Trends in Cognitive Sciences

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REVIEWS

Review

Individual Representation in a Community of Knowledge

Nathaniel Rabb,[1,*] Philip M. Fernbach,[2] and Steven A. Sloman[3]

An individual's knowledge is collective in at least two senses: it often comes from other people's testimony, and its deployment in reasoning and action requires accuracy underwritten by other people's knowledge. What must one know to participate in a collective knowledge system? Here, we marshal evidence that individuals retain detailed causal information for a few domains and coarse causal models embedding markers indicating that these details are available elsewhere (others' heads or the physical world) for most domains. This framework yields further questions about metacognition, source credibility, and individual computation that are theoretically and practically important. Belief polarization depends on the web of epistemic dependence and is greatest for those who know the least, plausibly due to extreme conflation of others' knowledge with one's own.

Highlights

The knowledge that supports many of our beliefs and attitudes resides not in our own heads, but in a community of knowledge constituted by other people, artifacts, and information repositories (e.g., libraries or the Internet).

Individuals are poor at distinguishing knowledge that is in their heads from knowledge that resides in the community. This leads them to overestimate how much they know or understand merely by participating in a community of knowledge.

This failure of differentiation has implications for public discourse. Extreme views about science and politics have been found to covary with knowledge overestimation.

Modeling individual cognition under collective knowledge is an emerging challenge for cognitive science.

The *a Priori* Case for Collective Knowledge

Consider the following statements: (i) smoking causes lung cancer; (ii) vaccines cause autism; (iii) natural selection causes animal features; (iv) God causes animal features; and (v) a secret cartel of bankers causes financial market variations. These statements share three important characteristics. First, they are consequential representations of relations in the world; an individual accepting one as true has a belief about the way things work that affords inferences and informs actions. Second, the truth of each depends on underlying mechanisms that are difficult or impossible to observe. Third, none can be independently verified by the individual because empirically testing them is either prohibitively difficult or impossible *a priori*.

Affirming any of these statements implies acceptance of a set of beliefs about how the world works: an abstract causal model. People adopt abstract causal models in large part because others tell them they are true. Therefore the process of representing the world is collective in a straightforward sense: an individual's beliefs depend on the beliefs of those around them. However, people also adopt causal models because various bits of evidence support the presence, or in the best cases, the details, of a plausible underlying mechanism. Still, much of this supporting evidence is also difficult or impossible to verify. To say that I believe smoking causes lung cancer or God causes animal features because Doll and Hill (1954) [1] showed that heavy smokers were 40 times likelier to die of lung cancer or Behe (1996) [2] showed that the complexity of nature cannot arise spontaneously, respectively, sounds more convincing than simply declaring the statements true by fiat. However, this evidence is yet more testimony. You can read the cited documents, but unless you happen to be an expert in population studies or cellular biology, you are in no position to judge whether the conclusions follow from the evidence marshaled. More to the point, regardless of your particular area of expertise, you are in no position to ascertain whether the events they describe really happened. Compounding the issue, the people who generated this evidence were in a similar position; they relied on the testimony of their forebears, colleagues, research staff, and so on.

[1]Department of Psychology, Tufts University, Medford, MA, USA
[2]Leeds School of Business, University of Colorado Boulder, Boulder, CO, USA
[3]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, Providence, RI, USA

*Correspondence:
natrabb@gmail.com (N. Rabb).

This web of **epistemic dependence** [3] (see Glossary and Box 1) gives trust in the testimony of others a central role in cognition, a fact well noted in developmental research [4]. However, it also makes the process of representing the world collective in another, complementary way. When an individual with no knowledge whatsoever of the relevant biology says 'smoking causes lung cancer', the claim is effectively underwritten by experts' presumed knowledge of the underlying mechanisms, a point that Putnam [5] made about word meanings but that comfortably transfers to causal representations. In these everyday cases, the individual's claim and, thus, their concomitant representation depend on details that they did not ever have (much less verify), and this is true even at the most advanced levels of knowledge [6] (Box 1). For this reason, theorists have claimed that the knowledge we rely on as individuals 'exists somewhere, just not in our heads' ([7], p. 150), that 'cognitive acts depend in general on a 'community of knowledge'' ([8], p. 86), and even that one's mental states could be 'partly constituted by the states of other thinkers' ([9], pp. 17–18). Such claims suggest a tantalizing picture of knowledge representation as an emergent phenomenon: an object found not in one or another person's head, but in the aggregation of the contents of many heads. The question we address here using recent evidence is how to cash out these claims without the need to posit extrasensory perception (ESP), a collective consciousness, or other theoretically loaded possibilities. The further question of whether a group can have knowledge is a live one [10], and there are convincing arguments that groups of organisms can have cognitive properties [11]. However, our concern here is with individual-level processes and how they support a community of knowledge, regardless of whether this phenomenon is best characterized as an emergent entity.

Three Varieties of Knowledge Representation

Some kinds of representation have relatively minimal dependence on other people's representations. For instance, episodic memory is defined with respect to a person's own subjective experience, although episodic memories include semantic elements [12] likely to depend on knowledge stored by the collective, and work on **transactive memory** [13] shows that some

Box 1. Epistemic Dependence All the Way Down

The conception of knowledge as a possession of the individual (arguably a product of Enlightenment-era unease with the monopolies of monarchs and churches on truth [122]) has lately come under philosophical attack. Although key themes in social epistemology are seen as early as Coady [125] or Goldman [126], and recent efforts explicitly link the project to hypotheses about **extended** or **distributed cognition** [127,128], Hardwig's work [3,129] best captures the intuitions driving this review (see also [124]). To illustrate why the individualist conception of knowledge requires revision, he gives the example [129] of hearing on NPR that coffee drinking may cause heart disease (C→H). If this event means he now has reason to believe C→H, then we face a dilemma. Either it is rational to believe C→H not because he has direct evidence, but because he believes NPR had reason to believe that the *New England Journal of Medicine* had reason to believe that the research scientists had reason to believe that their laboratory technicians had direct evidence, or else this belief and all others so formed (meaning most) are irrational. The social nature of knowledge in no way entails a relativist or postmodern view of truth; on the contrary, it is assumed that veridical representations of the world afford effective action, the goal of any cognitive system [130], and this assumption requires there be facts of the matter. Thus, the conclusion that beliefs about the world formed this way are inherently problematic should be avoided, and the task becomes examining the epistemic status of representations formed by these chains of appeals to authority.

Critically, experts and laypeople are in similar epistemic positions even though the granularity of their representations may differ. A physicist tells Hardwig [3] that, among his 98 co-authors on a paper, many could not say exactly how a given number in that paper was determined because they handled other aspects of the experiment. Strevens ([6], pp. 160–161) explicitly connects this thought to Type III (markers for) knowledge, which he considers part of normal scientific practice: 'The evolutionary biologists can explain selection events using models that **black-box** genetic and ecological processes; the geneticists can explain inheritance phenomena using models that black-box molecular processes; and so on'.

Although he is discussing explanations, the implications for individual cognition are clear. It would take a lifetime for experts in one field to learn the causal relationships known by experts in all related fields. Experts' mental representations (as well as their explanations) normally include 'black boxes' pointing to other experts' knowledge.

Glossary

Black-boxing: inserting markers in one's causal models that indicate contents assumed to be represented by others.
Cognitive offloading: reducing the information processing demands of a task by placing some of the burden elsewhere (e.g., counting on one's fingers, writing notes, or expecting others to remember).
Contagious sense of understanding: the effect whereby people increase judgments of their own understanding of some phenomenon because they believe others in their community understand it.
Distributed cognition: a theoretical framework that holds that cognitive processes are performed by multiple separate units; note that distributed cognition entails extended cognition but not vice versa.
Division of cognitive labor: how a cognitive task is distributed among agents.
Epistemic dependence: a state of affairs in which the truth of one's beliefs depends on the truth of those of others; under the community of knowledge framework, this applies to all beliefs that rely on testimony.
Extended cognition: a theoretical framework that holds that cognitive processes depend on elements outside of the individual.
Feeling of another's knowing: metacognitive awareness of another person's knowledge self-assessment.
Illusion of explanatory depth: the effect whereby people decrease judgments of their own understanding of some phenomenon after being asked to explain it in detail.
Transactive memory: the division of cognitive labor in memory; in a transactive memory system, members of a group represent each other's areas of expertise to selectively ignore information better retained by co-members and/or draw upon co-members' likely knowledge when it is needed.

memories are distributed across groups based on members' expertise. Procedural memories really do appear to be housed in the neural hardware of the agent, although even these can be misassessed after observation of others' procedural knowhow [14].

Our focus here is on representations of facts about the world and the way it works. We suggest that this kind of knowledge comes in three levels of detail: I highly detailed knowledge, which people have in a necessarily small number of domains (Type I); II broad and superficial knowledge, which people typically have for many domains (Type II); and III empty metaknowledge (Type III), that is, markers indicating knowledge housed elsewhere. Although we describe each separately for ease of explication, causal detail comes in degrees and individuals might have more or less of it for any given domain.

Detailed Knowledge in a Small Number of Domains

An individual's main contribution to the community of knowledge is through the expertise they offer in situations where they have a relatively high degree of domain knowledge (regardless of credentials [15]). People tend to have expertise about a few things, such as foci at school or work or as hobbyists, and personal things, such as family histories, life stories, and current environment (nobody knows the contents of your desk like you do). Exactly how expert and novice knowledge representations differ is beyond the scope of this review (cf. [16,17]), but we take it as given that they differ, and in particular, that expert representations are more detailed and fine-grained.

Our areas of expertise are necessarily few relative to the number of areas that are relevant to us. An individual can only master a small fraction of the complex issues that govern an election, of what must be done to build a modern building or run a company, of the available scientific knowledge, and so on. Thus, the average person knows remarkably little about politics [18,19], science [20], personal finance [21], or even how a bicycle works [22]. The world is overwhelmingly complex, and any individual can only master a small part of it. We depend on others' expertise all the time.

Superficial Knowledge about Many Things

Despite our limited expertise, humans operate flexibly and adaptively in the broad range of situations that confront us. More often than not, we depend on others' expertise for details, but we generally share enough superficial knowledge with experts and others to participate in an action or a conversation.

Much of the evidence for the superficiality of knowledge comes from studies of the **illusion of explanatory depth** (**IoED** [23]). Participants are asked to judge their understanding of an object, attempt to explain it, then rerate their understanding. People tend to be surprised by how poor their explanations are and decrease their judged understanding when rerating. The initial studies showed the effect for common artifacts (e.g., zippers and bicycles [22,23]) and natural processes (e.g., tides and rainbows; [23]), but the IoED appears to be pervasive and occurs for a wide range of complex causal systems (political policies [24–26], psychiatric disorders [27],or historical events [28]). People also overestimate their ability to distinguish semantically related terms (e.g., 'disease' and 'syndrome'), suggesting that knowledge of word meanings also tends to be superficial [29], as Putnam [5] proposed.

The pervasiveness of the IoED suggests that we are not in the habit of attempting to unpack our knowledge of how things work. Indeed, the effect is diminished for people asked to reflect on the mechanistic details of objects [30] or who are more reflective by nature [31]. Our superficial

knowledge is usually enough to adapt to a situation. We may not be lawyers, but we can understand a court case well enough to tell a story about it; we may not be football experts, but we can enjoy a game. We generally know enough to share common ground with others and situate ourselves correctly.

Markers for Knowledge Housed Elsewhere

Still more of what we know comprises markers for information that resides outside of our heads. The use of such markers implements a kind of **cognitive offloading** [32], and these markers can be either pointers to specific locations or mere placeholders. For instance, we retain pointers indicating the location of information initially available but now forgotten; we remember where we made notes but not what they said, or jettison information that we know can be retrieved from a computer or a camera [33–35]. Similarly, in classic transactive memory experiments, two individuals exposed to the same information selectively forget items that they expect their partners to retain based on knowledge of their partners' areas of expertise [36,37]. Here, the location is another person rather than an artifact, but the process is analogous: initially available information is not retained, and its location outside of the body is represented instead.

People also maintain placeholders marking likely locations of information kinds. In some cases, these locations are specific artifacts or people: if we wish to know something about population studies or cellular biology, we might know which text to read or whom to ask. Transactive memory findings show the value of such placeholders. In studies of working teams, the correlation between a team member's assessments of co-members' topic knowledge and those co-members' self-assessments predicts objective measures of team performance [38–40]. In these cases, the assumption of knowledge is based on specific experiences (i.e., interactions with co-members revealing their domain-relevant knowledge).

In other cases, people retain placeholders marking assumed knowledge without specifying its location. Adults are good at judging what sorts of experts likely contributed to a highly technical scientific finding, and their ability to make these judgments is unrelated to the extent of their relevant scientific knowledge [41]. The ability to accurately represent this **division of cognitive labor** develops early [42], and children begin to ascribe specifically causal knowledge to experts soon after [43].

A Framework for Individual Cognition under Collective Knowledge

This taxonomy of knowledge suggests a model of what individuals retain to operate in a community of knowledge. To successfully navigate a complex world despite the inherent limitations of individual cognition, a person must enhance their meager resources by taking advantage of those of others. The simplest way to do so is to scaffold one's own superficial (Type II) knowledge by retaining markers (Type III) indicating the external location or presumed existence of in-depth (Type I) knowledge. The idea is depicted in Figure 1. In Figure 1B, we see individuals who have only superficial knowledge that C causes E (e.g., Carbon in the atmosphere causes Extreme weather events). The justification for the superficial belief is found in the heads of experts (Figure 1A). The experts retain a more detailed causal model of how C causes E that both supports and elaborates on the beliefs of nonexperts.

This system affords rough and ready reasoning about all manner of phenomena. Even when an individual reasoner's understanding is shallow, as long as it is faithful to experts' knowledge, it will provide correct (although superficial) answers to potentially important questions, such as 'should we reduce the amount of carbon in the atmosphere?' and 'why are there more extreme weather events?'. The markers in this case indicate that deeper explanations are available.

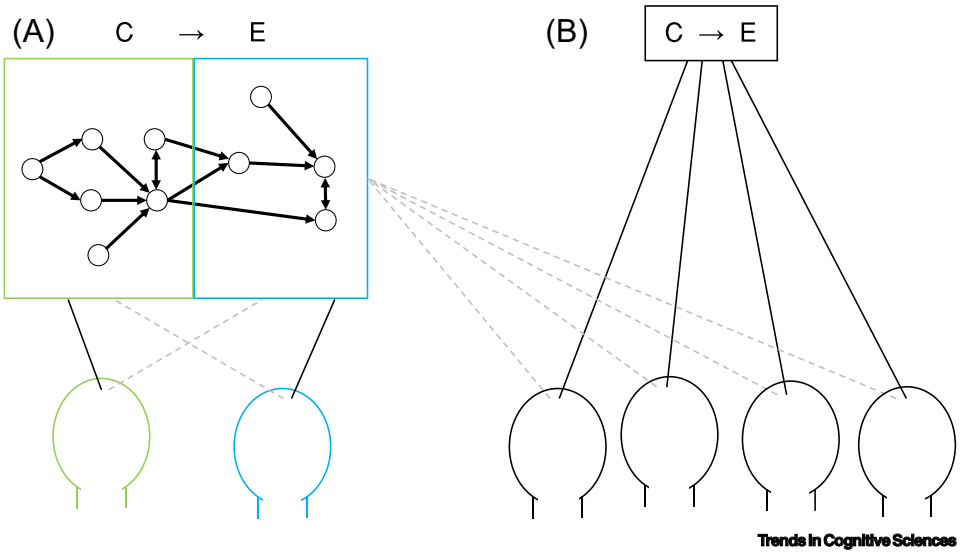

Figure 1. Three Kinds of Representation Support Collective Knowledge. Solid lines indicate information stored by the individual; dotted lines indicate awareness that information is stored elsewhere. The lay people in (B) represent that C causes E (Type II knowledge) but also represent (Type III) that experts have the Type I details of the underlying mechanism. The experts in (A) do indeed represent the mechanism (Type I knowledge), but the scope of each's expertise is restricted to a part of the larger phenomenon. Thus, the experts also have Type III knowledge: each knows that the other has a more detailed representation where their own knowledge stops. In the illusion of explanatory depth (IoED), lay people overestimate their own understanding, that is, they mistake their Type II knowledge for Type I knowledge, because they have Type III knowledge that is not distinguished from the Type I knowledge it marks. Under normal circumstances, this marking is sufficient since Type I knowledge can usually be obtained; thus, Type II knowledge is sufficient for ordinary reasoning and discourse.

The fact that superficial beliefs depend on experts' knowledge means that the answers even to superficial questions depend on the veridicality of expert knowledge.

Notice that, in normal circumstances, individuals derive no benefit from maintaining an index of exactly who retains every bit of knowledge. As long as one can access the information, such an index provides little benefit and would impose a substantial cognitive burden. On occasion, the failure to realize that one's knowledge includes markers does impose a cost, a form of overconfidence: People will tend to think that they can answer questions that they cannot. The IoED illustrates this. However, most of the time, it is not worth the effort.

The notion of markers for expert knowledge is hardly new; it has been discussed at length in the study of conceptual structure under the guise of 'essentialism' [44–46]. There, the idea is that individuals do not have access to the latent causes of observable properties; they rely on placeholders for experts to fill in the defining features and root generative causes that explain why objects have the properties that they do. The framework we defend gives markers a broader role than as stand-ins for essences. Markers can stand in for any detailed knowledge, whether it refers to root causes or mediating mechanisms.

Empirical Support for the Framework

Placeholders Are Conflated with Their Contents

The IoED suggests that people's knowledge tends to be more superficial than they initially estimate; the explanation attempt reveals their knowledge representations to be superficial Type II rather than detailed Type I. However, this framework also provides an explanation for

the IoED, namely, that this overestimation is caused by people confusing markers (Type III) for the knowledge itself (Type I). Further evidence for this possibility comes from the fact that mere access to the largest collectively generated information store in history, the Internet, increases people's assessments of their own thinking skills [47,48] and confidence that they can correctly answer questions without using the Internet [47,49] (Figure 2). Given the historical novelty of the Internet, it might be thought that conflation of others' presumed knowledge with one's own in these studies is an artifact of emerging technologies rather than a stable feature of cognition (see [50] for related discussion). However, egocentric bias in source monitoring errors has been directly observed in studies of the social contagion of memory (i.e., where the information source conflated with the self is a dyad partner rather than the Internet) [51], and even in studies of twins' childhood memories [52]. The inverse conflation, ascribing knowledge one does have to others who do not, has also been observed [53,54].

Additional evidence for markers indicating assumed knowledge comes from studies showing a **contagious sense of understanding**. These experiments [55,56] (Figure 2) manipulated presumed collective knowledge by stating that experts do or do not understand complex systems (fictional natural phenomena or political policies) while providing no explanatory information. Participants reliably rated their own understanding higher when told that others understand, and the effect was observed in between- and within-participants designs, despite warnings that the phenomena were difficult to understand meant to alleviate pressure to over-rate so as not to look foolish, irrespective of people's political ideologies, and when scale anchors emphasized that judgments should reflect respondents' own understanding. Critically, the effect did not occur when others understand but the information is impossible to access, a result consistent with the utility of markers that also suggests the effect is not caused by reduced ratings when others do not understand [55]. Another study [27] measured rather than manipulated collective knowledge, with similar results: Participants' rated understanding of psychiatric disorders tracked how well they believed society understands the disorders. In a related finding, people rated the quality of circular explanations ('That *X* did what it did because it's an *X*') higher when the name of the phenomenon ('*X*') was designated by the community rather than assigned ad hoc by an individual [57].

These findings suggest that, as our knowledge framework predicts, metacognition does not reliably distinguish one's own from others' knowledge. Why should it? In normal cases, the location of knowledge is not important as long as it can be retrieved when needed. Obviously, we are often able to distinguish our knowledge from that of others. Our point is that doing so does not happen automatically.

Collective Knowledge Allows Outsourcing of Conclusions

The claim that people only have expertise in a small number of domains predicts that people often outsource their conclusions, drawing on others to determine which beliefs to endorse rather than thinking through issues themselves. Strong direct evidence comes from the many demonstrations of the immense power of political partisanship. All else being equal, partisan cues dictate which policies people support [58–61], which scholarship candidates they consider more deserving [62], which faces they find more attractive [63], which experts in an irrelevant domain they trust [64], and whether they report remembering national events that did not in fact occur [65,66]. Many political scientists see default reliance on partisan cues as adaptive for reasons consistent with the present framework: When detailed information is not available, but a judgment is required, trusting the conclusion of one's group is often a reasonable shortcut (see [67] for discussion).

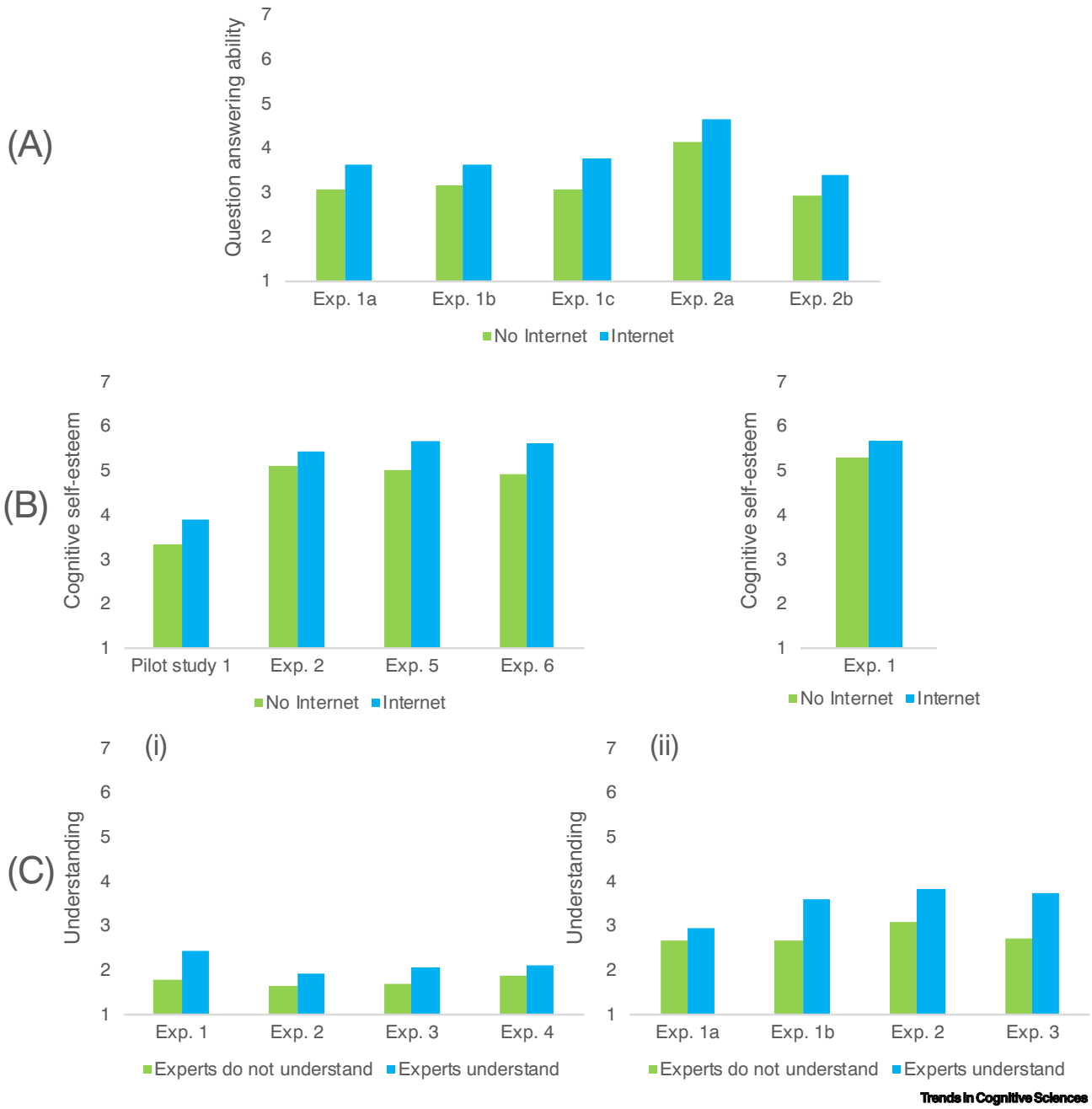

Figure 2. Making Collective Knowledge Salient Increases Knowledge Self-Assessments. Collective knowledge salience was manipulated either by asking respondents to use the Internet to answer questions (A,B) or by informing them that relevant experts have the knowledge (C). Dependent measures specifically queried respondents' own knowledge assessments: (A): 'How well could you answer detailed questions about [topic] similar to these?' [49]; (B): the Cognitive Self Esteem scale (agreement with sentences such as 'I am good at thinking') [47,48]; and (C): 'How well do you understand how [phenomenon] works?' [55,56]. One objection to the claim that this constitutes evidence of self/other knowledge conflation is that people could have interpreted 'you' in a plural sense and were aware that they were failing to distinguish their own knowledge from that of others. Yet, the same patterns were observed when respondents were instructed to answer assuming no access to outside sources [(A) [49], Experiment 2b], when they estimated the activity associated with knowledge retrieval in their own brain [(A) [49], Experiment 2a], and when scale markers minimized this ambiguity [(Ci) [55], Experiment 4].

Cues Indicating Collective Knowledge Increase Sense of Understanding

Finally, if an individual's sense of understanding is sensitive to the presence of markers for expert (Type I) knowledge, then cues merely suggesting (as opposed to direct assertions of) such knowledge could also generate markers and, hence, inflate people's sense of understanding. There is now substantial evidence that people prefer explanations with nonexplanatory scientific jargon over identical explanations without this jargon [68–72]. A plausible interpretation of this finding is that the jargon serves as a cue that experts understand [73].

Implications for Public Discourse

Public discourse at the time of writing is unsettling, too often insular and hostile. Interlocutors from opposing teams have trouble listening to one another, questions asked go unanswered, and answers often miss the topic at hand. Perhaps even more exasperating is the extent to which individuals maintain vociferous, unshakeable attitudes about complex issues that they do not understand deeply. Many people have strong, enduring attitudes about issues such as genetically modified organisms, global warming, and vaccination, despite a demonstrably shallow understanding of the relevant mechanisms [20,74].

The conventional account of this failure to communicate, the 'deficit model' [75], appeals to lack of information about the objects of judgment. On this view, people are too ignorant to appreciate the other side, ignorance leads to reliance on loud voices or group consensus (sources that might also be uninformed), and this leads to polarization. If only people were better informed, they would be able to discuss issues in a more constructive way. The standard method to try to overcome these deficits is to use education to change attitudes and foster productive public discourse. Recently, however, the deficit model has been challenged on the grounds that educational efforts rarely work [76]. In its place, a different model, 'cultural cognition', posits that attitudes are determined by shared cultural values, not by knowledge [77].

Both of these accounts are valuable, but they are incomplete because they do not consider the distributed nature of knowledge. Individuals' attitudes are underwritten by knowledge that exists in the community, but, as we have discussed, individuals often do not realize that they do not have enough knowledge in their own heads to justify an extreme attitude. As a result, unjustified attitudes can become entrenched because members of the community do not do enough to check their understanding. Recent evidence suggests that extreme scientific and political views are often associated with extreme overestimation of knowledge. This has been shown for opposition to genetically modified foods, gene therapy [78], and vaccination [79], in antiestablishment voting in a European referendum [80], and even in perceptual judgments [81]. The distributed nature of knowledge may also help explain why people accept fake news that comes to them through their community [82].

Concluding Remarks and Future Directions

This framework of collective knowledge raises new empirical questions (see Outstanding Questions). First, what makes a cognitive community? Different communities might recognize different sets of experts for the same domain [83] and so may hold competing causal beliefs. Sometimes, one set of experts is acting in bad faith (see [84] for discussion). However, modeling results show that two groups can arrive at opposing beliefs even when all parties update rationally from the same evidence [85–87]. This raises the question: does the contagious sense of understanding conferred by awareness of community knowledge require community co-membership? Prior work suggests it does, since people are more likely to accept claims from ingroup than outgroup members [88,89]. If so, how does community affiliation stack up against more commonly considered dimensions of source credibility (e.g., honesty and expertise [90])?

Outstanding Questions

How does the contagious sense of understanding conferred by awareness of collective knowledge depend on whether the knowledge is held by one's own community? Does community affiliation override or interact with more commonly considered dimensions of source credibility, such as honesty or expertise?

Given that the contagious sense of understanding is a metacognitive assessment, are more well-studied phenomena, such as confidence judgments and feelings of knowing, really judgments of collective rather than individual knowledge?

What computational processes allow individual representations to aggregate into veridical collective knowledge?

The observation that different communities have different experts raises another issue: when and why people trust experts [91,92]. Recent evidence suggests that people use various cues to adjudicate between conflicting expert claims, including superficial indicators of understanding (e.g., bar graphs [93]) or signs of vested interest ([94]; see also [95]). Although an integrated model of expertise perception and selection is beyond the scope of this review, the topic is timely given the present ease of accessing and repeating expert claims. Worryingly, merely repeating a claim increases belief in it [96,97], even when a single, expert information source is repeatedly cited, thus indicating that the repetitions do not constitute independent evidence [98].

Second, the contagious sense of understanding emerges from a metacognitive assessment, and more traditional metacognitive judgments are sensitive to others' as well as one's own representations. Confidence judgments track consensus more than accuracy when the two pry apart [99]. And an individual's feeling of knowing is conveyed through auditory and visual cues to others [100] whose subsequent **feeling of another's knowing** shows a distinct neural signature [101,102]. This raises the question: to what extent do metacognitive judgments in general reflect inferences about the knowledge of the collective rather than one's own knowledge?

Finally, what would a computational model of collective knowledge look like? Individuals are relatively ignorant, yet our species has succeeded in everything from collaborative physics and engineering that puts people on the moon to collaborative construction of buildings that do not fall down. Is this because collective behaviors arise entirely through local interactions with the environment and information sharing with others [103,104]? We have noted various cues people use to assess a claim (indicators of honesty, expertise, and community membership; and frequency of repetition [96,97]), and there are other plausible candidates (e.g., 'bandwagon cues' indicating popularity [105]). Perhaps these cues serve as individual-level information that facilitates the construction of collective knowledge, much as termites construct colonies without an executive controller that represents the finished product.

However, humans do represent their end goals and, when they can, try to understand what it takes to achieve them. Still, laypeople's causal models are coarse; to be accurate, they must be filled in by experts' more detailed representations. Accuracy requires that laypeople's and experts' models are compatible: They must be representing the same things at different levels of detail and they should make at least roughly consistent commitments and claims. Admittedly, causal beliefs can be inconsistent even within an individual [106,107], never mind between people, and experts do not always agree. However, to the extent that communities succeed in understanding, changing, and predicting the environment, the community's experts must have it right. There must be some agreement among laypeople and experts, and among experts themselves, or else buildings would fall down, and societies would immediately fail. Some recent formalisms, such as recursive Bayes nets [108], might offer a way to describe the kinds of nested representations a community would require (see [109] for discussion), but the issue awaits a thorough investigation.

The community of knowledge thesis joins a growing body of work proposing that features of individual cognition (e.g., reasoning [110], autobiographical memory [111], and metacognition [112]) are best understood by considering their roles in group behavior. Applied to knowledge representation, this perspective marks a departure from some traditional topics in cognitive science. For instance, the extensive literature on causal learning from direct observation [113] examines the processes that generate but a small fraction of actual causal beliefs. In addition, studies on the continued influence effect or the social contagion of memory may omit a key variable when ignoring information source credibility (cf. [114,115]). By contrast, topics less commonly

associated with individual cognition are likely critical for understanding individual representation in a community of knowledge; for instance, how network structure affects information spread [116–119] or how intraindividual dynamics affect collective intelligence [120] and group decision making [121–123]. Perhaps most important, this perspective reveals a dual aspect to the human project of knowledge formation. On the one hand, the web of epistemic dependence is incredibly powerful and largely accounts for our dominance as a species. On the other hand, its fragility is increasingly apparent, and the growing epistemic emergency caused by the encounter of the system with ever-more rapid and unfettered information spread is cause for alarm.

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