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How cultural evolution can inform the science of science communication—and vice versa

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Cultural evolution research is the study of how cultural traits (e.g., beliefs and behavioral patterns) stabilize, change and diffuse in populations, and why some cultural traits are more "attractive" (i.e., more likely to spread) than others. As such, cultural evolution is highly relevant for the emerging "science of science communication" (SSC) in that it can help organize and guide the study of science communication efforts aimed at spreading scientifically accurate information and inspiring behavioral change. Here, I synthesize insights and theory from cultural evolution with central findings and concepts within the SSC with the aim of highlighting the inherent, but underexplored, consilience between these two fields. I demonstrate how cultural evolution can serve as an unifying framework for the SSC and how, conversely, science communication can serve as a fertile testing ground for applying, exploring, and advancing cultural evolutionary theory in a real-world setting that matters. Lastly, I highlight merits and limitations of previous applications of cultural evolution to science communication and conclude with some particularly outstanding questions that emerge at the intersection between cultural evolution and science communication research.

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Introduction

The "science of science communication" (henceforth SSC) arose as a response to the need for evidence-based practices with which to communicate the findings and methods of science and inspire behavior that is consistent with a scientifically accurate worldview (Kahan, 2015; Kappel and Holmen, 2019). Science and science-based technologies are all around us, and we enjoy their benefits on a daily basis. At the same time, citizens of democratic nations are asked to make personal, social, economic, and political decisions on a host of complicated, science-based issues. And while we have more information at our disposal today compared to any other point in human history, there is also an increased amount of misinformation circulating (e.g., Acerbi, 2020; Bergstrom and West, 2020; Bode and Vraga, 2018; Lewandowsky et al., 2017, 2020; MacFarlane et al., 2020; O'Connor and Weatherall, 2019; Roozenbeek et al., 2020).

SSC is still in its infancy, but as a whole, it has been successful in identifying a range of factors that crucially influence the probability that (mis)information or behavioral patterns spread culturally (for comprehensive reviews, see Jamieson et al., 2017; National Academies of Sciences, Engineering, and Medicine, 2017). These factors broadly pertain to (1) the *content properties* of the information or behavior itself, (2) *individual conditions* (e.g., preexisting attitudes, values and worldviews), as well as (3) *social dynamics* (e.g., social norms and incentives). The main body of this paper is organized around these three sets of factors (see Table 1)[1,2].

Here, I demonstrate how the field of SSC can be fruitfully informed by a consilient field, broadly labeled "cultural evolution". Briefly put, cultural evolution researchers study the stability, change, and diffusion of cultural traits on an aggregate population-level as a function of both the content of the traits as well as the socio-personal dynamics surrounding cultural traits (for an accessible introduction, see Mesoudi, 2016). Cultural evolution research is highly interdisciplinary, methodologically pluralistic, and employs both formal modeling as well as fieldwork and experimental methods to understand the evolution and importance of culture (Creanza et al., 2017). A *cultural trait* (or *variant*; Richerson and Boyd, 2005, pp. 62–64) is understood here as anything that is—at least to some degree—socially transmitted or motivated, including beliefs, knowledge, attitudes, norms, traditions, practices, behaviors, stories, material objects, etc.

Cultural evolution is therefore obviously relevant to the SSC in that it can help identify factors that may increase the spread of accurate information and hamper the spread of misinformation. In addition, at least some cultural evolution researchers share the normative sentiment inherent in the SSC that understanding the origins and dynamics of beliefs and practices can guide campaigns for behavioral change and hence improve the well-being of individuals and societies (e.g., Efferson et al., 2020; Muthukrishna, 2020). However, the obvious connection between cultural evolution and the SSC currently remains underexplored.

Note here that I am advancing an *integrative* approach to cultural evolution in that I draw on theory and insights springing from different strains of cultural evolutionary research, particularly "cultural attraction theory" (Sperber, 1996) and "dual inheritance theory" (Boyd and Richerson, 1985). There is some dispute over the degree to which various strains of cultural evolution research differ in practice and in theory, or whether apparent disagreements mostly stem from differential emphases on various aspects of cultural evolution (e.g., Acerbi and Mesoudi, 2015; Buskell, 2019; Claidière et al., 2014; Morin, 2016; Scott-Phillips et al., 2018). However, for current purposes at least, I do not regard these disagreements as insurmountable to an integrative cultural evolutionary framework (see also Acerbi, 2020; Bendixen, 2019; Mesoudi, 2016).

This paper is not the first to note the obvious applicability of cultural evolution to science communication. However, while previous applications of cultural evolution to science communication issues have been very valuable as first approximations, I argue that they each suffer from important limitations that prevent them from taking advantage of the full scope of an integrative cultural evolutionary framework. I close with a few particularly outstanding questions that emerge at the intersection between cultural evolution and science communication research, specifically pertaining to the interaction between the three sets of factors.

In the following, then, I offer a concise *précis* of cultural evolutionary theory and insights relevant for the SSC. I show how cultural evolution research overlaps with and extends central themes, concepts, and findings within the SSC literature. The aim of this synthesis is to highlight the inherent consilience between these two fields and to provide researchers with a road map to explore this potential synergy more deeply.

In sum, I conclude that cultural evolution can serve as a guiding and unifying framework for the SSC and that science communication, in turn, can serve as a fertile testing ground for applying, exploring, and advancing cultural evolutionary theory in a real-world setting that matters.

Table 1 Overview (non-exhaustive) of the three main sets of psychological and social factors relevant for science communication, presented here as an *integrative* cultural evolutionary framework.

Factors	Brief description	Examples	Some cultural evolutionary implications
Content properties	The content and form of cultural traits	•Eliciting of emotions •Social relevance •Intentionality •Narratives •Framing	•Some traits are inherently more "attractive" and likely to spread than other traits •"Cultural linkage"
Individual conditions	Personal beliefs, attitudes, values, identities, worldviews, knowledge, cognitive styles and needs, etc.	•Inductive biases •"Epistemic vigilance" •Locus of control •Cognitive reflection •Ideology; religiosity; spirituality	•Some traits appeal more to some individuals than others •"Cultural linkage" •Polarization
Social dynamics	Social learning and social incentives	•Social norms •"Cultural cognition" •Social learning strategies •Sources of information •Social network characteristics	•Traits can spread and stabilize independently of content and personal appeals •"Spillover effects" •Tipping points •Polarization

Content properties

The content properties of a cultural trait influences the likelihood that trait will culturally spread. In cultural evolutionary terms, a trait is said to be "attractive" if it has some intrinsic transmission advantage over other traits—either because people are more likely to pay attention to, remember and transmit that trait due its content (Boyd and Richerson, 1985, p. 135), or because people psychologically "transform" or "reconstruct" communicated information into ever-more culturally attractive traits (Sperber, 1996).

For instance, a burgeoning literature, partly inspired by classical memory experiments (Bartlett, 1932), suggests that emotional content, especially the eliciting of negative emotions such as disgust or fear, increases the attractiveness of a cultural trait (e.g., Acerbi, 2019, 2020; Bebbington et al., 2017; Berriche and Altay, 2020; Blaine and Boyer, 2017; Eriksson and Coultas, 2014; Eriksson et al., 2016; Fessler et al., 2014; Stubbersfield et al., 2015, 2017a, 2017b; Vosoughi et al., 2018; however, see Altay and Mercier, 2020; van Leeuwen et al., 2018). Such a finding has consequences for the SSC. Converging evidence indicates that the eliciting of disgust and fear may be partly responsible for hampering science communication efforts, such as convincing people to vaccinate (Altay and Mercier, 2020; Miton and Mercier, 2015; Jiménez et al., 2018, 2020; Pluviano et al., 2017) and to accept the safety and benefits of genetically modified foods (Blancke et al., 2015).

Another category of content that may render a cultural trait more culturally attractive is socially relevant information (e.g., Acerbi, 2019, 2020; Berriche and Altay, 2020; Boudry et al., 2015; Mesoudi et al., 2006; Stubbersfield et al., 2015, 2017a, 2018), such as perceived intentionality or agency (Rosset, 2008). A perceived sense of intentionality has been identified as a crucial ingredient in conspiracy thinking (Douglas et al., 2016), which in turn has proven a serious obstacle to successful science communication. Conspiracy narratives undergird many scientifically inaccurate attitudes, e.g., towards vaccination, "alternative therapies", GMOs, climate change, political events, and pandemics such as the COVID-19 (Bavel et al., 2020; Douglas et al., 2019; Roozenbeek et al., 2020)[3]. In addition to other shared features (e.g., Butter and Knight, 2020; Prooijen, 2018; Uscinski, 2020), conspiracy theories are first and foremost infused with agency and intentionality (encapsulated in the intuition that "someone must be pulling the strings!") to explain grand events that, according to mainstream science and journalism, happen for more natural or systemic reasons (e.g., climate change; political upheaval; the natural origin and spread of diseases) (Leman and Cinnirella, 2013). The disproportionate amount of intentionality in conspiracy narratives may be one powerful reason for the popular appeal, or cultural attractiveness, of conspiracy theories—especially for those individuals who, for various sociodemographic reasons, may already lack a sense of control in their lives and therefore perceive important world events to be "deliberately orchestrated" (an illustration of how content biases may interact with individual conditions; see next section) (Douglas et al., 2019). Conspiracy thinking aside, perceived intentionality, or *anthropomorphism*, is also a plausible cognitive foundation for other pertinent cultural systems that may influence science communication efforts, for instance religion (Boyer, 2001; Guthrie, 1995; Peoples et al., 2016) and lay beliefs about the economy and politics (Bendixen, 2019; Caplan, 2007), such as the idea of an "invisible hand" guiding the economy (e.g., Forstmann and Burgmer, 2018).

In cultural evolution, what makes a cultural trait *inherently* attractive is variously referred to as "cognitive factors of attraction" (Sperber, 1996) or "content biases" (Henrich and McElreath, 2003; Richerson and Boyd, 2005), depending on the specific strain of cultural evolution. Cognitive factors of attraction or content biases are often thought of as stemming from the workings of reliably developing psychological apparatus[4], such as cognitive biases and heuristics. For instance, it is posited that the human mind is equipped with specific mental machinery that is finely tuned to respond to dangerous stimuli via emotions such as disgust or fear. Such emotions are plausibly argued to have evolved through natural selection as part of our species' "behavioral immune system" (Apicella et al., 2018; Schaller, 2011). In the same vein, to the extent that intentionality, social relevance and perceived agency constitute content biases, attending to such cues could be an adaptation for the complex life in social groups (Mesoudi et al., 2006).

It would be unreasonable to claim that something like a concept of "content bias" has eluded the SSC entirely. Lull and Scheufele (2017), for instance, discuss disgust sensitivity as one of several "predispositions" that influence public resistance towards GMOs. More generally, that cognitive biases and their derived logical fallacies obstruct science communication efforts is uncontroversial (e.g., National Academies of Sciences, Engineering, and Medicine, 2017; but see Jiménez et al., 2020, for a failed empirical attempt to demonstrate the importance of two well-known cognitive biases in the context of vaccine-related information). However, I here propose that a cultural evolutionary framework may help the SSC organize such observations in an unifying framework (see Table 1), as well as function as a source of inspiration for identifying novel content biases and explore them in more depth. Identifying content biases that obstruct the spread of scientifically accurate information and behaviors will allow practitioners to tailor more effective science communication campaigns, e.g., through *framing* (e.g., Druckman and Lupia, 2017) or by changing *narratives* (e.g., Davies et al., 2019), in a way that constructively addresses or circumnavigates the problematic appeals inherent in the issue at hand.

The notion of content biases underlines a central insight from the SSC, namely that there exists no silver bullet for successful science communication (Jamieson et al., 2017). What makes a communication effort successful on one science-based issue, say vaccination, is not necessarily relevant for another issue, say climate change—although some content biases (e.g., eliciting of emotions) may be relevant for several different issues. This challenge forces science communicators to be knowledgeable about the unique "root causes" of the specific issues about which they are communicating; and it is a challenge that is only deepened further when we consider the roles that individual conditions and social dynamics play in the success (or lack thereof) of science communication efforts.

Individual conditions

A foundational insight of the SSC pertains to how individuals' preexisting knowledge, attitudes, worldviews, and values impact the spread of (mis)information and behaviors (Jamieson et al., 2017; National Academies of Sciences, Engineering, and Medicine, 2017; Walter and Tukachinsky, 2019). If a behavioral pattern or piece of information contradicts an individual's current beliefs about the world, there is a lesser chance that it will be adopted. An attempt at correcting misinformation may even "backfire" (Nyhan and Reifler, 2010, 2015; Peter and Koch, 2015; Pluviano et al., 2017) and increase an individual's confidence in the misinformation—particularly if the correction challenges a central part of the individual's personal identity and worldview (Cook and Lewandowsky, 2011). While this "backfire effect" has proven somewhat elusive to document empirically (Cameron et al., 2013; Ecker et al., 2020; Haglin, 2017; Lewandowsky et al., 2020; Wood and Porter, 2019), the dynamic overlaps with other well-documented cognitive phenomena, notably *motivated*

reasoning and *confirmation bias*; terms that broadly describe the general human tendency to prefer information that align with preexisting beliefs and attitudes (Kessler et al., 2019).

In the framework put forth here, *individual conditions* include individual psychological differences in general. For instance, belief in "fake news" headlines appears associated with low cognitive reflection and high "Bullshit Receptivity" (the propensity to judge nonsense sentences as profound) (e.g., Bago et al., 2020; Pennycook et al., 2015; Pennycook and Rand, 2020). Likewise, anti-vaccination attitudes have variously been shown to be associated with individual differences in spirituality, personality, religiosity, political ideology, conspiracy thinking, disgust sensitivity, concerns with "naturalness" and "purity" as well as science literacy and trust (e.g., Browne et al., 2015; Hornsey et al., 2018; Rutjens et al., 2018a, 2018b; Wolters and Steel, 2017).

If indeed, as much evidence suggests, some cultural traits appeal to some people and not others due to individual psychological differences, this has some cultural evolutionary implications. First, it may lead to a form of polarization, absent any social influence, since different people are simply drawn to different beliefs and behaviors. Humans also have a tendency to prefer the company of like-minded or self-similar individuals, a phenomenon known in social network theory as *homophily* (e.g., McPherson et al., 2001). In combination, this may lead to groupings of like-minded individuals separated by ever-widening personal, social, and cultural gulfs. Political polarization is a well-documented phenomenon, and it appears to play a considerable role in science communication settings (Ecker and Ang, 2019; Kahan, 2010, 2012, 2015), at least in some cultural contexts (van der Linden, 2015). However, whether polarization mainly arises from individual conditions and homophily or from social dynamics—or a combination thereof—is currently unclear.

A second implication of some cultural traits being more appealing to some people over others may be that specific cultural traits will tend to travel together in "packages" (known as "cultural linkage") (Yeh et al., 2018). In line with this conjecture, and to stay with anti-vaccination attitudes as an illustrative case, Browne et al. (2015) found that the strongest predictor of anti-vaccination attitudes is the endorsement of unscientific and "natural" health treatments, such as homeopathy and "energy-based" therapies, as well as a general preference of complementary and alternative treatments over conventional therapies. This finding is consistent with much other work (Attwell et al., 2018; Buehning and Peddecord, 2017; Busse et al., 2008; Ernst, 2001; Yaqub et al., 2014) and suggests that rejection of vaccines and a fascination with "alternative", "natural", and "complementary" treatments may collectively constitute a complex that travel together culturally as one larger "package", possibly linked by individual inclinations towards conspiracy thinking[5] and/or "magical" beliefs about health (Bryden et al., 2018; Kata, 2010; Lewandowsky et al., 2013). In turn, cultural linkage may give rise to downstream dynamics, such as "hitchhiking" of some cultural traits upon others. If cultural traits that are assumed independent are, in fact, linked and dependent, this may seriously confound statistical analyses of the cultural transmission processes at work in a given case[6] (Buskell et al., 2019; Yeh et al., 2018; see also Kandler and Powell, 2018). Few studies have applied such theoretical insights to real-world scenarios, but science communication represents an exciting context in which to empirically explore cultural linkage and its consequences.

Compared to the *content properties* of a cultural trait (previous section) and the *social dynamics* surrounding cultural traits (next section), individual conditions remain relatively underexamined in cultural evolution theory and research. This might partly be due to (a) the challenges of incorporating something like personal beliefs, values, attitudes, worldviews, and identity into formal population-level modeling (however, see Galesic and Stein, 2019; Muthukrishna and Schaller, 2019; O'Connor and Weatherall, 2019, ch. 2; Weisbuch et al., 2005); and (b) that much cultural evolutionary modeling has sought to understand the evolutionary implications of different population structures (e.g., size, complexity, interconnectedness) and social learning strategies on the overall fitness of a population, not the spread of specific traditions per se (e.g., Fogarty and Creanza, 2017; Muthukrishna et al., 2014; Smolla and Akçay, 2019; Sterelny, 2017). Here, then, is a situation where the SSC has identified a crucial insight—namely that new information generally needs to match preexisting knowledge and values to become accepted—that can inspire advances in the field of cultural evolution.

However, the insight that novel information needs to be congruent with current beliefs and attitudes in order to spread is not entirely absent in cultural evolutionary work. For instance, Soerensen (2004) discussed how religious traditions can only be transmitted from one cultural context to another if the novel tradition is compatible with the predominant traditions of the present culture. Cultures are thus said to constitute a "cultural immune system" that "selects" which novel ideas to adopt. And although cultural immunology may be an emergent property of cultural systems, at bottom it arguably depends on individual-level cognitive processes.

Cultural evolutionary cognitive psychologists have also identified a category of so-called *inductive biases*, whereby individuals' knowledge and expectations influence what cultural information is acquired and transmitted (Griffiths et al., 2008). Formal analyses of and behavioral experiments with inductive biases point to the importance of understanding individuals' preexisting priors when modeling cultural evolution, since inductive biases may offset otherwise stabilizing forces, such as faithful copying (if inductive bias is at play, copying will only be "faithful" to the extent that the copied trait matches the inductive bias) and direct selection pressures ("a highly counter-intuitive hypothesis will fail to dominate a population, even if there are strong advantages to adopting it", Griffiths et al., 2008, p. 3513).

More generally, the cultural evolutionary term, *epistemic vigilance*, points to a suit of proposed cognitive mechanisms whose function it is to filter communicated information (Blancke et al., 2016; Sperber et al., 2010). Epistemic vigilance includes the ability to evaluate the trustworthiness of the source (see next section) as well as the relevance of the information and its fit with preexisting beliefs. Information that is relevant to an individual's worldview but runs counter to it is less likely to be accepted (Mercier, 2020[7]).

As these cultural evolutionary insights suggest, and as is already recognized in the SSC, science communicators must make sure to tailor their communication efforts so that it avoids directly challenging an individual's preexisting attitudes, beliefs, worldview, values and personal identity (Lewandowsky et al., 2017; National Academies of Sciences, Engineering, and Medicine, 2017).

Social dynamics

Much formal modeling work in cultural evolution has focused on the important role that social dynamics, including social learning, norms, and third-party norm enforcement, can play in diffusing and stabilizing a cultural trait (e.g., Boyd and Richerson, 1985; Henrich and Henrich, 2007; Richerson and Boyd, 2005). Social norms influence behavioral patterns through, for instance, "a desire to coordinate, fear of being sanctioned, signaling membership in a group, or simply following the lead of others" (Young, 2015, p. 359; see also e.g., Nyborg et al., 2016; Rhodes et al., 2020; Sunstein, 2019; Varnum and Grossmann, 2017).

A particular species of theoretical models has suggested that social norms and incentives can stabilize traits relatively

independently of the content of the traits themselves and even if the traits are harmful for individuals or the population as a whole (Boyd and Richerson, 1990, 1992). Through these and similar models, the SSC may gain theoretical and predictive insights into the social dynamics influencing the success (or lack thereof) of communication efforts aimed at guiding behavioral change by targeting prevalent social norms (Efferson et al., 2020; Muthukrishna, 2020).

Some empirical groundwork for this avenue of research has already been laid down in the SSC, for instance under the heading of the "cultural cognition thesis" (Kahan, 2010, 2012, 2015). Rather than evaluating issues on the grounds of bare facts, according to the cultural cognition thesis, people "endorse whichever position reinforces their connection to others with whom they share important ties" (Kahan, 2010, p. 296). In other words, public disagreement about science-based issues (e.g., climate change, GMOs, vaccination) does not necessarily stem from a lack of relevant knowledge. Instead, whether an individual adopts some information or behavior depends crucially on the social incentives associated with adopting or rejecting it. This could be viewed as a somewhat similar scenario to cultural evolutionary models wherein even harmful cultural traits can stabilize and spread through social incentivizing (i.e., third-party norm enforcement).

The cultural cognition thesis is a foundational concept in the SSC, but it remains to be investigated deeper both theoretically and empirically (van der Linden, 2015). For instance, what are the social or cultural prerequisites for a science-based issue to be influenced by the dynamics of "cultural cognition"? How does "cultural cognition" operate in cultural contexts that are less socially and politically polarized than the US? Qualitative predictions derived from modified cultural evolutionary models may help guide science communication research aimed at answering such and related questions as well as prime researchers to collect empirical data aimed at testing and improving the formal models and their predictive scope (Smaldino, 2017).

Additionally, cultural evolution research has identified a range of *social learning strategies* that plausibly evolved in our species in order for individuals to extract generally adaptive information and behavior from their environments (Boyd and Richerson, 1985; Henrich, 2015; Hoppitt and Laland, 2013; Laland, 2017; Mesoudi, 2011; Richerson and Boyd, 2005). These social learning strategies are employed flexibly and include heuristics on *whom* to imitate (e.g., the majority, or prestigious, successful and/or self-similar individuals), *when* to imitate (e.g., when uncertain, or when personal information is outdated) as well as *what* to imitate (e.g., "content biases", see above) (for a recent review of human social learning strategies, see Kendal et al., 2018).

While some recent research have questioned the degree to which people are swayed by social influence in actual (science) communication contexts (Acerbi, 2020; Mercier, 2020; Mercier and Morin, 2019; Morin, 2015), these social learning strategies potentially matter, since they can help illuminate the dynamics behind the diffusion of certain information or behavioral patterns (e.g., Barkoczi and Galesic, 2016) as well as identify, guide, and target communication and campaign efforts (see, however, Kandler and Powell, 2018). For instance, Efferson et al. (2020) formally modeled campaigns aimed at reversing harmful local traditions such as female genital cutting. Their models rely partly on "spillovers", an indirect effect whereby a behavioral change among some individuals inspire other individuals to change their behavior as well. This kind of spillover arises from conformist learning, where individuals seek (disproportionately) to behave as the surrounding majority. The spillover effect is a cost-effective and non-confrontational dynamic, and hence holds appeal, because it generates *endogenous* change: individuals influencing individuals instead of campaigners influencing individuals directly.

Again, that people generally tend to imitate and seek information from what they perceive to be majority (e.g., friends, family, local community, "common knowledge") or prestige (e.g., celebrities, media pundits, "social media influencers", "experts" (scientific or self-attested) etc.) sources is well-known within the SSC (e.g., Jamieson et al., 2017; National Academies of Sciences, Engineering, and Medicine, 2017). However, a cultural evolutionary perspective can help organize current findings of the SSC into a coherent framework, motivate science communication researchers to look for social learning dynamics that were previously overlooked (e.g., spillovers) and identify issues and contexts where specific social learning strategies are particularly pertinent.

Previous applications of cultural evolution to science communication

The obvious relevance of cultural evolution research to science communication, behavioral change, and the spread of (mis)information has been appreciated in some earlier work. However, although very valuable as first approximations, I submit that these earlier applications all suffer from important limitations[8].

The bulk of previous studies has aimed at identifying the content properties that make (mis)information cognitively and culturally attractive. These include framing effects, narrative, "counterintuitiveness", social relevance and intentionality, "psychological essentialism", emotional valence, especially the eliciting of negative emotions such as disgust and fear, as well as a variety of other cognitive biases, heuristics, and logical fallacies (Acerbi, 2019, 2020; Altay and Mercier, 2020; Berriche and Altay, 2020; Blancke et al., 2016, 2018, 2019; Blancke and De Smedt, 2013; Boudry et al., 2015; Claidière et al., 2017; Marie et al., 2020; Miton and Mercier, 2015; Jiménez et al., 2018, 2020; Pluviano et al., 2017; Stubbersfield et al., 2018).

A few exceptions need mention. Blancke et al. (2016; see also Boudry et al., 2015) discuss "science mimicry" (i.e., cloaking the information or behavior as "scientific" in order to exploit the authoritative status of science) as one strategy by which misinformation can spread. For instance, believers in clairvoyance and telepathy may refer to parapsychological journals for support for their paranormal beliefs. Understanding the appeal of science mimicry requires a focus on the *source* of information (e.g., prestige bias). While this counts as social influence in the framework laid out here (see Table 1), in the main parts of their work, Blancke et al. (2016, 2018, 2019; Blancke and De Smedt, 2013; Boudry et al., 2015) are preoccupied with the content of misinformation and pseudoscientific beliefs.

Marie et al. (2020; and, more broadly, the epistemic vigilance framework that they draw from, see Mercier, 2020; Sperber et al., 2010) also discuss the power of social influence and preexisting worldviews on the spread of (mis)information. However, when it comes to practical recommendations for science communicators, the authors largely ignore these factors and instead focus on content properties, such as framing and different forms of counter-argumentation.

There are several limitations of a narrow focus on content properties in a science communication context.

First, a pure content properties view at least implicitly subscribe to the "knowledge deficit model", the now defunct hypothesis that if only people had access to more correct information, then they would adjust their worldviews and behaviors to be more scientifically accurate (Simis et al., 2016). That individual conditions and social dynamics so fundamentally shape an individual's behavior and representational beliefs about the world severely undermines

this hypothesis. Of course, knowledge is a necessary, albeit insufficient, ingredient for forming scientifically accurate beliefs and behaviors (Jamieson et al., 2017; National Academies of Science, Engineering and Medicine, 2017). For instance, emerging evidence suggests that knowledge about flawed and misleading argumentation on a given issue (e.g., climate change) can to some degree "inoculate" people from misinformation on that issue (Cook et al., 2017; Jolley and Douglas, 2017; Lewandowsky et al., 2020; Roozenbeek and van der Linden, 2019). However, how this "inoculation effect" precisely relates to the "backfire effect" presented above (e.g., under which circumstances will a communicative act inoculate the receiver and when will it backfire?) remains unclear (Chan et al., 2017; De keersmaecker et al., 2019; Ecker et al., 2017, 2020; Peter and Koch, 2015; Schwarz et al., 2016; Swire-Thompson et al., 2020). Likewise, some research has focused on the role that knowledge, evidence and arguments can play in changing people's minds. Mercier and Sperber (2011, 2017), for instance, argue for an *interactionist theory of reasoning*, which emphasizes the social nature of argumentation through dialog and a free exchange of viewpoints. By recognizing that reasoning is a social activity (for instance, that people are more likely to be objective when evaluating other people's arguments than when producing arguments of their own), this view helps make sense of the conditions under which dialogs, debates, arguments, and reasons may be helpful tools in a science communication context (Mercier, 2016). But while some empirical evidence may support this approach (Altay and Lakhlifi, 2020), and in line with the framework put forth here, real-world debates on science issues (e.g., vaccines, climate change, GMO) are often complicated by psychological and social factors that are orthogonal to the arguments at hand (e.g., Kahan, 2017). Future research could look deeper into the role that arguments and reasoning play in the diffusion of cultural traits, and how reasoning may counteract social and content-based appeals of misinformation.

Note also a folk-psychological stance inherent in the knowledge deficit model, namely the notion that beliefs are the main drivers of behavior. However, we humans often act without having explicit, representational, causal beliefs about the world or about the deeper underlying motivations of our own behavior. Many daily acts—such as habits or complex series of procedures, such as cooking and religious rituals—arguably fall in this category. Further, to the extent that beliefs actually do influence behavior, it is even debatable how applicable current research on the importance of content properties in cultural evolution is, since much of this research study how content improve a cultural trait's memorability, not "believability" or "transmittability"[9]. However, as has also been pointed out in the context of religious beliefs (Gervais and Henrich, 2010), there is an important distinction between remembering something and believing in and/or acting upon it.

In addition, content properties generally do not satisfactorily account for *individual* (e.g., if anti-vaccination attitudes are so inherently attractive, why do we not all hold anti-vaccination attitudes?) nor *cultural* (e.g., why do the level of controversy of a science-based topic vary within and across nations?) differences in adoption of scientifically accurate information and behavior (cf. Bendixen, 2019, for similar criticisms in a related context). Here, individual conditions and social dynamics are crucial. However, a disproportionate focus on either of these sets of factors suffer from their own limitations.

The individual conditions, such as preexisting beliefs, attitudes and worldviews are important factors in determining the adoption or not of information or a behavior. But a narrow view on individual conditions ignores the fact that some content is inherently more attractive than other content and that social dynamics can powerfully influence people's attitudes, worldviews and behavior.

Conversely, as a representative of a social dynamics view, Efferson et al. (2020) focus on social learning (specifically conformity) of a behavioral tradition. The authors are right to base their models on the assumption that people do not always behave according to elaborate (or even basic) causal models of the world. Instead, humans often behave according to implicit customs, norms, traditions, etc., without always knowing *why* we behave as we do (Henrich, 2001, 2015), and important dynamics, such as spillover effects, endogenous change, polarization and tipping points, may arise as a result (Nyborg et al., 2016).

But social learning studies, such as Efferson et al. (2020; see also e.g., Muthukrishna and Schaller, 2019; O'Connor and Weatherall, 2019, and models reviewed herein), typically ignore content properties (traditions may be "attractive" in themselves (Miton and Mercier, 2015; Morin, 2015), which may off-set social dynamics) and other social learning strategies (such as *prestige bias*; Muthukrishna, 2020) as well as individuals' inductive biases, which may counteract (or, conversely, exaggerate) the effects of social dynamics (Griffiths et al., 2008).

This review of previous applications of cultural evolution to science communication and behavioral change should not be considered strictly critical. Indeed, the reviewed work has, in its own ways, pioneered important avenues for future research. However, as I have argued, each of these earlier approaches have not been comprehensive enough to take advantage of the full potential of an integrative cultural evolutionary framework. In order to achieve that, we need to consider how the different psychological and social factors interact. I elaborate on this point in the following, and final, section.

Looking ahead

As the previous section illustrates, and in addition to the open queries pointed out along the way, a few particularly outstanding questions emerge at the intersection between cultural evolution and science communication research[10]:

> How do content properties, individual conditions and social dynamics interact to influence the success (or lack thereof) of science communication efforts? Are any of these sets of factors more effective at spreading (mis)information and inspire behavioral change—in general and/or in particular cases?

The three sets of psychological and social factors (Table 1) interact in ways that are currently not well-understood. A promising avenue for future research would therefore be to explore the interaction and relative strengths of these sets of factors in science communication contexts with field studies and laboratory experiments (for empirical attempts at this in other contexts, see Acerbi and Tehrani, 2018; Willard et al., 2016; cf. also Bendixen, 2019). Such empirical results could then inform theoretical models, which may generate qualitative predictions that, in turn, can be tested with more focused data collection strategies (Smaldino, 2017).

Understanding the relative strengths of different factors is an important endeavor since the factors at work in a particular case have important implications for the success of science communication efforts. Different factors, such as different social learning strategies, have different dynamics, which can be targeted, e.g., tipping points, spillover effects, endogenous change, etc. (Nyborg et al., 2016). Whether we can rely on any given dynamic in a particular case depends on the social learning strategies—and other psychological and social factors—at work. Identifying the relevant factors informs science communicators about *how* (e.g., framing, narratives, etc.) and whom (e.g., prestigious people or the more or less receptive individuals) to target with their campaigns or interventions. Efferson et al. (2020), for instance, arrive

at the somewhat counterintuitive conclusion that in order for spillover effects to be most effective, campaigns should focus on the *least* receptive of individuals, because these individuals are (per definition) least likely to be influenced. Therefore, if campaigns succeed in changing the behavior of minimally receptive individuals, the more receptive individuals nearby are more likely to be affected by the conformist spillover effect, and the "ripple" of behavioral change may thus travel further in the population.

Efferson et al.'s (2020) findings are contingent on the specific social learning strategy under investigation, namely conformity (see also Muthukrishna and Schaller, 2019). Incorporating other social learning strategies into such models could help shed light on how behavioral change and diffusion of information is achieved in the real world. It remains to be explored, then, how prevalent conformity and other social learning strategies actually are in science communication contexts, and how derived social dynamics compete and combine with individual conditions and "attractive" content to determine the success (or lack thereof) of science communication efforts.

Conclusion

There exists an untapped reservoir of consilience between cultural evolution and science communication research. Cultural evolution can serve as a guiding and unifying framework for a mature SSC. Conversely, science communication offers an exciting and unique opportunity to put cultural evolutionary theory to the test in a real-world setting that matters.

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Notes

1 This three-part partition is not watertight and serves mostly heuristic purposes for the present discussion. For instance, it is uncontroversial that personal factors, such as identity and values, are shaped in a dialectical relationship with one's social surroundings, and that some issues are intrinsically more relevant under some socio-personal circumstances than others (e.g., Douglas et al., 2019).

2 It is possible that a fourth set of factors could in time be added to this framework, namely "ecological conditions", including material (in)security, the perceived harshness of the local environment, or any other local ecological condition or feature that might influence the salience of some cultural traits over others. There is evidence for such ecological influence in the formation and spread of religious beliefs (e.g., Purzycki, 2016) and cultural traditions in general (e.g., Morin, 2015; Varnum and Grossmann, 2017). More relevant to the present discussion, conspiracy thinking, which often complicates science communication efforts, seems to be more prevalent in politically unstable and materially insecure (e.g., marginalized, low-income, etc.) environments (e.g., Butter and Knight, 2020, section 3), or in times of crisis (e.g., conflicts, war, pandemics, etc.) (Douglas et al., 2019). However, since this potential category of factors has received practically no attention hitherto in the context of science communication, I leave it out for concision.

3 For instance, "Big Pharma" is said to secretly spread diseases or suppress "natural" cures to serious diseases such as cancer or pandemics such as COVID-19. The conventional food and farming industry is accused of selling "Frankenfoods" to the detriment of the health of the consuming public and the environment. And climate change has been labeled a "hoax" invented by scientists in order to increase their funding revenue or by foreign nations in order to gain the upper-hand in the world economy (e.g., Jamieson et al., 2017).

4 While current research has tended to focus on the cognitive constraints underlying the evolution of culture, cognition is not the only variable that influences the inherent attractiveness of a cultural trait. Historical, societal, and ecological features may also increase or decrease a trait's cultural attractiveness (see e.g., Morin, 2015; Varnum and Grossmann, 2017), although this line of empirical research remains relatively scant (Acerbi and Mesoudi, 2015; Scott-Phillips et al., 2018).

5 More generally, conspiracy theories also tend to go hand-in-hand, so that if an individual subscribes to one conspiracy theory, they are likely to subscribe to several others as well—even in cases of mutual contradiction (e.g., Miller, 2020a, 2020b; Wood et al., 2012; see also Douglas et al., 2019).

6 Many psychological survey and observational studies analyse their data by adding all predictor variables to the same regression model and then interpreting each coefficient as an effect estimate of the predictor on the outcome of interest. However, this constitutes a classical case of the "Table 2 Fallacy" (Westreich & Greenland, 2013), and may render the results unreliable by introducing various biases, especially if the goal is to establish causal relationships (e.g., Achen, 2005; Lübke et al., 2020; Rohrer, 2018). This problematic practice is aggravated further if cultural linkage is at play and not taken into account.

7 Mercier (2020) re-labels "epistemic vigilance" as "open vigilance".

8 Bavel et al. (2020) succinctly review evidence from the social and behavioral sciences relevant for understanding and solving psychological and social challenges in the wake of the COVID-19 pandemic, including how to communicate scientific information. In this specific context, the authors discuss both the importance of content properties of (mis)information (e.g., threat), individual differences in decision-making (e.g., risk perception), as well as social dynamics (e.g., norms and polarization). Although they do not coax their discussion in cultural evolutionary terms, they come very close to applying the kind of *integrative* approach to science communication that I am advancing here. See also Butter and Knight (2020), Douglas et al. (2019), Prooijen (2018), and Uscinski (2020) for similar integrative approaches to conspiracy thinking.

9 A subset of the cited studies on content properties (Altay and Mercier, 2020; Blaine and Boyer, 2017; Stubbersfield et al., 2018) employ a "motivations to share" paradigm, in which, typically, the participant is asked about their willingness to share a test item, or to select or modify, among a range of possibilities, one or a few test items (e.g., stories) to be passed on to another participant. Other work studies the sharing of information on real-world social media platforms (Acerbi, 2019; Berriche and Altay, 2020). While the motivations to share might in these settings vary across individuals and be somewhat opaque to the researchers (e.g., Mercier et al., 2018; Mosleh et al., 2020), such paradigms come closer to an ecologically valid measurement of the effect that different content properties have on the "transmittability" of cultural traits.

10 For further open research questions in the SSC, which could no doubt be fruitfully subjected to cultural evolutionary analyses, see National Academies of Sciences, Engineering and Medicine (2017, pp. 91–92, 95–96, 97–98).

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Additional information

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