Theory-based explanation as intervention

Kara Weisman & Ellen M. Markman

Psychonomic Bulletin & Review

ISSN 1069-9384
Volume 24
Number 5

Psychon Bull Rev (2017) 24:1555-1562
DOI 10.3758/s13423-016-1207-2

Psychon Bull Rev (2017) 24:1555–1562
DOI 10.3758/s13423-016-1207-2

BRIEF REPORT

Theory-based explanation as intervention

Kara Weisman[1] · **Ellen M. Markman**[1]

Published online: 17 January 2017

Abstract Cogent explanations are an indispensable means of providing new information and an essential component of effective education. Beyond this, we argue that there is tremendous untapped potential in using explanations to motivate behavior change. In this article we focus on health interventions. We review four case studies that used carefully tailored explanations to address gaps and misconceptions in people's intuitive theories, providing participants with a conceptual framework for understanding how and why some recommended behavior is an effective way of achieving a health goal. These case studies targeted a variety of health-promoting behaviors: (1) children washing their hands to prevent viral epidemics; (2) parents vaccinating their children to stem the resurgence of infectious diseases; (3) adults completing the full course of an antibiotic prescription to reduce antibiotic resistance; and (4) children eating a variety of healthy foods to improve unhealthy diets. Simply telling people to engage in these behaviors has been largely ineffective—if anything, concern about these issues is mounting. But in each case, teaching participants coherent explanatory frameworks for understanding health recommendations has shown great promise, with such theory-based explanations outperforming state-of-the-art interventions from national health authorities. We contrast theory-based explanations both with simply listing facts, information, and advice and with providing a full-blown educational curriculum, and argue for providing the minimum amount of information required to understand the causal link between a target behavior and a health outcome. We argue that such theory-based explanations lend people the motivation and confidence to act on their new understanding.

Keywords Explanation · Implicit theories · Behavior change

✉ Kara Weisman
kweisman@stanford.edu

[1] Department of Psychology, Stanford University, Jordan Hall (Building 01-420), 450 Serra Mall, Stanford, CA 94305, USA

Cogent explanations are an indispensable means of providing information and an essential component of education. Adults and children alike reason about many domains in terms of their lay theories (Carey, 2009; Gopnik & Wellman, 1994; Keil, 1994; Murphy & Medin, 1985; Wellman & Gelman, 1992), and effective explanations build on and enrich people's intuitive conceptual frameworks. Beyond this, we argue that there is tremendous untapped potential in using explanations to motivate *behavior* change—a relatively unexplored downstream effect of conceptual change. In this article, we explore how theory-based explanations can foster behavior change in several health domains.

Many pressing health problems persist despite widespread attempts to provide people with facts, advice, or instructions about how to improve their health. This has led some researchers to conclude that education is not an effective means of motivating health-promoting behaviors (e.g., Baranowski et al., 2003; Helweg-Larsen & Collins, 1997; Wansink, 2010).

In contrast, we argue that, by harnessing the ability of explanations to engender and enrich lay theories, education can be a powerful way of motivating behavior change. We know that lay theories facilitate learning, memory, and generalization. People are more likely to accept a proposition as true if it is consistent with their lay theories (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012) and are better able to learn and remember new information if it fits into some coherent structure (Rehder & Ross, 2001). Yet the main function of a coherent theory is to enable people to explain, predict, and intervene on some phenomenon—to reason both from effects to causes and from causes to effects. In this way, a coherent causal framework allows people to plan and execute effective interventions on the causal system, inferring how to start, stop, or change the outcome (Schulz, Kushnir, & Gopnik, 2007; Walker & Gopnik, 2014). There is thus good reason to believe that explanations designed to enrich lay theories could both help people understand health recommendations and lend them the ability, confidence, and motivation to *act* on their new understanding.

Such theory-based explanations differ substantially from other kinds of education-based interventions. For the reasons we just outlined, explaining the effectiveness of some target behavior by invoking a compelling causal framework has the potential to be much more convincing than simply listing facts or giving advice. In addition, we argue that a judiciously crafted explanation is very likely superior to a full-blown educational curriculum, in which irrelevant or overwhelming details might obscure the central message.

Guided by these observations, we present five guidelines for constructing an intervention that capitalizes on the power of explanations to motivate behavior change: (1) identify a specific target for behavior change that is clearly tied to a desired outcome; (2) identify the conceptual prerequisites necessary for understanding how and why engaging in this behavior would bring about the desired outcome; (3) assess the lay theories currently held by the target audience; (4) design educational materials precisely tailored to address the misconceptions and gaps in these lay theories; and (5) provide just enough information, in an accessible format, to impart confidence in the relevant causal framework.

To demonstrate the efficacy of this approach, we review four case studies in diverse health domains that compared targeted, theory-based explanations to alternative state-of-the-art interventions. Each study addressed a major health concern that would be substantially improved by people engaging in straightforward behaviors: (1) washing hands to prevent viral epidemics; (2) vaccinating children to stem the resurgence of infectious diseases; (3) completing the full course of antibiotics to reduce antibiotic resistance; and (4) eating a variety of healthy foods to improve unhealthy diets. Simply advising people to engage in these behaviors has been largely ineffective. In contrast, the studies we review demonstrate that theory-based explanations can play a vital role in addressing these recalcitrant health problems.

Case study 1: Viral epidemics

In 2003, Hong Kong was hit by an epidemic of severe acute respiratory syndrome. People shunned public spaces and wore facemasks everywhere. Ubiquitous public-service announcements warned against shaking hands and depicted proper handwashing techniques. Against this backdrop, Au et al. (2008) designed educational materials to help children understand the importance of handwashing as a preventive measure.

Au and colleagues based these materials on their earlier work with older children, which documented that children's intuitive theory about viruses and bacteria was primarily mechanical rather than biological. When asked why a piece of fish left on the counter becomes increasingly smellier, for example, children answered that the longer it is out, the more opportunity for bacteria to fall on it; children almost never mentioned that bacteria thrive in that environment and reproduce rapidly. The authors argued that knowing how to avoid infections requires understanding that viruses and bacteria are living things that can do harm only when they are alive, and that these organisms flourish and reproduce in some environments and die in others. Their "Think Biology" program, which was designed to improve children's understanding of how to prevent HIV, presented these concepts in a coherent causal framework that unified and explained standard anti-HIV precautions, which are typically taught as rote rules to follow. This program enabled American middle-schoolers to thoughtfully assess the risk of being infected with HIV in novel situations (Au & Romo, 1996).

Au et al. (2008) adapted this program for third- and fourth-graders in Hong Kong to motivate children to wash their hands to avoid getting colds or the flu. Children were divided into two training conditions.

In one condition, children received the adapted version of the Think Biology program. They learned that viruses and bacteria are microscopic living things, and that cold and flu viruses thrive in the human body and can survive on cool surfaces for hours, but are killed quickly by boiling, cooking, or disinfectants. The program also underscored that only live viruses can cause infections, and that these germs enter the body through the eyes, nose, and mouth.

In the other condition, children received a program developed by their teachers based on resources promoted by the Hong Kong Department of Health. They learned differences in symptoms between colds and different types of flu and their associated complications. Children also learned that you get sick when germs contained in droplets from other people's coughs and sneezes enter your body. Finally, they learned a list of behaviors to follow or avoid, and how to treat infections.

In both conditions, children were given pre- and posttest interviews that included questions about how certain behaviors would lead people to catch colds and flu; about which kinds of behaviors were riskiest; and about core causal mechanisms, such as whether dead germs can make people sick, how to kill germs, and how germs enter your body. At posttest, compared to children in the teacher-designed intervention, children in the Think Biology program reasoned more in terms of germs' survival and reproduction and were better able to identify risky and preventive behaviors.

Most impressively, the Think Biology program fostered theory-consistent *behavior* change. At pretest, when children were asked to help put crackers in bags to later give to other children, only 14% of children washed their hands before packing the crackers. After receiving either the Think Biology or the teacher-designed program, children were asked to help fold paper napkins for a party, and still only 14% of the children in the teacher-designed program washed their hands. Children in the Think Biology program, however, showed marked improvement: 41% washed their hands before touching the napkins. This is both a substantial improvement in handwashing and a striking generalization: In preparing for the party at posttest, the children weren't touching any food, only napkins.

Although reminders about handwashing were extremely prevalent in Hong Kong at the time and were part of the teacher-designed program in the control condition, there was plenty of room for improvement in this critical disease-prevention behavior. Children who learned to think about the conditions under which a virus lives and dies became capable of monitoring the need for handwashing across more varied situations and were motivated to act on their conceptual understanding.

Case study 2: Antibiotic resistance

We now consider how adults' conceptions of bacteria and antibiotics contribute to the growing problem of antibiotic resistance. The World Health Organization (WHO) recently warned, "A post-antibiotic era—in which common infections and minor injuries can kill—far from being an apocalyptic fantasy, is instead a very real possibility for the 21st century" (WHO, 2014b, p. ix). For many years, the WHO has offered simple guidelines for how patients can help prevent antibiotic resistance: Use antibiotics only when prescribed by a health professional; always complete the full prescription; and never share antibiotics with others or use leftover prescriptions (WHO, 2014a). Nonetheless, patient noncompliance remains a serious problem (Kardas, Devine, Golembesky, & Roberts, 2005).

In an unpublished study, Hasan and Markman (2014) aimed to address one central component of patient compliance—completing the full course of an antibiotic prescription—by providing adults with a coherent explanatory framework for how antibiotics work.

Hasan and Markman first analyzed gaps in the lay understanding of antibiotics and antibiotic resistance. Previous work has suggested that many adults have a faulty understanding of antibiotics (McNulty, Boyle, Nichols, Clappison, & Davey, 2007). In particular, 87% of patients who stop antibiotic treatment early report stopping because they feel better (Branthwaite & Pechère, 1996; see also Hawkings, Butler, & Wood, 2008). Even people who are aware of the threat of antibiotic resistance often believe that inappropriate use of antibiotics will cause the *patient*—rather than the bacteria—to become resistant to antibiotics (Davey, Pagliari, & Hayes, 2002).

With these gaps in mind, Hasan and Markman designed materials that explained two conceptual prerequisites necessary for understanding the importance of taking antibiotics for the full prescribed course: the distinction between antibiotics and medications that are taken for symptomatic relief, and the biological mechanism by which bacteria become resistant. They compared this intervention to two stringent control conditions: the information routinely provided to patients in materials accompanying prescription medications, and a newly developed website designed by the Centers for Disease and Control and Prevention (CDC) to combat antibiotic resistance.

In this study, participants reasoned about being prescribed an antibiotic for some ailment (either a sore throat or cough) and about being prescribed a nonantibiotic medication for the other ailment. Participants received actual pill labels and package inserts for each prescribed medication and were instructed to use this information however they normally would in their real lives. These package inserts contained detailed information about the medication, including common uses, drug interactions, how to take the medication, cautions, side effects, and what to do in case of an overdose or missed dose. In the case of antibiotics, the pill labels clearly stated, "Continue to take this medication until the full prescribed amount is finished."

In the package-insert only condition (n = 43), participants received no information beyond what was contained in these package inserts.

In the CDC condition (n = 44), at the beginning of the study participants were asked to explore the website of the CDC's newly released "Get Smart" campaign (CDC, 2013), which included explicit guidelines for how patients can prevent antibiotic resistance (e.g., "Take the antibiotic exactly as the doctor prescribes. Do not skip doses. Complete the prescribed course of treatment, even when you start feeling better"). However, these guidelines were embedded in a great deal of additional information, some of which was not critical to patients' understanding of how and why to change their own behaviors (e.g., "Three out of 10 children who visit an outpatient provider with the common cold receive an antibiotic…but antibiotics are not indicated for a common cold"), and some of which might even have dissuaded participants from completing the full course of antibiotics (e.g., "Overuse of antibiotics has helped create new strains of infectious diseases").

In the explanation condition (n = 38), participants were presented with an explanation that specifically focused on the conceptual prerequisites necessary for understanding *why* completing the course of antibiotics is effective and important. The text drew a clear distinction between antibiotics and medications prescribed for symptomatic relief: "Antibiotics target the root cause of an illness, killing the bacteria that cause the sickness at hand. In contrast, other medicines are used to treat symptoms and don't target the cause of the problem, making it prudent to stop taking those medicines when you feel better.

Antibiotics are different—to completely eradicate the cause of the illness, it is important to continue taking antibiotics for the full course rather than stopping treatment once your symptoms have been relieved." The intervention further explained the basic evolutionary biology behind antibiotic resistance, clarifying that deviating from the dosage and timing of an antibiotic prescription makes it less likely that all of the bacteria will be killed: "Bacteria are living organisms, and once they enter your body they begin to reproduce and multiply. The bacteria have varying levels of tolerance to the prescribed antibiotics. The weakest bacteria are killed off first, while the stronger bacteria take longer to succumb to the antibiotic....If you stop taking your antibiotics before killing off those more resilient bacteria, they will multiply at a rapid rate....The successive generations of these bacteria are more likely to become resistant to antibiotics, creating diseases that are very difficult to treat and that could be passed on to others around you."

Note that, in all three conditions, participants received clear instructions that they should complete the full course of antibiotics, but only the explanation condition explained how this prevents antibiotic resistance.

Participants in all conditions were then provided with the pill labels and package inserts for each prescribed medication (antibiotic and nonantibiotic) and were asked to reason about several hypothetical scenarios in which people might be tempted to stop short of taking the full course of a prescription. Participants judged how likely they would be to delay filling their prescription if they were busy; to take an over-the-counter medication recommended by a friend instead of the prescribed medication; to skip a dose if they were running late to a social engagement and forgot their medication at home; to seek a new prescription if they were on vacation and forgot to pack their medication; and to lower their dosage if they were feeling better after a few days of treatment. Participants also described what they would do if their symptoms vanished by the third day of treatment; if the medication made them nauseated; and if they dropped their remaining pills in the sink after finishing the majority of the prescription.

Responses were considered "compliant" if participants strongly endorsed filling their prescription immediately and strongly opposed substituting, skipping, or lowering doses of the prescribed medication. These responses revealed both participants' ability to generalize their conceptual understanding to new scenarios and their degree of conviction about the importance of antibiotic compliance.

Across conditions, participants distinguished between antibiotics and nonantibiotic medications in appropriate ways, giving more "compliant" responses when reasoning about scenarios in which they were prescribed antibiotics ($b = 0.79$, $z = 12.72$, $p < .001$)—but, importantly, participants in the explanation condition differentiated *more* between antibiotic and nonantibiotic scenarios compared to participants in the CDC and package-insert-only conditions ($b = 0.14$, $z = 3.14$, $p = .002$), who did not differ ($b = -0.08$, $z = -1.09$, $p = .276$). Considering only scenarios featuring an antibiotic prescription, post hoc analyses confirmed that explanation participants were more likely to be compliant than participants in the CDC condition, $\chi^2(1) = 13.25$, $p < .001$, or the package-insert-only condition, $\chi^2(1) = 6.03$, $p = .014$, who did not differ, $\chi^2(1) = 1.40$, $p = .238$. For example, 76% of participants in the explanation condition said they were "unlikely" or "very unlikely" to lower their dosage of an antibiotic if they were feeling better after a few days, compared to 48% in the CDC condition and 63% in the package-insert-only condition. Likewise, 66% of participants in the explanation condition clearly indicated that they would seek a replacement prescription if they dropped the last few days' worth of antibiotic pills down the sink, compared to 48% in the CDC condition and 49% in the package-insert-only condition. (Responses to the nonantibiotic scenarios did not differ across conditions.)

In short, an explanation that addressed necessary conceptual prerequisites led individuals to endorse completing the full course of an antibiotic prescription across a variety of challenging contexts. Participants who received this intervention were more likely to report intentions to engage in compliant behaviors even compared to participants given state-of-the-art materials from the CDC.

Case study 3: Vaccination

Our third case focuses on parents' increasing reluctance to have their children vaccinated against infectious diseases. This has resulted in the troubling reappearance of previously eradicated childhood diseases, including measles and pertussis. Parents' reluctance seems to stem primarily from the false belief that vaccines have dangerous side effects, such as the potential to cause autism.

Efforts to refute beliefs about the risks of vaccines have largely failed. In a recent study, Horne, Powell, Hummel, and Holyoak (2015) suggest three reasons for these failures: People with strong beliefs often succumb to a confirmation bias and discount negative evidence; it is difficult to provide convincing evidence for a lack of risk; and efforts to convince parents about the safety of vaccines sometimes backfire, actually strengthening beliefs that vaccines are risky.

Following insights from Lewandowsky et al. (2012) on how to combat misinformation, Horne and colleagues compared an intervention that attempted to counter beliefs about the danger of vaccines with an intervention that emphasized the risks of *failing* to have children vaccinated.

In the autism correction condition, participants read materials from a CDC website designed to counter beliefs about the risks of vaccines, including statements such as "A 2006 study published in the *Journal of Autism and Developmental Disorders* of 351 children with autism and 31 typically developing children did not find a link between MMR vaccination and autism." Given how poorly similar interventions have fared in the past, this was not expected to improve attitudes toward vaccines.

In the disease risk condition, participants read other material from the CDC that emphasized how serious childhood diseases can be. For example: "For Megan Campbell's 10-month-old son, a life-threatening bout of measles caused fevers spiking to 106 degrees and sent him to the hospital. 'We spent 3 days in the hospital fearing we might lose our baby boy,' Campbell said. '… For a while he seemed to be wasting away.'" This intervention was hypothesized to be more successful in improving vaccine attitudes.

In a control condition, participants read irrelevant scientific material.

Before and after reading these materials, participants completed a vaccine attitudes questionnaire, including items such as, "The risk of side effects outweighs any potential benefits of vaccines," and, "I plan to vaccinate my children." As with the antibiotic resistance study, we consider these responses both to reflect participants' conviction about the importance of vaccinating children and to indicate how they might act in the future.

As predicted, neither the autism correction condition nor the control condition resulted in any improvement in vaccine attitudes from pre- to posttest. However, the disease risk condition significantly improved vaccine attitudes, especially among the participants who were initially most negative. The authors argue that, by emphasizing the risk of childhood diseases rather than dwelling on the safety of vaccines, the disease risk intervention avoided backfiring effects and alerted participants to an important aspect of vaccination that they may have otherwise overlooked.

We would add that one of the core conceptual beliefs here is that parents view babies and young children as extremely vulnerable. Indeed, parents who research vaccine safety are likely to encounter many compelling explanations of why to avoid vaccinating children. Consider the following excerpt from a blog post titled "Six Reasons to Say NO to Vaccination": "Here is a list of some of the damaging ingredients in the vaccines on the market today: MSG, antifreeze, phenol (used as a disinfectant), formaldehyde (cancer causing and used to embalm), [the list continues with 18 more entries]…How could anyone possibly think injection of such a cocktail of poison could in any way help preserve and enhance your child's health?" (Pope, n.d., section #2, para. 1).

In our view, one reason that the disease risk intervention was successful is that it addressed an important gap in this lay theory of infant vulnerability: Skeptical parents focus on the danger of vaccines, but underestimate the severity of the diseases themselves. Instead of elaborating the causal link between the target behavior and the health goal, as in the other case studies we review, this intervention corrected a misconception about the importance of the health goal itself: Stories about infants suffering from diseases like measles enriched the conceptual framework by filling in the other side of infant vulnerability, thereby helping to persuade skeptics that the benefits of childhood vaccination outweigh the risks. In contrast, the flat denials of the risks of vaccines in the autism correction condition failed to penetrate participants' implicit theories that children are vulnerable and vaccines are dangerous poisons. Such statements offer no means of reconciling the reputed safety of vaccines with participants' beliefs.

Given this, should we abandon attempts to reassure parents that vaccines are safe? This conclusion may be premature: In addition to filling a gap in parents' lay theories by providing information about the risks of childhood diseases, we might also strive to correct misconceptions about the danger of vaccines with explanations precisely crafted to supplant parents' existing theories with a more accurate one.

Case study 4: Nutrition

Our final case study moves away from infectious diseases to consider the urgent need to improve the diet of American children. Obesity and diabetes have reached staggering proportions in the U.S., and the standard American diet falls far short of the nutritional requirements needed for optimal health: 93% of U.S. children fail to meet recommendations for vegetable consumption (Kim et al., 2014), instead consuming 40% of their calories from added sugars and solid fats (CDC, 2015). Of course, there are many social, cultural, economic, and practical forces at play in determining children's eating behaviors—but making nutritious food more accessible to children will not be of much help if they refuse to eat it.

Gripshover and Markman (2013) proposed that giving children a conceptual framework for understanding the need to eat a variety of healthy foods might make them more open-minded about trying foods that are offered to them. They selected the goal of dietary variety because it should remain a core component of nutritional education throughout development and should be robust over debates about what constitutes healthy food. It also avoids some of the pitfalls—for example, of emphasizing healthy versus unhealthy foods (which often implies that unhealthy foods taste bettter; Maimaran & Fishbach, 2014; Wardle & Huon, 2000), or teaching portion control (which might lead to eating disorders; S. L. Johnson & Birch, 1994).

Gripshover and Markman began with an analysis of children's current understanding of nutrition. Preschool-age children have a simple vitalism that leads them to believe that food is essential to life and that people cannot live on water alone (Inagaki, 1996; Inagaki & Hatano, 2004; C. Johnson & Wellman, 1982). They know that after you chew and swallow food, it goes into your stomach, and later you excrete it. But this crude input–output system provides no causal mechanism for how food could sustain life, or why people need to eat a variety of different foods to be healthy.

To provide such a causal framework, Gripshover and Markman's educational materials focused on several conceptual components that are required to understand the need to eat a variety of healthy foods. The training exploited children's incipient understanding of mixtures (Au, Sidle, & Rollins, 1993; Rosen & Rozin, 1993)—such as sugar dissolved in water, which you cannot see but you know is there because you can taste it—to explain that nutrients are heterogeneous components, too small to see, in seemingly homogenous foods. To provide a causal mechanism for how food can sustain life, the training explained that the stomach has "a special way" of breaking food up into smaller and smaller pieces until the nutrients pop out and then blood takes the nutrients to all parts of the body. In the key explanation of why it is important to eat a *variety* of healthy foods, the training emphasized that any given food provides some, but not all, needed nutrients, and different nutrients are required for different biological processes.

In two studies, five short books focusing on these conceptual prerequisites were read to children in small groups in their preschool classroom. In the first study, there was a no treatment control. In the second study, children in the control condition heard five short books recommended by the U.S. Department of Agriculture (USDA) for teaching young children about nutrition (USDA, 2012).

Children in the theory-trained group dramatically outperformed children in both control conditions on tests of their understanding of the basic concepts of nutrients, digestion, and the need for variety. For example, in response to the question "Why do you need blood?", control children either said they didn't know or confabulated reasons (e.g., "It's like a warning for your body. Like if you pick your nose, the blood comes out to warn your body—your fingers or something—that picking your nose to say no"). In marked contrast, theory-trained children gave explanations like, "To carry the nutrients around our body. So we can do things," or, "To get the nutrients everywhere. You need it to live."

In the critical test of behavior change, Gripshover and Markman also measured pre- to posttest changes in the foods children selected during snack time at their school, and found that theory-trained children showed greater increases in their selection of pieces of vegetables to eat than children in the control conditions. The snack-time routine at this school—where healthy food was passed around and children could select what they wanted—modeled healthy eating. In this supportive context, providing children with a coherent explanatory framework not only improved their conceptual understanding of nutrition but also motivated them to change their behavior in theory-consistent ways.

Discussion

The case studies we reviewed here highlight an understudied benefit of cogent explanations: They can empower people to change their behavior. In this way, theory-based explanations can function as powerful interventions for addressing current health crises.

In four health domains, explanations designed to address gaps and misconceptions in participants' lay theories led people to endorse target behaviors as effective means of achieving health goals. In the case of avoiding antibiotic resistance, for example, explanations that (1) distinguished between antibiotics and medications for symptomatic relief and (2) elaborated the evolutionary biology of bacteria led adults to predict they'd be more likely to practice antibiotic compliance in hypothetical scenarios (Hasan & Markman, 2014). Similarly, addressing misconceptions about the severity of childhood diseases improved adults' attitudes toward vaccinating children (Horne et al., 2015).

Moreover, in both of the cases that measured real-world outcomes, theory-based explanations successfully engendered actual behavior change. Providing children with an understanding of germs as organisms that thrive in some conditions and die in others led to more handwashing (Au et al., 2008), and teaching children a conceptual framework for understanding the importance of dietary variety led to increased selection of vegetables at snack time (Gripshover & Markman, 2013).

Theory-based explanations outperformed current best practices developed by the CDC, USDA, and Hong Kong Department of Health. Aside from representing the best efforts of national health authorities to address problems of critical importance, what these control conditions have in common is that they presented information in a relatively atheoretical way: For example, to combat the misconception that vaccines cause autism, the CDC materials employed in Horne et al.'s (2015) control condition included statements such as, "Many scientific studies have found no link between MMR vaccine and autism." In the absence of a conceptual framework, the facts and advice in these control conditions failed to change people's convictions or behaviors. This speaks to the power of explanations—above and beyond mere information—to foster conceptual and behavioral change.

At the same time, these control conditions also demonstrate that more information is not necessarily better. Some of these state-of-the-art interventions provided participants with a great deal of information, much of which was not relevant to the particular health goal. For example, the package inserts and CDC website on antibiotic compliance featured in Hasan and Markman's (2014) control conditions embedded instructions to complete the full course of an antibiotic prescription in the context of warnings about side effects, the dangers of overusing antibiotics, and so on. In contrast, the successful explanations targeted key conceptual prerequisites, isolated from superfluous or contradictory information.

What, then, is the ideal level of detail, specificity, and elaboration for an effective explanation-based intervention? We suggest that such explanations should provide the *minimum* amount of information required to understand the causal link between a target behavior and a health outcome. Presenting too many details about the causal process—such as the molecular biology underlying differences in "strength" across different bacteria, or the varied biochemical mechanisms by which the gut extracts nutrients from food—may obscure the more basic underlying logic of the system, detracting from the clear and coherent causal frameworks tailored to the particular health goal. Indeed, people find simple and parsimonious explanations preferable and more probable than complex ones (Lombrozo, 2007). This general preference for simplicity might very well extend to preferring streamlined explanations over more detailed expositions, at least when it comes being convinced to change one's behaviors.

The understanding provided by this kind of explanation will be incomplete: It could well include placeholder concepts and sketchy outlines of some causal mechanisms. For example, adults learning about antibiotic resistance don't need to know exactly how antibiotics kill bacteria or precisely why certain bacteria take longer to succumb to an antibiotic. Similarly, children learning about nutrition were taught that the stomach has "a special way" of breaking foods down in the course of digestion, leaving the precise mechanism of digestion vague. We know, however, that people are comfortable acting on the basis of even spotty theories—and often fail to realize that there are details they do not understand. Keil (2003) has argued that, while this "illusion of explanatory depth" sometimes causes problems, it can also be beneficial, allowing people to act when they have a sufficient understanding of their environment without being paralyzed by questions about details that are not critical to their goals. From our perspective, this indicates that people's motivation and behavior are constrained by their understanding of the facts and relationships that *matter*, and not by their understanding (or lack thereof) of details that aren't critical. Theory-based explanations can capitalize on Keil's insights by focusing on key components of a causal framework and glossing over the less important details.

By focusing on the underlying logic rather than the superficial details, such explanations might also make people's theories more robust to apparent counterevidence and new information. Without a cogent causal framework, when confronted with conflicting information or contradictory advice, people may start to doubt the best course of action—but with a compelling causal framework, superficial inconsistencies are less likely to shake people's conviction. This is particularly important in the health domain: While ongoing medical research frequently produces new insights and recommendations about the specific details of disease prevention, nutrition, and so on, the underlying logic of a given causal system is less likely to undergo radical revisions. Debates rage, for example, about how much protein, grains, or fat should be part of a healthy diet, but the more general and deeper fact that different biological processes require different combinations of nutrients—which necessitates eating a *variety* of healthy foods—remains incontrovertible. Moreover, cogent explanations that have left some details unspecified can readily be elaborated. For example, learning that digestion requires digestive enzymes and that the small intestine continues to extract nutrients from food should pose no problem for someone who has learned the stomach (somehow) extracts nutrients from food. Thus, such theories can serve as the foundation for elaboration and the integration of new information, without compromising their ability to guide people's reasoning and behavior.

Indeed, we know that coherent theories are resilient, and unlikely to be abandoned: The history of science is replete with examples of flawed theories that nonetheless proved extremely difficult to overhaul (Kuhn, 1962), and lay theories can be quite impervious to counterexamples and counterevidence (e.g., Carey, 1985; Hood, 1995; Lewandowsky et al., 2012). Seen in another light, this resistance to change speaks to the resilience of lay theories. To the extent that explanations establish coherent, reasonably accurate frameworks, they should guide people's reasoning and behavior not only immediately after an intervention but well into the future.

In several seemingly intractable health crises facing us today—viral epidemics, the reappearance of infectious diseases, antibiotic resistance, and unhealthy diets—theory-based explanations show great promise for changing people's beliefs and behaviors. We suggest that this approach could profitably be extended to other problems, especially when more traditional interventions have failed. Well-crafted, evidence-based explanations can play a pivotal role not only in conceptual change but also in convincing people to act on their newly acquired theories.

Acknowledgements This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program under Grant No. DGE-114747, and by a William R. & Sara Hart Kimball Stanford Graduate Fellowship.

References

Au, T. K., Chan, C. K. K., Chan, T., Cheung, M. W. L., Ho, J. Y. S., & Ip, G. W. M. (2008). Folkbiology meets microbiology: A study of conceptual and behavioral change. *Cognitive Psychology, 57*(1), 1–19. doi:10.1016/j.cogpsych.2008.03.002

Au, T. K., & Romo, L. F. (1996). Building a coheren conception of HIV transmission: A new approach to AIDS education. In D. L. Medin (Ed.), *The psychology of learning and motivation* (pp. 193–241). New York, NY: Academic Press.

Au, T. K., Sidle, A. L., & Rollins, K. B. (1993). Developing an intuitive understanding of conservation and contamination: Invisible particles as a plausible mechanism. *Developmental Psychology, 29*(2), 286–299. doi:10.1037/0012-1649.29.2.286

Baranowski, T., Cullen, K. W., Nicklas, T., Thompson, D., Baranowski, J., Cullen, K. W., & Thompson, D. (2003). Are current health behavioral change models helpful in guiding prevention of weight gain efforts ? *Obesity Research, 11,* 23S–43S.

Branthwaite, A., & Pechère, J.-C. (1996). Pan-European survey of patients' attitudes to antibiotics and antibiotic use. *The Journal of International Medical Research, 24*(3), 229–238.

Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.

Carey, S. (2009). *The origin of concepts*. New York, NY: Oxford University Press.

Centers for Disease Control and Prevention. (2013). *Antibiotics: Will they work when you really need them?* Retrieved from www.cdc.gov/getsmart

Centers for Disease Control and Prevention. (2015). *Nutrition and the health of young people*. Retrieved from http://www.cdc.gov/healthyschools/nutrition/facts.htm

Davey, P., Pagliari, C., & Hayes, A. (2002). The patient's role in the spread and control of bacterial resistance to antibiotics. *Clinical Microbiology and Infection: The Official Publication of the European Society of Clinical Microbiology and Infectious Diseases, 8*(Suppl. 2), 43–68.

Gopnik, A., & Wellman, H. M. (1994). The theory theory. In L. A. Gelman & S. A. Hirschfeld (Eds.), *Mapping the mind: Domain specificity in cognition and culture* (pp. 257–293). New York, NY: Cambridge University Press. doi:10.1017/CBO9780511752902.011

Gripshover, S. J., & Markman, E. M. (2013). Teaching young children a theory of nutrition: Conceptual change and the potential for increased vegetable consumption. *Psychological Science, 24*(8), 1541–1553. doi:10.1177/0956797612474827

Hasan, T., & Markman, E. M. (2014). *Implicit theories of medicine use: Clarifying misconceptions in taking prescribed medicine in order to increase compliance with antibiotics* (Masters thesis, Stanford University, Stanford, CA)

Hawkings, N. J., Butler, C. C., & Wood, F. (2008). Antibiotics in the community: A typology of user behaviours. *Patient Education and Counseling, 73*(1), 146–152. doi:10.1016/j.pec.2008.05.025

Helweg-Larsen, M., & Collins, B. E. (1997). A social psychological perspective on the role of knowledge about AIDS in AIDS prevention. *Current Directions in Psychological Science, 6*(2), 23–26.

Hood, B. (1995). Gravity rules for 2-4 year olds? *Cognitive Development, 10,* 577–598.

Horne, Z., Powell, D., Hummel, J. E., & Holyoak, K. J. (2015). Countering antivaccination attitudes. *PNAS Proceedings of the National Academy of Sciences of the United States of America, 112*(33), 10321–10324. doi:10.1073/pnas.1504019112

Inagaki, K. (1996). Young children's recognition of commonalities between animals and plants. *Child Development, 67*(6), 2823–2840.

Inagaki, K., & Hatano, G. (2004). Vitalistic causality in young children's naive biology. *Trends in Cognitive Sciences, 8*(8), 356–362. doi:10.1016/j.tics.2004.06.004

Johnson, S. L., & Birch, L. L. (1994). Parents' and children's adiposity and eating style. *Pediatrics, 94*(5), 653–661.

Johnson, C., & Wellman, H. (1982). Children's developing conceptions of the mind and brain. *Child Developement, 53*(1), 222–234.

Kardas, P., Devine, S., Golembesky, A., & Roberts, C. (2005). A systematic review and meta-analysis of misuse of antibiotic therapies in the community. *International Journal of Antimicrobial Agents, 26*(2), 106–113. doi:10.1016/j.ijantimicag.2005.04.017

Keil, F. C. (1994). The birth and nurturance of concepts by domains: The origins of concepts of living things. In L. A. Hirschfeld & S. A. Gelman (Eds.), *Mapping the mind: Domain specificity in cognition and culture* (pp. 235–254). Cambridge, UK: Cambridge University Press.

Keil, F. C. (2003). Folkscience: Coarse interpretations of a complex reality. *Trends in Cognitive Sciences, 7*(8), 368–373. doi:10.1016/S1364-6613(03)00158-X

Kim, S. A., Moore, L. V, Galuska, D., Wright, A. P., Harris, D., Grummer-Strawn, L. M.,…Rhodes, D. G. (2014). *Vital signs: Fruit and vegetable intake among children—United States, 2003–2010.* Retrieved from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6331a3.htm?s_cid=mm6331a3_w

Kuhn, T. S. (1962). *The structure of scientific revolutions*. Chicago, IL: University of Chicago Press.

Lewandowsky, S., Ecker, U. K. H., Seifert, C. M., Schwarz, N., & Cook, J. (2012). Misinformation and its correction: Continued influence and successful debiasing. *Psychological Science in the Public Interest, 13*(3), 106–131. doi:10.1177/1529100612451018

Lombrozo, T. (2007). Simplicity and probability in causal explanation. *Cognitive Psychology, 55*(3), 232–257. doi:10.1016/j.cogpsych.2006.09.006

Maimaran, M., & Fishbach, A. (2014). If it's useful and you know it, do you eat? Preschoolers refrain from instrumental food. *Journal of Consumer Research, 41*(3), 642–655. doi:10.1086/677224

McNulty, C. A. M., Boyle, P., Nichols, T., Clappison, P., & Davey, P. (2007). Don't wear me out—The public's knowledge of and attitudes to antibiotic use. *Journal of Antimicrobial Chemotherapy, 59,* 727–738. doi:10.1093/jac/dkl558

Murphy, G. L., & Medin, D. L. (1985). The role of theories in conceptual coherence. *Psychological Review, 92*(3), 289–316. doi:10.1037/0033-295X.92.3.289

Pope, S. (n.d.). Six reasons to say no to vaccination. Retrieved from http://www.thehealthyhomeeconomist.com/six-reasons-to-say-no-to-vaccination/

Rehder, B., & Ross, B. H. (2001). Abstract coherent categories. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*(5), 1261–1275.

Rosen, A. B., & Rozin, P. (1993). Now you see it, now you don't: The preschool child's conception of invisible particles in the context of dissolving. *Developmental Psychology, 29*(2), 300–311. doi:10.1037/0012-1649.29.2.300

Schulz, L., Kushnir, T., & Gopnik, A. (2007). Learning from doing: Intervention and causal inference. In A. Gopnik & L. Schulz (Eds.), *Causal learning: Psychology, philosophy, and computation* (pp. 67–85). New York, NY: Oxford University Press.

U.S. Department of Agriculture. (2012). *Team nutrition.* Retrieved from http://teamnutrition.usda.gov

Walker, C. M., & Gopnik, A. (2014). Toddlers infer higher-order relational principles in causal learning. *Psychological Science, 25*(1), 161–169. doi:10.1177/0956797613502983

Wansink, B. (2010). From mindless eating to mindlessly eating better. *Physiology and Behavior, 100*(5), 454–463. doi:10.1016/j.physbeh.2010.05.003

Wardle, J., & Huon, G. (2000). An experimental investigation of the influence of health information on children's taste preferences. *Health Education Research, 15*(1), 39–44. doi:10.1093/her/15.1.39

Wellman, H. M., & Gelman, S. A. (1992). Cognitive development: Foundational theories of core domains. *Annual Review of Psychology, 43,* 337–375.

World Health Organization. (2014). *Antimicrobial resistance: Global report on surveillance*. doi:10.1007/s13312-014-0374-3

World Health Organization. (2014b). *WHO's first global report on antibiotic resistance reveals serious, worldwide threat to public health.* Retrieved from http://www.who.int/mediacentre/news/releases/2014/amr-report/en/