The Cultural Fabric of Human Causal Cognition

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Abstract

Causal cognition emerges early in development and confers an important advantage for survival. But does this mean that it is universal in humans? Our cross-disciplinary review suggests a broad evolutionary basis for core components of causal cognition, but also underlines the essential role of culturally transmitted content as being uniquely human. The multiple ways in which both content and the key mechanisms of cultural transmission generate cultural diversity suggest that causal cognition in humans is not only colored by their specific cultural background, but is also shaped more fundamentally by the very fact that humans are a cultural species.

Keywords

Causal Cognition, Culture, Evolution, Language, Sociality

—A boy sneezes. A woman flinches. A cat jumps. A glass breaks. Water is spilled.

If you were to observe this string of events, you would probably not retell it in such simple terms. Instead you would be likely to turn it into a story, such as the following:

> "A boy sneezed, which made his mother flinch (maybe because she is superstitious and thought it would bring bad luck). The flinch scared the cat, which jumped and knocked the glass. The glass then fell down and broke, spilling the water that was inside."

Compared to the isolated pieces of information, the story is extended both by additional context (here regarding the relationship between boy and woman or that the water was in the glass) and in terms of connections: "made [her do something]", "scared", or "because". We also generated a somewhat speculative account of the woman's mental state by adding a conjecture on the flinch as an effect of the sneeze.

This story exemplifies important aspects of *causal cognition*: 'perception' of cause-effect relationships; assumptions about regularities in the physical world (such as that falling glasses are likely to break, or that fluids disperse when released from a container); attributions of causative mental states to cats and women (the cat being scared, or the woman being scared due to a superstitious belief). All of this is guided by a desire to understand what is going on by linking events in a meaningful way.

On a more abstract level, causal cognition can be understood as cognition concerned with causality, that is, with the relation between at least two entities or events, one of which (the "cause") gives rise to the other ("the effect"). It refers to how such causal relations are perceived and represented, both mentally and in language, how they are learned and reasoned about, and how all of this is harnessed in order to reach goals. These activities serve a number of important functions: They help us to diagnose causes, to predict future events, and to avoid or control the outcomes of these events. This range of activities is fundamentally challenged, however, by the invisible and abstract nature of causality itself. Indeed, going right back to David Hume in the 18th century, philosophers have claimed that causality is nothing but "a cognitive illusion" (Waldmann, Hagmayer, & Blaisdell, 2006, p. 307). The strength of this illusion is rooted in the fact that, from an evolutionary perspective, a capacity for causal cognition confers enormous advantages. Being able to use one's understanding of cause-effect relations to change the course of events in a manner beneficial to oneself is so powerful that it has been considered the driving force in human evolution (Lombard & Gärdenfors, 2017; Stuart-Fox, 2015).

This raises an important question: To what extent does the introductory story constructed from unconnected facts reflect general human tendencies of ascribing causal structure? Or, to put it in more abstract terms: Is causal cognition the same for all humans, or is it shaped by culture? Conjectures on this are far from straightforward. On the one hand, the capability to make causal judgments that are valid holds a clear evolutionary advantage. As we will discuss in more detail in the next section, non-human animals show evidence of this capability, and children appear to possess some causal knowledge early on. A widely shared, even if implicit, presumption is therefore that causal perception, learning, and reasoning are based on universal processes. On the other hand, causal mechanisms are typically invisible, the understanding of them is often poor, and some of the compelling impressions of causality that emerge when observing interactions are simply not justified, thus indicating that people do not objectively notice what's going on. Frequently, as we will describe further down, people also nerely take what others have told them as a given, a tendency which opens the door widely to a cultural impact on human causal cognition. The assumption that causal cognition may be shaped by culture is further supported by increasing evidence that culture also has a pervasive influence on other cognitive activities, even basic ones, such as those involved in visual illusions or spatial representations (e.g., Segall, Campbell, & Herskovits, 1963; Majid, Bowerman, Kita, Haun, & Levinson, 2004; overviews in Henrich, Heine, & Norenzayan, 2010).

Despite the long-standing preoccupation with causal cognition, the role that culture plays in causal cognition has been addressed astonishingly rarely and is poorly understood. And yet it is critical for the comprehensive understanding of a key human capacity. Causal cognition pervades our everyday lives, underlies our attitudes and assumptions, informs our judgments and decisions, and has a bearing on our emotions and behavioral intentions. Arguably, social interactions in humans would look radically different in the absence of causal cognition, and neither religion nor science and technology would have emerged if people hadn't pondered about the potential causes of what they observe. Appreciating the range of cultural diversity within this hallmark feature of humankind is thus imperative.

In our attempt to chart the role of culture in human causal cognition across disciplines, we begin by outlining those aspects we assume to be distinct to, and shared by, humans, as corroborated by comparative research, prehistoric archaeology, and developmental psychology. We then take on board findings from anthropological, cross-cultural, and cross-linguistic studies regarding the extent to which causal cognition may vary. The claim we eventually aim to defend is that human causal cognition is not only colored by an individual's specific cultural background, but is shaped more fundamentally by the very fact that humans are a cultural species.

The Shared Foundations of Causal Cognition

Ideally, the baseline for assessing culture's influence on causal cognition would be an inventory of those parts that are *not* affected by culture, but such a baseline is almost impossible to establish. Due to a lack of instances of human cognition that are uninfluenced by culture, we are compelled to draw inferences on theoretical grounds. Moreover, processes of biological adaptation, individual learning, and cultural transmission have been interacting in complex manners over the course of human evolution. To disentangle one from the other, we therefore need to combine perspectives from different disciplines on non-human species, human evolution, and human development. Taking into account indications of causal cognition across species, back into prehistory, and from very young children allows us to identify what we humans share with our closest primate relatives, what we have acquired since our lineages parted in the course of evolution, and what appears to be innate in humans.

Origins of Causal Cognition Across Species

While sharing most of their genetic make-up, humans clearly outperform their closest primate relatives in terms of cognitive skills. The question is therefore not whether there *are* differences in causal cognition between human and non-human species, but rather whether these differences are of a *qualitative* or *quantitative* nature. Can we delineate those specific cognitive competencies that humans share with non-human species from those that are uniquely human?

Comparative research across species corroborates evidence of a broad evolutionary basis for core components of causal cognition (overviews in Emery & Clayton, 2004; Schloegl & Fischer, 2017). Specifically, non-human species appear to be able to extract information on causal regularities and to distinguish between causality and covariation and between observational and interventional predictions. Several species also use or make tools as well as meta-tools, which indicates that they perceive specific actions as causing distinct consequences and that they recognize causally relevant properties of tools. Chimpanzees, for instance, consider weight but not color to decide which box may contain food (Hanus & Call, 2011). Such diverse species as rats and New Caledonian crows have been shown to be sensitive to causal structure (Blaisdell, Sawa, Leising, & Waldmann, 2006) and even to consider unobservable causal mechanisms (Taylor, Miller, & Gray, 2012). Most likely, some of these capabilities are based on abstract and analogical reasoning (Smirnova, Zorina, Obozova, & Wasserman, 2015; Taylor, Hunt, Holzhaider, & Gray, 2007; Taylor et al., 2012).

It is less clear whether species other than humans base their problem-solving behavior on hierarchically structured plans (Taylor, 2014); are sensitive to the difference between deterministic and probabilistic causal relations and to the directionality that distinguishes cause-effect from effect-cause reasoning; or gain ‘strong’, explicit causal knowledge from insight, in contrast to ‘weak’, implicit causal knowledge based on learning processes (Schloegl & Fischer, 2017; Seed, Hanus, & Call, 2011). Whereas this set of skills is available to humans, no convincing evidence has so far been reported for non-human species. Yet, while a lack of evidence for non-human species may not mean evidence of a lack, more compelling differences between human and non-human causal cognition emerge along more general dimensions.

First, non-human animals are discernibly less interested in detecting causal mechanisms and generalizations than are humans (Vaesen, 2012). Second, social cues appear to be less informative for non-human primates. For instance, non-human primates are able to infer the goals of others (Buttelmann, Schütte, Carpenter, Call, & Tomasello, 2012); yet when copying problem-solving behavior, they tend to copy only those parts they consider relevant and goal-conducive, while ignoring ritualistic add-ons (Horner & Whiten, 2005; Clay & Tennie, 2018). They are also able to learn from diagnostic interventions, but only when they perform these interventions themselves; when they are demonstrated to them by others, the same interventions do not improve their understanding (Völter, Sentís, & Call, 2016). And third, the integration of content-specific information is more challenging for non-human species. Such information does appear to both facilitate and constrain causal reasoning in non-human primates, for instance when learning causal structure is aided by the functional properties of objects, but not by arbitrary symbols (Hanus & Call, 2011; Seed et al., 2011; Taylor & Gray, 2014). Nevertheless, the causal beliefs of non-human species are claimed to be "largely content-free" and not linked to any theory-like representations (Penn & Povinelli, 2007, p. 111).

Humans, by contrast, with their predisposition for shared intentionality (Tomasello, Carpenter, Call, Behne, & Moll, 2005), not only take social cues into consideration, but even use them actively for teaching and learning. In so doing, they gain access to a vastly larger body of knowledge, which also enables the integration of content into causal reasoning to a much greater degree (we will come back to this).

Traces of Causal Cognition in Prehistory

About 7 million years of evolution separate modern humans from their last common ancestor with chimpanzees and bonobos. When *Homo sapiens* emerged a couple of hundred thousand years ago, the species was equipped with a unique set of cognitive competencies and skills, which are absent in its closest primate relatives (Wood, 2010). Can we trace human evolution in order to figure out when and how the human characteristics of causal cognition emerged?

Archaeological research on the cognitive evolution of humans (overviews in Coolidge, Haidle, Lombard, & Wynn, 2016; Wadley, 2013) rests on material remains, and specifically on tools. Types of tools can be classified in terms of procedural complexity to diagnose when and how the human-specific characteristics of causal cognition likely emerged (Haidle, 2014). The most basic type, that is *simple tools* like a stick, are applied directly and require only an elementary perception of cause-effect relations, together with goal-directed manipulation. *Secondary* or *meta-tools* transform an object into a primary tool (e.g., when using a stone to sharpen the stick) and therefore require abstract, analogical reasoning, possibly also recursion, and a hierarchical organization of action sequences (Stout, Toth, Schick, & Chaminade, 2008; Taylor et al., 2007). Whereas the usage both of simple tools and meta-tools is documented for non-human animals (Taylor & Gray, 2014), the production of *composite tools* is restricted to the human line. Here, separate elements with different qualities are combined in such a manner that the components unfold their effect jointly (such as when gluing a tip to a shaft). Fabrication of compound adhesives presupposes experimentation—in psychological terms: diagnostic interventions—together with an understanding of the effects which material properties may have. The combination of components that complement rather than simply enhance each other, hence producing *complementary tools* such as a bow-and-arrow set (Lombard & Haidle, 2012), requires an even more abstract understanding of cause-effect relations. Finally, extending causal reasoning beyond purely material objects and effects to the understanding that mental representations may also unfold causal power allowed humans to invent *notional tools* (i.e., signs)—an achievement requiring not only abstract but also symbolic reasoning. The expansion of the causal chain in tool manufacture along the above steps both required and scaffolded an increasing understanding of causal structure (Haidle, 2014).

When modern humans left Africa some 50,000 years ago, they had already developed technology across all types of Haidle's (2014) taxonomy. Moreover, they had begun to cross larger bodies of water; to use fire; and had invented language (Henshilwood et al., 2002; Wadley, 2013). Since then, even though cultural diversity has amplified vastly, the cognitive endowment on which this is based has been the same for all human populations. With regard to causal cognition, this includes a capacity for generating theory-like representations, for symbolic thinking, and for the hierarchical organization of problem-solving strategies. Together, these skills provide the basis for abilities such as drawing inferences about abstract relations or engaging in deliberate diagnostic interventions.

Besides this cognitive endowment and the predisposition for shared intentionality, all human populations also possess a uniquely powerful tool for cultural transmission. For at least 50,000 years, if not much longer, language has allowed humans to share their ideas. Put simply: People were not merely interested in the things going on in the world; they were also interested in what other people made of them, and they were able to talk to each other about their thoughts.

Predispositions for Causal Cognition in Human Infants

Humans are already embedded in social relations soaked with culture from birth, and arguably even before. Yet, opportunities for individual learning and cultural transmission are still limited in pre-linguistic children, leaving space for the emergence of innate predispositions and capabilities as a product of maturation. Can we delineate these emerging abilities from those that need to be learnt and hence are confined to specific cultural traditions?

Psychological research on human development indicates that even human infants possess basic abilities for recognizing causal events, based on the same spatial and temporal characteristics of the event as those considered by adults (overviews in Muentener & Bonawitz, 2017; Schulz, 2012). These include the harnessing of information on statistical regularities for drawing inferences on causal structure and for causal learning (Gopnik, Sobel, Schulz, & Glymour, 2001; Sobel & Kirkham, 2006). Besides these domain-general abilities, infants also appear to possess domain-specific concepts, linked specifically to object motion and the agency of persons. As an example, by as early as six months of age (and perhaps even earlier), children seem to represent motion events in terms of causal structure, for instance as an interaction between two entities in which one transfers force onto another. The former is assigned the causal role of *agent*, the latter the role of *patient*. In children, a specific concern with dispositional agents (i.e., agents whose actions may be intentional and goal-directed) is presumably reinforced by the progressive experience with their own agency (Mascalzoni, Regolin, Vallortigara, & Simion, 2013; Saxe, Tenenbaum, & Carey, 2005), that is, by the experience of being in control of one's own actions and thus of the events they cause (Haggard & Tsakiris, 2009).

Some researchers propose an even larger body of domain-specific "core knowledge" (Spelke & Kinzler, 2007), which extends beyond a concern with the motion of objects and the agency of persons. It has also been claimed that for each of a number of domains (such as the physical, the biological, and the social world), specific cognitive systems are in place that provide basic assumptions on the causal properties of characteristic entities (Wellman, Hickling, & Schult, 1997), such as that solid objects move as whole entities and on continuous paths, and that they behave differently from liquids (Hespos, Ferry, Anderson, Hollenbeck, & Rips, 2016). These assumptions, in turn, can be used to reason about events in these domains (Spelke & Kinzler, 2007), and perhaps even to recognize the boundaries between these domains (Notaro, Gelman, & Zimmerman, 2001).

By about four years of age, children are able to integrate domain-specific concepts and domain-general abilities, further supported by a number of *inductive biases* that help them to constrain and select from possible inferences. As a consequence, they are able to categorize objects and events based on causal information, to understand the emergence of causal properties from internal parts, or to reason causally with the help of counterfactuals (Muentener & Bonawitz, 2017). As mentioned previously, human children exhibit a much greater interest in causal mechanisms and generalizations than do non-human species (Vaesen, 2012). This all-embracing interest, automatically applied across all cognitive domains (Corrigan & Denton, 1996; Sobel & Kirkham, 2006), apparently drives them to improve their understanding of causal systems by way of diagnostic interventions, be it by observing others' interventions or by spontaneously developing interventions of their own volition (overview in

Schulz, 2012). Importantly, these self-designed interventions are causally meaningful and often successful in changing the behavior of causal systems (Schulz & Bonawitz, 2007)—an observation that supports the notion of children as "intuitive scientists" (Gopnik, Meltzoff, & Kuhl, 1999; Kuhn, 1989). In contrast to their non-human relatives, human children are also prepared to learn from the causal interventions of others. Moreover, when evaluating the informativeness of these interventions, they appear to be sensitive to social cues, which indicate, for instance, the knowledge or intention of the actor (Kushnir, Wellman, & Gelman, 2008).

It should be noted that although children are not culture-free versions of human adults, research in this field has relied largely on culturally homogeneous samples—a research practice that has been challenged on several grounds (Henrich et al., 2010; Medin & Bang, 2014). As a consequence, caution is warranted when drawing generalizations, and we will come back to possible differences in cognitive development further down. Still, the overall conclusion that children do possess a broad range of abilities related to causal cognition may well hold; and the course of our argument is unaffected by whether or not we take for granted that most of the abilities summarized here likely reflect abilities shared by all human populations.

The Shared Mechanisms of Culture's Influence

Human culture involves the transmission of potentially arbitrary social structure, behavioral habits, and belief systems (D'Andrade, 1981), for instance whom one regards as kin or in-group, how one tends to grasp a knife for cutting fruits, or what one deems to be responsible for a drought. While across generations and between groups, such transmissions result in the diversification of structure, habits, and belief systems, the mechanisms that enable this diversification are shared by all human populations. Besides general learning mechanisms, they include the species' sociality, its predisposition for teaching and imitative learning, and its language faculty. Here, we briefly describe each of these three mechanisms and their potential impact on causal cognition, before outlining what is known about actual diversity in causal cognition in the next section.

Human Sociality

The level of a species' sociality depends on how strongly its members associate across all stages of life to form cooperative societies. Unlike ants or bees, human societies lack the level of innate role differentiation required for the highest level of sociality according to biological definitions. Nevertheless, they are characterized by an extraordinary degree of cooperation, which allows for highly flexible, multifarious, and complex interactions. The specific human brand of sociality rests on the ability to create a shared mental world (Enfield & Levinson, 2006; Tomasello et al., 2005). Humans' understanding of conspecifics involves insights into and attributions of mental states and motivation, that is, an interpretation of what others may perceive, know, or believe, of which emotions, attitudes, and intentions others may hold, or of why others behave in certain ways (Call & Tomasello, 2008).

While perspective-taking and an understanding of mental states may, at least in parts, be present in some other primates, marine mammals, and a few bird species (Taylor, 2014; Tomasello, Call, & Hare, 2003; Tschudin, 2006), one characteristic that is likely unique to humans is their willingness to *convey* such states within and for the purpose of collaborative interactions (Tomasello & Carpenter, 2007). This "shared intentionality" can be observed early in life, when infants begin to point things out to their caregivers (Tomasello et al., 2005), and in the course of psychological development it helps to transform important social-cognitive skills. Where, for instance, chimpanzees simply follow the gaze of conspecifics or engage in social manipulation, group activity, and social learning, human toddlers are capable of creating joint attention, cooperative communication, collaboration, and instructed learning (Tomasello & Carpenter, 2007). In other words, they are intrinsically motivated to share interest, attention, and information, and this sharing paves the way for human culture and the accumulation of knowledge.

These characteristics of human sociality have several implications for causal cognition. First, the knowledge shared often contains information that is relevant for causal reasoning and learning. Second, the understanding of psychological factors in other people's inner lives is causally relevant in itself, insofar as it helps to explain human behaviors in terms of mental states. And third, the ability for shared intentionality prepares humans to take into account social cues when pondering causal mechanisms (Kushnir et al., 2008). The latter is particularly important for a second mechanism involved in cultural transmission and diversification: teaching.

Teaching and Imitative Learning

The ability to take perspective and to diagnose others' lack of knowledge, combined with a motivation to help them understand, is a human characteristic that is instrumental for the persistence and evolution of human culture (d'Errico & Banks, 2015; Tomasello, 2016). This is reflected not only in the greater willingness of humans to instruct their offspring and peers, but also in the ability of the latter to recognize a teaching intention and in their willingness to pay attention to and copy the observed behavior (Csibra & Gergely, 2009). While broadly speaking, the purpose of teaching is to help others acquire knowledge, skills, or values, the way in which this goal is pursued may differ, and the same holds for learning from teaching. Even the most simple form of learning, *imitative learning*, requires an understanding of intentional agents and perspective-taking; for *instructed* and *collaborative learning*, concepts of agents need to be more sophisticated, and requirements involve coordinated and integrated perspective-taking, respectively (Tomasello, 2016).

All three are uniquely human forms of learning, and differ in important ways from *emulation*, a pattern of social learning also observed in non-human species. While emulation favors the achievement of the behavior's goal over the reproduction of its form (Whiten, McGuigan, Marshall-Pescini, & Hopper, 2009), imitation favors the latter over the former. The (high-fidelity) reproduction even of details of the behavior that are obviously causally irrelevant is called *overimitation* (Lyons, Young, & Keil, 2007). In human children, it appears to emerge between the ages of 18 and 36 months and to steadily increase into adulthood (Horner & Whiten, 2005; Lyons et al., 2007; McGuigan, Makinson, & Whiten, 2011). While it is perhaps not *universally* human (Berl & Hewlett, 2015)—albeit widespread across cultures (Nielsen, Mushin, Tomaselli, & Whiten, 2014)—it does seem to be at least *uniquely* human: Neither captive and highly trained chimpanzees (Horner & Whiten, 2005), nor orangutans (Nielsen & Susianto, 2010), nor untrained and non-encultured bonobos (Clay & Tennie, 2018) exhibit this behavior.

The high fidelity observed in copying behavior has several implications. In the short run, it ensures the rituals and normative behavior that strengthen group cohesion (Legare & Nielsen, 2015). This comes at a cost, however. Unlearning specific components of a behavioral repertoire as irrelevant is challenging for human children (Lyons et al., 2007). This also entails a reluctance to be innovative—an area in which other species actually outperform human children (Legare & Nielsen, 2015). In the long run, the preparedness for (over-)imitation promotes the rapid adoption of available knowledge and technological culture as well as the accumulation thereof over time (Lyons et al., 2007). In doing so, however, it also introduces elements of content into causal cognition that are based on believing rather than understanding, and that may have more to do with cultural conventions than with causal mechanisms. This modification of 'natural' explanations by cultural input is particularly strongly attested to with respect to beliefs in supernatural powers. For instance, when asked whether death terminates all bodily and mental processes, younger children adopt a biological perspective; only at a later age do they come to consider beliefs in an afterlife as an alternative account (Astuti & Harris, 2008; Barrett & Behne, 2005; for other instances of such a recourse to supernatural explanations on top of a natural one, see also Evans-Pritchard, 1937; Legare & Gelman, 2008; Widlok, 2014).

At the same time as humans are soaking up the vast body of causally relevant, and often causally opaque, knowledge provided to them from early childhood onwards, they are thus also acquiring the underlying explanatory frameworks that previous generations came up with and that continue to pervade observed relations with (culture-specific) interpretation.

Language as a Tool

While probably all species use communication systems of some sort or another, the system developed by humans is unique in its expressive power. Language is arguably humankind's most important tool, for both the generation and the exchange of thoughts, and allows humans to elaborate, store, and communicate insights, interpretations, and ideas.

A range of cognitive processes operate perfectly well in the absence of language, and non-human species have demonstrated impressive skills in reasoning and problem-solving (Taylor, 2014; Tomasello et al., 2003). Undoubtedly, though, language massively enhances most of these abilities: by adding levels of codability to perception, levels of abstraction and recursion to reasoning, levels of elaboration to insights, or levels of representation to memory. Language helps to explicate causal beliefs, and to integrate them in a systematic manner for constructing theory-like representations, which are assumed to guide causal reasoning in humans (Penn & Povinelli, 2007).

Besides its key role for cognition, language is also the central means for sharing ideas with other people, and in this sense is also highly relevant for causal cognition, in at least two ways. First, the possession of a sophisticated communication tool is indispensable for the creation of a joint mental world (Enfield & Levinson, 2006). Being able to share information about mental states greatly facilitates an understanding of mental states in other people. It can come as no surprise, therefore, that language in general, and the use of mentalistic notions in particular, appears to play a decisive role for the development of mental reasoning abilities and a *theory of mind* in children (Pyers & Senghas, 2009; Ruffman, Slade, & Crowe, 2002).

Second, language also facilitates teaching in qualitatively new ways, in that it allows humans to complement or even replace implicit learning from observations with explicit learning from instruction, as when children request and receive causal explanations by way of why-questions (Callanan & Oakes, 1992; Chouinard, 2007; Frazier, Gelman, & Wellman, 2009). Importantly, the sharing of beliefs is not restricted to pedagogical contexts, but may also emerge in other settings of social exchange. Receiving explanations for causally relevant matters speeds up the learning process tremendously and expands the amount of knowledge that people may gain in the course of their lifetime. By helping to integrate new knowledge and beliefs into larger explanatory frameworks, language affords the accumulation of causal knowledge that is so characteristic of our species.

The Cultural Diversity of Causal Cognition

Sociality, teaching, and language faculty are among the key enablers of human culture, giving rise not only to uniquely human characteristics, but also to an amazing diversity in these characteristics. Part of this latter effect is attributable to the output that these mechanisms produce given different input. Another part is due to the fact that even the key enablers themselves are potential sources for diversification. Here, we compile evidence from cultural anthropology, ethnolinguistics, and cross-cultural psychology pointing at possible ways in which causal cognition may vary across cultures as a consequence of how the key enablers operate.

Content as a Source of Cultural Differences

As discussed before, content information plays a crucial role for human causal cognition. Most of the time, people do not simply learn from covariational data; rather they are guided by content-specific beliefs about properties, relations, and interactions, and by a priori assumptions about how multiple causes are combined in a given domain (Waldmann, 2007). New information is integrated into content-rich causal models and other theory-like representations (Penn & Povinelli, 2007), which in turn affect how this information is collected, learned, and organized. This top-down processing eventually allows humans to go "beyond the information given" (Waldmann et al., 2006). In view of this crucial role of content for human causal cognition, differences in the former will generate differences in the latter. In the following, we first illustrate how differences in content may emerge, before addressing the implications of these differences.

Sources of differences in content information. In principle, the assumptions and beliefs that constitute causal knowledge may derive from one of three sources: Some may be innate or may emerge with maturation, as has been claimed for the body of 'core knowledge' (Spelke & Kinzler, 2007), some will be arrived at through individual experiences, and some will be learned from other people.

For the first source, we would not, by definition, expect any cultural diversity, except perhaps for the unfolding of those conditions that trigger maturation. But note that research on core knowledge has been largely based on studies using samples that were restricted in terms of cultural and experiential background. If these studies are replicated with broader samples, the picture may change (Ross, Medin, Coley, & Atran, 2003).

The potential for cultural diversity may also appear to be limited for the second source of causal knowledge, that is individual experiences, but only at first glance. Which experiences one gathers and what one learns from these experiences is at least partly shaped by the (physical and cultural) environment in which one grows up (Medin & Atran, 2004). In other words, even if the general learning mechanisms and the processes specific to causal perception and reasoning were universal, the body of knowledge and inferences gained from it would still vary due to different environments. Importantly, there is evidence that even the processing itself, all the way down to perception, might be affected by characteristics of one's environment, as with the Müller-Lyer illusion that appears to emerge more strongly for people accustomed to the straight lines and right angles of a "carpentered world" (Segall et al., 1963; and see Gregory, 2009). Thus, while it is likely that humans perceive the spatiotemporal regularities on which causal impressions are based in similar ways, we should not take it for granted that the processes involved in causal cognition are entirely independent of a person's upbringing.

In addition to such an external patterning of experiences, observations may also simply be mistaken, either due to perceptual and inferential biases (Matute, Blanco, Yarritu, Díaz-Lago, Vadillo, & Barberia, 2015; McCloskey, 1983; Michotte, 1963) or because of misinterpretations and inaccurate memories (Kempton, 1986; Lawson, 2006).

Of course, it is still possible to gain content-relevant information from one's own experiences and inferences. In a world of non-animated objects and physical forces, subjective accounts can be tested against reality. Most people would therefore agree that the breaking glass in the introductory example results in the spilled water. However, the less transparent and the more complex the relations at stake—and especially so when animates and social agents are involved—the less likely it is that individual observations will be sufficient for a satisfactory explanation (see also Stuart-Fox, 2015). When moving from the physical domain to the biological and psychological domain, the underlying causal principles become even more opaque, and even if people established the same rule-like generalizations from the regularities they observe, *accounting* for these regularities would still be up to conjecture and hence diversity. One may have an idea about why the boy sneezed—typically, it's a symptom of a common cold—but alternatives are to be found (e.g., he might have put his nose into the pepper pot or a dusty corner). Why the woman flinched or the cat jumped, though, is impossible to know. The woman can at least be asked, provided a shared language, and she would probably disclose what she believes to be the reason, which may or may not be accurate. But both her and an observer's account would be influenced by what they know and believe about cats and people, that is, by larger explanatory frameworks related to the natural world and to people's mental lives (Lillard, 1998; Medin & Atran, 2004).

One's own observations and inferences are likely the most important way of obtaining content-relevant information in infancy, as discussed earlier. But even in combination with the inventory of core knowledge assumed to be available to all human children, insights gained from exploration provide only a minor set of the facts and beliefs that humans come to hold in the course of their lives, and there remains a qualitative step to be taken from this set to a full-fledged theory of what is going on in their environment. The older one grows, the more likely it therefore becomes that this set stems from the third**,** and for humans likely the most important, source of causally relevant knowledge: other people (e.g., Callanan & Oakes, 1992). Our species' sociality, its predisposition for teaching and imitative learning, and its language faculty ensure that an enormous and ever-increasing body of knowledge, from stand-alone beliefs about simple things to theory-like frameworks, is transmitted by way of teaching, social exchange, and occasionally mere participation. As Roy D'Andrade famously expressed it, "[m]ost of what any human ever thinks has been thought before, and most of what any human ever thinks has been learned from other humans. Or, to put it another way, most of what anyone knows is cultural knowledge" (1995, p. xiv). This body of knowledge is cultural not only in the sense that its origin is cultural transmission, but also in that it is culture-specific, hence giving rise to diversity in people's causal beliefs and explanatory models across cultures.

Consequences of differences in content information. As content is a crucial component in human causal cognition, differences in people's causal beliefs and explanatory models have multiple consequences.

First, and perhaps somewhat obviously, what people believe directly affects the outcome of their causal reasoning, inferences, and behavior. For instance, the way in which people conceptualize how a thermostat functions guides the way in which they interact with it (Kempton, 1986). The same can be observed across a wide range of examples and domains (Ross, Medin, & Cox, 2007; White, 1995). In some cases, this may have disastrous consequences, such as when a lack of accurate knowledge about how regulatory systems work leads people to form mistaken beliefs, to generate inaccurate models of the underlying causal mechanisms, and to make fatal decisions (Dörner, 1996).

Second, the content of causal beliefs and explanatory models not only impacts the outcome of cognitive processing, but can even change the processing itself. This may be more controversial, given the widespread tendency in cognitive science to attribute cultural differences in causal cognition—as in cognition more broadly—almost exclusively to differences in the content of knowledge, while considering the processes operating on this knowledge to be universal (Muentener & Bonawitz, 2017; for discussion, see Bender, Beller, & Medin, 2017). However, recent years have seen increasing evidence for the assumption that content and processes indeed interact in intricate ways. For instance, whereas participants with only basic knowledge about biological species tend to rely on category-based induction (Lynch, Coley, & Medin, 2000), rich content knowledge enables people to harness reasoning strategies based on causal mechanisms, such as those implicated in ecological relations: An enzyme might be shared by two species not only because these species are related, but because members of one species are eaten by members of the other (Bailenson, Shum, Atran, Medin, & Coley, 2002; López, Atran, Coley, Medin, & Smith, 1997; Proffitt, Coley, & Medin, 2000). Availability of such knowledge also appears to determine the conceptual changes pre-school children are going through (Ross et al., 2003; for an overview, see Medin & Atran, 2004).

When moving from isolated pieces of knowledge to theory-like models, implications amplify. As mentioned earlier, much of the knowledge and beliefs about the biological or the social world are organized by such overarching models or *explanatory frameworks* (Lillard, 1998; Medin & Atran, 2004). These frameworks provide structure for drawing inferences, guide the interpretation of data, and suggest an "epistemological orientation": a specific way of looking at and understanding the world (Medin & Bang, 2014). For instance, many Amerindian groups take a more holistic approach to their environment, according to which species (including humans) are interconnected in multiple yet often symmetric ways (Bang, Medin, & Atran, 2007). This approach is reflected in an explanatory framework that suggests a relational perspective on nature, emphasizing communication and exchange. As a consequence, members of such groups appear to be less likely to draw asymmetric or anthropocentric inferences—even as children—when reasoning about causal mechanisms in biology (Ross et al., 2003); they are more likely to detect a disposition for cross-species communication and cooperation in non-human animals (Ojalehto, Medin, Horton, García, & Kays, 2015); and they are more likely to assign social agency not only to animals, but also to plants—in line with recent findings in biology (Ojalehto, Medin, & García, 2017a, 2017b).

A more holistic perspective is also associated with different patterns in other cognitive activities related to causal cognition. For instance, some of the strongest biases in social and cognitive psychology include the causal asymmetry bias and the correspondence bias. The *causal asymmetry bias* leads people to perceive, understand, and describe physical interactions not as symmetric relations, but in terms of a relation between cause (agent) and effect (patient), that is a "doer" and a "done-to", and to overestimate the former's contribution to the unfolding event at the expense of the latter (White, 2006). The *correspondence bias*, formerly called *fundamental attribution error* (Gilbert & Malone, 1995), leads people to overestimate the role of dispositional factors in causal attributions, at the expense of situational influences, as when an observed involuntary activity like praising an unpopular politician is still attributed to personality traits or attitudes rather than to the external factors acting on the individual. Both biases are less pronounced or even reversed for groups with a more holistic perspective or style of thinking (Beller, Bender, & Song, 2009b; Bender & Beller, 2011; Choi, Nisbett, & Norenzayan, 1999; Peng & Knowles, 2003), a pattern we will come back to. With a holistic perspective, the assignment of agency shifts in more general ways, from a sole focus on the individual person to an additional consideration of superindividual actors such as groups and polity (Duranti, 1994; Morris, Menon, & Ames, 2001), or of non-human entities, such as plants, the ocean, or the sun, as well as supernatural and spiritual entities (Bird-David, 1999; Norenzayan & Hansen, 2006). Other implications of a more holistic perspective include greater attention to background information as compared to the central figure in a scene (Nisbett & Miyamoto, 2005), which bears on the range of potential factors people will take into consideration when pondering causal mechanisms.

The third consequence of differences in explanatory frameworks, finally, is the most profound, namely when beliefs are so powerful that they contribute to the creation of a world that is in line with these beliefs. This is particularly true for the social domain, which to some extent is made up of culture-specific assumptions about people's inner lives and motives. For instance, the extent to which reflections on others' mental states are a topic of interest and conversation varies across cultures (Lillard, 1998). Several groups appear to adopt a distinctly behavioristic approach, largely considering mental states to be ultimately private and opaque, and rarely or never making use of mentalistic terms. Against this background, attempts to gain a first-person-like perspective on others are not valued as much as in other cultural settings, and not even always positively (Robbins & Rumsey, 2008; Throop, 2008), with profound effects even on developmental trajectories (Träuble, Bender, & Konieczny, 2013). As a consequence, people in such societies appear to be more concerned with the effects of an action than with its causes. This concern is reflected in how behavior is explained, justified, evaluated, and sanctioned, namely in terms of its outcome rather than in terms of the underlying intentions or motives, thereby reconfirming the initial conceptualization of the social world (Lillard, 1998; Shore, 1982; and see Astuti & Bloch, 2015).

Shared Mechanisms as Source of Cultural Differences

Although shared by all human groups, even the key enablers of human culture are not necessarily implemented in a uniform manner or operating in the exact same way. Preferences for patterns of sociality, teaching strategies, and grammatical structures vary across cultures and languages. Here, we illuminate how this variability contributes to diversity in causal cognition.

Preferences for patterns of sociality. While humans are a social species, they still differ in the extent to which sociality is foregrounded and implemented. Specifically, the way in which the relationship between the individual and the group is conceptualized differs across cultural settings, with values being more individualistic or collectivistic (Triandis, 1995), the concept of the self being more independent or interdependent (Markus & Kitayama, 1991), implicit theories of agency being more focused on the individual or the group (Morris et al., 2001), or systems of thought being more analytic or holistic (Nisbett, Peng, Choi, &

Norenzayan, 2001). Collectivistic values and an interdependent self-concept, for instance, are more likely to emerge in a cultural environment shaped by complex social networks with prescribed role relations, where attention to context is important. They are typically accompanied by a focus on duties over rights, and by a strong concern with mutual obligations and social harmony. By contrast, individualistic values and an independent self-concept are more likely to emerge in a cultural environment that imposes fewer social constraints, and are more typically accompanied by a focus on rights over duties and by the importance of personal accomplishments for one's identity (Miller, 1984; Markus & Kitayama, 1991).

By taking these differences in social orientation as a starting point, cross-cultural research in social psychology has found analogous differences in cognitive processing on several levels, especially in the social domain (reviewed in Oyserman, Coon, & Kemmelmeier, 2002). For instance, participants with a tendency towards the collectivistic, interdependent end of the scale appear to pay more attention to the broader context, are more likely to notice relationships and changes, and are more willing to take these into consideration when engaging in causal attributions. Moreover, people with a collectivistic orientation are also more likely to hold social groups, rather than a single person, accountable for a given action (Morris et al., 2001); they base their assessment on a larger body of information, including a greater number of possible causes (both proximal and distal); and they are more aware of the complex distribution of direct and indirect consequences of events (Choi, Dalal, Kim-Prieto, & Park, 2003; Maddux & Yuki, 2006). Such differences in causal attribution for social events also affect the ascription of responsibility, emotional responses, and behavioral intentions (Beller, Bender, & Song, 2009a), and they appear to spill over to the physical domain, at least to some extent (Beller et al., 2009b; Peng & Knowles, 2003).

Teaching strategies. While teaching, and learning from teaching, appears to be a human universal, the strategies on which teaching is based are not. For instance, the extent to which caregivers invest in explicit verbal instruction, as compared to simply serving as role models, varies considerably across cultures. While the former is particularly pronounced in middle-class families and educational systems in the Western world, apprenticeship or "guided participation" of children in the activities of their caregivers appears to be more prevalent in traditional, small-scale societies (Lancy & Grove, 2010; Rogoff, 2003). In the latter, children are often expected to learn from observation, imitation, and practice, rather than from being instructed. Likely linked to this are cultural differences in requests for explanation on the part of the child. Language data from Belize, Kenya, Nepal, and Samoa revealed a similar amount of information-seeking questions in 3-5-year-olds' utterances to the amount of such questions posed by middle-class Western children, but a much lower proportion of explanation-seeking questions (Gauvain, Munroe, & Beebe, 2013). Importantly, these children also spend substantially more time with peers than do children in the US-American reference samples, in which an individual parent, and typically the mother, was the key interaction partner (Gauvain et al., 2013).

This difference in teaching strategies distinctly affects the extent to which explanations come to bear on causal reasoning and learning. While information on causes and mechanisms, for instance, can be directly conveyed through explicit verbal instruction, in cultural settings, which focus on guided participation, such information needs to be detected or inferred. In other words, children themselves have to actively seek information on causal structure, and if encouraged, this likely stimulates exploration. If discouraged, it may instead shift the interest from causal information and an understanding of the underlying mechanisms to covariational information and observations of outcome.

Some support for this shift in interest comes from studies dealing with reasoning about mental states. In several Pacific societies such as Samoa, for instance, the reluctance described earlier to speculate about the feelings, intentions, or thoughts of others, occasionally summarized as "opacity of other minds" (Robbins & Rumsey, 2008), is particularly pronounced. While social life is rich and complex in Samoa, and children learn to participate in social interaction early on, they receive very little explicit teaching; instead, they are expected to learn from observation (Mayer & Träuble, 2013; Ochs, 1988). As mentioned earlier, the amount of explicit teaching about others' mental states appears to affect the ease with which children acquire an understanding of such notions (Mayer & Träuble, 2013; Vinden, 1996). Since reasoning about mental states is itself a powerful tool for the diagnosis of causality in the social domain, differences in its onset attest to the profound consequences that culture-specific teaching strategies may have for causal cognition.

Grammatical Structures. While all humans possess language—and are even able to create language in the absence of linguistic input (Senghas, Kita, & Özyürek, 2004)—little in the human world is as diverse as human languages (Evans & Levinson, 2009; Levinson & Gray, 2012). This diversity has implications for causal cognition in that each single language, while enabling the encoding and communication of causally relevant information, does so in distinct ways. Causal relations can be mapped onto grammatical structure in numerous ways and across different elements of a clause, including onto syntactic categories such as subject, onto verb semantics, morphology, resultative constructions, or animacy distinctions as coded in noun phrases (e.g. Pickering & Majid, 2007; Wolff, Jeon, & Li, 2009). As a consequence, languages differ substantially, for instance, in how finely they dissect causal chains (Bohnemeyer, Enfield, Essegbey, & Kita, 2010), in whether they describe changes as active or passive (Ikegami, 1991), or in how they assign and classify the causal roles of agent and patient (Duranti & Ochs, 1990). In so doing, they also suggest a distinct causal perspective with implicit assumptions about structure.

These distinct ways of mapping causal relations onto grammatical structure have implications for causal reasoning and may even affect eye-witness memory. Languages differ, for instance, in whether or not they specifically mark the agent of an event—something that so-called ergative languages like Samoan or Tongan do. Speakers of such languages tend to shift the assignment of causal roles from one entity to the other when the agent is marked in the ergative case (Beller et al., 2009b; Bender & Beller, 2011, 2017; Duranti, 1994). Besides grammatical categories, even habitual patterns of linguistic framing appear to affect which aspects of the same causal event participants pay attention to, encode, and remember. One such pattern is a preference for non-agentive phrasings, that is, phrasings in which explicit information on the agent may be dropped (as in "the ball moved" instead of "he moved the ball"). When shown videos of intentional and accidental events, speakers of three languages alike provided agentive descriptions for the intentional events; however, speakers of those languages with a preference for non-agentive phrasings were less likely to do so for the accidental events, and were less likely to remember the agents of accidental events (Fausey & Boroditsky, 2011; Fausey, Long, Inamori, & Boroditsky, 2010).

Finally, for individuals who speak more than one language, even the question of which of these languages is activated in a given task makes a difference. As research on the *foreign language effect* suggests, using a language other than one's mother tongue renders outcomes relatively more important than intentions when making moral evaluations (Geipel, Hadjichristidis, & Surian, 2016).

How Cultural is Human Causal Cognition?

Causal cognition arises from the desire to link events in a meaningful way. Inter alia, it involves perceiving cause-effect relations, learning from regularities, generating representations of the underlying causal structure, and using characteristics of an entity to account for surface properties and to predict patterns of behavior. Abilities like these confer an important advantage for survival, as they help one to gain control over what is going on in one's environment. Research across species, back into prehistory, and on development enables us to delineate which of these general abilities are shared with other species and which are specific to our own. Methodological concerns notwithstanding, this research suggests a broad evolutionary basis for core components of causal cognition, but also points to three aspects in particular in which even the abilities of infants transcend those of non-human species: the greater and likely innate interest in causal mechanisms, coupled with a drive to design interventions for exploring causal structure; the extent to which content information is integrated into theory-like representations; and the extent to which causal learning and reasoning may be guided by social cues. While these aspects are likely shared by all humans, they also prepare the ground for an impact of human culture on causal cognition.

In the following, we first discuss the nature of the differences between causal cognition in humans and other species. We then turn to the issue of whether cultural diversity is a prerequisite in order to consider causal cognition as cultural.

Culture Makes Human Causal Cognition Unique

Obviously, causal cognition in humans differs from that of other species. But are these differences qualitative or quantitative in nature? Our answer to this question is: both. More precisely, some differences are only differences in degree, while others constitute non-continuous leaps.

Differences in degree are observed for all of those components that have a broad evolutionary basis. As reported earlier, also non-human species exhibit abilities to extract information on causal regularities, perceive actions as causing distinct consequences, recognize causally relevant properties, are sensitive to causal structure, or consider unobservable causal mechanisms. Humans clearly do better in this regard than non-human primates or corvids, especially when tasks are more complex, when hierarchically structured plans are required to solve a problem, or when sophisticated causal notions are involved, such as for differentiating between deterministic and probabilistic relations. Arguably, this advantage is largely due to the greater computational capacities of humans. It is also possible that the advantage is linked to, and perhaps entirely carried by, cultural scaffolding. For instance, the possession of language may well be crucial for developing sophisticated causal notions in the first place. In either case, it would not seem justified to assume a qualitative difference between humans and their closest competitors with regard to the basic processes involved in causal cognition.

Qualitative differences do emerge, by contrast, for those components of causal cognition that are subject to cultural transmission. While cultural transmission is not unique to humans, the key mechanisms on which it relies in humans are unique: It is the human brand of sociality that makes people interested in what others think, the predisposition for teaching and imitative learning that makes them willing to share their thoughts, and the faculty for language that provides the tool for doing this efficiently. These mechanisms, combined with the greater interest in causality, foster the accumulation of an ever increasing body of causally relevant knowledge, beliefs, and inferences, which serve as the content of causal cognition. While parts of this content may be innate or obtained through individual experiences, the bulk of it is culturally transmitted, thereby complementing a purely empirical access to causal content with a social avenue.

One means by which culture gets involved in causal cognition is therefore through its content, which is pivotal to causal cognition in humans. The knowledge one gathers, the beliefs one holds, and the inferences one draws do not only affect one's decisions and behavior—when integrating them in theory-like representations, they also guide information processing itself in a top-down manner. Culture-specific beliefs do so in distinct ways, for instance by shifting the focus of attention, by suggesting where or even when to search for causal information, and by affording different reasoning strategies. Culture-specific beliefs may also mold the very domain on which they operate, as is the case with folk-psychological theories of mind that form peoples' consideration of mental states when accounting for behavior.

A second means by which culture gets involved in causal cognition is through the mechanisms that enable cultural transmission. These mechanisms do not operate in the exact same manner everywhere, but are themselves shaped by culture. Differences emerge, for instance, in the relative extent to which the individual is seen as independent from the group; in the extent to which explanations are valued over observations; or in the extent to which agency is grammatically marked. These differences in the patterns of sociality, teaching strategies, and linguistic grammars have implications not only for how much and what kind of knowledge is transmitted, but also for which perspective people tend to take, what they pay attention to, or how many details they memorize.

Considering the extent to which both the content and the processing involved in human causal cognition—in fact, even the situations in which it occurs—are affected by cultural beliefs and practices, we propose that the distinctly and uniquely human components of causal cognition are quintessentially cultural in nature. It is here where the leap between human and non-human causal cognition is non-continuous.

Culture Permeates Human Causal Cognition

A widespread working hypothesis is to accept an influence of culture for those aspects for which cultural differences are documented. In the absence of such evidence, the default assumption seems to be that the foundations of causal cognition are not only culturally invariant, but non-cultural. This perspective is problematic for at least two reasons.

First, the prime reason for any absence of such evidence is the paucity of studies that systematically test components of causal cognition in diverse cultural settings (cf. Henrich et al., 2010; Medin, Bennis, & Chandler, 2010). Only if we investigate the potential of cultural impact can we draw any inferences on whether a component of causal cognition is or is not universal. In the few cases that effectively attempted this, the findings do point to a striking potential for cultural diversity (cf. Bender et al., 2017). If we take into account that the prime source for content—cultural transmission—is an extremely powerful agent of diversification, and that even its key mechanisms are culturally patterned, this should not actually come as a surprise. It is thus well possible that, when turning unconnected facts into a story (as in the introductory example), other people may attribute the cat's jump directly to the sneeze, rather than to the woman's flinch; may refer to more distal causes, such as the boy having caught a cold; or may simply denote the most important outcome: "A glass got broken". In short: Even if all people alike *knew* that breaking glasses result in spilled water, it is still likely that the ways in which they pay attention to, encode, and communicate this information would differ.

Second, while investigating the potential for, and extent of, cultural diversity in causal cognition would be a valuable goal in and of itself—a goal that is still all too often sidelined in this research field—it should not deflect our attention from the fact that culture permeates causal cognition even when *not* generating any cultural differences. As we pointed out earlier, content-relevant information can be gained from one's own experiences and inferences. In fact, even what one learns from others must, at some point in time, have been arrived at by somebody. Systematic observations improve an understanding of regularities and provide hints at causal relationships. For the most transparent domains, ensuing accounts can be scrutinized, which is why many of them have a substantial probability of converging over time and across cultural settings. After all, this is what has helped humans throughout history to develop tools and techniques, improve their understanding of weather and solids, or their means for subsistence and navigation. The fact that we do find similar patterns in some domains of causal cognition is therefore arguably not so much due to innate knowledge, but rather an outcome of the convergence in learning from interaction with the world—simply because the world to which most of it refers is the same for all human populations. For instance, the insight that harvesting success in agriculture can be improved by fertilization and irrigation has been achieved independently in different parts of the world. Likewise, the knowledge of how to construct boats for sailing, how to determine time and position based on the constellation and movement of stars, or how to use plants for treating diseases attests to the corrective power exerted by the world on emerging cognitive models. Still, most of this causal knowledge would be unavailable to any human if it were not passed on to them from previous generations. The accumulation of knowledge, its integration into explanatory frameworks, and its sharing through cultural transmission lay the foundation for almost all daily-life endeavors in causal cognition.

So, even if the patterns of sociality, teaching, and language worked in exactly the same manner across cultures, there would be no need—and in fact no reason—to assume that what people come to believe is the same across cultures; too diverse would be the starting points, too random new discoveries, too prone to alteration the process of transmission. And even if their outcome did not differ across cultures, these key enablers of cultural transmission would still leave their mark on causal cognition in distinct ways. For instance, if all humans alike conceived of individual persons as independent from their group, one consequence would be a generally stronger focus on dispositional factors when accounting for behavior. As suggested by tentative empirical evidence (Beller et al., 2009b; Peng & Knowles, 2003), the social concepts of persons and their psychology may even spill over to other domains, affecting not only how reasons and motives are attributed to other people, but also how causes and effects are inferred for non-social events.

To put it simply, causal cognition in humans is superimposed—from the start—by a cultural layer. This layer is not only provided as part of cultural learning, but may vary across cultures, both in terms of the content added, and in terms of the degree to which it is considered relevant. Even in the absence of cultural differences in people's responses to causal tasks, however, what they base their responses on is still a complex result of generally human processing abilities, individual development, and cultural upbringing. Undoubtedly, humans do possess general cognitive abilities that help them to process causally relevant information in almost universal ways, and they do make use of them. But they do not make use of them in every situation that requires causal explanations, and they do not use them in ways that are unaffected by their own cultural nature. This renders culture a constitutive feature of causal cognition early on, and even before substantial cultural differences in causal cognition may have emerged.

Implications and Open Questions

If we accept that causal cognition in humans is unique because of the profound impact of culture, then research in this field must take this impact into account in both theorizing and study designs. A more comprehensive perspective including both the cultural diversity in, and the cultural fabric of, causal cognition is essential for any attempt to understand the complex interactions in the world people live in and the way in which they deal with these interactions.

The former task, understanding interactions in the world, is undertaken by researchers in the natural sciences, the latter by researchers in the various fields of the cognitive and social sciences. All of these scientists are members of a cultural species, and were brought up in a specific cultural setting that includes a specific type of education. Understanding that each and every causal account we may come up with bears the stamp of culture in general, and likely that of one or more cultural traditions in particular, may therefore help us to uncover blind spots even in scientific enterprises. For instance, the explanatory frameworks dominating Western world-views made it more difficult for biologists trained at Western universities to recognize, or even search for, evidence of deliberate cross-species cooperation in animals (Ojalehto et al., 2015) or of kin recognition and support in plants (Ojalehto et al., 2017a, 2017b). Likewise, for decades, the theory of mind prevalent in Western Europe and North America guided how psychologists conceptualized and investigated agency (Lillard, 1998; Morris et al., 2001).

Given that cultural impacts on causal cognition are still hugely understudied, open questions abound. For instance: How profound are the observable differences in causal accounts across cultures, and how thoroughly do these differences in content affect the processing of information? Data on the former are available in principle, but are often hidden in extensive ethnographies and are therefore not easily accessible in a systematic manner. Research on the latter indicates that respective effects may be substantial (overview in Medin & Atran, 2004). One domain in which differences in content are particularly pronounced is ethno-medicine. Causal models of illness vary substantially both within and across cultural groups. These models have implications for how an illness is experienced, what type of information about an illness is regarded as essential, and how an illness is treated (Luhrmann, Padmavati, Tharoor, & Osei, 2015; Lynch & Medin, 2006). But even though findings like these were ground-breaking, very few studies picked up on them by actually investigating the mutual dependence of content and processing in other domains of causal cognition.

Another set of questions revolves around how profound cultural differences in the key mechanisms of cultural transmission are. With regard to the patterns of sociality, the focus of interest has been placed almost exclusively on the individualism/collectivism dichotomy and related concepts, at the expense of other dimensions along which sociality may also vary, such as the relative proportion of values (e.g., security or conformity) emphasized in a given cultural setting (Schwartz, 1994, 2012), or the patterns in which relational models (i.e., communal sharing, authority ranking, equality matching, and market pricing) are combined to organize social relationships (Fiske, 1992). Differences along alternative dimensions may have similarly serious implications for causal cognition. For instance, while a strong valuation of conformity might attenuate a concern for underlying causes in favor of outcomes, a valuation of security is more likely to stimulate causal and counterfactual reasoning. Such implications, however, have barely been investigated.

With regard to teaching, the focus of interest has been placed on those strategies prevailing in the Western middle classes, at the expense of alternative strategies (Lancy & Grove, 2010; Rogoff, 2003). A teaching approach based on apprenticeship affects whether and how children ask for explanations or engage in causal exploration. But again, more research is needed to survey the extent of diversity in this field and to investigate its implications. For instance, while apprenticeship capitalizes more on (over-)imitation than instruction-based teaching does, it might, in the long run, encourage learners more strongly to explore underlying causal structures on their own, compared to those who receive explicit instructions and explanations. The increased embodiment involved in active exploration, in turn, arguably affects how causal information is processed. In view of recent evidence that overimitation is not observed in some cultural groups (Berl & Hewlett, 2015), and that asking why-questions is not equally pronounced across cultures (Gauvain et al., 2013), it would thus be important to shed more light on the details and scope of cultural learning in a more diverse range of cultural settings.

The emerging trend to investigate mental reasoning and theory-of-mind abilities across cultures is an important step in this direction, but such attempts need to be extended to causal cognition more broadly. Whereas cultural groups that emphasize mental states may provide their children with a head-start in theory-of-mind reasoning and in folk psychology more generally, groups that deemphasize them in favor of relations and concordant behavior may instead provide a head-start in relational reasoning and in folk sociology. If true, this could also explain the cultural differences in attribution often accounted for in terms of collectivism versus individualism and of related frameworks.

Differences in language are also more profound than had long been assumed (Evans & Levinson, 2009). The question of whether such differences may have implications for cognition has been the subject of controversial debate for decades, but causal cognition in particular has attracted little attention in this regard—despite the fact that language may be the most important tool for grasping a concept as elusive as causality.

Finally, all those questions revolving around the evolution of causal cognition require revision if we change the perspective from which of its components are inherited to how culture enables people to expand on these shared foundations. If we take for granted that humans are more strongly interested in causal mechanisms than their closest relatives, the question arises of which selective pressures would have favored this interest in just our lineage. How important was it, in turn, for the emergence of the key mechanisms that enable cultural transmission, and was it itself simply a corollary of, or a driving force in, the emerging possibility to exchange ideas by way of language? And if human children really possess an innate body of knowledge on causally relevant properties and relations, how and when would this core knowledge have evolved?

In order to address questions like these, concerted efforts across disciplines, timescales, and levels of analysis appear to be the most promising way forward in this field of research. Such interdisciplinary collaboration would, however, presuppose a reorientation of the field, which remains dominated not only by an acultural approach, but also by a good deal of conceptual and methodological narrowness. The prototypical project in this field investigates how individuals (human and non-human) infer and reason about cause-effect relations.

Insofar as the extraction of information on regularities and causal structure is regarded as key, the adopted methods prioritize context-free, and hence often artificial or even fictitious tools and scenarios. The prevailing disregard for cultural impacts is reflected in a methodological disregard both for sample diversity and ecological validity. On conceptual grounds, the perspective advocated in this paper—that causal cognition should be understood as including the concepts, models, and theories that inform people's cognitive processing—is by no means consensual in the field. And the inclusion of social agency as an exemplar of causal cognition is well-nigh controversial. Yet, the conceptual distinction between (physical) causes and (social) agency is one of precisely those culturally inherited presumptions that Western psychologists impose on the research field. With a relational rather than a dispositional perspective (cf. Ojalehto et al., 2017a, 2017b), the boundaries not only between these domains (Rothe-Wulf, 2014), but also between artificially secluded research fields, might well dissipate.

Conclusion

The ability to use one's understanding of cause-effect relations for changing the course of events in a manner beneficial to oneself is so advantageous that its foundations evolved in several species independently. In human evolution, it is even claimed to be the "one cognitive competence that underlies all later human achievements" (Stuart-Fox, 2015, p. 249). Here, we have argued that the specifically human brand of causal cognition was made possible—and as a consequence continues to be molded—by human culture, and that it is this impact of culture that reflects a profound discontinuity between human and non-human causal cognition. Cultural transmission of knowledge and beliefs, which constitute the content so important in human causal cognition, as well as the mechanisms that enable this transmission, are extremely powerful agents of diversification. Investigating the range of this diversity in causal cognition should thus be of paramount interest in this field of research. Equally essential for advancement is the acknowledgement that even those cognitive concepts and processes that converge across cultures are still a product of human culture. If we ignore the dual role of culture—as the fabric of causal cognition and as a driver for its diversification—a comprehensive understanding of one of our core capabilities will be out of reach.

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