

What does it mean for culture to ‘shape’ cognition?

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ABSTRACT

Human culture and cognition vary widely across groups, but how exactly culture ‘shapes’ cognition remains underspecified. Here, we outline four qualitatively different pathways by which culture can shape cognition. In this framework, culture can (i) Privilege some cognitive processes, while leaving alternative processes intact, (ii) Prune unused alternative processes, which are irretrievably lost (iii) Produce new cognitive processes, or (iv) have no effect on cognition at all. To illustrate the utility of this framework, we apply it to three debated effects of culture on cognitive processes, including visual illusions, large exact number abilities, and spatial-numerical associations. The distinctions we propose can serve to reframe longstanding debates, sharpen empirical predictions, and open new avenues of research in cognitive diversity.

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How culture shapes cognition

Many longstanding debates in the study of the mind have turned on whether a given cognitive ability is universally available to all people – perhaps because of our innate biological inheritance – or variable across groups, learned by each individual anew [e.g. 1–5]. While it is clear that culture supplies the content for many consequential and often higher-order cognitive processes — such as political views, religious outlooks, and economic preferences [5–7] — its effects on fundamental cognitive processes — such as how we perceive, reason, represent, and decide — remain debated.

A guiding goal of cross-cultural psychology is characterizing variation across diverse human populations [8]. This endeavor includes not only charting the scope of cognitive diversity, but also uncovering its mechanisms, that is, clarifying the principles by which the structure of experience produces the structure of human minds [9]. This growing literature has regularly documented substantial psychological variation across cultures, leading researchers to frequently conclude that culture “shapes”, “influences”, or “affects” cognition [10,11], but such claims are often underspecified: How does culture shape cognition and how do these effects differ in kind? The answer can help to clarify the mechanisms that underlie the cognitive process in question, whether it varies across groups or not. In previous answers to this question, researchers have classified the effects of a particular type of cultural experience (e.g. reading, language; [12]) on various cognitive domains (and brain organization; e.g. [13–15]) and documented the various types of cultural experience that affect a specific cognitive domain (e.g. number [16], memory [17,18], or others [19]). One more general framework, proposed by Norenzayan & Heine [5], seeks to classify psychological universals in any domain, but does not specify the ways in which cognition may be, in their words, “elaborated, added to, and possibly modified by cultural experience” (see **Box 1** for discussion), the primary focus of our efforts here. We argue that effects of culture on cognition can be categorized into a small number of classes and that making these qualitative distinctions among effect types can help researchers reframe longstanding debates, sharpen hypotheses, generate novel predictions, and clarify universal mechanisms of cognitive diversity.

Four pathways through which culture can shape cognition

We propose a simple framework that delineates four types of effects of culture on cognitive processes: One in which culture has no effect and three in which culture has

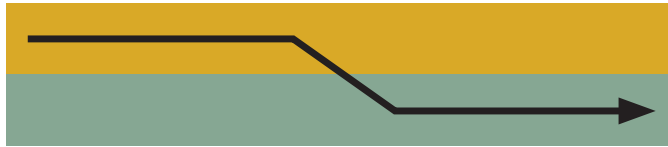
significant – but qualitatively different – effects on cognition: Privileging one cognitive process over others, Pruning away a given process, or Producing new processes altogether. This framework therefore expands the set of alternatives from the minimal pair that typically characterizes many debates (i.e. “Does culture shape a given cognitive process or not?”) to a four-alternative set, including three ways in which culture can be said to “shape” cognition. We focus on effects across an individual’s lifetime and primarily across cultural groups, though the framework can in principle be applied to other timescales (see **Box 2**) and to individual differences within groups (see **Box 3**).

Figure 1 presents a visual representation of our framework, with its four pathways. Although the number of possible cognitive processes is vast, for simplicity each pathway in our figure includes just two hypothetical alternative cognitive processes (represented by colored strips). The pathways differ in (a) whether culture moves people from one process to another and (b) the status of those processes before and after this transition. In the first of these pathways, culture has no effect on the cognitive process of interest. Empirically, such cognitive processes should exhibit regularity in their development across groups, even in vastly different cultural settings. To be clear, cognitive processes in this pathway are not necessarily innate; they can either reflect features of our biological inheritance or universal features of the natural world (like gravity or light generally originating from above) [5]. In the other pathways, culture influences cognition in one of three ways. In the Privileging pathway, cultural inputs favor one cognitive process over latent alternatives, without eliminating these alternatives. In these cases, we would expect to find variation in the cognitive process of interest across cultures and contexts, but importantly, individuals should retain the capacity to adopt alternative processes given other input. By contrast, in the Pruning pathway, cultural inputs determine the set of available cognitive processes, and cause the irreversible loss of alternatives. Empirically, this requires that people show variation in the cognitive process of interest but that they cannot adopt alternative processes found in others, even with extensive training. In the Producing pathway, cultural inputs create a new cognitive process, expanding the set of available alternatives. Importantly, such a cognitive process should be found only among people who have experience with the requisite cultural practice, and should be absent from groups without sufficient experience with that practice, including young children and non-human animals.

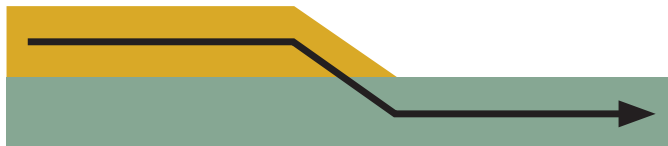
No effect



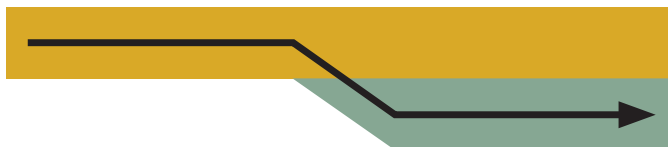
Privilege



Prune



Produce



Time →

Figure 1: Four pathways by which culture can shape cognition. Colored strips represent alternative cognitive processes and black arrows represent hypothetical paths between these alternatives. From top to bottom: *No effect*: culture does not exhibit any significant influence on a cognitive process. *Privilege*: culture privileges one cognitive process over another, but the other remains available. *Prune*: culture determines which of various cognitive processes people use and alternative processes are unrecoverable, as if pruned. *Produce*: culture produces a new cognitive process, expanding the set of alternatives.

As both cultural experience and cognitive processes are characterized by immense diversity and complexity, their interactions are similarly diverse. A large literature focuses on how cognition shapes culture, especially over evolutionary time [20], but here, we focus only on the causal arrow pointing in the other direction (i.e. how culture shapes cognition). One point of ambiguity in these endeavors, although not the one we focus on here, is the use of the words “culture” and “cognition,” which can vary

dramatically across (sub)disciplines and even among individual scholars. Rather than try to resolve the ambiguity of these abstract terms, here we take a broad view of both, as the framework we present is not specific to narrow definitions of either. For present purposes, “culture” may be any feature of a person’s experience that is the product of other people – past, present, near, or far – including both information that is directly transmitted among individuals (e.g. weaving techniques and social norms) and information embedded in the built environment (i.e. cultural artifacts like buildings and tools). This definition is sufficiently broad so as to include any number of tangible artifacts and behavioral conventions, but not so broad as to include physical laws, natural environments, or physiological structures. We are similarly permissive in our use of “cognition” or “cognitive process”, in which we mean to include any psychological process or mental state, from low-level perceptual processes to high-level conceptual representations. Our goal is not to suggest an authoritative definition of either term, but rather to offer a framework that can apply to the broadest possible set of questions. It is important for researchers to specify which aspect(s) of culture is interacting with which aspect(s) of cognition, but the ambiguity we seek to address here is not in these nouns, *per se*, but in the verb: What does it mean for culture to ‘shape’ a cognitive process? Below, we demonstrate how the distinctions we propose can inform psychological theory and motivate new research.

Applying the framework: Three case studies

Here, we consider three case studies that demonstrate the framework’s utility in interpreting existing research and motivating new research in cross-cultural cognitive science: Perception of visual illusions, large exact number representations, and spatial representations of number.

Case study #1: Susceptibility to visual illusions

To evaluate how deeply culture can affect cognition, many scholars have focused on how and whether culture can shape low-level features of visual perception, such as the perception of length or depth. They reason that if culture can indeed shape even these fundamental processes, then perhaps its effects are more pervasive than often assumed. Many empirical assessments of cultural variation in visual perception have focused on susceptibility to visual illusions [21], as they provide a simple, portable way to test differences in perception without the need for more complex psychophysical methods. A

now-classic case study in this domain is the Müller-Lyer illusion, comprised of two lines of equal length that end in either outward-facing or inward-facing arrowheads [22]. Low-level processes involved in the perception of the Müller-Lyer illusion (and others like it that may rely on similar processes) create an illusory effect in which the line with the outward-facing arrowheads appears longer than the one with inward-facing arrowheads.

In one tradition, the Müller-Lyer has been touted as the textbook example of informational encapsulation, in which no amount of knowledge, belief, desire, or emotion can eradicate the illusion that one line appears longer than the other [23]. This view best aligns with the “no effect” pathway. A competing tradition, however, puts susceptibility to the Müller-Lyer illusion in the extreme opposite category, arguing that it is not only influenced by culture, but produced by it. On one popular account, the illusion results from exposure to culturally-determined visual stimuli, such as carpentered corners that are common in rectangular buildings [24,25]. In principle, sufficient exposure to the relevant visual stimuli (such as carpentered corners) could be enough to produce the illusion at any age, although some scholars have suggested there may be a sensitive window for such effects [26]. In line with this view, some findings have suggested that individuals who inhabit “environments largely free of right angular corners and parallel lines — such as the Zulus who live in a 'circular culture' of round huts — do not suffer these illusions” [27]. However, these findings have recently been critically reassessed [16], both in light of concerns regarding the original cross-cultural work and also in light of new findings suggesting a greater degree of universality (e.g., the emergence of the illusion in non-human animals such as lizards and fish, as well as the finding that congenitally blind children perceive the illusion mere hours after having their sight restored)[22].

In our framework, this debate is between the two most extreme pathways: No effect or cultural production. However, as the framework makes explicit, this all-or-nothing comparison is one of many logical possibilities: cultural experience could also influence perception of the illusion without *producing* it. That is, cultural inputs could in principle privilege susceptibility to the illusion, leading to variation in its strength across groups. On this account, susceptibility to the illusion should be relatively consistent in young children across cultures and then diverge over the course of cognitive development, as a function of experience with the relevant cultural input (e.g. carpentered corners). For any adults who show little or no susceptibility, exposure to the cultural input should be able to modulate the strength of the illusion, a prediction that distinguishes the Privileging account from a Pruning account. Although the empirical work (arguably) favors a subset of these accounts over others [22],

entertaining all four pathways can help identify overlooked alternative explanations and generate testable questions.

This line of argument can also be applied to understanding purported cultural effects on other visual illusions, more broadly, and underscores the importance of specifying which specific cultural inputs are affecting which specific cognitive processes. Different visual illusions, for example, do not all engage the same cognitive processes. It may be true that cultural inputs are more likely to influence higher-level processes, such as attention and memory, as opposed to lower-level perceptual processes such as depth or length perception. As this case study illustrates, our proposed framework can advance such yes-or-no debates by offering more (and more nuanced) ways in which cognition might be shaped by culture, with contrasting empirical predictions.

Case study #2: Large exact numbers

Perhaps the most dramatic effects of culture on cognition are those in which culture produces an entirely new cognitive ability, expanding the set of alternatives. This theoretical possibility is at the center of a longstanding debate in numerical cognition about whether and how language ‘shapes’, ‘restructures’, ‘facilitates’ or ‘underpins’ number concepts [28]. Developmental and comparative research makes clear that at least some numerical abilities are innate: Newborn infants, non-human primates, and a variety of vertebrates and invertebrates can distinguish small quantities exactly (up to about four) and can even distinguish much larger quantities approximately (e.g. ten vs. thirty dots) [29–31]. More controversial are the numbers that compose many everyday experiences – exact quantities larger than four: numbers like seven or sixteen. On some accounts [4,32], these large exact numbers are part of our biological inheritance, supported by an innate neural mechanism that “allows an unbounded set of discrete values to be represented” [28]. In this case, cultural input should have little or no effect on basic numerical abilities. Alternative accounts posit that experience with verbal counting systems (e.g. “one, two, three...” and perhaps other external symbol systems [33,34]) not only facilitates but indeed produces large exact number concepts in children, allowing people to represent quantities larger than four with precision [35–38].

To test these competing accounts, researchers have studied numerical representations across cultures, including among Indigenous Amazonian cultures with no words for large exact quantities. Notably, the Pirahã of Brazil have words to describe approximate

amounts (e.g. “some”, “few”, “many”), but appear to lack number vocabulary for any exact quantity, not even “one” [39,40]. Perhaps as a consequence, they rely entirely on small exact and large approximate number representations, according to several studies of their non-verbal numerical abilities. In those studies, Pirahã adults saw a number of objects (e.g. a row of seven spoons) and were asked to make another set of objects of ‘the same number’ (e.g. seven pebbles) without aligning them one-to-one [39,40]. Critically, these tasks are not inherently linguistic, as neither the experimenters nor the participants name the quantities in question. Yet people appear to need number language (or some other culturally-constructed symbol system) to succeed: Without words for large exact numbers, Pirahã adults only made exact matches up to about four and approximated for larger sets. Similar findings have been documented in other groups whose languages lack large exact number words [41,42], in individuals who have mastered only some such words [43], and in studies that experimentally manipulate the availability of number language [44] (but see [28,45]). Although the evidence remains largely correlational, it challenges the notion that culture has no effect on large exact number concepts or even that it only facilitates these abilities. Rather, one interpretation of these findings is that culture is producing a new cognitive ability in the domain of number, as it may do in other domains as well [12].

Case study #3: The mental number line

The previous case studies describe work that adjudicates between two of the four pathways we have laid out. However, in order to clarify how culture shapes a given cognitive process, researchers should ultimately address all four pathways. In the final case study, we do so for a single cognitive phenomenon: the mental number line.

People implicitly associate smaller numbers with one side of space and larger numbers with the other side, forming a mental number line (MNL; see **Figure 2**) whose direction varies across cultures: In some groups, it increases from left to right and in others from right to left [e.g. 46]. This variation has long been attributed to culture-specific directional practices like reading, writing, and counting, but the precise role of such practices has often been underspecified or unsupported [e.g. 47,48]. Below, we use our framework to outline how recent studies can be synthesized to clarify whether and *how* culture influences this fundamental feature of numerical cognition.

Does culture produce the mental number line?

In principle, the mental number line could be the product of cultural experience alone, learned from scratch by each individual from human-made artifacts (e.g. graphs and rulers) and practices (e.g. finger counting). If so, people without sufficient exposure to the relevant cultural experiences should lack any mental number line. This hypothetical possibility is challenged by studies of human infants and non-human animals, who also show signs of a mental number line despite having little or no cultural experience [49,50, but see 51]. Additional evidence comes from studies of certain cultures, where adults show systematic space-number associations (albeit without preferred direction), despite having little experience with reading, counting, and other direction-specific cultural practices [52,53— see Figure 2]. Together, the evidence suggests that culture can influence — but does not fully produce — the mental number line.

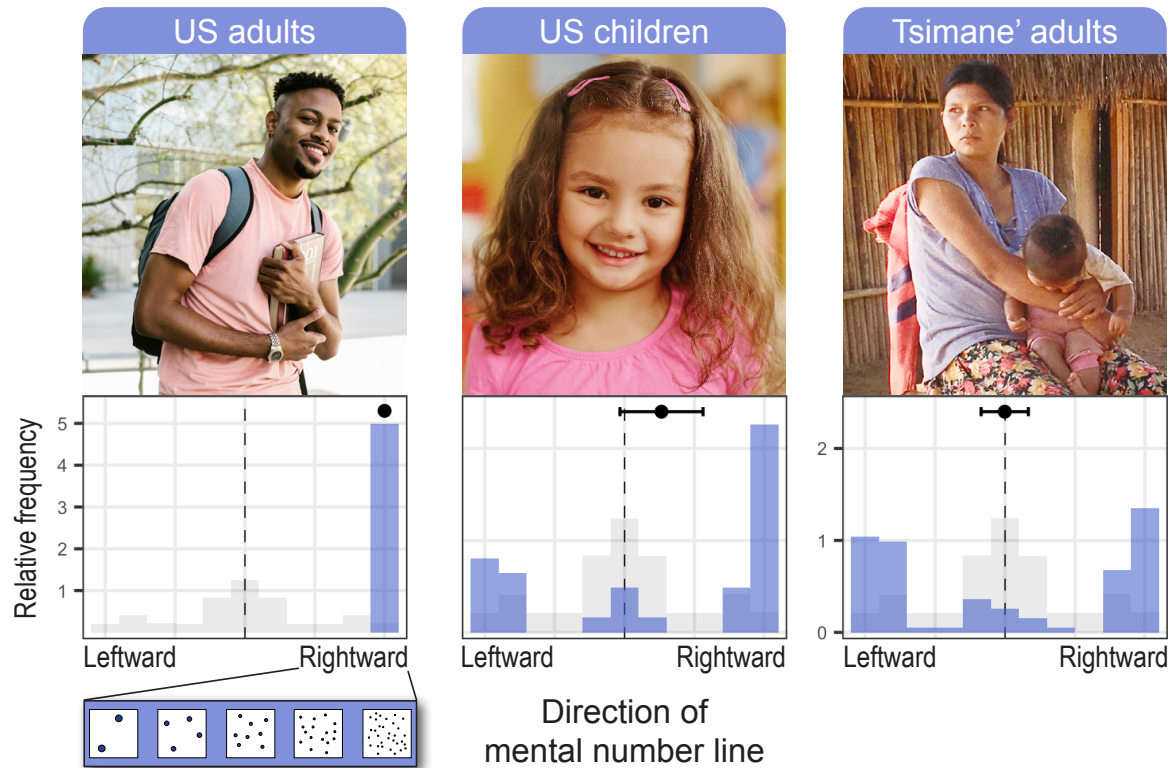


Figure 2. Mental number lines across ages and cultures. In a study of three groups [52], participants were asked to arrange number stimuli on a lateral response board (as in example shown). The strength and direction of these response mappings were scored to create a measure of spatial-numerical associations. Colored bars show the relative frequencies of these scores. Points show group means and bars show standard errors. Whereas US adults uniformly mapped numbers from left to right (left plot), US children and Indigenous Tsimane' adults (center and right plots) were equally likely to produce mappings that increased to the left as to the right. In

each group, response mappings differed from chance distribution (light gray bars), indicating that people used space systematically, even in the absence of a conventional mapping direction.

Does culture Privilege or Prune variants of the mental number line?

Given that culture does not Produce the mental number line, what role does it play in its structure and at what timescale? In principle, the mental number line could be flexible early in life and then harden in adulthood. This possibility is especially easy to imagine in highly numerate cultures, where people are awash in depictions of numbers that reinforce a left-to-right mapping from early in life (e.g. on graphs, calendars, keyboards, rulers, and kindergarten walls). What happens to alternative mappings – like the right-to-left mental number line – in the face of such strong cultural conventions? Are they overwritten (i.e. Pruned) by years of consistent cultural experience or do they remain latently available (i.e. Privileged)? The answer is central to specifying the type of effect culture has on these cognitive processes and to evaluating competing theoretical accounts of their structure.

To find out, Pitt & Casasanto [11] changed people’s typical cultural experience by manipulating it in the lab. In a training phase, participants read English text or counted on their fingers in one of two directions, either left-to-right or right-to-left, and then performed tests of their implicit spatial associations. These participants – U.S. American university students – had spent their entire lives immersed in cultures with strong left-to-right conventions. If their cultural experience had truly Pruned alternative versions of the mental number line, then those alternatives should have been lost. On the contrary, the results showed remarkable flexibility, even in these deeply-enculturated adults. Participants in the “standard” left-to-right training condition showed the typical left-to-right mental number line, whereas participants in the right-to-left training condition showed mappings that were extinguished or even reversed. This surprising flexibility (see [11] for discussion) has also been found for spatial mappings of time, emotional valence, and musical pitch [52,54,55], showing that even decades of experience is not enough to Prune such constructs. Rather, in these cases, culture appears to shift the weight of evidence toward one prepotent possibility, while leaving alternatives intact [56]. In clarifying that culture Privileges rather than Prunes these mappings, these results support a general account that explains why certain aspects of cultural experience influence certain aspects of cognition [56]. In this way,

distinguishing pathways can clarify not only the scope of cognitive variation, but also its causes, illuminating the cognitive mechanisms that support human-level reasoning about numbers, time, and other abstract domains [11].

Broader Implications & Considerations

Uniform effects of culture

We have focused primarily on how cultures vary across groups, but some aspects of cultural experience appear to be universal across human groups, at least at some level of abstraction. For example, all human cultures speak language and use tools, even if the individual languages and toolsets vary dramatically across groups. In principle, such high-level cultural universals could have uniform effects on human cognition (at various timescales; see **Box 2**), whether via Privileging, Pruning, or Producing pathways. However, such effects cannot be evinced by any amount of cross-cultural comparison because a uniform effect would be indistinguishable from a null effect. In this way, cross-cultural psychology is inherently blind to what could be some of the most pervasive effects of culture on cognition, precisely because they are so pervasive. Studying these effects therefore requires methods from comparative psychology, in which humans are compared to non-human animals, and from developmental psychology, in which humans are compared at different stages, as they are enculturated [57,58].

Cultural tools as cognitive technologies

Material culture is full of practices and artifacts used to augment our impressive but limited perceptual and cognitive abilities. For example, timekeeping tools like hourglasses, clocks, and calendars improve people’s ability to measure, plan, and predict the temporal structure of events [59]. Tools like abacuses, spreadsheets, and finger counting help people to better track, compare, and compute numerical information [39,60,61]. And writing systems and writing implements like paper and keyboards allow people to use information far beyond the limits of their biological memories [62]. Given that these ‘cognitive technologies’ greatly expand what people can do, it is tempting to assume that these improvements in human ability represent changes to underlying cognitive processes, but this assumption is not always warranted. Rather, we suggest that such tools represent one form of cultural input, and, consequently, can shape cognitive processes by any of the pathways we propose – including no effect at all –

even in the face of observed changes in behavior (e.g. improve precision, accuracy, or consistency).

For example, in many cultures, people are able to navigate back to their starting point – an ability called ‘dead reckoning’ – using spatial cues available in the visual environment to chart their course, even when the destination is unseen [63,64]. Using a compass can improve performance in such tasks, helping people to travel more direct routes, but such performance improvements do not necessarily imply an effect of culture on cognition. Many cultural tools – compasses, calculators, and clocks among them – may serve primarily as cognitive crutches, allowing people to bypass the mental processes that would be required to perform a given task (like navigating between two points, adding two numbers, or assessing the duration of an event), which are effectively offloaded to the tool [65]. In this way, people’s cognitive abilities can in principle remain stable (or even deteriorate), even as their performance in the task improves.

Alternatively, experience navigating by compass could change the way people habitually solve navigation tasks, even when they are not using a compass, for example by privileging geocentric (e.g. North-South) spatial representations over egocentric (e.g. left-right) ones. Identifying the effects of cultural technologies on cognition (if any) likely requires studying people who do not have access to the relevant tool or practice during testing, as in verbal interference paradigms, which seek to characterize effects of language by precluding its use during behavioral tasks [66].

Relative frequencies of each pathway

Although the four pathways we propose are given relatively equal treatment here, they are unlikely to occur with equal frequency in reality. A great many cognitive processes are likely evolutionarily ancient, shared across taxa, and impervious to cultural input. We suspect that the most common and prevalent cultural effects fall into the category of Privileging, where cultural inputs bias one process over another, while leaving alternatives intact. In this way, culture may function as a flexible coordination mechanism through which individuals can efficiently align on which cognitive processes and behaviors to adopt across variable contexts. By contrast, we suspect that Pruning is relatively rare. In principle, eliminating unused alternatives can be adaptive, if maintaining flexibility is costly [67]. Indeed, many biological processes are highly path dependent, both at the timescale of natural selection [68] and ontogenetic development [69]. However, humans exhibit extraordinary cognitive flexibility [70], an adaptation that, on some accounts, allowed *Homo* to thrive during periods of volatile environmental change [71] and consequently allowed our genus to inhabit an unusually wide variety of

ecologies. Existing evidence suggests that culture Produces at least some cognitive processes, such as large exact number representations, but the prevalence of this pathway is an ongoing point of debate.

Concluding remarks

Decades of cross-cultural study have revealed enormous diversity in human culture and cognition, yet claims that culture ‘shapes’ cognition have often been left underspecified. Here, we propose a framework that classifies these effects into four theoretical pathways — Privileging, Pruning, Producing, and No Effect – with the goal of moving beyond asking whether culture matters to asking how, when, and why it does. The framework we propose makes categorical distinctions to facilitate analysis but natural phenomena rarely fall into perfectly discrete categories, and reasonable people may disagree about how exactly to classify a given process. Rather, variation is often continuous but ‘spiky’, with fuzzy boundaries between adjacent clusters [72], and we suspect the same is true of the pathways we propose. For example, the Pruning pathway depends on how recoverable disfavored processes are and the Producing pathway is distinguished by how new the cognitive process is. Rather than attempting to establish precise criteria for these distinctions, our framework does what all classification systems attempt to do: Lend useful structure to variation. In this way, all frameworks are wrong, but some are useful. We hope it will help researchers negotiate this variation by reframing existing debates, revealing untested assumptions, clarifying underlying mechanisms, and identifying new opportunities for research (see **Outstanding Questions**).

Box 1. Complementary frameworks

Our framework is not the first to lend structure to the study of cognitive diversity. Notably, Norenzayan & Heine [5] proposed a hierarchy of psychological universals that aligns partially with our framework. At the top of their hierarchy are “accessibility universals,” psychological processes that exist in all minds, are used for the same purpose, and are equally accessible, a category that aligns with our No effect pathway. They then distinguish cognitive processes that are latently available to all adults but which some groups either disprefer (i.e. “functional universals”) or use for different functional ends (i.e. “existential universals”). Both types fall within our Privileging pathway, insofar as alternative processes remain available but are differentially weighted by experience. The frameworks further diverges in their treatment of “non-universals” — cognitive processes found in only some groups. Norenzayan & Heine group these into a single category, without distinguishing whether such differences reflect the loss of existing processes or the emergence of new ones, what distinguishes Pruning and Producing. These differences reflect complementary goals: Norenzayan & Heine (2005) classify types of universals, yielding multiple universals and a single category of non-universals, whereas we classify types of differences, yielding the opposite. Just as “it is crucial to be clear as to which level of universal one is referring to” (ibid, p. 772), it is also crucial to be clear what kind of effect culture is having, if any.

Beyond this, other frameworks focus on specific aspects of culture (e.g. language) or specific cognitive domains (e.g. numerical cognition, memory; [13,73]). One notable example is a proposal on linguistic relativity by Wolff & Holmes (2011), which delineates seven ways language might influence thought [12]. Many of their effect types are specific to language (e.g. Thinking before vs. after language), but others have clear analogs in our framework: Their “Language as meddler” category aligns with the Privileging pathway and their “Language as augments” aligns with the Producing pathway (also see [74]). These distinctions among linguistic effects may be considered “species” of the more general cultural effects we delineate. In this way, such typologies can operate within our framework, while making additional distinctions specific to the cultural feature or cognitive domain in question.

Box 2. Effects at various timescales

Our case studies focus on the effects of culture on the cognition of individuals over the course of a single lifespan. However, culture can theoretically shape cognitive processes at many timescales, from minutes to millennia. At one end of this spectrum are effects of the immediate cultural context. For example, a study of Russian-Hebrew bilinguals shows that the direction of the mental number line depends on culture-specific practices: Participants showed different – even opposite – spatial-numerical associations depending on the language in which the tasks were administered [75]. Importantly, people show similar flexibility even for cultural practices that are entirely novel, as shown by the training studies described in this article. In those experiments, brief experience with right-to-left reading or counting transiently changed people’s implicit associations, even though they likely had little or no prior experience with such cultural practices [11,76]. Such findings suggest that although culture acts on people throughout their lives, it does not always take years or even weeks to measurably influence cognition. Rather, even habitual patterns of thinking can be rapidly – if transiently – shaped by the structure of the immediate cultural context in a matter of minutes [56].

On the other end of the spectrum are effects of culture over generations and across evolutionary time. At these larger time scales, cultural innovations can accumulate, yielding the tools, technologies, institutions, and conventions that compose the cultural milieu that individuals inherit [9,77,78]. Repeated exposure to cultural inputs across long time scales can potentially intersect with evolutionary processes [79], leading to phenomena such as gene-culture coevolution [80,81]. Classic examples of gene-culture coevolution focus primarily on physical traits (e.g. the advent of dairy farming leading to lactase persistence [82], starch-rich diets leading to duplications in the gene that codes for salivary amylase [83]), but these can theoretically also extend to cognitive processes. Some have argued, for instance, that several unique features of human cognition — such as sensitivity to social norms [84] or imitative learning [85]— could have arisen as a result of direct selection for cultural transmission [e.g. 86], though debate continues [87]. Although outside the scope of this paper, our framework can also be applied at this evolutionary time scale, over which culture could in principle Produce, Prune, or Privilege cognitive processes across millennia.

Box 3. Cultural variation within groups

The paper focuses primarily on differences across diverse cultural groups, but cultural experience also varies along various within-group dimensions, and our framework is readily applicable at these levels, as well. First, cultural experience varies systematically as a function of age; Children typically experience less of the cultural practices of adults and engage in qualitatively different cultural practices altogether [88]. This variation provides leverage on the cognitive effects of cultural practices over the course of enculturation in an individual's lifetime, rather than across cultures [57].

Second, adults differ in their cultural experiences, even within the same nominal group. Some of this variation is generational, producing systematic differences in cultural experience in successive generations [89]. Other variation is primarily generated by social and economic variables like wealth, occupation, and market integration. For example, among the Shuar of Ecuador, decision-theoretic preferences can vary dramatically between communities [90]. Such variation also exists at the individual level, even within the same small communities. For example, whereas some Indigenous Tsimane' adults can read, write, and do basic arithmetic, other adults in the same small village – their neighbors – have none of these skills, in part because of differences in formal schooling [91]. In principle, any systematic difference in cultural experience – whether across ages, individuals, or contexts – could shape cognitive processes through the same pathways that apply to group-level differences.

Further, although we focus on the effects of culture-specific experiences, our framework can theoretically be extended to any source of systematic variation in experience, including variation not just across and within cultures, but also across languages, ecologies, sensory abilities (like vision and audition), and even bodily characteristics (like biological sex and height), many of which vary within cultural groups. For example, handedness produces within-group variation in the way people represent emotional valence: Right-handers implicitly associate positive emotions with the right side of space and negative emotions with the left, whereas left-handers form the opposite spatial associations [54]. This effect can be characterized as an example of physical experience Privileging one representation over another, independent of culture [92].

Outstanding Questions

- What kind of cognitive domains are most susceptible to cultural production? And conversely, what kind of cultural inputs are most likely to have cognitive effects?
- What empirical signatures can best differentiate privileging, pruning, and producing?
- Do these pathways dissociate at the implementation level (i.e. in neural tissue)?
- Can longitudinal data help arbitrate between pathways when behavior looks similar?
- All cultural practices involve cognitive processes (e.g. tango dancing involves sophisticated motor programs, parallel parking involves mental representations of the car's position). In this way, all cultural experience can be said to shape cognition in some way. When are such effects of theoretical interest?
- How can we distinguish between culture producing a new process versus augmenting or extending an existing one? Where do we draw the boundary between “new” and “improved”?
- How can comparative studies with non-human animals most effectively be used to distinguish between the pathways?
- How can we best distinguish uniform effects of culture from no effects of culture?

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