cycloheximide withdrawal, indicating that the "gravitational pull" between neurons is compromised. Yamaguchi *et al*. conclude that this looser coupling between the cells of AVP-deficient SCN is sufficient to maintain normal circadian function in a steady state, but makes the SCN more responsive to extreme perturbation because the cells are no longer held back by tight phase-locking across the circuit.

Whether it is simply a happy accident that loss of AVP signals leads to this novel state, or there is some deeper SCN design principle is unclear. More widely, the study by Yamaguchi *et al*. shows how neuropeptidergic signaling confers circuit-level properties on a population of neurons. In itself, neuropeptidergic generation of emergent properties is not unusual, having been especially well characterized in invertebrate systems (*9*). What is particular about the SCN is the time frame involved, with neuropeptidergic signals encoding very precise information over a span of hours and days, rather than milliseconds and minutes. Given that the circadian phenotype is pronounced and stereotypical, and in cell culture it emerges from a circuit of less than 10,000 neurons (which is the approximate number of neurons of some invertebrate nervous systems), it should be possible to perform a comparable cellular and molecular analysis of the system that defines our biological time. Beyond that, identifying how neuropeptidergic cues from the SCN maintain the circadian coherence across the brain, which is essential for normal sleep and wakefulness, will provide a new level of understanding to the greatest emergent property of all: states of consciousness.

If developing AVP receptor antagonists did help us to jet ever more frantically about the planet, it would affect only a small minority of people. In the context of clocks and public health, however, there is a more insidious threat. Epidemiology shows that rotational shift work is a killer, increasing risks of cancer, and cardiovascular and metabolic diseases (*10*, *11*). If the 24/7 society is here to stay, helping shift-workers adjust more rapidly to their schedules by working with, rather than against, their SCN must be a good thing. Added to that, sleep disorders are a growing problem, for both normal aging and various dementias, and exploiting AVP signaling to tighten up the aging clock and its control over sleep may prove a useful tool. But there remains a final thought. After 4 billion years of circadian evolution (*12*), can you really cheat on circadian time?

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SOCIAL SCIENCE

A Risky Science Communication Environment for Vaccines

Neglecting the science of science communication puts the value of decision-relevant science at risk.

Dan M. Kahan

Controversy over childhood vaccinations is an instance of what might be styled the "science communication problem"—the failure of compelling scientific evidence to resolve public dispute over risks and similar facts (*1*). This problem itself has been the focus of scientific study since the 1970s, when psychologists began to investigate the divergence between expert and public opinion on nuclear power. Indeed, the science of science communication that this body of work comprises can now be used not just to explain controversy over risk but also to predict, manage, and in theory avoid conditions likely to trigger it. The example of childhood vaccinations illustrates these points—and teaches an important practical lesson.

One recurring source of risk controversy is a dynamic known as "cultural cognition." Both to avoid dissonance and to protect their ties to others, individuals face a strong psychic pressure to conform their perceptions of risk to those that distinguish their group from competing ones—a bias in reasoning that can actually intensify as the public becomes more science literate (*2*).

A major factor in the dispute over climate change, cultural cognition has contributed to controversy over at least one childhood vaccine as well. In 2006, the U.S. Centers for Disease Control (CDC) recommended universal immunization of adolescent girls against the human papilloma virus (HPV), which is sexually transmitted and causes cervical cancer, but political dispute blocked legislative mandates in every state but one. Experimental evidence showed that individuals tended to selectively credit information relating to the vaccine's risks and benefits in patterns reflecting their cultural predispositions (one perceived risk was that vaccination would lead to the engagement of unsafe sex). The resulting polarization was amplified when individuals were exposed to cues—whether explicit, such as news reports (*3*), or tacit, such as fictional advocates of varying appearances (*4*)— suggesting the vaccine was a focus of group conflict.

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Shots of controversy. Conflict over childhood vaccinations reflect the inadequate attention given to understanding factors in the science communication environment that influence the public understanding of science.

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The same insights that explain the controversy over the HPV vaccine, however, imply that it need not have occurred. It was likely inevitable that people of opposing cultural orientations would react divergently to a high-profile campaign to enact legislation mandating vaccination of 11- to 12-year-old girls for a sexually transmitted disease. Yet there was nothing inevitable about the HPV vaccine being publicly introduced in a manner so likely to generate cultural conflict.

Merck, the manufacturer of the HPV vaccine Gardasil, sought approval from the U.S. Food and Drug Administration (FDA) through the agency's fast-track review process, which is reserved for treatments of serious diseases—in this case, for a female-only vaccine for cervical cancer. After approval, the company sponsored a nationwide lobbying campaign directed at state legislatures to add the vaccine to the schedule of immunizations required for school enrollment. These were profit-driven choices (*5*), aimed at enabling Merck to establish a dominant market position for Gardasil before GlaxoSmithKline could secure approval for its rival product, Cervarix. If Gardasil had not been fast-tracked, the FDA would have approved both Gardasil and Cervarix for boys and girls only 3 years later. At that point, both vaccines would have become available immediately even without mandates through private insurance and a host of programs designed to assure universal access to childhood vaccines.

Had the HPV vaccine taken this path, it would have followed the uneventful course that marked introduction of the hepatitis B virus (HBV) vaccine into the U.S. public health system. Hepatitis B, like HPV, is sexually transmitted and causes cancer (*6*). The CDC endorsed universal childhood HBV vaccination—for boys and girls, a much less jarring proposal—in the 1990s. There was no political controversy. Rather, states steadily added the HBV vaccine to mandatory vaccination schedules through the customary mechanism—not high-profile legislative enactments, but guidelines routinely promulgated by public health administrators operating outside the political realm (*7*). The HPV vaccine might well have been handled in the same way had it not been introduced as a mandatory, girls-only shot for a sexually transmitted disease in a nationwide legislative campaign [(religious groups were not opposed to FDA approval of the vaccine per se (*8*)]. But even more important, parents' first exposure to information on HPV vaccine would not have been from partisan news outlets. Rather, they would have learned about the vaccine from their pediatricians. The same studies reporting that culturally diverse individuals would polarize if exposed to cues of group conflict showed that in the absence of such cues, members of all groups could have been expected to trust expert advice (*4*, *5*). Parents do trust their pediatricians on the HBV vaccine, which retained coverage of 90% of children during the period when HPV mandates were being debated in state legislatures (*9*, *10*). The rate for completing the HPV immunization series now stands at an anemic 33% for adolescent girls, and 7% for boys (*11*).

Many experts and medical groups warned that the HPV vaccine was being introduced in a manner likely to engulf it in controversy (*5*, *8*). Their concerns were not rejected. They were simply never considered. There was and remains no process in the FDA or the CDC for making evidence-based assessments of the potential impact of their procedures on the myriad everyday channels through which the public becomes apprised of decision-relevant science.

Similar inattention to the quality of the science communication environment leaves other childhood vaccines vulnerable to controversy too. In the United Kingdom, childhood vaccination rates are only now recovering from the scare induced by the now-discredited 1998 study of Dr. Andrew Wakefield linking the measles, mumps, and rubella (MMR) vaccine to autism. By contrast, the United States experienced no such decline—vaccination rates for MMR, pertussis, and polio have been at or above 90% (the target level) for over a decade, and the proportion of children receiving no vaccinations has remained below 1% (*9*, *10*). But there are enclaves, some populated by strident opponents of mandatory immunization, where vaccination rates fall dangerously short of the national average, and where local outbreaks of childhood diseases periodically occur. Evidence-informed risk communication strategies are essential to identify and counteract any influence that could cause ungrounded fears of vaccines to spread to the general population.

Ironically, one such influence is empirically uninformed risk communication. The media and advocacy groups routinely lament a "growing distrust of vaccinations" (*12*) and a resulting "erosion in immunization rates" (*13*), claims belied by CDC statistics. Emphatic assertions that a technology poses no danger can actually enhance its perceived riskiness (*14*). In addition, people tend to contribute voluntarily to public goods—such as herd immunity—when they believe that others are doing so but refrain when they perceive widespread free-riding (*15*). Thus, misleadingly implying that increasing numbers of parents are fearfully refusing vaccination could create exactly such fear and resistance.

Also ill-advised is a popular trope that links resistance to childhood vaccination with disbelief in evolution and doubt of climate change as instances of public "distrust in science." Critics of mandatory vaccination are small in number and their hostility to vaccines is generally unshared by the majority of the population. Positions on evolution and climate change, by contrast, are highly charged symbols for large cultural groups. Finding poplular discourse with the claim that childhood vaccination is part of the same package of partisan stances as these issues (*16*) needlessly risks provoking the same cultural cognition dynamics that impeded reasoned public engagement with the HPV vaccine.

Empirically uniformed and counterproductive risk communication is the inevitable by-product of the absence of a systematic, evidence-based alternative. Decades of study show that the sources of public controversy over decision-relevant science are numerous and diverse. There is, however, a single factor that connects them: The failure of democratic societies to use scientific knowledge to protect the science communication environment from influences that prevent citizens from recognizing that decision-relevant science contributes to their well-being.

Online

sciencemag.org

Podcast interview with author Dan M. Kahan (http://scim.ag/ed_6154).

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