The cognitive and social origins of randomization devices

Tal Boger (tboger1@jhu.edu) [a], Dorsa Amir (dorsa.amir@duke.edu) [b, c]

[a] Johns Hopkins University, Department of Psychological & Brain Sciences
[b] Duke University, Department of Psychology & Neuroscience
[c] Duke University, Department of Evolutionary Anthropology

Abstract:

From throwing dice to reading tea leaves, humans across diverse cultures, eras, and geographies rely on decision aids that produce randomness. What purpose do these aids serve, and why do cultures create them with such regularity? In this Perspective, we unify these seemingly disparate tools as *randomization devices*, and argue that they culturally evolved to solve two recurrent problems, one cognitive and one social. Specifically, randomization devices produce strong, unpredictable randomness, whereas human cognition does not; and randomization devices externalize decisions in ways that create a social buffer between decision-makers and outcomes. The design of such devices reflects these constraints, even in relation to unique mechanistic features. We focus on one such property — causal opacity — as an important feature of randomization devices that subserves their function and arises in diverse literatures spanning cultural evolution, computer science, and political philosophy. Taken together, we argue that the widespread recurrence of randomization devices reflects widespread cognitive constraints and social demands.

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1. Introduction

It's Election Day, 400 B.C., and a new cohort of public officials is set to take office in Athens. Instead of checking a box or writing a name, citizens partake in an unusual ritual: They approach a large marble slab — a *kleroterion* — and insert a bronze token into one of its rows of slots. When the time comes, citizens watch as a simple mechanism of falling dice decides, row by row, who will take office. A white die; they are chosen. A black die; they are not.

Thousands of miles away in Northern Canada, a Naskapi oracle holds the shoulder bone of a caribou over hot coals and carefully observes how the bone cracks in the heat. Hunters believe this pattern of cracks provides a map, guiding them in the direction of live caribou.

On the complete opposite side of the planet, a Chinese court diviner performs a nearly identical ritual, burning the scapula of an ox and interpreting the patterns of cracks it produces — not to help guide a hunt, but to foresee what the future holds for the king.

Although these practices may appear esoteric or rare, this is not the case. Across disparate cultures, geographies, and epochs, humans have engaged in practices like the above, and many more like it. We burn bones, roll dice, read tea leaves, flip coins, interpret the movements of animals, and more (**Figure 1**). But why? What binds these seemingly disparate practices together, and what is their purpose? Here, we argue that these diverse cultural practices share a key function in common: they produce *randomness*. More specifically, we unite these artifacts and practices together as *randomization devices* — tools designed to generate random outputs that support decision-making.

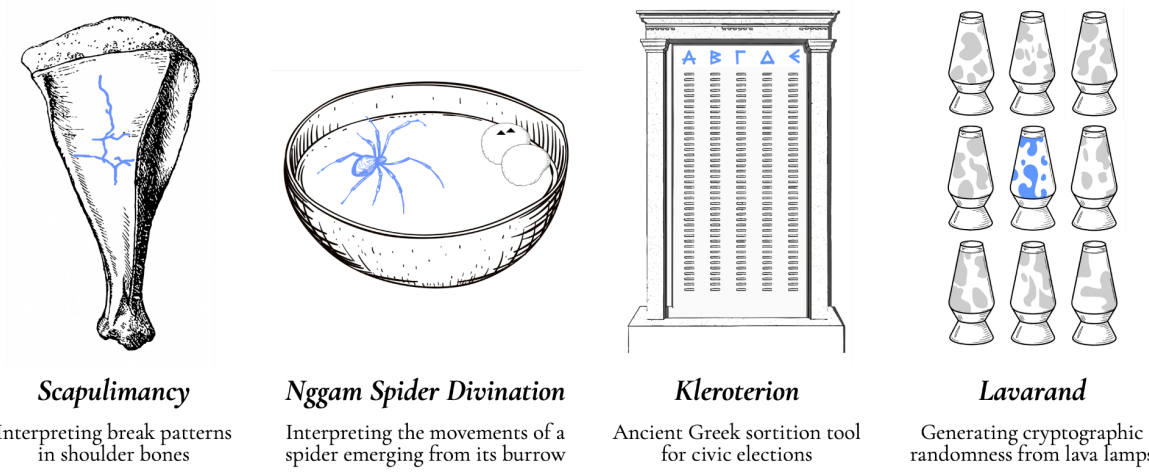

Figure 1: A variety of randomization devices across cultures. Although any given device seems specialized, diverse cultures often independently created such devices, whether by burning bones or interpreting the motion of spiders. These artifacts serve important purposes even today. For example, to achieve cryptographic security, some companies such as Cloudflare rely on lava lamps, as their dynamic heating results in random motion ('Lavarand').

Why did these tools evolve with such regularity across diverse cultures, and what underlying features unite them? In this Perspective, we establish *randomization devices* as a coherent class of cultural tools, unifying practices and artifacts with ostensibly disparate functions, often explored in isolation across diverse disciplines. Then, we offer an integrated account of the cultural evolution of randomization devices by outlining the cognitive and social constraints that engender such devices. First, we bring together representative examples from the ethnographic record to illustrate (a) the broad range of randomization devices across cultures and (b) the diverse functions and implementations of these devices. Then, we suggest that randomization devices constitutively provide solutions to both a cognitive problem (the mind's inability to generate truly random outputs) and a social one (no human-originated output can be trusted to be unbiased). The cognitive and social problems contextualize not just the recurrent invention of these tools, but the specific cases (e.g., domains or situations) in which they are deployed. Cultures use randomization devices precisely where human-generated randomness proves insufficient, as we expand upon in the sections that follow. For both the cognitive problem and the social problem, diverse fields — spanning cultural evolution, computer science, and political philosophy — describe one especially important feature of randomization devices: causal opacity. We analyze the nature of causally opaque versus causally transparent randomization devices, integrating the approaches discussed in these literatures across different levels of analysis. Together, these arguments unify an otherwise-disparate set of tools under a common theory, offering a new lens through which to understand one of humanity's most recurrent and ubiquitous cultural inventions.

2. A diversity of randomization devices across cultures

Throughout history, diverse cultures have produced an enormous variety of randomization devices, a small fraction of which appears in **Table 1**. Some devices, like dice, will be familiar to people from a huge swath of societies, and have been for some time: Archaeological evidence, for instance, suggests that dice have been part of Native American cultures for at least 12,000 years (Madden, 2026). Other devices, like spider divination or the burning of bones, are more culture-specific and may appear quite esoteric. These devices differ not only in their surface features but also in their functional domain — e.g., we might use dice for gambling but spider divination for questions of illness. We argue that, despite this variability in function and design, these devices share a common, underlying logic. As such, we unify randomization devices at the computational level over and above their vast differences at the algorithmic and implementational levels (Marr, 1982).

Practice	Era	Location	Citation	Method	Function or domain	Opaque?	Description
Chinese yarrow stalk divination (*I Ching*)	~1000 BC, ongoing	China	Smith, 2012	Cleromancy	Decision-making under uncertainty	Yes	49 yarrow stalks are manipulated to generate one of 64 hexagrams for guidance on decisions
Chinese oracle bone divination	~1200-1000 BC	China	Keightley, 1978	Scapulimancy	Decision-making under uncertainty	Yes	Ox scapula is heated with a bronze rod until cracks appear and are then interpreted by diviners
Ancient Greek *kleroterion*	~600–300 BC	Athens, Greece	Dow, 1939	Sortition	Procedural justice	No	Random selection of public officials using the kleroterion machine. Explicitly random to prevent corruption and ensure fair representation across tribes.
Ancient Roman bird augury	~700 BC to 400 AD	Rome	Beard et al., 1998	Augury	Decision-making under uncertainty, anti-coordination	Yes	Augurs observed the flight, calls, and feeding behavior of birds before military campaigns and political decisions to determine divine approval.
Kantu' bird augury	Traditional, ongoing	Borneo (Kalimantan), Indonesia	Dove, 1993	Augury	Decision-making under uncertainty, anti-coordination (agriculture)	Yes	Kantu' swidden horticulturalists use bird sightings and sounds to select new agricultural plots, effectively randomizing site selection and avoiding decision-making biases
Naskapi bone divination	Traditional, documented 1935	Labrador, Canada	Speck, 1935; Moore, 1957	Scapulimancy	Decision-making under uncertainty, anti-coordination (with prey)	Yes	Various animal bones (e.g., caribou shoulder blades) are burned and the resulting cracks interpreted to determine hunting locations, introducing randomness into hunting routes.
Pre-Columbian dice casting (*Patolli*)	Traditional	Central Mexico, Mesoamerica	Voorhies, 2017	Cleromancy	Decision-making under uncertainty, gambling	No	Participants cast beans onto a surface without deliberate control. *Patolli* was used both as a divination tool and played as a game of chance.
Bamana sand divination (*tabi*)	Traditional, ongoing	Mali, Senegal	Eglash, 1997	Amathomancy	Decision-making under uncertainty	Yes	A diviner rapidly strikes a bed of sand to produce a pattern of marks, which are then interpreted.
Tibetan dice divination (*Mo*)	Traditional, ongoing	Tibet and Himalayan region	Dotson, 2019	Cleromancy	Decision-making under uncertainty	Yes	Dice are rolled to consult deities before important decisions including travel, medical treatment, or business. The randomness of the dice is attributed to

							divine communication rather than chance.
Azande poison (*benge*) oracle	Traditional, ongoing	Central Africa	Evans-Pritchard, 1937	Theriomancy	Decision-making under uncertainty	Yes	Poison (*benge*) is administered to chickens while questions are posed; the chicken's survival or death determines the answer. Used to settle disputes, identify witches, and make major decisions. Randomness comes from the unpredictable physiological response.
Mambila spider divination (*Nggam)*	Traditional, ongoing	Cameroon and Nigeria	Zeitlyn, 1987	Theriomancy	Decision-making under uncertainty	Yes	A diviner places an upside-down pot on top of a burrowed spider (or crab). Leaf cards are arranged around the burrow, and the way the spider moves the cards determines the answer to a question. Used to diagnose illness, identify witches, and make legal decisions. Randomness comes from the unpredictable movement of the spider.
Florentine civic elections (*imborsazione*)	~1300-1500 AD	Italy	Sintomer, 2023	Sortition	Procedural justice	No	Eligible citizens' names were placed into leather purses; names were then drawn at random to fill civic offices including the Signoria.
Ghost-leg lottery (*Amida-kuji*)	Ongoing	Japan	Inoue, 2006	Sortition	Procedural justice	No	A visual lottery using vertical lines connected by random horizontal rungs. Each person picks a top line and follows it to the bottom, with outcomes determined by the random placement of rungs. Still widely used today for assigning tasks or turns.
Tibetan golden urn	Modern (18th century to present day)	China	Oidtmann, 2018	Sortition	Procedural justice	No	Names were written down on ivory slips and then placed in a gold-plated pot. Tibetan elites and Qing officials conducted the draws in order to select various religious leaders in Tibetan Buddhism (e.g., the Dalai Lama, the Panchen Lama, etc.).
Military conscription by lottery	Modern	United States	Angrist, 1991	Sortition	Procedural justice	No	Birth dates were drawn at random from capsules to determine conscription order. (*Note*: The 1969 draw

							famously failed to achieve true randomness due to inadequate mixing.)
Poker strategy	Modern	Global	Harrington & Robertie, 2023	Electrical (mechanical)	Anti-coordination	No	To implement a balanced strategy without having to recall each past move, poker players look at the second hand on their watch to make random decisions. For example, to help make a random decision among events with 80% probability/20% probability, a player might decide based on whether the second hand is between 0 and 47 (80%) or 48 and 59 (20%).
Monetary rewards by lottery (*ERNIE*)	Modern (mid 20th century)	United Kingdom	Thomson, 1959	Electrical	Procedural justice	No	A monthly prize draw uses a true-random electrical source called ERNIE (Electronic Random Number Indicator Equipment) to randomly award interest to premium savings bonds. Similar practices underlie common modern lotteries that award prize money.
Random number tables	Modern (early-mid 20th century)	Global	RAND Corporation, 1955	Electrical	Computing, statistics	No	Researchers and companies released random number tables: books with large numbers of true-random digits for use in research and computing. In this case, random numbers were generated via an electronic roulette wheel with a random frequency pulse source.
Modern encryption methods (e.g., Lavarand)	Modern	Global	Taylor & Cox, 2011	Electrical	Anti-coordination	No	True random number generation for cryptographic security, using physical processes (e.g., Cloudflare's Lavarand system uses live cameras pointed at a wall of lava lamps) to seed random number generators. Explicitly random by design: unpredictability is the entire point, as any pattern would compromise security.

Table 1: An ethnographic sampling of randomization devices and associated practices across diverse cultures and eras. Of course, many randomization devices exist beyond the ones covered here; this table attempts to provide a small (and perhaps representative) subset of these hugely diverse devices. This sampling covers randomization devices across eras (e.g., from modern devices like Lavarand to ancient devices like oracle bones), geographies (e.g., East Asia, Africa, North America, etc.), and cultural scales (e.g., from industrialized urban societies to smaller-scale societies of foragers).

Consider how these tools work. *Scapulimancy*, the burning of shoulder bones, exploits microscopic variations in the material structure of bone — variations so small and so numerous that they are functionally unpredictable. *Amathomancy* captures the complex patterns that arise from perturbations to soil or sand, as in the case of Bamana sand divination, in which a diviner rapidly strikes a sand surface to produce a series of marks. Here, too, the patterns in the sand result from functionally unpredictable variation in the dispersion of small particles. Other traditions co-opt other sources of noise: *Capnomancy* uses the flow of smoke, *hydromancy* the motion of water, and *theriomancy* the movement of wild animals.

These devices frequently form the basis of diverse divination rituals around the world; indeed, the suffix *-mancy* denotes these practices as such. While divination has multiple purposes, functionalist accounts hold that these practices are "primarily cognitive" (Hong & Henrich, 2021; Hong, 2025a; Hong, 2025b) methods used to "generate information, usually to assist subsequent decision-making" (Hong, 2025b). And as Boyer (2020) argues, people "generally use divination when other ways of finding out the underlying facts are out of reach". Therefore, divination often appears in high-stakes, socially or morally consequential settings, which we discuss below, and when decisions must be made under conditions of high Knightian uncertainty (many 'unknown unknowns'). These high-stakes, uncertain scenarios invite a particular kind of reliance on randomization devices. For instance, in the aforementioned case of Naskapi scapulimancy, divination is much more frequent in times of food shortage, during which "the shoulder-blade oracle may be consulted as often as every three or four days" (Moore, 1957).

Randomization devices, however, are not limited to divination, aiding in many cases of decision-making under uncertainty. For example, we often use randomization devices to help with anti-coordination — i.e., when we want to 'mismatch' adversaries. Consider the case of encryption, wherein true-random sources secure sensitive data such as financial information or passwords from adversaries. A modern example of a randomization device built explicitly for the purpose of anti-coordination is Cloudflare's 'Lavarand' system, where live cameras pointed at a wall of lava lamps integrate the randomness inherent in the fluid dynamics of heated wax to seed cryptographic random number generators. This is a (somewhat more whimsical) instantiation of the electrical randomization devices of decades past — e.g., RAND Corporation's 'random number tables', which were distributed for use in research and computing, or ERNIE's electrical random generators, used in lotteries; see **Table 1**.

Additionally, many randomization devices throughout history helped allocate resources to equally meritorious recipients, assisting in cases of procedural justice. As with the *kleroterion*, for instance, Florentines in the Renaissance engaged in the process of '*imborsazione'* (lit. 'into the purse'), which involved sealing slips of paper with citizens' names into individual leather purses, depositing them into a chest, and randomly drawing from them when public office needed to be filled. And even today, in modern Japan, schoolchildren engage in small acts of randomization by playing the 'ghost-leg lottery' (*Amida-kuji* 阿弥陀籤) — a race through a hand-drawn grid of randomly placed horizontal rungs — to determine who gets which sweets. These examples and others suggest that randomization devices likely cluster around a number of functional domains, including decision-making under uncertainty, anti-coordination, and procedural justice.

These devices vary dramatically in their cultural context, their physical forms, and their historical moments. They even vary in their use cases; we rely on some for decision-making under uncertainty, others for anti-coordination, and still others for procedural justice. What these devices do share, however, is their *function*: they consistently produce unpredictable and uncontrollable outputs. Below, we expand upon the cognitive and social pressures which we argue brought about their recurrent invention across diverse epochs and ecologies.

3. Solving a cognitive problem: Randomization devices produce what the mind cannot

Humans appear to be poor randomizers; when asked to generate sequences of random numbers, people make a variety of systematic errors. We favor certain numbers, avoid repetition, and disprefer 'runs' or 'streaks' (for review, see Wagenaar, 1972; Bar-Hillel & Wagenaar, 1991; Nickerson, 2002). Such results have led many scholars to suggest that humans entirely lack a capacity for randomization — e.g., Slovic et al. (1974) write: "[p]eople have a very poor conception of randomness; they don't recognize it when they see it and they cannot produce it when they try". In other words, the possibility of a "mental random device" — a cognitive instantiation of a randomizing device — has been nearly universally rejected (e.g., Bar-Hillel & Wagenaar, 1991). Perhaps randomization devices culturally evolved, then, to fill in for the absence of a mental random device.

We believe there is merit to this hypothesis, though recent work paints a more nuanced picture of human random behavior. In some cases, recent results challenge the premise that humans cannot randomize at all, instead suggesting that surprisingly strong random behavior arises in certain tasks. For example, a variety of studies demonstrate high degrees of context-sensitivity in random behavior, such that individuals produce near-random behavior in dyadic, strategic games (Rapoport & Budescu, 1992; Budescu & Rapoport, 1994; Boger et al., 2026). Thus, perhaps in some contexts, humans can successfully produce *near*-random outputs. A separate line of work

helps situate random behavior in terms of our other cognitive capacities. For example, consistent individual differences arise when people generate randomness; random behavior is highly idiosyncratic, in ways that remain stable across tasks and even across time (e.g., Schulz et al., 2021; Boger et al., 2025; Boger & Yousif, 2026). And more generally, generating randomness implicates a variety of cognitive capacities, such as working memory or executive control (e.g., Biesaga & Nowak, 2024; Baddeley, 1966). These findings point to the possibility that human randomness is better characterized as a constrained, context-sensitive, and idiosyncratic capacity, rather than an absent one.

Even under this more nuanced picture of random behavior, however, we argue that randomization devices still provide substantial functional benefits (see **Figure 2**). Human-generated randomness likely suffices for everyday decisions that require some degree of stochasticity, such as how to fairly share, or how to play rock-paper-scissors. But in other contexts — e.g., when other cognitive or social pressures come into play, as when a person must decide where to lead a hunt during a time of food scarcity or when a healer must treat a mysterious and seemingly random illness — our ability to randomize falls short, creating a need for external randomization devices.

In some cases, the output of a randomization device requires further interpretation in order to culminate in a decision, such as the subsequent interpretation of the cracks in a bone or the movement of birds. A natural tension arises then for the cognitive problem: Given that humans struggle to produce and perceive randomness, perhaps they distort or read meaning into a randomization device's output, whether knowingly or not. This tension has been acknowledged in the literature. For instance, critics of Moore's (1957) foundational account of Naskapi scapulimancy have argued that the practice could not function as advertised, since diviners retain considerable interpretative discretion in reading the bone's cracks, thus undermining the randomness of the device (Slaughter, 1981; Vollweiler & Sanchez, 1983). Certain randomization devices explicitly avoid this issue (a topic we return to later in discussing causal opacity), but we also note that simple heuristics allow for users of a randomization device to circumvent their own biases. As mentioned above, many randomization devices capture physically random processes, such as the flow of smoke, the motion of water, or the spread of heat. A user of these devices might pre-specify or explicitly state a decision rule to avoid introducing personal biases into interpretation — e.g., "if the smoke flows to my left, the answer to my question is 'yes', and if it flows to my right, the answer to my question is 'no'." Thus, the fact that some randomization devices require interpretation need not invalidate the cognitive problem. Rather, randomization devices directly address our inability to produce randomness, providing a qualitatively different output from what the mind produces.

Like other cultural tools, randomization devices can augment or offload processes in human cognition. These devices thus contribute a new case study to a larger question in cognitive

science about the kinds of cognitive processes that can be culturally offloaded and the kinds of genuinely new cognitive capacities external tools can provide (Clark & Chalmers, 1998; Heyes, 2018; see also Amir & Pitt, 2026). However, unlike other tools that produce new capacities (such as symbolic number systems, which enable the mind to distinguish large exact numbers), randomization devices offer an entirely new capacity — the ability to produce truly random outputs — without that capacity then entering into cognition itself. In other words, the creation of cultural products such as symbolic number systems allows the mind to distinguish large exact numbers, which approximate number systems cannot; but the creation of randomization devices does not allow the mind itself to produce truly random outputs. In this way, randomization devices offer a unique class of cultural tools that greatly aid cognition but produce 'no effect' on cognition itself (as in the framework of Amir & Pitt, 2026).

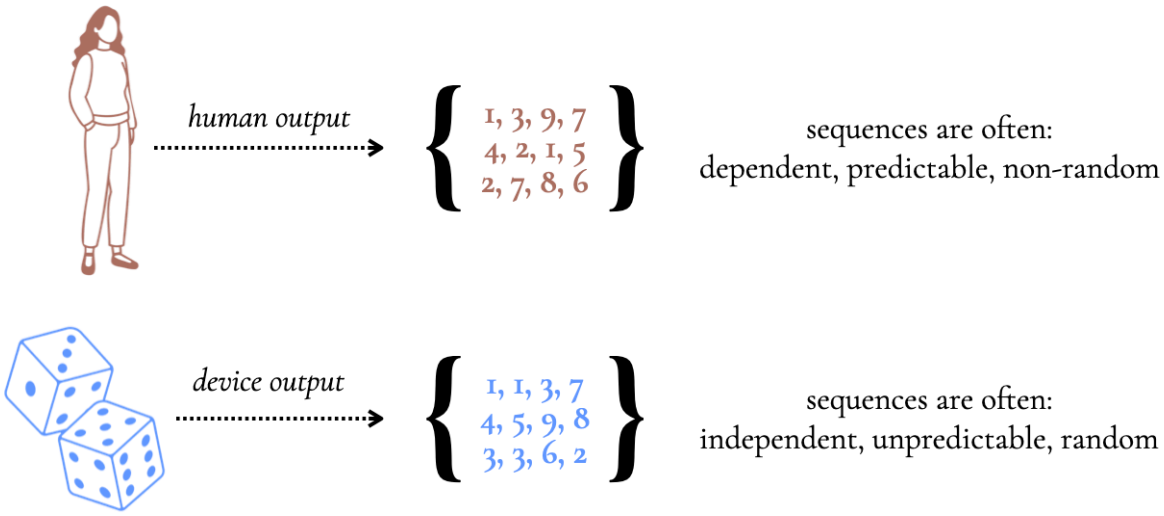

Figure 2: Randomization devices solve a cognitive problem. Humans often struggle to produce randomness. In contrast, external randomization devices produce outputs that are unpredictable and often unaffected by other processes or contexts.

4. Solving a social problem: Randomization devices offer impartiality

The cognitive problem is insufficient on its own to fully explain the cultural evolution of randomization devices. Even if humans possessed a mental true-random device (i.e., some mechanism that produces perfectly random outputs without constraints from central cognition), a second, distinct problem would nonetheless remain: no individual's outputs, however random, can be trusted to be fully impartial. As a thought experiment, imagine a random lottery that narrows a pool of candidates down to two finalists. A single person then chooses between those two finalists, perhaps even 'at random'. Everything preceding the human intervention is impartial, yet the injection of human choice feels as if it corrupts the entire process. In other words, our perception of an outcome's fairness depends not only on the actual randomness produced, but also on the impartiality of the random-generating process. In this way, even the

(unlikely) existence of a mental true-random device would not render external randomization devices obsolete. Convergent but distinct cultural evolutionary pressures thus likely contributed to the development of external randomization devices that solve this additional, social problem.

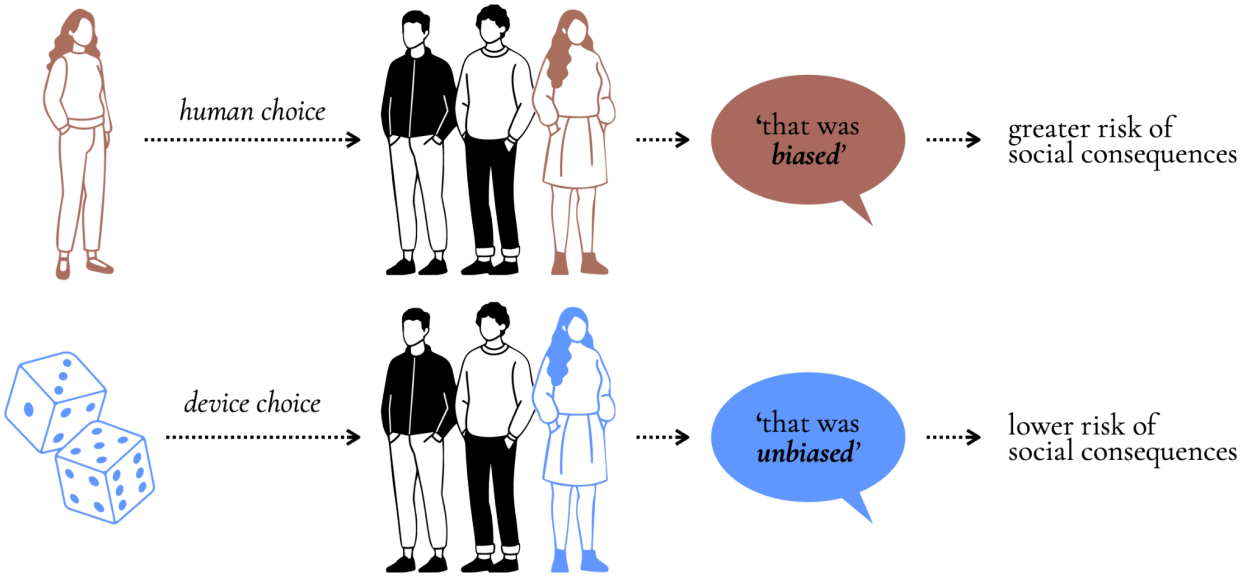

Figure 3: Randomization devices solve a social problem. Human outputs are subject to bias. Thus, when a human chooses 'randomly', the outcome may sow social distrust or conflict, as evaluations of the outcomes are inextricably tied to evaluations of the person who 'produced' that outcome. External randomization devices break the link between outcome and generator, introducing a social buffer.

In line with this argument, the use of randomization devices in the ethnographic record extends far beyond cases where cognitive limitations are the chief concern, whether in our ability to randomize or in other processes like working memory. Humans regularly use such devices to impartially and fairly assign roles, prizes, and even punishment. Randomization devices like the Athenian *kleroterion* and the Florentine *imborsazione* have many analogs across cultures. For example, military drafts — most (in)famously in the Vietnam War — often utilize randomization devices to draw candidates from an eligible pool, and prize lotteries allocate winnings through similarly random processes, such as a ticketed raffle or a bingo cage. In many decisions (random or not), we designate neutral, external sources as key decision-makers, such as a referee in a game, a judge in a trial, or even the mechanism of an auction when selling goods. As such, considerations of fairness and impartiality permeate many key cultural conventions or devices; randomization devices are no exception.

Though some randomization devices allow for human input or tampering, such as using weighted dice in place of fair dice, others attempt to reduce or even forbid it by design. For example, some devices operate publicly, such that any tampering would be visible to observers; others rely on the behavior of non-human animals (e.g., spider divination), such that humans'

desires or wishes cannot affect the outcomes; and still others rely on dynamic physical processes (e.g., a live fire), entirely removing the potential influence of living beings. In each case, the 'task' imposes little to no cognitive load. For example, to choose the winner of a simple lottery, one needs to randomly generate only a single number. Yet the involvement of a human necessarily introduces bias, if only because of people's individual differences in random behavior (Boger et al., 2025; Boger & Yousif, 2026). The latter two cases — as in spider divination and scapulimancy — raise an especially interesting distinction between the generation of a device's output and its subsequent interpretation. Randomization devices externalize only the generation step. Even in cases where humans must interpret the device's output, such as a diviner reading cracks on a scapula, the device ensures that the *input* to that interpretation could not be tampered with or produced with prejudice. Randomization devices thus create impartiality by externalizing the random-generating process.

Scholars of decision theory and philosophy have long recognized that randomization devices resolve these social concerns of partiality. Stone (2011) argues that the distinctive value of lotteries lies precisely in their impartiality, which he terms the "sanitizing" effect. Others describe the same phenomenon in a variety of ways: Icard (2021) calls it the relinquishing of "authorship", Boyer (2020) "ostensive detachment", and Dowlen (2009) the "blind break". Similar arguments can be found in the broader literature on sortition, which emphasizes the legitimizing effect of randomness (Broome, 1984; Elster, 1989); and in the literature on divination (e.g., Ahern, 1981), where scholars suggest that randomization devices ensure "at least in the eyes of the beholders, that no one has inappropriately affected the outcome of the divinatory procedure" (Johnston, 2001). These findings converge with other evolutionary accounts that underscore sensitivity to others' motivated reasoning as a regular and deep feature of social cognition (Mercier & Sperber, 2017).

The psychological literature provides convergent evidence for the prevalence and importance of the social problem; human involvement reduces our perceptions of impartiality (e.g., Keren & Teigen, 2010), an effect that emerges early in development (Shaw & Olson, 2014; Grocke et al., 2015). A variety of findings in cognitive and developmental psychology implicates this judgment as one that may stem from our understanding of 'agents' more broadly. Even in infancy, humans seem to appreciate that agents can produce either order or disorder, but that inanimate forces can produce only disorder (Newman et al., 2010). As such, it's possible that the mind possesses an early-emerging (and perhaps innate) expectation that the involvement of an agent opens the door to a disruption in randomization. Research on statistical reasoning in infants provides strong evidence for a robust, early-emerging sense of 'fairness' in sampling. Infants as young as 8 months old make rational statistical inferences (e.g., about the sampling distribution of marbles in a box; Xu & Garcia, 2008; Téglás et al., 2007; Téglás et al., 2011), such that they expect a randomly drawn sample to reflect the population's proportions. However, such intuitions flexibly incorporate knowledge about preferences and whether, for example, such draws occurred fairly,

insofar as infants expect blindfolded draws to be random but sighted or preference-laden draws to be non-random (Xu & Denison, 2009). Thus, although we struggle to produce random sequences, we hold strong intuitions about whether certain sampling processes occurred randomly or fairly, making the social problem especially thorny.

Beyond concerns of partiality, the externalization of decisions to randomization devices garners a related social benefit: the outsourcing of responsibility. The outcomes of many decisions — from mundane ones, like where to eat, to consequential ones, like whom to elect — often carry implications for the decision-maker. If an outcome is unfavorable, it can invite blame or generate conflict (see discussion in Boyer, 2020). For instance, if a single person drafts men for war 'randomly', then when a drafted soldier sustains an injury, the blame can still fall on the decision-maker. In these cases, external randomization devices create a social buffer between the decision-maker and the outcome. As the personal costs to the decision-maker increase, the need for an externalizing solution often increases too. Consequently, many randomization devices emerge in exactly these high-stakes circumstances (e.g., drafting men for war, choosing where to hunt during a time of food scarcity, and so on). These patterns suggest that randomization devices not only generate randomness but also reshape how we socially attribute and evaluate decisions.

5. Causal opacity and causal transparency

Having established that randomization devices solve cognitive and social problems, we now highlight a design feature that reflects both constraints simultaneously and has been a topic of past inquiry (e.g., Hong & Henrich, 2021). Randomization devices vary in their *causal opacity* — that is, how visible, understandable, and verifiable their random-generating process is to both users and onlookers. Some devices are causally opaque: Scapulimancy produces cracks whose physical origins are complex and hidden, and whose interpretation requires specialist knowledge (Boyer, 2020; Singh, 2018). Other devices are causally transparent: The *kleroterion* operates by a simple, publicly visible mechanism whose output is verifiable by others.

Causal transparency requires not only verifying the outcome of the randomization device, but also understanding its possible space of outputs. For example, imagine a program that rolls a die with an unknown number of sides. After each roll, the user of the device receives a picture of the face on which the die landed, in a way that obscures its shape. The *outcome* here is verifiable, but such a device is not fully transparent in the sense that its possible outputs remain unknown, making the user unable to evaluate the device. The die might have 3 sides, or it might have 300 sides; these two different possibilities result in vastly different evaluations of what it means for the (unknown) *n*-sided die to land on ‘2’ four times in a row. For each device, the degree of causal opacity — realized both by its verifiability and by its space of outputs — serves a functional role.

Interestingly, considerations of this idea arise independently across disparate literatures spanning cultural evolution, computer science, and political philosophy. Below, we synthesize these traditions and argue that these different approaches examine the same underlying phenomenon across different levels of analysis. Then, we connect these issues to the functional domains of randomization devices and the problems they solve.

In the field of cultural evolution, scholars have suggested that certain randomization devices, and many cultural devices more broadly, 'work' *because* they are causally opaque. The majority of this discussion has centered on divination practices. For example, Henrich (2015) writes that if people "came to understand that bird augury or bone divination didn't actually predict the future, the practice would probably be dropped or people would increasingly ignore ritual findings in favor of their own intuitions". Hong (2025a) develops this idea further, arguing that causally opaque practices are more readily transmitted across generations precisely because it is hard for practitioners to rationally evaluate and reject these practices (at least, relative to causally transparent ones). In other words, causal opacity is a feature, not a bug. This is consistent with a broader principle in cultural evolutionary theory that practices can persist and spread because of their downstream benefits, even when the proximate mechanisms that produce those benefits remain opaque (Boyd & Richerson, 1985; Henrich, 2015; Derex et al., 2019). A complementary account, championed by Sperber (1996), holds that opaque beliefs are harder to evaluate, and precisely because of that difficulty, are both more stable and more readily transmitted across generations. Consistent with this, empirical work on ritual transmission suggests that causally opaque practices are not only rated as more efficacious (Legare & Souza, 2012) but also reproduced more faithfully (e.g., Nielsen et al., 2015).

Certain functional domains of randomization devices — namely, anti-coordination — even seem to require causal opacity in some sense. Specifically, the output of a randomization device must remain hidden from an adversary in order for that device to achieve anti-coordination. For instance, if a poker player uses a decision aid for when to bluff, they must ensure their opponents do not know the nature of that decision aid, lest their behavior be predicted and exploited. In this way, such devices remain causally transparent to the user, who can verify the output, but must do so while being causally opaque to adversaries.

In political philosophy and computer science, domains of inquiry far removed from divination, scholars have underscored the importance of causal *transparency* in randomization devices. Interestingly, the need for causal transparency was a major part of the need for, and development of, *pseudo-random algorithms* — processes whose outputs approximate randomness, but arise from deterministic formulas — as an alternative to *true-random* sources — algorithmically unpredictable sources of randomness. Most instantiations of randomness in a computer for use in games, simulations, and so on, rely on pseudo-random algorithms instead of a true-random

device. Knuth (2014) notes two reasons why this preference emerged, both of which invoke causal transparency. First, in many situations (e.g., for simulations or statistical analyses), we often want computers to create reproducible randomness — but "it is impossible to reproduce calculations exactly a second time" with a true-random device (Knuth, 2014). Knowledge of the pseudo-random algorithm and its seed allows any person to recreate a set of random outputs, as when we set a random seed in Python or R; but definitionally, true-random devices do not allow for such reproducibility. Second, and perhaps more importantly, "such machines have tended to suffer from malfunctions that are extremely difficult to detect". In other words, causal opacity comes with a cost: When the randomization device breaks, it is not clear (a) whether it is broken, (b) why it is broken, and (c) how to fix it. Pseudo-random algorithms address these issues by way of their causally transparent design — they contain just a few parameters and a mathematical formula, as opposed to true-random devices which contain specialized hardware that may falter at any number of often interrelated stages. A similar theme arises in the political philosophy literature, where the legitimacy of sortition has been argued to depend on the causal transparency of the randomization device. For example, Dowlen (2009) writes that sortition and lotteries work precisely when "those participating or closely connected with the result can witness the procedure to ensure that no wilful interference is taking place", making the process transparent to its participants. Similarly, Thibaut and Walker (1978) write that "the procedure most likely to produce justice is that procedure which facilitates the fullest possible report of inputs prior to determination", a direct acknowledgment of causal transparency.

Notably, scholars of different traditions have focused on opacity in randomization devices at different levels of analysis. Cultural evolutionists have asked whether the device's opacity supports its transmission across generations, political philosophers have asked whether the generation process itself is transparent and verifiable, and computer scientists have asked whether the underlying mechanism can be inspected and whether its outputs are reproducible. The fact that researchers from diverse disciplines and perspectives regularly converge on the importance of causal opacity across multiple levels of analysis suggests that this constitutes a key feature of randomization devices as a class of tool.

The consequences of causal opacity and causal transparency relate back to the cognitive and social problems described above. Devices that aid in procedural justice — e.g., *imborsazione*, the *kleroterion*, or the Vietnam draft lottery — seem to often implement causally transparent designs. The reason for this may be that causal transparency can solve the social problem: It ensures that onlookers know that the process works impartially, and even allows onlookers to verify the device's outputs and process themselves. Perhaps as the social problem grows, the need for causal transparency similarly increases.

For the cognitive problem, causal transparency plays a different role. Causally transparent devices allow users to easily diagnose when (or if) the device falters, as in the case of

pseudo-random algorithms above. This ensures that, to verify the functioning of a randomization device, a user need not rely on their perhaps flawed evaluation of its randomness. Note that we do not mean to argue that all of the 'best' randomization devices use causally transparent designs, or even that a device must be causally transparent in order to solve the social problem. Indeed, in many cases, causal opacity helps the device's transmission, as in the case of divination practices. Perhaps, then, the need for causal transparency and its relationship to the social problem grows when one must coordinate across a larger community. For example, in a small community, onlookers may personally know the diviner and thus trust their interpretation of the randomization device; but in a case like the Vietnam draft, the randomization device must coordinate across millions of citizens, making causal opacity no longer feasible. Thus, the degree of causal opacity a randomization device requires may scale inversely with the size of the audience whose trust it must earn.

6. Concluding thoughts and future directions

The cultural evolution of randomization devices has been examined, in fragments, across diverse disciplines. Here, we present a unifying account of these devices. In doing so, we focus on two problems randomization devices solve, one cognitive and one social. Though the cognitive and social problems exist independently (as, e.g., even in the absence of the cognitive problem, the social problem alone likely creates enough of a need for randomization devices), they interact in certain ways. For example, a strong version of the social problem might worsen the cognitive problem, insofar as a decision-maker might be so intent on generating a perceived 'fair' outcome that they choose an explicitly non-random way of doing so. Conversely, a strong version of the cognitive problem might worsen the social problem, insofar as onlookers might evaluate a decision-maker's 'random' outcome as unfair or non-random if they struggle to generate randomness in other settings. Though one problem may appear more dire or fundamental than the other in certain settings, the broad range of functional domains for randomization devices makes it difficult to explicitly denote one problem as more important than the other. In this way, we argue that randomization devices constitutively solve both the cognitive problem and the social problem, insofar as they produce strong randomness, externalized from an individual's inputs or control; as long as the resulting randomness has some function, then a device's output seems to solve both problems. As such, both problems are of great import on their own, and they interact in ways that magnify the need for randomization devices.

Along with bringing together ideas from diverse disciplines, our framework generates unique and testable predictions, both ethnographically and empirically. First, earlier in this work, we highlighted the role that randomization devices play in divination practices such as *shamanism*, which occur with substantial regularity across cultures (Singh, 2018; for extended discussion, see Singh, 2025). Interestingly, not every culture relies on specialized diviners (or *shamans*) — and cases of shamanic absence can be interesting and informative on their own. For instance, Singh

(2018) notes that these practices did not culturally evolve in some societies, such as the Tiwi of Northern Australia — perhaps because, as Hart and Pilling (1960) note, "their physical environment was on the whole a satisfactory and not a hostile universe". This potentially implicates environmental (in)stability as a causal factor in reliance on divination. As we saw above in the case of the Naskapi, the bone oracle was more frequently consulted in periods of food scarcity. Similarly, Trobriand Islanders (in Papua New Guinea) relied on magic for open-sea fishing but not inner lagoon fishing, because the latter provided "abundant results without danger and uncertainty" (Malinowski, 1948). Thus, randomization devices, both in the context of divination and outside of it, are likely used with higher frequency in more unpredictable environments and when the stakes are higher. Our framework predicts this insofar as higher-stakes settings exacerbate both problems; in such settings, (a) the cognitive problem worsens as various cognitive resource limitations might further impede our ability to produce randomness, and (b) the social problem worsens because higher-stakes settings necessarily carry more dramatic consequences, thus increasing the need for a fair, external outcome. Systematic cross-cultural and within-society examinations could shed light on this prediction, perhaps even partialing out the roles of environmental harshness (e.g., low mean) and environmental unpredictability (e.g., high variance) on the use of these devices. A meta-ethnographic analysis of this type — where, e.g., one quantifies the relationship between a culture's environment and its reliance on randomization devices, or catalogs regularities in the various domains in which randomization devices arise — using large ethnographic corpora (such as eHRAF World Cultures or the Standard Cross-Cultural Sample) strikes us as a particularly feasible and interesting avenue for future work.

Relatedly, our initial foray into the ethnographic literature suggests that randomization devices cluster into at least three recurrent functional domains: (1) *anti-coordination,* in which randomness prevents others from exploiting predictability in behavior (Von Neumann & Morgenstern, 1944; Miller, 1997), as in the case of encryption, (2) *procedural justice*, in which randomness ensures impartiality and reduces the risk of social sanctions, as in the *kleroterion*, and (3) *decision-making under uncertainty*, in which randomness is invoked to navigate choices whose outcomes are unknowable, as in the case of scapulimancy. These functions are analytically distinct, resolving discrete social and cognitive problems, yet all are served with the same kinds of tools. Importantly, these functions are not exhaustive, which further reflects the broad application of randomization devices. Other devices might serve functions beyond the three classes defined here, and many randomization devices can be used to serve multiple functions. For example, many societies culturally evolved dice and dice-like objects, not only for decision-making under uncertainty (Dotson, 2019; Madden, 2026), but also for anti-coordination (Reinhold, 1995), procedural justice (Stone, 2011), and games (e.g., gambling). This convergence suggests that randomization devices are not a grab bag of unrelated artifacts, but rather a coherent class of tools that occur with regularity because they resolve challenges that also appear with regularity. A systematic mapping of the domains in which randomization

devices appear or do not appear, along with a closer analysis of the distinct functions these tools serve, would sharpen our understanding of what conditions are necessary or sufficient for their evolution.

Next, to the empirical predictions: Although a substantial literature analyzes human random behavior, relatively less attention has been paid to the ways in which we conceptualize and interact with external randomization devices. For example, here we argued that randomization devices diverge from other tools in that their outputs qualitatively differ from what cognition produces. Whether or not people intuitively appreciate this distinction remains an open empirical question, as is when and whether people choose to use randomization devices at all. Future work might test whether individuals rely on randomization devices in higher-stakes or more demanding settings; whether individuals prefer randomization devices for some problems over others (e.g., feeling the need to use randomization devices for procedural justice but not anti-coordination); and whether either of these two possibilities covaries with an individual's assessment of how a randomization device differs from their own ability to produce randomness. Our framework also offers predictions for features such as causal opacity. Whereas prior work in cultural evolution primarily analyzes causal opacity as it relates to group- or culture-level transmission, it is an open question whether individual people are sensitive to the causal opacity of randomization devices. Might the broad, large-scale transmission of causally opaque devices reflect individual-level, small-sample sensitivities to these same features? This could be tested by offering people access to a causally opaque randomization device when playing a strategic game (e.g., matching pennies) and examining whether they transmit that device to others.

Synthesizing evidence from disparate disciplines, we have suggested that randomization devices evolved because the mind cannot always produce strong, unpredictable randomness, and because no individual's outputs, however random, can be fully trusted to be bias-free. Despite their remarkable diversity, randomization devices thus denote a unified class of cultural tool that offers new abilities to its users without that ability affecting cognition itself.

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