doi.org/10.1016/S0016-7878(81)80008-9.

[306] M. Domínguez-Rodrigo, J. Serrallonga, J. Juan-Tresserras, L. Alcala, L. Luque, Woodworking activities by early humans: a plant residue analysis on Acheulian stone tools from Peninj (Tanzania), Journal of Human Evolution. 40 (2001) 289–299.

[307] M.K. Bamford, Fossil leaves, fruits and seeds, Paleontology and Geology of Laetoli: Human Evolution in Context: Volume 1: Geology, Geochronology, Paleoecology and Paleoenvironment. (2011) 235–252.

[308] P.W. Hodges, V.S. Gurfinkel, S. Brumagne, T. Smith, P. Cordo, Coexistence of stability and mobility in postural control: evidence from postural compensation for respiration, Experimental Brain Research. 144 (2002) 293–302.

[309] G.C. Plassche, T.A. Fortney, C. Morrissette, J.F. Korzelius, C.A. Popkin, Fighting in professional ice hockey: it’s time for a change, The Physician and Sportsmedicine. (2022) 1–9.

[310] D. Biderman, 11 Minutes of Action, Wall Street Journal. (2010). https://www.wsj.com/articles/SB10001424052748704281204575002852055561406 (accessed

March 12, 2022).

[311] M.S. Orendurff, J.D. Walker, M. Jovanovic, K. L. Tulchin, M. Levy, D.K. Hoffmann, Intensity and Duration of Intermittent Exercise and Recovery During a Soccer Match, The Journal of Strength & Conditioning Research. 24 (2010) 2683. https://doi.org/10.1519/JSC.0b013e3181bac463.

[312] L. Liebenberg, Persistence hunting by modern hunter-gatherers, Current Anthropology. 47 (2006) 1017–1026.

[313] C.C. Wilmers, L.A. Isbell, J.P. Suraci, T.M. Williams, Energetics-informed behavioral states reveal the drive to kill in African leopards, Ecosphere. 8 (2017) e01850.

[314] B. Merker, A note on hunting and hominid origins, American Anthropologist. 86 (1984) 112–114.

[315] J.F. O'Connell, K. Hawkes, N.B. Jones, Hadza Scavenging: Implications for Plio/Pleistocene Hominid Subsistence, Current Anthropology. 29 (1988) 356–363. https://doi.org/10.1086/203648.

[316] M. Domínguez-Rodrigo, E. Baquedano, E. Organista, L. Cobo-Sánchez, A. Mabulla, V. Maskara, A. Gidna, M. Pizarro-Monzo, J. Aramendi, A.B. Galán, Early Pleistocene faunivorous hominins were not kleptoparasitic, and this impacted the evolution of human anatomy and socio-ecology, Scientific Reports. 11 (2021) 16135.

[317] M. Henneberg, V. Sarafis, K. Mathers, Human adaptations to meat eating, Human Evolution. 13 (1998) 229–234.

[318] M. Domínguez-Rodrigo, T.R. Pickering, The meat of the matter: an evolutionary perspective on human carnivory, Azania: Archaeological Research in Africa. 52 (2017) 4–32.

[319] J.L. Lekuton, H. Viola, Facing the Lion: Growing Up Maasai on the African Savanna, National Geographic Books, 2009.

[320] M.J. Goldman, J.R. de Pinho, J. Perry, Beyond ritual and economics: Maasai lion hunting and conservation politics, Oryx. 47 (2013) 490–500. https://doi.org/10.1017/S0030605312000907.

[321] O. Holt, If You're Second You Are Nothing: Ferguson and Shankly, Unabridged edition, Pan Books, 2007.

[322] C. Darwin, The Expression of the Emotions in Man and Animals, University of Chicago Press, 1965.

[323] W.J. Dominey, Mobbing in Colonially Nesting Fishes, Especially the Bluegill, Lepomis macrochirus, Copeia. 1983 (1983) 1086–1088. https://doi.org/10.2307/1445113.

[324] J.R. Coomes, G.E. McIvor, A. Thornton, Evidence for individual discrimination and numerical assessment in collective antipredator behaviour in wild jackdaws (Corvus monedula), Biology Letters. 15 (2019) 20190380. https://doi.org/10.1098/rsbl.2019.0380.

[325] C. Leuchtenberger, S.B. Almeida, A. Andriolo, P.G. Crawshaw, Jaguar mobbing by giant otter groups, Acta Ethol. 19 (2016) 143–146. https://doi.org/10.1007/s10211-016-0233-4.

[326] B. Graw, M.B. Manser, The function of mobbing in cooperative meerkats, Animal Behaviour. 74 (2007) 507–517. https://doi.org/10.1016/j.anbehav.2006.11.021.

[327] E. Lloyd, K. Kreetiyutanont, J. Prabnasuk, L.I. Grassman, C. Borries, Observation of Phayre's leaf monkeys mobbing a clouded leopard at Phu Khieo Wildlife Sanctuary (Thailand) / Observation des singes Trachypithecus phayrei assaillant un panthére nébulense au sanctuaire de faune de Phu Khieo (Thaïlande), Mammalia. 70 (2006) 158–159. https://doi.org/10.1515/MAMM.2006.028.

[328] T. Iwamoto, A. Mori, M. Kawai, A. Bekele, Anti-predator behavior of gelada baboons, Primates. 37 (1996) 389–397. https://doi.org/10.1007/BF02381374.

[329] M. Hiraiwa-Hasegawa, R.W. Byrne, H. Takasaki, J.M.E. Byrne, Aggression toward Large Carnivores by Wild Chimpanzees of Mahale Mountains National Park, Tanzania, FPR. 47 (1986) 8–13. https://doi.org/10.1159/000156259.

[330] N. Corredor-Ospina, M. Kreyer, G. Rossi, G. Hohmann, B. Fruth, First report of a leopard (Panthera pardus)–bonobo (Pan paniscus) encounter at the LuiKotale study site, Democratic Republic of the Congo, Primates. 62 (2021) 555–562. https://doi.org/10.1007/s10329-021-00897-8.

[331] M. Nakamura, K. Hosaka, N. Itoh, T. Matsumoto, T. Matsusaka, N. Nakazawa, H. Nishie, T. Sakamaki, M. Shimada, Y. Takahata, M. Yamagami, K. Zamma, Wild chimpanzees deprived a leopard of its kill: Implications for the origin of hominin confrontational scavenging, Journal of Human Evolution. 131 (2019) 129–138. https://doi.org/10.1016/j.jhevol.2019.03.011.

[332] A. Srivastava, Cultural Transmission of Snake-Mobbing in Free-Ranging Hanuman Langurs, FPR. 56 (1991) 117–120. https://doi.org/10.1159/000156535.

[333] E.M. Thomas, The Lions and the San: How could a people survive for thousands of years with so many predators in their midst?, The American Scholar. (2022). https://theamericanscholar.org/the-lions-and-the-san/ (accessed September 21, 2023).

[334] S.N. Awathale, B.B. Dudhbhate, R.R. Rahangdale, C.D. Borkar, N.K. Subhedar, D.M. Kokare, Denial of food to the hungry rat: A novel paradigm for induction and evaluation of anger-like emotion, Journal of Neuroscience Methods. 341 (2020) 108791. https://doi.org/10.1016/j.jneumeth.2020.108791.

[335] C. Boesch, The real chimpanzee: sex strategies in the forest, Cambridge University Press,

2009.

[336] K. Westhues, Mobbing: a Natural Fact (Graz lecture, 2007), Workplace Mobbing in Academe & Beyond. (n.d.). https://www.kwesthues.com/graz0701.htm (accessed April 28, 2022).

[337] B. Rensberger, The lace of evolution, The New York Times. (1974) 223.

[338] N. Munger, L. Leakey, R. Ardrey, AGGRESSION AND VIOLENCE IN MAN—A Dialogue Dr. L. S. B. Leakey Mr. Robert Ardrey, Munger Africana Library Notes. 9 (1971) 24pp.

[339] M. Mahat-Shamir, K. Lebowitz, Y. Hamama-Raz, “You did not desert me my brothers in arms”: The continuing bond experience of men who have lost a brother in arms, Death Studies. 46 (2022) 415–424. https://doi.org/10.1080/07481187.2020.1737275.

[340] L. Tórrez, N. Robles, A. González, M.C. Crofoot, Risky Business? Lethal Attack by a Jaguar Sheds Light on the Costs of Predator Mobbing for Capuchins (Cebus capucinus), Int J Primatol. 33 (2012) 440–446. https://doi.org/10.1007/s10764-012-9588-1.

[341] K.M. Jack, M.R. Brown, M.S. Buehler, S. Cheves Hernadez, N. Ferrero Marín, N.K. Kulick, S.E. Lieber, Cooperative rescue of a juvenile capuchin (Cebus imitator) from a Boa constrictor, Sci Rep. 10 (2020) 16814. https://doi.org/10.1038/s41598-020-73476-4.

[342] M.A. Changizi, R.M.F. McGehee, W.G. Hall, Evidence that appetitive responses for dehydration and food-deprivation are learned, Physiology & Behavior. 75 (2002) 295–304. https://doi.org/10.1016/S0031-9384(01)00660-6.

[343] W. Craig, Appetites and Aversions as Constituents of Instincts, Biological Bulletin. 34 (1918) 91–107. https://doi.org/10.2307/1536346.

[344] R. Miller, M.L. Lambert, A. Frohnwieser, K.F. Brecht, T. Bugnyar, I. Crampton, E. Garcia-Pelegrin, K. Gould, A.L. Greggor, E.-I. Izawa, D.M. Kelly, Z. Li, Y. Luo, L.B. Luong, J.J.M. Massen, A. Nieder, S.A. Reber, M. Schiestl, A. Seguchi, P. Sepehri, J.R. Stevens, A.H. Taylor, L. Wang, L.M. Wolff, Y. Zhang, N.S. Clayton, Socio-ecological correlates of neophobia in corvids, Current Biology. 32 (2022) 74-85.e4. https://doi.org/10.1016/j.cub.2021.10.045.

[345] L.M. Elbroch, H. Quigley, Observations of Wild Cougar (Puma concolor) Kittens with Live Prey: Implications for Learning and Survival, The Canadian Field-Naturalist. 126 (2012) 333–335. https://doi.org/10.22621/cfn.v126i4.1380.

[346] A. Kitchener, Watch with mother: A review of social learning in the Felidae In Box HO, editor; & Gibson KR, editor.(Eds.), Mammalian social learning: Comparative and ecological perspective (pp. 236–258), (1999).

[347] C. BUSSE, Leopard and Lion predation upon Chacma Baboons living in the Moremi Wildlife Reserve, Botswana Notes and Records. 12 (1980) 15–21.

[348] B.J. Wilson, S.R. Harris, Language and cooperation in hominin scavenging, Evolution and Human Behavior. 38 (2017) 376–396.

[349] A. Szilágyi, V.P. Kovács, T. Czárán, E. Szathmáry, Evolutionary ecology of language origins through confrontational scavenging, Philosophical Transactions of the Royal Society B. 378 (2023) 20210411.

[350] W.H. McNeill, Keeping Together in Time: Dance and Drill in Human History, Harvard University Press, 1997.

[351] M. Kinoshita, H. Okamoto, Acetylcholine potentiates glutamate transmission from the habenula to the interpeduncular nucleus in losers of social conflict, Current Biology. 33 (2023) 2121–2135.

[352] H. Okamoto, B.-W. Cherng, H. Nakajo, M.-Y. Chou, M. Kinoshita, Habenula as the experience-dependent controlling switchboard of behavior and attention in social conflict and learning, Current Opinion in Neurobiology. 68 (2021) 36–43.

[353] P. Silva, R. Duarte, P. Esteves, B. Travassos, L. Vilar, Application of entropy measures to analysis of performance in team sports, International Journal of Performance Analysis in Sport. 16 (2016) 753–768. https://doi.org/10.1080/24748668.2016.11868921.

[354] V.K. Borooah, J. Mangan, Measuring competitive balance in sports using generalized entropy with an application to English premier league football, Applied Economics. 44 (2012) 1093–1102. https://doi.org/10.1080/00036846.2010.537638.

[355] Y. Neuman, D. Vilenchik, Modeling Small Systems Through the Relative Entropy Lattice, IEEE Access. 7 (2019) 43591–43597. https://doi.org/10.1109/ACCESS.2019.2907067.

[356] J.H. Martínez, D. Garrido, J.L. Herrera-Diestra, J. Busquets, R. Sevilla-Escoboza, J.M. Buldú, Spatial and Temporal Entropies in the Spanish Football League: A Network Science Perspective, Entropy. 22 (2020) 172. https://doi.org/10.3390/e22020172.

[357] L. Grosenick, T.S. Clement, R.D. Fernald, Fish can infer social rank by observation alone, Nature. 445 (2007) 429–432.

[358] A.B. Sargeant, L.E. Eberhardt, Death Feigning by Ducks in Response to Predation by Red Foxes (Vulpes fulva), The American Midland Naturalist. 94 (1975) 108–119. https://doi.org/10.2307/2424542.

[359] R.K. Humphreys, G.D. Ruxton, A review of thanatosis (death feigning) as an anti-predator behaviour, Behavioral Ecology and Sociobiology. 72 (2018) 1–16.

[360] A. Arshamian, M. Laska, A.R. Gordon, M. Norberg, C. Lahger, D.K. Porada, N. Jelvez Serra, E. Johansson, M. Schaefer, M. Amundin, A mammalian blood odor component serves as an approach-avoidance cue across phylum border-from flies to humans, Scientific Reports. 7

(2017) 13635.

[361] S. Nilsson, J. Sjöberg, M. Amundin, C. Hartmann, A. Buettner, M. Laska, Behavioral responses to mammalian blood odor and a blood odor component in four species of large carnivores, PloS One. 9 (2014) e112694.

[362] Sniffing animals as a diagnostic tool in infectious diseases, Clinical Microbiology and Infection. 26 (2020) 431–435.

[363] L.L. Kerley, G.P. Salkina, Using scent-matching dogs to identify individual Amur tigers from scats, The Journal of Wildlife Management. 71 (2007) 1349–1356.

[364] L.M. Harvey, J.W. Harvey, Reliability of bloodhounds in criminal investigations, Journal of Forensic Sciences. 48 (2003) JFS2002118.

[365] W. Roebroeks, M.J. Sier, T.K. Nielsen, D. De Loecker, J.M. Parés, C.E. Arps, H.J. Mücher, Use of red ochre by early Neandertals, Proceedings of the National Academy of Sciences. 109 (2012) 1889–1894.

[366] I. Reiger, Scent rubbing in carnivores, Carnivore. 2 (1979) 17–25.

[367] M. Mussi, M.M. Skinner, R.T. Melis, J. Panera, S. Rubio-Jara, T.W. Davies, D. Geraads, H. Bocherens, G. Briatico, A. Le Cabec, J.-J. Hublin, A. Gidna, R. Bonnefille, L. Di Bianco, E. Méndez-Quintas, Early Homo erectus lived at high altitudes and produced both Oldowan and Acheulean tools, Science. 0 (2023) eadd9115. https://doi.org/10.1126/science.add9115.

[368] S.M. Kotikot, A. Flores, R.E. Griffin, J. Nyaga, J.L. Case, R. Mugo, A. Sedah, E. Adams, A. Limaye, D.E. Irwin, Statistical characterization of frost zones: Case of tea freeze damage in the Kenyan highlands, International Journal of Applied Earth Observation and Geoinformation. 84 (2020) 101971.

[369] A. DeRusso, D. Fan, J. Gupta, O. Shelest, R.M. Costa, H.H. Yin, Instrumental uncertainty as a determinant of behavior under interval schedules of reinforcement, Frontiers in Integrative Neuroscience. 4 (2010) 1737.

[370] K.T. Quach, S.H. Chalasani, Flexible reprogramming of Pristionchus pacificus motivation for attacking Caenorhabditis elegans in predator-prey competition, Current Biology. 0 (2022). https://doi.org/10.1016/j.cub.2022.02.033.

[371] V.H. Sridhar, L. Li, D. Gorbonos, M. Nagy, B.R. Schell, T. Sorochkin, N.S. Gov, I.D. Couzin, The geometry of decision-making in individuals and collectives, Proceedings of the National Academy of Sciences. 118 (2021) e2102157118. https://doi.org/10.1073/pnas.2102157118.

[372] M. Grabowski, K.G. Hatala, W.L. Jungers, B.G. Richmond, Body mass estimates of hominin fossils and the evolution of human body size, Journal of Human Evolution. 85 (2015) 75–93.

[373] T. Chen Zeng, J.T. Cheng, J. Henrich, Dominance in humans, Philosophical Transactions of the Royal Society B: Biological Sciences. 377 (2022) 20200451. https://doi.org/10.1098/rstb.2020.0451.

[374] D. Maestripieri, Macachiavellian intelligence: how rhesus macaques and humans have conquered the world, University of Chicago Press, 2019.

[375] E. Jooste, R.T. Pitman, W. van Hoven, L.H. Swanepoel, Unusually High Predation on Chacma Baboons (Papio ursinus) by Female Leopards (Panthera pardus) in the Waterberg Mountains, South Africa, FPR. 83 (2012) 353–360. https://doi.org/10.1159/000339644.

[376] M. Hayward, P. Henschel, J. O'Brien, M. Hofmeyr, G. Balme, G.I. Kerley, Prey preferences of the leopard (Panthera pardus), Journal of Zoology. 270 (2006) 298–313.

[377] M. Hayward, W. Jędrzejewski, B. Jedrzejewska, Prey preferences of the tiger P anthera tigris, Journal of Zoology. 286 (2012) 221–231.

[378] M. Hayward, Prey preferences of the spotted hyaena (Crocuta crocuta) and degree of dietary overlap with the lion (Panthera leo), Journal of Zoology. 270 (2006) 606–614.

[379] M.W. Hayward, G.I. Kerley, Prey preferences of the lion (Panthera leo), Journal of Zoology. 267 (2005) 309–322.

[380] M.W. Hayward, J. O'Brien, M. Hofmeyr, G.I. Kerley, Prey preferences of the African wild dog Lycaon pictus (Canidae: Carnivora): ecological requirements for conservation, Journal of Mammalogy. 87 (2006) 1122–1131.

[381] M. Hayward, M. Hofmeyr, J. O'brien, G.I. Kerley, Prey preferences of the cheetah (Acinonyx jubatus)(Felidae: Carnivora): morphological limitations or the need to capture rapidly consumable prey before kleptoparasites arrive?, Journal of Zoology. 270 (2006) 615–627.

[382] T. Londei, The cheetah (Acinonyx jubatus) dewclaw: specialization overlooked, Journal of Zoology. 251 (2000) 535–547.

[383] C. Carbone, A. Teacher, J.M. Rowcliffe, The costs of carnivory, PLoS Biology. 5 (2007) e22.

[384] C.B. Ruff, B.A. Wood, The estimation and evolution of hominin body mass, Evolutionary Anthropology: Issues, News, and Reviews. (2023).

[385] F. Palomares, T.M. Caro, Interspecific Killing among Mammalian Carnivores., The American Naturalist. 153 (1999) 492–508. https://doi.org/10.1086/303189.

[386] S.M. Durant, Living with the enemy: avoidance of hyenas and lions by cheetahs in the Serengeti, Behavioral Ecology. 11 (2000) 624–632.

[387] J.D. Henry, Red fox : the catlike canine, Washington, D.C. : Smithsonian Institution Press, 1996. http://archive.org/details/redfoxcatlikecan0000henr (accessed June 30, 2023).

[388] D. Maestripieri, K. Wallen, Affiliative and submissive communication in rhesus macaques, Primates. 38 (1997) 127.

[389] S.Y. Long, Hair-nibbling and whisker-trimming as indicators of social hierarchy in mice, Animal Behaviour. 20 (1972) 10–12. https://doi.org/10.1016/S0003-3472(72)80167-2.

[390] M. Foucault, The Ethics of the Concern of the Self as a Practice of Freedom. Ethics: Subjectivity and Truth, Ed. Paul Rabinow. Trans. Robert Hurley. New York: New. (1997) 281–302.

[391] K. Lorenz, Ritualized fighting, in: The Natural History of Aggression, Academic Press, London, 1964: pp. 39–50.

[392] R.F. Oliveira, J.F. Silva, J.M. Simoes, Fighting zebrafish: characterization of aggressive behavior and winner–loser effects, Zebrafish. 8 (2011) 73–81.

[393] M. Briffa, S.M. Lane, The role of skill in animal contests: a neglected component of fighting ability, Proceedings of the Royal Society B: Biological Sciences. 284 (2017) 20171596.

[394] L.V. Harper, K.M. Sanders, The effect of adults' eating on young children's acceptance of unfamiliar foods, Journal of Experimental Child Psychology. 20 (1975) 206–214. https://doi.org/10.1016/0022-0965(75)90098-3.

[395] E.H. Hagen, G.A. Bryant, Music and dance as a coalition signaling system, Human Nature. 14 (2003) 21–51.

[396] E.H. Hagen, The biological roots of music and dance: Extending the credible signaling hypothesis to predator deterrence, Human Nature. 33 (2022) 261–279.

[397] J.R. Krebs, The significance of song repertoires: The Beau Geste hypothesis, Animal Behaviour. 25 (1977) 475–478. https://doi.org/10.1016/0003-3472(77)90022-7.

[398] Y. Neuman, N. Israeli, D. Vilenchik, Y. Cohen, The adaptive behavior of a soccer team: An entropy-based analysis, Entropy. 20 (2018) 758.

[399] Pairwise comparisons of mitochondrial DNA sequences in subdivided populations and implications for early human evolution., Genetics. 136 (1994) 673–683.

[400] S.C. Walpole, D. Prieto-Merino, P. Edwards, J. Cleland, G. Stevens, I. Roberts, The weight of nations: an estimation of adult human biomass, BMC Public Health. 12 (2012) 1–6.