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Increasing Vaccination: Putting Psychological Science Into Action

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Summary

Vaccination is one of the great achievements of the 20th century, yet persistent public-health problems include inadequate, delayed, and unstable vaccination uptake. Psychology offers three general propositions for understanding and intervening to increase uptake where vaccines are available and affordable. The first proposition is that *thoughts and feelings* can motivate getting vaccinated. Hundreds of studies have shown that risk beliefs and anticipated regret about infectious disease correlate reliably with getting vaccinated; low confidence in vaccine effectiveness and concern about safety correlate reliably with not getting vaccinated. We were surprised to find that few randomized trials have successfully changed what people think and feel about vaccines, and those few that succeeded were minimally effective in increasing uptake. The second proposition is that *social processes* can motivate getting vaccinated. Substantial research has shown that social norms are associated with vaccination, but few interventions examined whether normative messages increase vaccination uptake. Many experimental studies have relied on hypothetical scenarios to demonstrate that altruism and free riding (i.e., taking advantage of the protection provided by others) can affect intended behavior, but few randomized trials have tested strategies to change social processes to increase vaccination uptake. The third proposition is that interventions can *facilitate vaccination directly* by leveraging, but not trying to change, what people think and feel. These interventions are by far the most plentiful and effective in the literature. To increase vaccine uptake, these interventions build on existing favorable intentions by facilitating action (through reminders, prompts, and primes) and reducing barriers (through logistics and healthy defaults); these interventions also shape behavior (through incentives, sanctions, and requirements). Although identification of principles for changing thoughts and feelings to motivate vaccination is a work in progress, psychological principles can now inform the design of systems and policies to directly facilitate action.

Keywords

vaccination, risk perception, affect, social processes, default, intervention, public health

One of the great public-health achievements of the 20th century is vaccination against infectious diseases. It saves millions of lives and billions of dollars annually (Centers for Disease Control and Prevention [CDC], 1999). Vaccination schedules have expanded steadily over the years as effective vaccines have increased in number. This success has produced strong public support for childhood vaccination (Gellin, Maibach, & Marcuse, 2000).

In this context, it is perplexing to some that vaccine providers and programs face substantial headwinds. Uptake is highly variable across vaccines. Most infants get their recommended vaccines in most countries, even as many adults and health-care providers routinely skip the seasonal-influenza vaccine. The benefits that

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accrue from vaccination individually and collectively are contingent on individuals' behaviors, and thus the public-health benefits are established or threatened by the behavior of individuals. The success of vaccination programs has left people largely unaware of, and unconcerned about, diseases they have never seen and heard little about. Vaccination regularly generates controversy in traditional and social media, often because of unsubstantiated safety concerns (e.g., Dunn, Leask, Zhou, Mandl, & Coiera, 2015). Program managers and providers lack evidence-based tools for effectively addressing the resulting dips in the public's confidence in vaccination. In these many ways, advances in vaccinology fall prey to the behavioral puzzle of variable vaccine uptake.

Psychology offers insight into why people engage in health behaviors, including vaccination. However, the empirical findings that can inform and constrain psychological theories about vaccination appear in disconnected literatures across psychology, public health, medicine, nursing, sociology, and behavioral economics. We sought to integrate this scattered literature and to better understand how the findings inform and constrain psychological theories when applied to vaccination.

Psychological theories offer three general propositions for understanding and increasing vaccination. The first proposition is that thoughts and feelings motivate getting vaccinated, yet the veracity of this claim is not well established. For instance, it makes intuitive sense that people get vaccinated because they feel at risk. But is this true? And if so, do interventions that can increase risk perceptions lead to higher rates of vaccination? A second proposition is that the social context of vaccination has a large impact on uptake. A new mother in a parenting group, who hears that her peers are getting vaccines for their children, might become more inclined to do the same. But do studies support this intuition? A third proposition is that it is possible to use psychological principles to increase vaccination directly without modifying people's thoughts, feelings, or social experiences. For instance, structuring the decision to get vaccinated as the default behavioral option is promising, but we do not know which forms of defaults are most effective and under what conditions.

Our review examines the evidence for, and implications of, these three general propositions by examining psychological principles as applied to understanding and increasing vaccination coverage. We consider these issues in contexts where vaccines are generally available and affordable (Thomson, Robinson, & Vallée-Tourangeau, 2016) because, under those circumstances, psychological processes have the most opportunity to exert an influence. Supply-side issues that affect vaccination coverage in many countries are important but are not the focus of our review (Zaffran et al., 2013).

The first section of our article situates vaccination in a public-health context. The following sections examine the evidence for the three psychological propositions about vaccination and their implications for intervention strategies for increasing uptake. Section 2 reviews what people think and feel about vaccination and implications for behavior; Section 3 examines social processes in the context of vaccination; and Section 4 examines approaches to changing vaccination behavior directly. The final section summarizes which of these psychological propositions have the greatest potential to increase vaccination coverage and how and when to deploy interventions based on them. In particular, we conclude that the most effective current methods for facilitating vaccination intervene on behavior directly, rather than attempting to change what people think and feel or their social context.

To show how psychological science can offer new insights into vaccination behavior, the sections that follow apply the three general psychological propositions (thoughts/feelings, social processes, directly affecting behavior) to understanding how provider recommendation may exert its effects. Provider recommendation is a strong motivator for getting a vaccination. For example, in one study, 38% of adolescent boys received a human papillomavirus (HPV) vaccine if their parents received a provider recommendation, but only 2% received the vaccine if the parents did not receive a recommendation (Reiter, Gilkey, & Brewer, 2013; Reiter, McRee, et al., 2013). The impact of provider recommendation holds true across all vaccines studied (Pandolfi et al., 2012; Wiley & Leask, 2013). Although many of the relevant studies are cross-sectional and rely on patient self-report, they suggest that provider recommendation can be a potent intervention, and some approaches, such as presumptive recommendations, are even more effective than standard recommendations (Brewer et al., 2017). Developing a better understanding of why and when provider recommendations increase vaccination could make them more effective.

Researchers in the field of vaccination have offered frameworks to organize and make sense of this research and identify new directions for intervention (e.g., Dubé et al., 2013; Kaufman et al., 2017; Nowak, LaVail, Kennedy, & Sheedy, 2013), but looking at influences on vaccination behavior from a psychological perspective can offer useful insights. Studies commonly evaluate complex, multicomponent interventions and show that they are effective at increasing vaccination (e.g., Briss et al., 2000; Rashid et al., 2016). Thinking about the psychological processes at play

can shed new light on the intervention components likely to be most effective and why and when they are effective. Our goal is to examine key psychological factors that shape vaccination uptake and offer promise for intervention to increase vaccination coverage, but we do not cover all forces that shape vaccine-related thoughts and actions.

Section 1: Vaccination and Public Health

To orient readers, we review the basics of vaccination, identify the three main problems facing vaccination, and discuss the role of vaccination activists.

Vaccine "basics"

Vaccines protect against infection by viruses and bacteria by mimicking an infection in order to activate the body's natural immunity. Most childhood vaccines require multiple doses to produce strong immunity to disease and may require periodic booster doses to counteract waning immunity over time. Seasonal-influenza vaccine requires an annual dose because the circulating pathogens change year to year. Some vaccines require only a single dose, especially those for older adults. Vaccination protects the person vaccinated and others around them by reducing the spread of disease. An additional benefit to society can accrue if sufficient *herd immunity* develops. This happens when enough people are vaccinated that the pathogen cannot reproduce. The threshold required for herd immunity varies by disease, but it typically ranges between 80% and 90% vaccination of the population (Doherty, Buchy, Standaert, Giaquinto, & Prado-Cohrs, 2016; Fine, 1993). The failure of herd immunity as a result of vaccine coverage falling below a threshold can trigger outbreaks that tie up significant resources and can lead to disease and sometimes death.

Routine vaccination of infants, children, and adults prevents around 2 to 3 million deaths every year in developed and in developing countries, according to World Health Organization (WHO; 2013) estimates. Elimination of smallpox through vaccination accounts for the majority of these lives saved, and ongoing routine vaccination programs account for the rest. Vaccines are cost-effective because of the value assigned to reductions in morbidity and mortality (Ozawa, Mirelman, Stack, Walker, & Levine, 2012). The seasonal-influenza vaccine even provides cost savings because it reduces the need for sick care and missed days of work as a result of illness. (Peasah, Azziz-Baumgartner, Breese, Meltzer, & Widdowson, 2013). The seasonal-influenza vaccine saves about $117 for every dose delivered to older adults in the United States (Nichol, Margolis, Wuorenma, & Von Sternberg, 1994), although other estimates are lower; data are unavailable for low-income countries. Given that vaccines are both effective and cost-effective, the Gates Foundation declared 2011 to 2020 to be the "Decade of Vaccines" to maximize their impact. The World Health Organization and its 194 member states followed with a global plan to extent the "benefits of immunization to all people, regardless of where they are born, who they are, or where they live" (WHO, 2013, p. 5).

The substantial value offered by vaccination has led to guidelines for routine delivery of vaccines from birth to old age. An inspection of vaccination schedules (Fig. 1) shows most vaccines are used in the first months of life, when surrogates such as a parent and health-care provider make these decisions. Between birth and 18 months, babies get as many as 10 vaccines (e.g., hepatitis B, polio, rotavirus) with additional doses up to age 6. Many countries recommend that adolescents receive a booster vaccine—Dtap, dTpa, or Tdap—for diphtheria, tetanus, and pertussis (whooping cough; the "a" indicates that the pertussis component of the vaccine is acellular) as well as meningitis and HPV vaccines (both of which require multiple doses). High-income countries typically recommend the seasonal-influenza vaccine for people from 6 months through adulthood. Vaccines recommended for older adults are also available, including shingles, pneumococcus, and seasonal-influenza vaccines.

The varied number and purpose of vaccines across the life span creates a rich behavioral ecosystem to which psychological science can contribute important new insights. Vaccination achieves its promised benefits only when most individuals behave according to vaccination recommendations. The impact of different psychological principles may depend, in part, on the specific vaccine, its schedule, and the larger clinical and social context of vaccination. For example, adoption of HPV vaccines in the United States was hampered by its initial licensure and marketing for adolescent girls but not boys; confusion about HPV infection, the HPV vaccine, and sexual activity; outrage over early industry efforts to promote legislation requiring the vaccine in all 50 states (Colgrove, Abiola, & Mello, 2010); and the transformation of these energies into an unease about the vaccine among parents. These contextual issues slowed adoption of HPV vaccines, which created a problem that persists to this day despite voluminous data showing that the vaccine is highly effective and safe (Gee, Weinbaum, Sukumaran, & Markowitz, 2016). In contrast, two other vaccines for adolescents licensed the year before the HPV vaccine—Tdap booster and meningitis—have already met national coverage goals (Reagan-Steiner et al., 2016), and a new pneumococcal

a

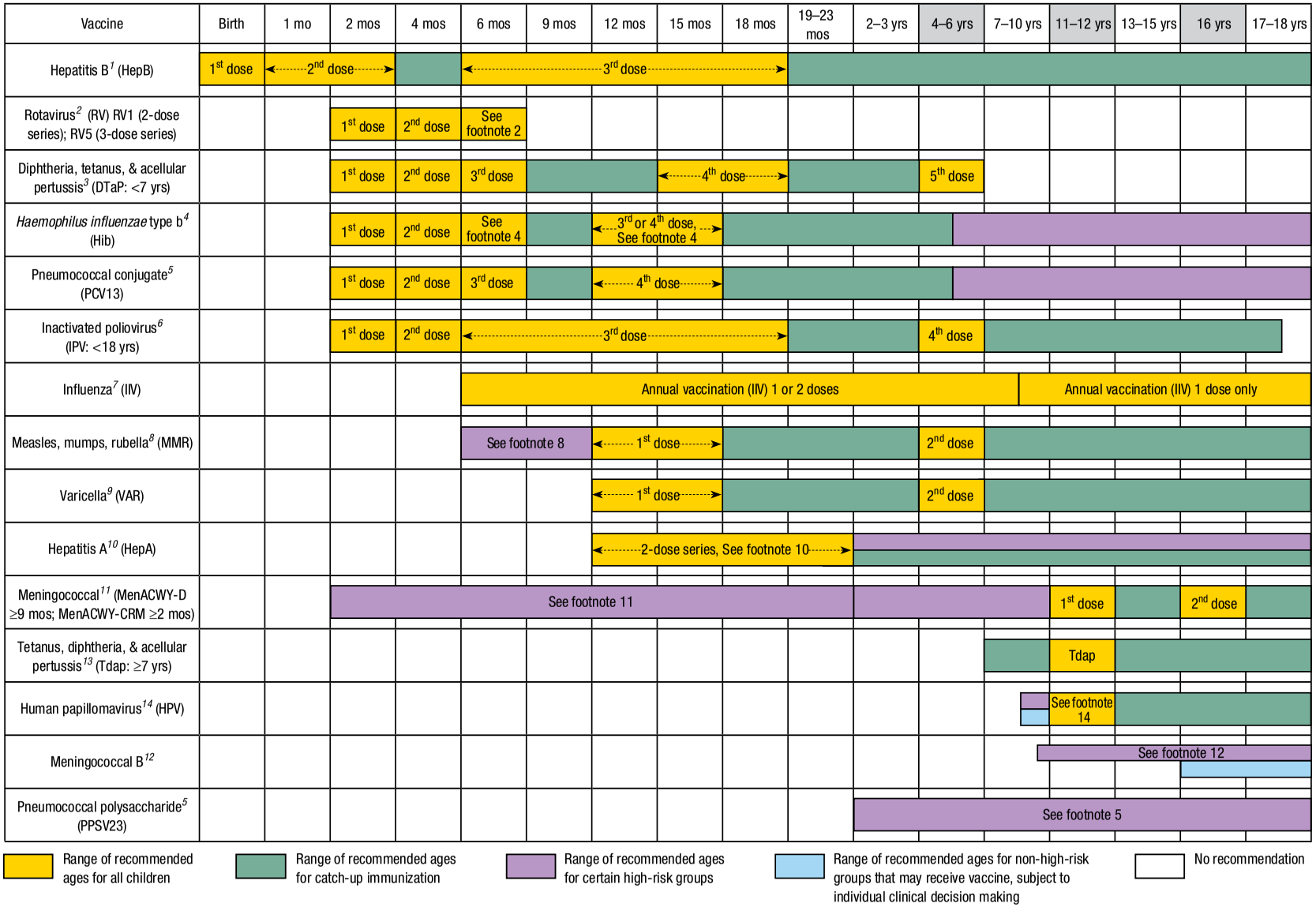

Fig. 1. Recommended immunization schedules from (a) the U.S. Centers for Disease Control and Prevention (2018) and (b) the World Health Organization (2017). For footnote definitions, please see source.

b

Summary of WHO Position Papers - Recommendations for Routine Immunization

Antigen		Children		Adolescents	Adults	Considerations
Recommendations for all immunization programmes						
BCG		1 dose				Exceptions HIV
Hepatitis B		3–4 doses (see footnote for schedule options)		3 doses (for high-risk groups if not previously immunized) (see footnote)		Birth dose Premature and low birth weight Co-administration and combination vaccine Definition high-risk
Polio		3–4 doses (at least one dose of IPV) with DTP				bOPV birth dose Type of vaccine Transmission and importation risk criteria
DTP-containing vaccine		3 doses	2 Boosters 12–23 months (DTP-containing vaccine) and 4–7 years (Td)	1 Booster 9–15 yrs (Td)		Delayed/interrupted schedule Combination vaccine Maternal immunization
***Haemophilus influenzae* type b**	**Option 1**	3 doses, with DTP				Single dose if > 12 months of age Not recommended for children > 5 years old Delayed/interrupted schedule Co-administration and combination vaccine
	Option 2	2 or 3 doses, with booster at least 6 months after last dose				
Pneumococcal (Conjugate)	**Option 1**	3 doses, with DTP				Vaccine options Initiate before 6 months of age Co-administration HIV+ and preterm neonates booster
	Option 2	2 doses before 6 months of age, plus booster dose at 9–15 months of age				
Rotavirus		Rotarix: 2 doses with DTP RotaTeq: 3 doses with DTP				Vaccine options Not recommended if > 24 months old
Measles		2 doses				Combination vaccine; HIV early vaccination; Pregnancy
Rubella		1 dose (see footnote)		1 dose (adolescent girls and/or child bearing aged women if not previously vaccinated; see footnote)		Achieve and sustain 80% coverage Combination vaccine and Co-administration Pregnancy
HPV				2 doses (females)		Target 9–14-year-old girls; Multi-age cohort vaccination; Pregnancy Older age groups ≥ 15 years 3 doses HIV and immunocompromised

Fig. 1. (continued)

vaccine for infants, licensed the year after the HPV vaccine, has also been rapidly adopted (Harriman et al., 2011). Thus, efforts to use psychological insights to promote vaccination are unlikely to be a one-size fits all endeavor. For this reason, we next consider in greater detail the meaning of vaccination as a behavior and the challenges facing uptake.

Vaccination behaviors

Getting vaccinated is a behavior that appears simple but is actually the result of a complex series of behaviors, all of which are contingent on an interlocking system of people, funding, policies, and permissions (Table 1). Children and adults go to a provider to get vaccinated, the provider is employed by a clinic or program, and funding comes through policies established by legislators or perhaps insurers or even nongovernmental organizations. Each of these actors has different goals and resources, and each can take many actions that support or undermine vaccination. Studying vaccination means also studying a myriad of underlying behaviors by these various actors. Thus, "vaccination behavior" can be as different as a Pakistani mother who walks 2 hours to a larger town to get her child vaccinated or a World Health Organization advisory group meeting in Geneva to review evidence and recommend a schedule for routine vaccination.

We will generally focus on vaccine uptake by individuals, which across a population is called *vaccination coverage*. High coverage is important because it creates direct benefits for vaccinated individuals and indirect benefits for their communities. Coverage is high and steady for childhood vaccination and is rising for new vaccines, including those for adolescents. Vaccine coverage is often above 90% for individual vaccines delivered during childhood in high-income countries, and it is even higher for some individual vaccines. For example, in 2016, 86% of children worldwide received at least one dose of a measles vaccine, and coverage was highest (94%) in the Americas and Europe (Casey et al., 2016).

Coverage is inextricably tied to how people access vaccination and health care. People may get vaccines by *active seeking*, sometimes called demand, or through *passive acceptance*. The importance of actively seeking versus passively accepting them may vary by country and by the person's age. In high-income countries, hospitals routinely offer vaccines for babies when they are born, then during routine visits in pediatric or other primary-care settings, and later sometimes through their schools. Teens receive vaccines in school or during routine medical care, but fewer teens than children have routine medical visits (Ziv, Boulet, & Slap, 1999). Adults more often receive vaccines opportunistically when they see a provider for other health-care services, and

Table 1. Examples of Behaviors That Lead to Increased Vaccination

Agent	Behavior example
Adult, parent	Keep personal records of received and recommended vaccines
	Make appointment for vaccination
	Accept vaccine offered by health-care provider
	Sign consent to vaccination at school
	Request vaccination at a pharmacy
Provider	Stock all recommended vaccines at site of care
	Recommend vaccination to patients at all types of visits
	Enact standing orders for vaccination
	Record vaccines in electronic health record
	Record vaccines in regional immunization registry
	Complete training requirements and attend continuing education
Employer	Host vaccination clinics that offer convenient, free vaccines to employees
	Promote vaccination to employees
Regional immunization program manager	Manage the supply of vaccines
	Coordinate quality improvement visits to providers
	Sponsor mass-vaccination clinics in schools
	Conduct communication campaigns
	Manage crisis communication
Legislator	Require vaccination to attend school or college or to access government services or payments
	Fund vaccination program schedules
	Purchase vaccines
	Regulate and support program implementation, including service delivery and vaccine-safety systems
	Evaluate programs
	Pledge contributions to global vaccination initiatives

Table 2. Problems With Vaccination Uptake

Problem	Description
Inadequate coverage	Not meeting goal for vaccination coverage
Delay	Vaccination after the recommended age
Instability	Sudden drop in vaccination coverage after vaccine-safety scare

preventive services vie for limited time during these visits (Yarnall, Pollak, Østbye, Krause, & Michener, 2003). Thus, in high-income countries, accepting offers of vaccination is especially important for children for whom a vaccine is routinely offered, whereas active seeking may be more important for vaccination of teens and adults for whom vaccine is less routinely offered. In contrast, in low- and middle-income countries, parents must often actively seek out vaccination regardless of age, and the impact of practical barriers (e.g., transportation, opportunity costs) can be magnified (Hickler, MacDonald, Senouci, & Schuh, 2017). In low- and middle-income countries, encouraging active demand for vaccination is often the key consideration.

Even as vaccination is common and widely accepted, vaccination programs face challenges. All countries that are asked about such challenges report them, including countries with low, moderate, and high incomes (H. J. Larson, Jarrett, Eckersberger, Smith, & Paterson, 2014). We next review three key problems with vaccine uptake in the areas of coverage adequacy, timeliness, and robustness (Table 2).

Inadequacy. One problem is *inadequacy*, which we define as vaccination coverage that falls below a stated vaccination goal. For example, the United States has established Healthy People 2020, a set of objectives for health behaviors, including coverage targets for various vaccines. Coverage can be problematically low for people who face substantial barriers or actively refuse vaccination (Omer, Salmon, Orenstein, DeHart, & Halsey, 2009; Rainey et al., 2011). The relative contribution of these barriers depends on the country and the health-care system in place there. Receipt of the complete set of recommended childhood vaccines is suboptimal in most countries. More than a quarter of 19- to 35-month olds in the United States do not have all recommended vaccines (Hill, Elam-Evans, Yankey, Singleton, & Dietz, 2016). Vaccine coverage for adolescents and adults is lower still (CDC, 2016). Older adults do the best of any age group on uptake of the seasonal-influenza vaccine, but less than a third get the new shingles vaccine in the United States (W. W. Williams et al., 2017), in part because insurance coverage for the vaccine is spotty and, although only doctors can prescribe it, doses are available primarily at pharmacies.

Health-care providers regularly come into contact with people who are old, sick, or have compromised immune systems. Carrying infectious diseases such as influenza or hepatitis to these groups can be deadly. Health-care workers in 11 European countries have seasonal-influenza vaccination coverage below 30% (P. R. Blank, Schwenkglenks, & Szucs, 2009). Coverage also varies by role and setting. In the United States, seasonal-influenza vaccination coverage is above 90% for workers in hospitals, 80% in outpatient care, and below 70% in long-term care (Black et al., 2016).

Explicit *refusal* of vaccines when offered can lead to low coverage, as can inaction, such as not going to a provider or ignoring vaccination campaigns. Some U.S. parents (6%–25%) have refused one or more vaccines for their children (Gilkey, McRee, et al., 2016; Gilkey, Reiter, et al., 2016; Gust, Darling, Kennedy, & Schwartz, 2008; P. J. Smith et al., 2011). A large minority of parents who initially refuse a vaccine agree to it later (Dempsey et al., 2011; Kornides, McRee, & Gilkey, in press). Actively refusing all vaccines is rare, typically around 1% to 2% in high-income countries (Beard, Hull, Leask, Dey, & McIntyre, 2016; Dempsey et al., 2011; Hill, Elam-Evans, Yankey, Singleton, & Dietz, 2016; Samad et al., 2006; P. J. Smith et al., 2011). Refusal of all vaccines is more common among White children with older, university-educated mothers living in higher income households (Samad et al., 2006; P. J. Smith et al., 2011). Vaccine refusal explains a substantial proportion of measles cases and some pertussis cases (Phadke, Bednarczyk, Salmon, & Omer, 2016), although this may vary by country, depending on access to vaccination.

Delay. Another problem is *delay*, which we define as receiving a vaccination after the recommended age. Low coverage reflects both individuals who will never be vaccinated and those for whom vaccination is delayed but eventually occurs. Like low coverage, delay can be the result of a deliberate choice, passive inaction, or forces external to the individual, such as a vaccine shortage. Over a third of U.S. infants remain undervaccinated for 6 months or longer past the recommended age (Luman et al., 2005). A quarter of U.S. parents report having delayed one or more vaccines for young children (Gilkey, McRee, et al., 2016). Some parents spread out doses according to alternative schedules for reasons that include concerns about pain or safety (Dempsey et al., 2011; Gust et al., 2008). Young children whose parents intentionally delay one or more vaccinations are more likely to remain undervaccinated (Smith, Humiston, Parnell, Vannice, & Salmon, 2010). Many physicians (40%) report that difficult interactions with parents about spreading out of vaccines

decreases their job satisfaction (Kempe, O'Leary, et al., 2015). However, providers are also a source of delay. For example, some providers recommend delaying the HPV vaccine or other vaccines (Gilkey, Malo, Shah, Hall, & Brewer, 2015). Timeliness is also a problem in low- and middle-income countries, in part because of challenges related to supply (Akmatov & Mikolajczyk, 2012).

Claims of rising vaccine refusal or delay are commonplace in the research literature, but the data are largely indirect (Cooper, Larson, & Katz, 2008; Omer et al., 2009). The most direct example is that refusal of HPV vaccination for adolescents increased by 10 percentage points over 4 years (Gilkey, Calo, Marciniak, & Brewer, 2017). However, this conclusion relies on comparing coverage estimates made using different methods. Requested exemptions from school requirements for vaccination have also increased in the United States (Gowda & Dempsey, 2013; Omer, Richards, Ward, & Bednarczyk, 2012; P. J. Smith et al., 2017), although studies do not show contemporaneous drops in vaccination. In Australia, registered objection to vaccination remained stable between 1999 and 2015 (Beard et al., 2016). "Shot limiting" (having two or fewer vaccines at a doctor's visit before the age of 9 months) increased over a 3-year period and was associated with more medical visits and fewer vaccine doses delivered (Robison, Groom, & Young, 2012). Undervaccination among 2-year-olds increased over a 4-year period in a study of eight U.S. managed care organizations (Glanz et al., 2013), although national data did not show corresponding decreases. The number of pediatricians who experienced a parent's refusal of vaccines went up by 13 percentage points over 7 years in the United States (Hough-Telford et al., 2016). Refusal of required childhood vaccines experienced a small increase (0.5%) in the first 2 years of a national U.S. study but was flat in the final years of the study (Omer, Porter, Allen, Salmon, & Bednarczyk, 2017). In sum, we are unaware of compelling evidence of substantially increased refusal and delay, and recent U.S. data suggest that refusal may be stable.

Instability. A third problem is *instability*, which we define as a sudden drop in coverage, often as a result of a vaccine-safety scare. Although instability also has some overlap with low coverage, the emphasis is on reductions in coverage over a relatively short time. For example, in Japan, unconfirmed reports of safety issues facing the HPV vaccine surfaced in the media (Hanley, Yoshioka, Ito, & Kishi, 2015). Within 2 months, Japan's government removed a proactive recommendation for the HPV vaccine, which caused uptake to plunge from around 70% to less than 1%. Denmark and Ireland have also seen large declines in HPV vaccination following the lobbying of groups of parents formed through a shared belief about the role of the vaccine in any health problems their children experienced. Italy had a substantial drop in seasonal-influenza vaccination after a safety scare (Rosselli, Martini, Bragazzi, & Watad, 2017). Given that safety scares emerge with regularity, national vaccination programs need practical advice about what they can do to prepare for specific, unanticipated vaccine-safety scares and to maximize the robustness of uptake.

Citizen activism

One of the factors affecting vaccination uptake, particularly during safety scares, is the activism of citizens. It is important to distinguish between citizen activism and vaccination behavior, a distinction media coverage often misses. Refusing vaccines does not make one an antivaccination activist. Furthermore, the small numbers of activists mean that their own vaccination choices have minimal direct impact on vaccination coverage overall. Rather, they can influence the behavior of policymakers, social networks, and individuals through messages and activism. We review below what is known about antivaccination activists, and then we review the more recent provaccination movement.

Antivaccination activism has existed in some form for more than 200 years (Wolfe & Sharp, 2002). Radical antivaccine groups assert that vaccines are unsafe and ineffective; reformist groups accept some aspects of vaccination but call for better vaccine testing or compensation for adverse events that occur after vaccination (Hobson-West, 2007). Health conditions that the groups have attributed to vaccines include autism in children and autoimmune disorders in adolescents, even though research findings invariably do not support a connection to vaccination (Maglione et al., 2014). For example, in the Philippines and, more recently, in Kenya, activists spread unsubstantiated theories that tetanus toxoid vaccine is subversively used to control fertility (H. Larson, 2014; Mandlhate & Heinonen, 2014). Some have suggested that personal-injury lawyers have contributed financially to antivaccination activism to create an environment supportive of claims and litigation (Deer, 2011). Physicians supporting alternative vaccination schedules or spreading out doses can reinforce activists' stances that vaccines are problematic (Sears, 2011).

Radical antivaccine activists use four tactics. They skew the science, shift their hypotheses, censor dissenting opinions, and attack critics with personal insults and lawsuits (Kata, 2010). For example, antivaccine health concerns evolve as old theories are sufficiently refuted (e.g., vaccines and sudden infant death syndrome), and new theories gain currency and new champions (e.g., vaccines and autism; Leask, Chapman, & Cooper Robbins, 2010). New vaccines bring the

possibility for attributions to existing diseases with uncertain etiology (e.g., the HPV vaccine and unsupported links to autoimmune disorders).

When and how antivaccination activism affects individual behavior is poorly understood, but we suspect that the effect is nonlinear. The instability in uptake of some vaccines in countries is likely due in part to lack of political will among authorities in the face of public outcry. In the 1970s, antivaccine activists contributed to the erosion of pertussis programs in Australia, Ireland, Italy, Japan, the Russian Federation, Sweden, the United Kingdom, and the former West Germany (Gangarosa et al., 1998; Poland & Jacobson, 2001). After considerable morbidity and mortality, these eight countries reinstated their pertussis vaccination programs. Recent experiences in Japan, Italy, Denmark, and India are also illustrative of the outsized influence that antivaccination activists can have on vaccination coverage by influencing policymakers and providers.

In the simplest terms, antivaccination activists tell a good story, whereas messages from official sources tend to be factual, cryptic, and forgettable (Downs, de Bruin, & Fischhoff, 2008; Reyna, 2012). Antivaccine messages often use first-person testimony by alleged victims or their parents to describe specific and vivid health harms, harnessing the known psychological finding that anecdotes about one person are often more influential than statistics about large populations (Borgida & Nisbett, 1977; Kogut & Ritov, 2005). The messages sometimes co-opt expert authority, for example by sourcing whistle-blower doctors and scientists who claim a vast cover-up of information by pharmaceutical companies conspiring with governments (Leask & Chapman, 1998). The stories elicit emotions such as anger, fear, and regret, as well as medical mistrust, an approach that may build on risk judgments' large emotional component (Loewenstein, Weber, Hsee, & Welch, 2001). As a result, antivaccine messages are interesting, memorable, and in demand. Antivaccine websites are of lower quality (K. E. Wiley, Steffens, Berry, & Leask, 2017), yet they appear prominently in search-engine results (L. Y. Fu, Zook, Spoehr-Labutta, Hu, & Joseph, 2016). Little research is available on how to counter antivaccine messages. Section 2 reviews this issue in greater detail, in the Interventions to Increase Confidence subsection.

The relatively recent emergence of provaccine activists has yet to be the focus of research; we offer several observations based on our understanding of this area. Advocates in favor of vaccination have typically been health-care providers or scientists until the recent emergence of provaccination activists. Examples include groups of citizens who rally on social media to counteract the presence of antivaccination activists and parents affected by the loss or illness of a child from a vaccine-preventable disease who become organized campaigners. Some provaccination activists lobby for stricter vaccination laws or the funding of a new vaccine program. Many countries have national and regional provaccine coalitions. In the United States, these coalitions exist in many states and nationally, funded by the federal government and nongovernmental organizations. These organizations are typically networks of vaccination professionals and other stakeholders and have funding that precludes political advocacy. Very little is known about the distribution, characteristics, and impacts of such provaccine actors and networks.

Conclusion

In summary, routine vaccination involves many people and around 20 vaccines, delivered in different settings, to people of different ages who have different resources and access to medical care. Vaccination behavior can be affected by the behaviors of providers, employers, immunization managers, legislators and other organizations. The action of getting a vaccine is the behavior our article generally focuses on. Vaccination problems include inadequate coverage of vaccines among children, adolescents, and adults; delaying beyond the recommended age; and sudden drops in vaccination coverage in the face of safety scares. Active refusal is not the main concern for most vaccines; delaying or spreading out vaccination is more of a concern, especially in high-income countries. Inadequate active demand in low- and middle-income countries is also a problem. Activist efforts are attention grabbing and can occasionally have a large impact on vaccine coverage in a nation, primarily by influencing policy, but antivaccination advocates themselves represent a very small proportion of unvaccinated people.

Given the incredible impact and value of vaccination, its underuse in countries where it is available and affordable is an avoidable tragedy. This ongoing crisis motivates the focus of our article on understanding why people get vaccinated and why they do not. Psychology can help to address vaccination problems related to coverage, timeliness, and robustness. In the next sections of our article, we examine these problems from three different psychological perspectives: how people think and feel, social processes, and facilitating behavior directly. The sections (a) examine theoretical and conceptual frames for analyzing vaccination problems, (b) review correlational evidence, and then (c) consider interventions based on these theories.

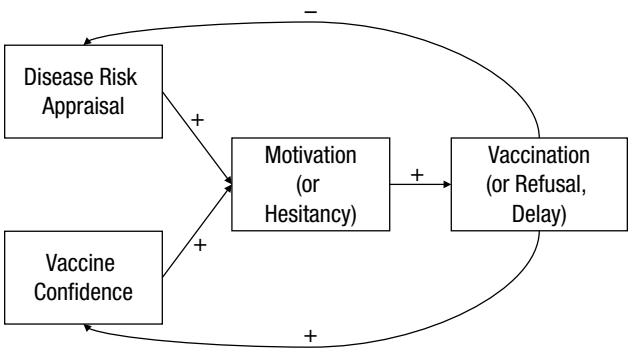

Fig. 2. Thoughts and feelings that influence vaccination. Risk appraisals include perceived risk, worry, anticipated regret, and fear. Confidence includes positive and negative attitudes toward vaccination and attitudes toward vaccination providers and systems. Motivation includes intentions, hesitancy, willingness, and acceptability. Vaccination behavior includes uptake, delay, and refusal. Associations are positive (+) or negative (–).

Section 2: What People Think and Feel

Being motivated to get vaccinated is in many ways the result of deliberation by individuals. It makes sense then that substantial research has explored how thoughts and feelings inform people's motivation to get vaccinated. One general area of investigation is how people view the infectious disease (the hazard). This research includes risk appraisals such as perceived risk and worry. Another general area of investigation is how people react to vaccination itself (the behavior). This research involves confidence, which includes measures such as perceived vaccine effectiveness and concern about side effects. We review the key findings from these and related areas and, at the end of this section, apply them to the question of why physician recommendation is so effective.

We see risk appraisals, confidence, motivation, and behavior as distinct and separable constructs. These distinctions and their causal ordering are similar to several theories of behavior such as the theory of planned behavior and the theory of reasoned action (Fishbein & Ajzen, 2010). Furthermore, the models suggest that risk appraisals and confidence in vaccination can increase motivation to get vaccinated, which in turn leads to increased vaccination (Fig. 2). We examine each of these constructs below.

Appraisals of risk

One way to think about motivators of vaccination is to imagine people as rational actors, pursuing best outcomes for themselves and those close to them. Thus, to understand vaccination and other health behaviors, psychologists first looked to utility models developed by economists. These models propose that people make decisions by thinking about potential consequences. People appraise both how likely and how bad (or good) the consequences would be and opt for the action that leads to the best future. These intuitions about maximizing expected utility animate many of the key models of health behavior (Weinstein, 1993), including the health-belief model (Janz & Becker, 1984), the theory of planned behavior and theory of reasoned action (Fishbein & Ajzen, 2010), and protection-motivation theory (Rogers, 1975). These models identify appraisals of disease risk as key motivators of behavior.

Risk appraisals as correlates of vaccination. In the context of vaccination, risk appraisals focus on the infectious agent and the harm it can cause. Widely studied risk appraisals include *perceived likelihood* (how likely a person is to get infected) and *perceived severity* (how bad the infection would be). Meta-analyses have shown that both these risk beliefs are associated with vaccination behavior (Brewer, Chapman, et al., 2007) and other heath behaviors (Floyd, Prentice-Dunn, & Rogers, 2000; Harrison, Mullen, & Green, 1992). Across 12 studies, people who perceived higher likelihood of harm (r = .26) were more likely to receive a vaccination. Likewise, among people with higher perceived severity of harm, vaccination was more likely, although the association was smaller (r = .16 across 32 studies). Some researchers suggest *perceived vulnerability* (feeling personally susceptible) is separate and distinct from beliefs about likelihood or severity. This belief is also associated with receiving a vaccination (r = .24 across 15 studies; Brewer, Chapman, et al., 2007).

Research on risk appraisals has also focused on *anticipated regret*, the expectation that an unpleasant outcome will lead a person to wish they had made a different decision (Sandberg & Conner, 2008). Researchers have proposed that anticipated regret is a primary motivator of receiving a vaccination. A recent meta-analysis largely supported this speculation (Brewer, DeFrank, & Gilkey, 2016). Anticipating that one would regret a decision *not* to get vaccinated was associated with receiving a vaccination (r = .27) in 18 studies. Anticipated regret stood out as a stronger predictor of intentions than other types of anticipated affect (e.g., anticipated guilt). Anticipated regret was also generally a stronger predictor of intentions and behavior than other risk appraisals, such as perceived likelihood, perceived severity, and worry (Brewer et al., 2016). This may be because the construct captures a combination of affect and cognition or because anticipated regret taps a natural process of imagining the consequences of a vaccination decision.

Another conceptualization of risk appraisal is a lack of concern about vaccine-preventable diseases (H. J. Larson et al., 2014). As advances in vaccine development make vaccinations more effective, fewer people have personal experiences with the diseases. It is unclear whether this lack of experience lowers perceived risk or mutes affective reactions to the disease. Furthermore, because some vaccines, such as the seasonal-influenza vaccine, are repeated periodically (Gierisch, Reiter, Rimer, & Brewer, 2010), people receive ongoing feedback from past vaccination behavior and its consequences (or lack thereof). Not receiving a vaccination and experiencing no repercussions can reinforce the decision not to get vaccinated in the future (Kahn & Luce, 2006). Low concern remains an understudied area in part because no standard measure exists and studies to capture the phenomenon are difficult and costly to conduct. Disease outbreaks due to low vaccination can increase uptake immediately thereafter (Oster, 2016).

An empirical approach is to look at how different risk appraisals intercorrelate. Such an approach led to the tri-risk model, which identifies three correlated risk components, each of which has unique predictive value with respect to health behaviors (Ferrer, Klein, Persoskie, Avishai-Yitshak, & Sheeran, 2016). The first component is *deliberative risk*, which includes likelihood beliefs, such as beliefs about chance, probability and risk. A second component is *experiential risk*, which includes susceptibility beliefs, vividness, and gut-level impressions. These first two components correspond loosely to the constructs of perceived likelihood and perceived vulnerability described previously. As reviewed above, these beliefs are associated with receipt of various vaccines among many different populations.

A third component of the tri-risk model is *affective risk*, which includes worry, anxiety, and fear. Worry motivates people to get vaccinated. People are more likely to get the seasonal-influenza vaccine if they worry about getting the flu or expect that getting vaccinated would make them worry less (Chapman & Coups, 2006; Weinstein et al., 2007). The finding holds in various populations such as healthy adults, asthmatic children, pregnant women, and gay and bisexual men (Gorman, Brewer, Wang, & Chambers, 2012; Reiter, McRee, Katz, & Paskett, 2015; Szilagyi, Rodewald, Savageau, Yoos, & Doane, 1992; Tucker Edmonds, Coleman, Armstrong, & Shea, 2011) and with various vaccines, such as the seasonal-influenza vaccine, the HPV vaccine, and the pandemic influenza vaccine (Bish, Yardley, Nicoll, & Michie, 2011; Setbon & Raude, 2010). Few studies have examined the role of fear of infection or disease as a motivator of vaccination, and there has yet to be a meta-analytic assessment of the role of affect in motivating vaccination.

Risk reappraisal as a correlate of vaccination. A perennial question is whether new vaccines, by making people feel protected and thus less at risk, encourage people to "spend" that risk surplus on unhealthy patterns of behavior. This phenomenon, sometimes called *risk compensation, disinhibition*, or *licensing*, is especially problematic when vaccines are imperfectly effective and people overestimate the protection they receive. For example, getting the Lyme disease vaccine (which is no longer on the market but was ~70% effective) could confer a false sense of security and prompt a drop-off in protective behavior. A study with U.S. adults found that Lyme disease vaccination indeed reduced perceived likelihood of infection, but it did not reduce self-protective behavior such as checking for ticks after being outdoors (Brewer, Cuite, Herrington, & Weinstein, 2007). Likewise, many studies have found that girls and women who have received the HPV vaccine are not more likely to engage in sexual behavior, become pregnant, or get sexually transmitted infections compared with those who have not received the vaccine (Bednarczyk, Davis, Ault, Orenstein, & Omer, 2012; Liddon, Leichliter, & Markowitz, 2012). If anything, those who received the HPV vaccine were more likely to use condoms when having sex (Liddon et al., 2012). Evidence for licensing effects in moral behavior suggests the effect is small at best (Blanken, van de Ven, & Zeelenberg, 2015). Thus, disinhibition as a result of vaccination is unlikely.

Interventions to increase risk appraisals. Although ample evidence points to a correlation between risk appraisals and vaccination, few intervention studies provide evidence for a causal link. A handful of interventions that have successfully changed risk appraisals have increased vaccination coverage (Sheeran, Harris, & Epton, 2014). Across five studies of tetanus and influenza vaccination that successfully changed risk appraisals (including perceived likelihood, perceived severity, and negative affect), the pooled effect size was $d = 0.33$, a moderate-sized intervention effect. No intervention studies isolating the effect of changes in anticipated regret on vaccination have been published. However, a recent national television campaign in the United States played on anticipated regret to motivate parents to get the HPV vaccine for their adolescent children, and studies have used interventions theorized to harness anticipated regret to motivate other health behaviors, such as weight loss (Volpp et al., 2008).

Research on various health behaviors has found that fear-appeal interventions are generally effective in changing behavior and are especially effective when

people experience both heightened fear and a feeling of efficacy for taking action to ameliorate the threat (Tannenbaum et al., 2015). Reviews have not identified studies showing that fear communication increases vaccination coverage (Tannenbaum et al., 2015). For example, in a classic study, eliciting fear increased intention to receive a tetanus vaccination but did not affect actual vaccination uptake (Leventhal, Singer, & Jones, 1965).

However, fear communication can elicit anger and other forms of message reactance (Brehm, 1966; Hall et al., 2016, 2017). Those reactions are associated with having less intention of and not getting vaccinated (Betsch & Böhm, 2016; Leventhal et al., 1965). Thus, fear communication may increase intentions to get vaccinated, whereas anger toward the message may undermine its impact.

Summary of risk appraisal research. Risk appraisal research has yielded strong evidence for correlates of vaccination. Of particular interest is that anticipated regret is likely the risk appraisal with the strongest correlation to vaccination behavior. However, the area has yielded few insights into how to increase vaccine uptake, in part because vaccination interventions based primarily on risk appraisals are few. More than 50 years have passed since the first small trial used a fear appeal to motivate vaccination (Leventhal et al., 1965), yet we are aware of few experiments that have pursued this question in the interim (e.g., Ordoñana, González-Javier, Espín-López, & Gómez-Amor, 2009).

Confidence

Separate from perceived risk of harm, health-behavior theories also focus on beliefs about protective action. These behavioral beliefs show up, for example, in the health-belief model as perceived benefits (Janz & Becker, 1984) and in the theory of planned behavior and theory of reasoned action as attitudes (Fishbein & Ajzen, 2010). As applied to vaccination, some refer to behavioral attitudes as *confidence*. Definitions are somewhat imprecise but generally include beliefs that vaccines work, are safe, and are part of a trustworthy medical system. Confidence in this sense includes vaccination attitudes and overlaps with faith and trust in vaccines. Public-health experts have prioritized confidence in vaccines because of the impact that vaccine scares have had on policy, national programs, primary care, and patient well-being as noted in Section 1.

Measurement of confidence. Understanding how best to measure vaccine confidence is a priority globally. It is an important indicator of success in meeting objectives in the WHO (2013) Global Vaccine Action Plan. Their proposed indicators include "percentage of countries that have assessed (or measured) confidence in vaccination at subnational level" and "percentage of un- and undervaccinated in whom lack of confidence was a factor that influenced their decision" (WHO, 2013, p. 92). The National Vaccine Advisory Committee in the United States has also recognized the importance of vaccine confidence surveillance (National Vaccine Advisory Committee, 2015). For this reason, we address the issue of measuring confidence in some depth.

One way to think about vaccine confidence is as a nested set of beliefs and attitudes. A United States government working group defined vaccine confidence as the trust that parents and providers have in recommended vaccines, providers who give vaccines, and processes that leads to vaccine licensure and national vaccination schedules (National Vaccine Advisory Committee, 2015). European researchers have similarly argued that confidence suggests "trust in the vaccine (the product), trust in the vaccinator or other health professional (the provider), and trust in those who make the decisions about vaccine provision (the policymaker)" (H. J. Larson, Schulz, Tucker, and Smith 2015, screen 2). We focus here mostly on thoughts and feelings about vaccines, leaving a more extensive discussion of trust in providers to Section 3.

Scales for measuring vaccine confidence typically have subscales for vaccine *benefit* (e.g., perceived effectiveness), vaccine *harm* (e.g., side effects, safety), and sometimes trust in providers. A large number of vaccine confidence measures exist for specific vaccines. For example, a confidence scale specific to the HPV vaccine is the Carolina HPV Immunization Belief and Attitude Scale (CHIAS; McRee, Brewer, Reiter, Gottlieb, & Smith, 2010). The 16-item scale includes subscales labeled "effectiveness," "harms," "uncertainty," and "barriers." A 17-item scale for influenza vaccine confidence, validated in three countries, has subscales for "influenza perceptions," "influenza vaccine perceptions," "trust in vaccine stakeholders," and "social influence" (Wheelock, Miraldo, Thomson, Vincent, & Sevdalis, 2017).

Relatively few scales exist to measure attitudes toward vaccines in general. One scale, the Vaccination Confidence Scale, has eight items that assess vaccine "benefits," "harms," and "trust in healthcare provider" (Gilkey et al., 2014). A four-item short form consists of the perceived benefits subscale and performs as well as the entire scale, suggesting that harms and trust beliefs may be less important in these scales (Gilkey, Reiter, et al., 2016). The scale's psychometric properties have been favorably evaluated with national probability samples containing a total of 18,977 U.S. parents of young children and adolescents. Another scale, the

Parent Attitudes About Childhood Vaccines, has 15 items that assess "safety/efficacy," "general attitudes," and "behavior" (Opel et al., 2011, 2013). The scale's psychometric properties have been evaluated with a convenience sample of 437 U.S. parents of young children.

Some researchers have used single-item measures or multiple items analyzed individually. A consortium based in the United Kingdom used four items (efficacy, safety, importance, and religious beliefs). The measures of perceived vaccine effectiveness, safety, and importance were highly correlated. In their survey of 65,819 individuals in 67 countries, vaccine confidence was quite high overall (H. J. Larson et al., 2016). The lowest endorsement of vaccines as being safe was in European countries, especially in France. Across the countries, confidence was higher in high-income countries and in countries with lower mean education; at the level of respondents, confidence was higher among those with higher incomes and education.

Finally, some researchers are working on ways to assess vaccine confidence using traditional and social-media indicators. The Vaccine Sentimeter uses natural-language processing to analyze data from mainstream media sources and Twitter (Bahk et al., 2016). Others have used machine learning to characterize vaccine sentiment of online posts, including Twitter (Dunn et al., 2015). In sum, (a) the field has many measures of confidence, (b) measuring positive and negative attitudes toward vaccination is necessary, and (c) measuring confidence in specific vaccines adds predictive power beyond general vaccine confidence.

Confidence as correlate of behavior. Confidence is associated with vaccine uptake (Schmid, Rauber, Betsch, Lidolt, & Denker, 2017), including in numerous prospective studies, but the conditions that strengthen or weaken the association are not yet well understood. In the context of seasonal-influenza vaccination, a systematic review found that uptake was associated with higher perceived effectiveness in all 17 studies that assessed the construct (Chapman & Coups, 1999a). In the context of HPV vaccination, perceived effectiveness has been associated with uptake in some studies but not others (e.g., Brewer et al., 2011; Gilkey et al., 2017; Reiter, McRee, et al., 2013; Reiter, Brewer, Gottlieb, McRee, & Smith, 2009). Studies have shown mixed findings for an association between vaccination and perceived harms and relatively few associations with trust in providers (Gilkey, McRee, et al., 2016; Gilkey, Reiter, et al., 2016). Many confidence studies have used patient or parent self-report of vaccination behavior, but some have used large national probability samples with confirmation of vaccination by clinic records and have reached similar conclusions (Gilkey, McRee, et al., 2016; Gilkey, Reiter, et al., 2016).

Interventions to increase confidence. Interventions appear to be able to increase vaccine confidence, but the impact of increased confidence on uptake is unknown. A randomized controlled trial (RCT) in Pakistan found that discussion groups increased positive attitudes toward childhood vaccination (R. Amin et al., 1997). The trial also found increased uptake for two of three children's vaccines, although no mediation analysis was performed. A systematic review found that educational interventions (including brochures, pamphlets, and posters) increased vaccination confidence in 8 of 15 studies (Sadaf, Richards, Glanz, Salmon, & Omer, 2013); none of the studies assessed impact of confidence on vaccine uptake.

Other studies of educational interventions found little or no effect on vaccination. A Cochrane review concluded that face-to-face educational interventions had uncertain effects on vaccination (Kaufman et al., 2013). Systematic reviews for the CDC's Community Guide to Preventive Services said evidence was insufficient to recommend education programs that were community wide (which may include small or mass media, person-to-person interactions, and community mobilization) or clinic-based client education. A systematic review of community-focused interventions identified two trials in low-income countries (Saeterdal, Lewin, Austvoll-Dahlgren, Glenton, & Munabi-Babigumira, 2014). An RCT in India found that public meetings and leaflet distribution increased the number of children who had received at least one vaccination and increased tetanus vaccination among pregnant women (Pandey, Sehgal, Riboud, Levine, & Goyal, 2007). Neither clinic-based nor community-wide education has been shown to be effective in increasing vaccination, according to systematic reviews (Community Preventive Services Task Force, 2015).

Several studies conducted since these reviews were published show the heterogeneity of study designs and findings. An educational effort using a video and written information in primary-care clinics targeted parents with low vaccine confidence (S. E. Williams et al., 2013). The intervention increased positive attitudes about vaccination but not did not increase vaccine uptake. An online experiment showed that providing information about vaccine safety and efficacy can have unpredictable effects on concerns about vaccination and may even increase such concerns in some circumstances (Nyhan, Reifler, Richey, & Freed, 2014). Another online experiment found that, in terms of increasing vaccine confidence, correcting autism myths was ineffective but describing the disease risk that vaccination can address was effective (Horne, Powell, Hummel, &

Table 3. Structured Approaches for Clinicians to Address Vaccination Concerns

Method	Components	Evidence
CASE	Corroborate: acknowledge parent's concerns without judgment About me: describe own vaccination expertise Science: explain the relevant scientific findings Explain/advise: explain why the science suggests the patient should be vaccinated and recommend vaccination.	None. (Approach described in Public Health Live!, 2010)
EASE	Elicit parent's main concern Acknowledge parent's concern without judgment Share commitment to vaccination Explain the science	Parent vaccination confidence not assessed. Increase in vaccination not attributable to EASE. (Brewer et al., 2017)
Ask, Acknowledge, Advise	Ask parent for concerns Acknowledge parent concerns without judgment Advise/educate about diseases and vaccine's benefits and risks, recommend vaccination, and end with plan of action	Not effective in increasing parent vaccination confidence. Vaccination not assessed. (Henrikson et al., 2015)

Holyoak, 2015). Finally, a series of experiments showed that strong statements that vaccines do not cause risk can backfire and actually increase concerns about vaccine harm, but only when the source of the information is a pharmaceutical company (Betsch & Sachse, 2013).

Effective interventions targeting people low in confidence do not yet exist. For example, no evidence has established a best practice for providers to address parents' concerns and questions about vaccination. Several suggested approaches based on communication skills taught in medical curricula have the general format of eliciting parents' concerns, acknowledging them without judgment, providing information, and recommending vaccination (Silverman, Kurtz, & Draper, 2005; Table 3). Perhaps the earliest such approach is the CASE method (Table 3) developed by Singer, a vaccine advocate (Public Health Live!, 2010). Despite being widely disseminated, the CASE method has not been the subject of empirical research. The related EASE approach was one part of a communication training that increased vaccine uptake, but the evaluation did not isolate whether EASE itself was effective (Brewer et al., 2017). The ask-acknowledge-advise approach was ineffective in changing parent vaccine confidence in a trial that trained providers (Henrikson et al., 2015).

Research from cognitive and social psychology suggests several important steps to counteract misinformation that may be useful when addressing vaccination myths (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012). First, understand people's mental models of vaccination (Downs et al., 2008), identify how the rumor fills a gap in the model, and offer an alternative explanation. Second, use repeated statements to counteract the misinformation, but avoid repeating the incorrect statement, which can make it seem familiar and true. Third, emphasize what is true to avoid a familiarity backfire effect that further entrenches the myth in people's minds. Fourth, warn listeners before sharing a myth to make them less likely to be influenced by it. Fifth, use materials that are engaging, simple, and in plain language. As Lewandowski and colleagues (2012) stated, "If the myth is simpler and more compelling than your debunking, it will be cognitively more attractive, and you will risk an overkill backfire effect" (p. 123). Sixth, consider whether your material might threaten closely held values of your audience. If it might, focus on potential benefits instead of risks and harms, consider using self-affirmation (Sherman, Nelson, & Steele, 2000), and consider using approaches that change behavior directly without challenging people's values (see Section 4).

Perhaps the most important advice is to instill an accurate understanding of vaccination to before people develop false beliefs that, once established, can be difficult to correct (Jolley & Douglas, 2017). Useful insights come from fuzzy-trace theory (Blalock & Reyna, 2016; Reyna, 2008) which suggest that aiding the creation of meaning (i.e., gist) allows people to remember and later take action on the information (Reyna, 2012). Antivaccine messages often impart a memorable idea (or gist) and use emotion to add meaning to their "facts" (Reyna, 2012). The use of first-person narratives in antivaccine messaging may be another reason for its potency (Winterbottom, Bekker, Conner, & Mooney, 2008, but see Bekker et al., 2013). To have impact, official communications about vaccines should have a clear take-home message, tell a memorable story, and elicit feeling (Shelby & Ernst, 2013).

Summary of confidence research. A great deal of research on vaccine confidence has accumulated without yielding insights for increasing vaccination coverage. Many dozens of confidence measures exist, and they often correlate with vaccine uptake. Yet we do not know how to reliably increase vaccine confidence. Interventions to increase confidence through persuasion and education have had no appreciable or reliable effect on vaccination coverage. Despite the international fascination with vaccine confidence, the direct impact of increased confidence on vaccine uptake is unknown.

Vaccination motivation and hesitancy

We conceptualize motivation as wanting to get vaccinated or being open to it. Motivation includes the overlapping constructs of intention, willingness, acceptability, and hesitancy. Thus, hesitancy is a motivational state of being conflicted about or opposed to getting vaccinated. We specifically define hesitancy as not including past vaccination or refusal. As others have noted, past research has had an imprecise definition of vaccination hesitancy; some definitions have included attitudes, confidence, delay, and refusal (Bedford et al., 2017), a lack of precision that has hindered progress in research (Peretti-Watel, Larson, Ward, Schulz, & Verger, 2015).

People demonstrate a range of motivation for being vaccinated: (a) asking for vaccination when providers do not raise the issue, (b) being open to receiving a vaccination when presented with the idea but not being especially proactive, (c) having a passive hesitancy, (d) being initially resistant to vaccination but open to persuasion; and (e) being steadfastly opposed to some or all vaccines (Benin, Wisler-Scher, Colson, Shapiro, & Holmboe, 2006; Gust et al., 2005; Cooper Robbins, Bernard, McCaffery, Brotherton, & Skinner, 2010). A study of U.S. parents identified the prevalence of five groups in relation to vaccine acceptance: "immunization advocates," strongly in favor of vaccines (33% of adults); "go along to get alongs" (26%); "health advocates," generally trusting of doctors and to some extent vaccines (25%); "fencesitters" (13%); and "worrieds" (2.6%; Gust et al., 2005). Benin et al. (2006) described people who (a) accept or do not question vaccines, (b) accept vaccines but have concerns, (c) delay or reject some vaccines, or (d) reject all vaccines. Cooper Robbins et al. (2010) proposed a two-axis taxonomy, with engagement (passive and active) on one axis and vaccination behavior (vaccinated or not) on the other axis. Most people who have not gotten vaccinated did so passively (Pearce, Marshall, Bedford, & Lynch, 2015; Samad et al., 2006). As noted in Section 1, a very small proportion of people express ardent opposition to childhood vaccination in the form of refusal of all vaccines (1%–2%).

Public-health authorities identify vaccine hesitancy as an important problem, but few immunization managers for national programs identify it as area for concern (Dubé, Gagnon, Nickels, Jeram, & Schuster, 2014; Omer et al., 2009). We are unaware of direct evidence showing that hesitancy has become more common.

Motivation as correlate of behavior. Motivation is associated with a broad range of behaviors, both those related to health and those unrelated (for a review of systematic reviews, see Webb & Sheeran, 2006). The association is reliable and large (d = 1.47). For example, among parents who intended to get the HPV vaccine for their adolescent daughters, 38% did so in the next year compared with 10% who did not intend to get their daughters vaccinated (Brewer et al., 2011). However, a sizable gap exists between intentions and behavior (Sheeran, 2002). Although many parents in the example above intended to have their daughters vaccinated and did so, the majority of parents did not act on their favorable intentions (Brewer et al., 2011). The example illustrates a common finding of asymmetry in the link between intentions and behavior, sometimes called literal inconsistency (Fishbein & Ajzen, 2010). Among parents who did not intend to have their children vaccinated, 90% met those intentions; in contrast, among parents who did intend to have their children vaccinated, only 38% did so (Brewer et al., 2011; DiBonaventura & Chapman, 2005). Inaction is an easier goal to meet.

People have many ideas of actions they want to take to be healthier, but they often do not follow through. A large literature has examined conditions that undermine the association of intentions and behavior (Sheeran & Webb, 2016; Webb & Sheeran, 2006), including such barriers as vaccine shortages (Brewer et al., 2011; DiBonaventura & Chapman, 2005) and logistical obstacles (Witteman, Chipenda Dansokho, et al., 2015). For example, during the shortage of seasonal-influenza vaccine in 2004–2005, many people who attempted to get vaccinated were turned away. Intentions assessed in the fall of 2004 were associated with later vaccine uptake among those *not* turned away, but the two variables were unassociated among those who had been turned away at least once (Brewer et al., 2011). Other moderators include the stability of one's intentions over time, with stronger associations for people with more stable intentions (DiBonaventura & Chapman, 2005).

Motivation interventions. Interventions can address hesitancy in several different ways. First, an intervention can be designed to increase motivation to be vaccinated. Interventions that successfully increase intentions reliably increase many health behaviors (Sheeran & Webb, 2016; Webb & Sheeran, 2006). Many studies have successfully

increased people's intentions to get vaccinated. We are aware of no studies demonstrating that increasing intentions or reducing hesitancy increases vaccination coverage (Jarrett et al., 2015; Webb & Sheeran, 2006). Researchers have proposed *motivational interviewing* as a way to address vaccination hesitancy (Leask et al., 2012). Communication skills that are part of this approach focus on working with resistance, identifying motivation to be vaccinated, and evoking and reinforcing change talk (Miller & Rollnick, 2013). Motivational interviewing is effective in many contexts (Rubak, Sandbæk, Lauritzen, & Christensen, 2005), but studies do not yet show that it increases vaccination coverage. An RCT of motivational interviewing in a pediatric clinic showed an increase in HPV vaccination that was not statistically significant (51% vs. 56%; Joseph et al., 2016), and an uncontrolled study of the technique did not increase vaccination uptake in a community pharmacy but did increase readiness for two of five vaccines examined (Brackett, Butler, & Chapman, 2015). Challenges to routine use of motivational interviewing include the length of training (a median of 9 hr), although briefer trainings are in development (Lundahl et al., 2013). In addition, vaccination is but one of many issues to cover in medical visits; such visits last only 18 min on average for adults in the United States (Olson et al., 2004), but even very brief motivational interviews take 10 to 20 min (Lundahl et al., 2013).

Second, an intervention can target a group of parents with a known motivation profile (e.g., hesitant). No published interventions designed to target hesitant parents have led to an increase in vaccination coverage (Sadaf et al., 2013; S. E. Williams, 2014), although some targeted interventions have changed intentions, which the authors interpret as a proxy for behavior. Third, interventions can focus on parents who intend to have their children vaccinated and try to close the intention-behavior gap (Sheeran & Webb, 2016; Webb & Sheeran, 2006). Interventions to increase the correspondence of intentions and behavior include minimizing logistical barriers and addressing implementation intentions, which we discuss in a later section on changing behavior directly (Section 4).

Other topics related to thoughts and feelings

Decision aids. To help patients make informed health-care choices, decision aids describe treatment options' benefits and harms, often including numerical estimates of their likelihood or magnitude; guide people to clarify the value they place on those benefits and harms; and encourage people to make a choice (Stacey et al., 2017). Decision aids were originally developed for situations with clinical equipoise—that is, situations in which options are available, but no single option is best, given the best evidence. The absence of a best action for a population makes a "best" decision one that is based solely on the preferences of the individual patient. Decision aids address the general call for more informed and participatory health-care interactions.

We suggest that it is inappropriate to offer vaccination decision aids as part of routine clinical practice with all patients. Vaccination is not a situation of clinical equipoise: Evidence strongly favors vaccination, national recommendations clearly indicate who should be vaccinated, and the option to not be vaccinated affects people beyond the individual decider. In the context of patients who have already expressed vaccination hesitancy, decision aids could be a helpful adjunct to communication from health-care providers.

Studies of decision aids have not tested them specifically in hesitant populations. However, RCTs with general populations show limited effects on vaccine uptake but positive effects on intentions and attitudes. In an RCT with pregnant women in New Zealand, a decision aid about the measles-mumps-rubella (MMR) vaccine did not increase women's self-reported vaccination of their infants (Wroe, Turner, & Owens, 2005), but it did increase their intentions to vaccinate and vaccination timeliness; it also reduced anxiety about vaccination. In an RCT with parents in the United Kingdom, an online decision aid did not increase MMR vaccination; uptake was 100% in the intervention group and 99% in the usual-care group (Shourie et al., 2013). However, the decision aid reduced people's internal conflict about the decision. In a pre-post uncontrolled study in Australia, an evaluation of an earlier version of the United Kingdom decision aid found increased positive parental attitudes toward MMR vaccination (Wallace, Leask, & Trevena, 2006). In an RCT with parents in the United States, giving risk information and an online values-clarification exercise did not increase parental self-report of having their children vaccinated against seasonal influenza in the 6 months after the exercise (Witteman, Chipenda Dansokho, et al., 2015). The intervention increased parents' intentions to have their children vaccinated, especially among parents hesitant to do so. In an RCT in the United States, a decision-support tool increased the number of physicians who themselves got hepatitis B vaccine or screening (Clancy, Cebul, & Williams, 1988). In an RCT, a decision aid led to more positive HPV vaccination attitudes, but the study did not assess behavior (Kennedy, Sapsis, Stokley, Curtis, & Gust, 2011). In an RCT with health-care personnel in Canada, a decision aid improved "confidence" and reduced uncertainty but did not increase intention to get the seasonal-influenza vaccine (Chambers et al., 2012).

In summary, one trial has shown that decision aids increase vaccination uptake and several others have not;

one showed increased vaccination intentions and another increased timeliness. Although studies have observed increased knowledge and satisfaction and reduced decisional conflict in the limited evaluation of vaccination decision aids to date, the importance of these outcomes for increasing vaccination coverage is unclear. Some of the trials had relatively small samples (~100) and thus were underpowered to detect even modest differences. Moreover, the limited samples precluded examining whether decision aids were more effective for people who are hesitant about vaccination (but see Witteman, Dansokho, et al., 2015). The many limitations of the studies make any conclusion tentative.

Past behavior as correlate of vaccination. Having received a vaccination in the past is a reliable predictor of receiving a vaccination in the future. Having received an influenza vaccine strongly correlates with getting the vaccine in a subsequent year (Chapman & Coups, 1999a; Schmid et al., 2017). Receiving one recommended vaccine is associated with being more likely to receive other recommended vaccines (Kessels et al., 2012), an insight that is useful in the context of new vaccines and pandemics (Bish et al., 2011). The pattern holds across parents and children (Robison & Osborn, 2017). Although past behavior is an important correlate, the past behavior itself can be the result of various psychological mechanisms, several of which we discussed earlier, as well as structural factors. In other words, past behavior should reflect people's thoughts and feelings about vaccination to the extent that these constructs explain why people got vaccinated in the past (Weinstein, 2007). This means that it may be more productive to study and intervene in the psychological antecedents of vaccination.

Irrationality. Much of the material in this section on thoughts and feelings about vaccination presumes that people are rational creatures who thoughtfully seek out information and then impartially and accurately make sense of it. However, people's busy lives mean that they cannot spend limitless time seeking out all possible information; information is overly abundant even for the casual seeker, and making sense of it all can require more cognitive capacity than people have at any one time. One result is that people take mental shortcuts, called *heuristics*. These generally save time and effort but also lead to predictable irrational errors, called *biases* (Tversky & Kahneman, 1974).

One such bias is the *omission bias*, a preference for inaction even when taking action is substantially more beneficial (Ritov & Baron, 1990, 1999). In the context of vaccination, people give disproportionate weight to harms of receiving a vaccination and dismiss harms that accrue from not receiving a vaccination. For example, when a hypothetical scenario attributed symptoms to a vaccine adverse event rather than to a disease, parents said that symptoms would be more severe and last longer (Brown et al., 2010). Exhibiting the omission bias is associated with lower parent willingness to have their children get the pertussis vaccine (Asch et al., 1994) and with lower vaccination coverage (Meszaros et al., 1996). Likewise, seasonal-influenza vaccination is less common among healthy adults who showed the omission bias (DiBonaventura & Chapman, 2008). Some have hypothesized that the omission bias may be a marker for negative attitudes toward vaccination or anticipated regret (Connolly & Reb, 2003). To date, the omission bias has not been the target of interventions to increase vaccination uptake.

Another bias that may affect vaccination is the *confirmation bias*, the tendency to seek out or overweight information that is consistent with one's original hypothesis (Klayman, 1995). This tendency to favor one's original position and to find evidence consistent with that view may help to explain why those opposed to vaccination maintain that position despite the sound evidence presented to them by others. A classic study (Lord, Ross, & Lepper, 1979) demonstrated that presenting evidence does not cause individuals to bring their beliefs more in line with the evidence but instead causes them to hold their original beliefs more strongly. Presenting the same evidence to two groups with polarized views does not bring their viewpoints closer together but actually increases the polarization between the groups. Cultural cognitions that reflect strongly held moral values shape beliefs about some vaccines, making those beliefs difficult to change (Kahan, 2013; Kahan, Jenkins-Smith, & Braman, 2011). In the words of a vaccine-hesitant person in an online discussion who rejected evidence of vaccine safety, "The science is tainted by bias. Do some more reading" (Rodriguez, 2016).

Other thoughts and feelings. This section reviews research on thoughts and feelings most commonly studied in the context of vaccination. We acknowledge that this focus on some constructs but not others is somewhat artificial, excluding, for example, values and self-efficacy (A. B. Amin et al., 2017). Many of these other constructs are correlated with vaccination (Bish et al., 2011). However, to our knowledge, none has been the basis of effective interventions and thus would not meaningfully change this section's main conclusions.

Health-care providers vaccinating themselves. A goal for many health-care organizations is full vaccine coverage of their staff, but few reach this goal without extensive interventions that often include requirements for vaccination (see Section 4). Health-care workers'

reasons for receiving or not receiving a vaccination are similar to those of the general population (Capolongo, Dibonaventura, & Chapman, 2006). Research suggests that the same psychology that motivates the general public to get vaccination also motivates health-care providers, including risk appraisals and vaccine confidence (Corace et al., 2016; Herzog et al., 2013).

Conclusion

Thoughts and feelings are not currently a reliable basis for interventions to increase vaccination. Risk appraisals and confidence may be productive bases for future interventions, but the literature has more gaps than answers at this point, as we noted earlier. Increasing fear of harm is known to increase health behaviors, but the facilitating and constraining conditions in the context of vaccination are not well understood. Interventions have increased people's confidence and intentions, but the impact on actual vaccination behavior is not known.

Correlational studies show that what people think and feel motivates their vaccination behavior, generally in line with the model in Figure 2. Risk appraisals include thinking (perceived likelihood, perceived severity, susceptibility/gist), feeling (fear), and amalgams of the two (anticipated regret, worry). Of the risk appraisals, anticipated regret has the strongest association with vaccination behavior, but its causal role is unclear. Likewise, many varieties of confidence exist, and it is easy to measure confidence. With respect to confidence, attitudes regarding whether vaccination is safe or harmful are more closely tied to vaccination behavior than trust in providers or the health-care system. Research on confidence is not yet synthesized to identify whether some aspects of vaccine safety and vaccine harm are more motivating than others. Appraisals of risk and vaccine confidence are associated with greater motivation, which in turn is associated with being more likely to get vaccinated. The recursive paths in Figure 2 also have some support; the literature shows that being vaccinated lowers perceived risk. Confidence may similarly be the result of experiences with vaccination (e.g., Schuler, Reiter, Smith, & Brewer, 2011), but this pathway has been little studied. Prospective studies are needed in this area given the substantial interest from policymakers and practitioners.

The literature has generally not considered whether risk appraisals and confidence are epiphenomena (Brewer, Weinstein, Cuite, & Herrington, 2004). Risk appraisals and confidence may be the result of vaccination or other processes that correlate with vaccination. For example, perceived likelihood and severity of vaccine-preventable disease are measurable in surveys, but survey answers could arise from some more fundamental sense of threat that could be gist-like or affective in nature. The sense of threat could motivate behavior and at the same time inform appraisals of risk and in this way create a spurious correlation of risk appraisals and vaccination. Above all, the sense of threat could motivate behavior even in the absence of perceptions of likelihood or severity. Evidence has accumulated in other areas suggesting that affect may sometimes cause, and at other times result from, risk appraisals (Kiviniemi et al., 2017).

Just as the relationship between perceived risk and vaccination behavior can be bidirectional (i.e., risk perceptions guiding behavior, and behavior updating beliefs about risk), so too are risk perceptions and vaccination behavior affected by the behaviors and beliefs of the larger social group. As we discuss in more depth in Section 3, others' vaccination-related beliefs and behavior—especially close others—can affect an individual's risk for infection, risk appraisals, and vaccination confidence and hence that individual's vaccination behavior.

Provider recommendations. Although health-care provider recommendations are influential, psychological science has not yet fully explained why they motivate vaccination uptake. Any of the mechanisms described in this section on thoughts and feelings can provide reasonable explanations. If a provider recommends HPV vaccination, it may cause people to see the hazards as more likely and severe or to see themselves as more susceptible. A recommendation could increase beliefs in the vaccine's safety and reduce concerns about harm. Any of these changes would presumably increase motivation to get a vaccination. Presumptive announcements that a child is due for vaccination may be the most potent form of provider recommendation (Brewer et al., 2017; Opel et al., 2015), as we discuss in Section 4.

Providers must address parents' vaccination questions and concerns many times a day, yet no evidence-based practice exists for doing so effectively. Most currently suggested approaches involve some element of acknowledging patients' concerns as a first step (see Table 3). Self-affirmation and motivational interviewing techniques were developed specifically to address this sort of problem (Leask et al., 2012), and at least one intervention has used motivational interviewing as part of a multicomponent trial to increase vaccination uptake (A. F. Dempsey, personal communication, May 14, 2017). Psychological research on reactance, debunking myths, and resistance to new information offers additional insights for such interventions (Hall et al., 2016, 2017; Lewandowsky et al., 2012).

Up to this point, we have focused on the psychology of the individual. However, people are social creatures whose thoughts and feelings also bear on their social

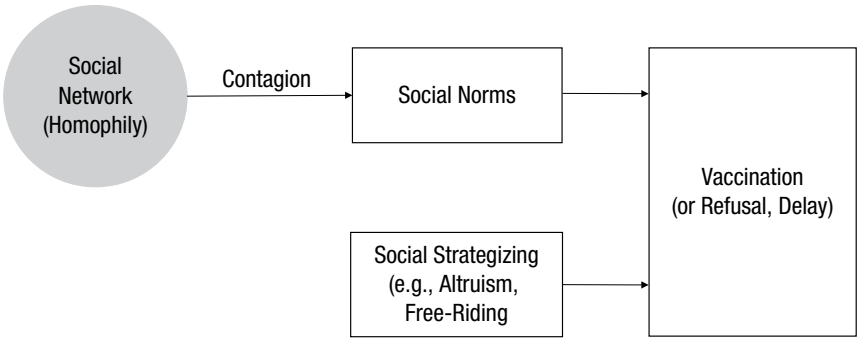

Fig. 3. Social processes that influence vaccination. The gray circle shows the social phenomenon, and the boxes show person-level constructs.

context. We next turn to understanding how such social processes affect vaccination.

Section 3: Social Processes

Vaccination is an inherently social activity because it takes place in the context of human interactions, and receiving a vaccination (or not) affects the health of others. In this section, we examine the influence of social interactions, from simple dyads to complex population networks and strategic behavior, on vaccination (see Fig. 3). The first theme in this section is social *dyads*, such as the relationship between patient and provider. Patients most often obtain vaccinations from their health-care providers, and consequently the trust relationship between providers and patients is paramount. Effective providers recommend vaccination to their patients, and the way in which providers and patients interact has critical implications for vaccination adherence. Another important social dyad is parents and children. Because the majority of vaccinations are on the pediatric schedule, parents make decisions about vaccinating their children more often than people directly decide to vaccinate themselves. Consequently, the caretaking relationship between parents and children is a potentially important influence on vaccination choices.

The second theme in this section is *social networks*, which play an important role in vaccination attitudes and behavior. Individuals may confer with family members, friends, and members of their social network about vaccination attitudes, making vaccination decisions a part of their social identity. The third theme in this section is *social norms*. People tend to fit their actions to the behavior and expectations of others, and vaccination is no exception. Thus, the norms they perceive can be influential. Health providers' own vaccination behavior, and how they propagate social norms about vaccination among their colleagues, is important because their own vaccination protects patients from infection.

The fourth theme in this section is *vaccination strategic behavior*. Vaccination affects health at the population level because it protects the unvaccinated through herd immunity. As a result, strategic motivations to shield others from infection (i.e., *altruism*) can drive vaccination behavior, and the temptation to take advantage of the protection provided by others (i.e., *free riding*) can deter vaccination. These four themes, which we explore below, show how studying vaccination in a social context is a key part of understanding the patterns of when people do and do not receive a vaccination.

Social dyads

Provider-patient dyads. Most vaccination decisions take place in the context of a relationship. Patients typically receive vaccinations from a physician, nurse, or pharmacist. People consistently rate these three professions among the highest for honesty and ethical standards (Gallup, 2016). Trust is a key component of vaccine confidence (Gilkey et al., 2014); however, variation in trust of health-care providers does not appear to explain variation in vaccination coverage (Gilkey, McRee, et al., 2016; Gilkey, Reiter, et al., 2016). Thus, it is not clear that trust in providers is the reason that provider recommendations of vaccination are so influential: Patients who feel less trust are not any less likely to get vaccinated. Trust in government bodies who set vaccination schedules and recommendations may be a more important determinant of vaccination uptake, or at least motivation. Indeed, trust in government predicts H1N1 vaccination (Freimuth, Musa, Hilyard, Quinn, & Kim, 2014), and trust in the U.S. Food and Drug Administration (FDA) predicts stated willingness to take antiviral medication (Quinn, Hilyard, Castaneda-Angarita, & Freimuth, 2015).

Surrogate decision making. Parents and other surrogates decide, with providers' advice, whether minors will receive vaccinations because laws often prevent minors from giving consent. As offspring enter adolescence, they

become more involved in vaccination decisions. Half of teens play some role in decisions to get the HPV vaccine, and by age 17, a quarter make the decision on their own (McRee, Reiter, & Brewer, 2010). Even so, many teens are uncomfortable making vaccination decisions without consulting their parents (Kennedy, Stokley, Curtis, & Gust, 2012). Some parents see vaccination decisions as an opportunity to increase children's involvement in their health-care decisions as they grow into adulthood. Although many interventions target parents or other caregivers, we know little about how interventions differently affect people who are deciding about vaccines for themselves or others.

In studies of families, adolescents and their parents have quite similar attitudes about HPV vaccination (Moss, Reiter, & Brewer, 2015; Vietri, Li, Galvani, & Chapman, 2012). It would be difficult to examine agreement in vaccination attitudes between parents and younger children, but the data from adolescents suggests that parents provide a good proxy for their children's vaccination preferences.

Research on decision making in general has demonstrated that being in the surrogate role can alter preferences. People value the future consequences of health decisions (e.g., disease prevention) similarly whether they make the decisions for themselves or for someone else (Cairns & van der Pol, 1999). Some evidence shows that people are more risk averse when making decisions for others than when deciding for themselves (Roszkowski & Snelbecker, 1990). In addition, surrogates tend to choose more aggressive treatment for others than the patients would choose for themselves, an overtreatment bias (Fagerlin, Ditto, Danks, Houts, & Smucker, 2001). Surrogates' greater risk aversion and greater interest in treatment compared with people choosing for themselves could explain why parents are more positive about vaccinating their adolescent children against HPV than the children are about getting vaccinated (Vietri et al., 2012). Thus, the many vaccination decisions that parents make on behalf of their children are of no small importance.

Other dyads. Multiple aspects of family relationships may shape vaccination behavior. For example, dynamics within a couple have important influences on health behavior; the behavior of one person influences the health behavior of the other (Lewis et al., 2006). Classic studies have shown that individuals imitate the behavior of those around them (Bandura, 1971), suggesting that individuals may imitate the vaccination behavior of others. Thus, one family member may encourage vaccination among others through example, recommendation, or by scheduling vaccination appointments for other family members.

Social networks

A social network is a web of relations and interactions between people. Vaccinators tend to know and associate with other vaccinators, and nonvaccinators tend to know and associate with other nonvaccinators (Onnela et al., 2016). This clustering of vaccination attitudes can be explained in terms of social-network theory.

Social-network theory posits that a person's place in a social network predicts the degree to which that person and other network members influence one another's beliefs and behavior. That is, a person who is centrally located in the network will be more heavily influenced by others and also have a larger influence on others than a person with sparser network connections (Centola, 2015).

People tend to self-select with whom they associate—a concept called *homophily*. Homophily is a correlational phenomenon in which, for a variety of reasons, including self-selection, people cluster in physical and social space on the basis of similarity. Furthermore, influence tends to travel across networks—called *contagion* (Mcpherson, Smith-Lovin, & Cook, 2001). In contrast to homophily, contagion is an explicitly causal process whereby influence passes through social networks. Through these two processes of homophily and contagion, network members tend to have characteristics that are similar to those of their close contacts (Christakis & Fowler, 2013).

Of particular importance to public health is that network connections spread both information and infection, and thus location with the network puts people at risk for disease. Someone with high *degree centrality* is connected to many other network members and thus is in a key position to be a superspreader of an infectious disease (Wasserman & Faust, 1994). For example, an individual with a more central location in the network will catch an infectious disease earlier on average than someone with a more peripheral position (Christakis & Fowler, 2010). Someone with high *closeness centrality* has short communication paths through the network to other agents and is thus in a key position to spread vaccination information, as is someone with high *information centrality*, which is a measure of all network paths originating from a specific actor (Wasserman & Faust, 1994). Thus, a person's place in the network contributes to the spread of an epidemic in multiple ways.

Correlational evidence. Correlational studies demonstrate that individuals with similar health characteristics tend to cluster together in a network. Thus, for example, smokers tend to associate with other smokers and nonsmokers with

other nonsmokers. Furthermore, when one smoker quits, other network contacts are more likely to quit than they otherwise would have been (Christakis & Fowler, 2008). However, with correlational data, it is not possible to fully disentangle whether homophily or contagion is the source of these effects (Shalizi & Thomas, 2011). Few observational studies have examined homophily and contagion related to vaccination in social networks, although some have demonstrated geographical clustering of undervaccinated children (Lieu, Ray, Klein, Chung, & Kulldorff, 2015).

Modeling simulations, often built using observational data, support the conclusion that clustering exacerbates disease spread. Nonrandom mixing of individuals in a network can explain why disease outbreaks occur even when the level of immunity exceeds the herd-immunity threshold that would be needed to prevent progression of an epidemic under the assumption of random mixing (Glasser, Feng, Omer, Smith, & Rodewald, 2016). One modeling analysis of social networks demonstrated that homophily in social networks—individuals with similar vaccination views clustering together—results in pockets of disease susceptibility and increased likelihood of disease outbreak (Salathé & Bonhoeffer, 2008). A similar analysis (Eames, 2009) demonstrated that clustering of parents' vaccination opinions results in clustering of unvaccinated children and hence more disease outbreaks. This result is sensitive to both the extent of parents' opinion clustering and the overlap between the parents' and children's networks (e.g., parents who share opinions have children who interact). A final modeling article (F. Fu, Rosenbloom, Wang, & Nowak, 2011) demonstrates that imitating others within a social network can result in low vaccination coverage, under certain assumptions, because individuals end up imitating successful free riders. The role of free riding is discussed in a later section.

The spread of infectious disease requires physical contact or proximity, often a result of ongoing geographical clustering of people but also a result of travel and migration. In contrast, the spread of ideas does not require physical proximity and can occur via in-person conversation, distance communication, media, and social media. Thus, the networks that spread disease may only partially overlap the networks that spread vaccination information. Studies have found marked clustering of sentiment about vaccination in social-media conversations about vaccination (Dunn et al., 2015). Indeed, such conversations can be tracked as an indicator of social-network support for vaccination (Bahk et al., 2016; Centola, 2013).

Social contagion and disease contagion can interact when the social network and geographical cluster overlap (Bauch & Galvani, 2013). For example, a highly connected node in the social network (e.g., a celebrity) could spread suggestions that vaccines are risky, resulting in the spread of beliefs and an associated decrease in the number of people who get vaccinated (social contagion). Consequently, an infectious disease could spread easily through the network (disease contagion), which may in turn prompt individuals to get vaccinated (Bauch & Galvani, 2013).

Experimental network studies. Correlational evidence from real-world behaviors such as smoking leaves open the question of whether clustering of similar people is solely the result of homophily or also results from contagion. Experimental evidence indicates that health behavior does indeed spread through social networks via contagion (Centola, 2010). In an ambitious online experiment, more than 1,500 participants were randomly assigned to one of two network structures that allowed them to interact virtually with other participants. Investigators observed the spread across the network of a specific health-relevant behavior: registering for an online health forum. Specified seed nodes in the network sent messages to their neighbors encouraging them to register, which initiated the behavior in the network. The investigators then observed how the actual participants in the study continued to spread the behavioral recommendation (and the actual behavior) across the network. One network structure—the clustered lattice, which had a high level of clustering in which each node's neighbors were linked to one another—led to wider diffusion than the other network structure (random or "unstructured" network; Centola, 2010). A similar study demonstrated that homophily increases adoption of the new health behavior (Centola, 2011). In this study, 700 online participants were randomly assigned to either a homophilous network or an unstructured network. In the homophilous network, participants were clustered by individual characteristics (e.g., gender, age, body mass index). A few seed nodes in each network initiated use of a diet diary, and investigators observed the spread of this behavior across the network. The spread was faster in the homophilous network. These studies indicate that social networks do indeed have a causal effect on health behavior via contagion and that homophily amplifies that contagion effect.

Network studies on vaccination. Although carefully controlled network experiments have not examined vaccination behavior, Centola's work suggests that vaccination attitude and behavior spread causally through social networks. Network homophily and contagion help to explain why negative attitudes toward vaccination cluster geographically. Although parents with strong principled objections to childhood vaccinations make up a tiny fraction of the population, they tend to live near other like-minded families and associate with them socially (Beard et al., 2016; Onnela et al., 2016). The geographical

clustering is important because it can contribute to the spread of infectious disease (Glasser et al., 2016; Ndeffo-Mbah et al., 2012). Communities with a sizable number of vaccine refusers will lack herd immunity; consequently, if an infectious disease is introduced, it can spread easily among the community.

Methodological issues. Studies on health social networks face some challenging methodological issues. In some studies of social networks, the participants self-report on the vaccination attitudes or other characteristics of their network members (e.g., Brunson, 2013; Nyhan, Reifler, & Richey, 2012), whereas in others, the behavior of each network member is objectively assessed (Christakis & Fowler, 2008). In other studies, the structure of the social network is experimentally controlled, and the behavior of each network node is objectively measured (Centola, 2010, 2011). The latter method provides more experimental control but less realism (for a discussion of methodological strengths and weaknesses in social-network studies, see Centola, 2013).

The evidence supports the existence of homophily and contagion as two distinct sources of clustering in networks, although data are spotty in the specific area of vaccination. Because homophily is a correlational phenomenon whereas contagion is a causal process, evidence for contagion is difficult to obtain outside of experiments in which the behavior of target nodes is manipulated (e.g., Centola, 2010). Little is known about the psychological mechanisms for contagion, but social norms are one candidate explanation.

Social norms

Social norms, the tacit rules that members of a group implicitly recognize and that affect their decisions and behavior, are one influence that spreads across networks. The focus theory of normative conduct (Cialdini, Kallgren, & Reno, 1991) identifies two types of social norms. Descriptive norms indicate the behavior of relevant others and inform behavior by example. Injunctive norms represent how important others would like one to behave, and they influence behavior via informal reinforcements or punishments. Experimentally manipulated social-norm interventions affect behaviors such as littering (Kallgren, Reno, & Cialdini, 2000), hotel towel reuse (Goldstein, Cialdini, & Griskevicius, 2008), and energy conservation (Nolan, Schultz, Cialdini, Goldstein, & Griskevicius, 2008). For example, a descriptive social-norm intervention in which hotel guests learned that 75% of the other guests reuse their towels during their stay increased towel reuse (Goldstein et al., 2008).

One limitation of social-norm interventions is that when a behavior is uncommon, publicizing that descriptive norm will not encourage the behavior (Blanton, Köblitz, & McCaul, 2008). For example, the message "Many past visitors have removed petrified wood from the park, changing the natural state of the Petrified Forest" conveys the descriptive norm of the negative behavior (removing petrified wood) and consequently encourages that behavior. It would be more effective to use a positive descriptive-norm message, such as "The vast majority of past visitors have left the petrified wood in the park, preserving the natural state of the Petrified Forest." If that is not possible, then an injunctive-norm message is preferable, such as "Please don't remove the petrified wood from the park, in order to preserve the natural state of the Petrified Forest." In a field study, this injunctive message was more effective at preventing theft than the negative descriptive message, and the positive descriptive message was intermediate (Cialdini et al., 2006).

Social-norm correlational studies. A large number of correlational studies have linked vaccination to norms. Many of these correlational studies use the theory-of-reasoned-action and theory-of-planned-behavior paradigm to examine the association between subjective norms and vaccination intentions. In the theory of planned behavior, subjective norms are assessed as ratings of the extent to which people important to the participant want him or her to get vaccinated and thus correspond to injunctive norms. Several studies show cross-sectional correlations between injunctive norms and vaccination intentions or behavior. For example, Juraskova et al. (2012) demonstrated that subjective norms were correlated with intentions to get vaccinated against HPV. Gerend and Shepherd (2012) found an association between subjective norms and HPV vaccination behavior.

Studies also show a correlation between vaccination and perceived injunctive norms. In one, college students' support for vaccination in their social networks predicted their intentions to receive an H1N1 vaccine (Nyhan et al., 2012). In a study by Brunson (2013), parents self-reported their vaccination decisions and the vaccination attitudes of members of their social networks. Parents who did not meet the recommended vaccination schedule believed that a larger fraction of their social network recommended nonvaccination. This predicted decisions better than demographic characteristics of the parents themselves. Health-care workers were more likely to get vaccinated against H1N1 if they reported being encouraged by family or coworkers to do so (Stokes & Ismail, 2011).

Social-norm-intervention studies. Unlike the field studies employing social-norm interventions to modify hotel towel-reuse behavior or petrified-wood collection, no intervention studies in vaccination have tested the effects of a theoretically pure social-norm manipulation

on uptake. Nevertheless, the lessons from findings outside vaccination are applicable to the design of vaccination campaigns. For example, in fall 2015, Rite Aid pharmacies launched an advertising campaign to promote influenza vaccination that said "Get your flu shot today because 63% of your friends didn't." This message was presumably designed to encourage vaccination by emphasizing that the infection risk was high because of the large number of unvaccinated individuals with which one has contact. In contrast, the descriptive norm research, such as the petrified-wood study, would suggest that this message might actually drive vaccination coverage down ("if very few others are getting vaccinated, then I won't either"). Indeed, a laboratory experiment varied the characteristics of a hypothetical vaccine (Hershey, Asch, Thumasathit, Meszaros, & Waters, 1994) to allow examination of the impact of perceived descriptive norms, what the authors called "bandwagoning." Participants were more likely to say they would get vaccinated when many others were already getting vaccinated. The Rite Aid campaign was designed to counter the motive to free ride ("Because so few others are vaccinated, I can't free ride and thus need to get vaccinated"). However, the Hershey et al. (1994) experiment findings suggest that bandwagoning is the primary behavioral factor. Consequently, the Rite Aid message may have been ill-conceived and ineffective. Their campaign was short-lived.

A few vaccination field studies have used multifaceted interventions that have social-norm components, suggesting that social norms could have a powerful influence on vaccination behavior. Health-care workers at a Swiss hospital who received the influenza vaccine were given a badge to wear that read "I am vaccinated against influenza to protect you." (Iten, Bonfillon, Bouvard, Siegrist, & Pittet, 2013). Nonvaccinated health-care workers were required to wear a face-mask during the seasonal influenza epidemic period and to wear a badge that read "I wear a mask to protect you." In the year that this policy was introduced, vaccination coverage increased to 37%, compared with 21% to 29% in the decade before the intervention.

Note that this study did not use a traditional descriptive or injunctive social-norm message. Instead, the badges had the potential to make salient the descriptive social norm, because health-care workers could easily see how many of their coworkers had been vaccinated. However, this could backfire and reduce vaccination coverage if the norm revealed that few people got vaccinated. In addition, it is likely that the badges set up an injunctive social norm. Finally, because the badge messages were visible to patients, they took on the role of norm-enforcers. Any health-care worker who was not wearing a vaccination badge could be negatively evaluated by patients.

In another study (Riphagen-Dalhuisen et al., 2013), similar badges with prosocial messages were used as part of a large multimodal intervention to promote influenza vaccination among hospital health-care workers. Those in the intervention condition received a multifaceted program that included education and testimonials from role models. In addition, vaccinated health-care workers in the intervention group received pins that said "deliberately vaccinated for you." The vaccination rate was 20% in the control group compared with 32% in the intervention group. The multifaceted nature of the intervention likely contributed to its efficacy but also limits conclusions about which aspects of the intervention were effective. It is possible to speculate, however, that the use of the pins created a descriptive and injunctive norm, as described above. Note that the pins used in this intervention also highlight the prosocial motivation for getting vaccinated (protecting patients). As discussed in the next subsection, prosocial motives on their own, apart from norms, may drive people to get vaccinated. Indeed, previous research has indicated that prosocial messages affect other behaviors of health-care workers, such as hand washing (Grant & Hofmann, 2011).

Because individuals learn about descriptive social norms, in part, by observing the behavior of others, it should be possible to change social norms by sufficiently changing the behavior of the group. Thus, group behavior changed by another intervention strategy (e.g., incentives; see Section 4) could set a new group norm and thus serve to perpetuate the effect of the initial intervention. Examining the potential interdependence of different intervention strategies, in particular, as they unfold over time, is an important topic for future research.

Strategic behavior and social preferences

Social norms arise as external influences (e.g., what others think of me) and as internal motivations (e.g., what is right or good) that arise from calculations about vaccination as a social behavior. Vaccination protects a person's unvaccinated primary contacts as well as her or his secondary contacts (the people her or his contacts know). This external benefit can give rise to the motivation of altruism, the desire to help others without expectation of personal benefit. It can also give rise to the motivation of free riding, intentionally benefitting from others' action without contributing.

As explained earlier, herd immunity occurs when a critical portion of a community is vaccinated against a contagious disease (usually > 90%); most members of the community are protected against that disease even if they have not been vaccinated because the spread of

contagious disease is contained. Certain individuals cannot be vaccinated and depend on the protection provided by the vaccination of those around them, known as cocooning. For example, in the United States, infants are not routinely immunized against measles until after 12 months of age. However, infants younger than 12 months are susceptible to infection and severe complications if exposed to measles. For example, of the 125 people infected with measles during the January 2015 measles outbreak at two Disney theme parks in the United States, 12 were infants too young to be vaccinated (Zipprich et al., 2015). Of the 11 children infected with measles during the February 2008 San Diego outbreak, 3 were infants younger than 12 months, and 1 of these was hospitalized (Hassidim et al., 2008).

Because of herd immunity, vaccination produces positive externalities—it results in benefits to people beyond the person vaccinated. One group that benefits from the vaccination of others is older adults. The seasonal-influenza vaccine is effective for younger adults, but it may provide little or no benefit to older adults because the immune response to the vaccine decreases with age (Osterholm, Kelley, Sommer, & Belongia, 2012). In addition, although hospitalizations and deaths from influenza are particularly high among older adults and infants (N. M. Smith et al., 2006; W. W. Thompson et al., 2003), children of all ages and young adults are disproportionately responsible for spreading the infections (Brownstein, Kleinman, & Mandl, 2005). Because the population primarily spreading infections only partially overlaps with the population suffering the most severe consequences of getting infected, a surprising conclusion is that older adults can be more effectively protected by vaccinating their younger contacts than by vaccinating the older adults directly (Halloran & Longini, 2006; Monto, Davenport, Napier, & Francis, 1968). However, modeling shows that, to achieve this population-optimal outcome, younger contacts would need to be vaccinated at rates higher than self-interest alone would indicate (Galvani, Reluga, & Chapman, 2007). To minimize mortality across the population, school-age children and young adults (who are disproportionately responsible for spreading influenza to others) would need to be vaccinated, even though they experience fewer and less severe health harms than older adults. Vaccination among the young thereby provides indirect protection of older adults as well as people who cannot be vaccinated, such as patients undergoing treatment for cancer and others with compromised immune systems.

Game theory offers a theoretical lens through which one can analyze vaccination behavior (Bauch & Earn, 2004). Originating from economics, Game Theory concerns the behavior of rational agents whose interactions with one another determine the benefits and harms to one another. Consequently, each agent's decision affects not only his individual payout but also the payouts of others, and it is necessary to predict the behavior of other agents to plan one's own best response. Within this framework, vaccination decisions are a type of social dilemma in which the choice to be vaccinated increases the public good by conferring herd immunity, and the choice not to be vaccinated represents free riding on others' vaccinations. This framework would suggest that, without vaccine requirements, vaccination coverage might fail to reach levels sufficiently high to achieve herd immunity, a topic further discussed in Sections 4 and 5.

A classic economic prediction in game theory is that agents will free ride (not get vaccinated) when doing so maximizes their individual payout. Behavioral variations of game theory (Camerer & Fehr, 2006) allow for agents to have social preferences—that is, preferences that depend on the outcome of others. Under social preferences, an agent may get vaccinated to confer a benefit to contacts by preventing the spread of infectious disease. This analysis, derived from game theory (Bauch & Earn, 2004), raises questions about whether patients and health-care workers understand the concept of herd immunity and use it as a motivation for their vaccination decisions—either as a reason not to get vaccinated (because they can free ride) or as a reason to get vaccinated (because they can altruistically confer a benefit to others).

Observational evidence. Are people motivated to get vaccinated because of the benefit that vaccination confers to others? They sometimes say that they are. Patients and health-care workers both sometimes give prosocial reasons as a retrospective rationale when asked why they got vaccinated. A systematic review found that 30% to 60% of parents agree that community benefit was an important reason for getting their children vaccinated (Quadri-Sheriff et al., 2012). Qualitative analyses of a parents' online chat room (Skea, Entwistle, Watt, & Russell, 2008) and parents' focus groups (Leask, Chapman, Hawe, & Burgess, 2006) revealed that some parents do spontaneously name herd immunity and protection of others as a motivation to vaccinate their children. In a questionnaire study, health-care workers self-reported that self-interest and protecting patients were their first and second most important reasons, respectively, for getting vaccinated against influenza (Hakim, Gaur, & McCullers, 2011). Other studies with health-care workers show similar findings of altruistic motives (Bautista, Vila, Uso, Tellez, & Zanon, 2006; Christini, Shutt, & Byers, 2007).

Hypothetical-scenario studies. Hypothetical scenarios provide experimental control, allowing a test of whether

benefit to others affects judgments about vaccination. Several hypothetical-scenario studies have explored the respective roles of altruism and free riding as motivations for vaccination. A classic study described earlier varied whether the vaccine hypothetically protected only the self or also prevented transmission to others. The study also varied the proportion of the population that was vaccinated (Hershey et al., 1994). Although this design allowed examination of the impact of perceived descriptive norms, it also examined the impact of opportunities to free ride (the more people who get vaccinated, the less benefit I get from getting vaccinated), and the goal to act altruistically (the fewer people who get vaccinated, the more I can benefit others by getting vaccinated myself). Participants' vaccination-intention ratings showed evidence of both altruism and free riding. As mentioned above, however, the largest effect was bandwagoning: Participants were more likely to get vaccinated when many others were already doing so.

In a hypothetical scenario study somewhat similar to the Hershey et al. study (Betsch, Böhm, & Korn, 2013), participants read scenarios that varied the information given about herd immunity. When the individual benefit of herd immunity was communicated, intentions to get vaccinated were lower. However, communicating the social benefit of vaccination reduced this tendency. These results, which are similar to findings outside the vaccination literature (Grant & Hofmann, 2011), suggest that the tendency to free ride on the vaccination of others can be reduced by communicating the social benefit that vaccination provides.

Increasing people's understanding of herd immunity could increase vaccination coverage (because people understand the opportunity for altruistic vaccination) or decrease vaccination coverage (because the opportunity for free riding becomes clear). In a scenario study, Betsch, Böhm, Korn, and Holtmann (2017) found that explicitly communicating the role of herd immunity increased people's intention to get vaccinated, especially among participants from Western, individualist cultures. In Eastern, collectivist cultures, intention to get vaccinated was high even without the herd-immunity communication. In another scenario study that showed an altruistic motivation for vaccination (Vietri et al., 2012), participants responded to scenarios that varied the percentage of the population that was already immune to the infectious disease. As long as participants learned that they themselves were at no risk of infection, then their stated likelihood of getting vaccinated increased as the percentage of the population that was immune decreased—indicating that more individuals would benefit from the protection provided by participants' own vaccination.

Böhm, Betsch, Korn, and Holtmann (2016) explored prosocial motivation for health-care-worker vaccination in a hypothetical scenario study. American and Korean community members responded to a scenario in which they played the role of a health-care worker who could get vaccinated at a cost to themselves; however, if enough other health-care workers got vaccinated, patients would benefit. Vaccination responses in this prosocial scenario were higher among participants in Korea (a collectivist culture) than among participants in the United States (an individualist culture), and this difference was mediated by viewing vaccination as a social act. This study suggests that vaccination among health-care workers might be increased by promoting collectivist values and the view that vaccination is a social rather than individual behavior.

These scenario studies indicate that social preferences for altruism or for free riding may influence vaccination decisions. Furthermore, reinforcing altruistic motives may offset free riding. Although the hypothetical scenario studies in this subsection provide experimental control, they do not allow observation of actual vaccination behavior. Thus, it is unclear how these results would generalize to real-world settings.

Laboratory game studies. In hypothetical-scenario studies, the main limitation is that participants' responses have no real consequences (although research shows that preferences are frequently similar with and without consequences). Laboratory games offer a solution by providing real consequences for decisions—albeit monetary and not health consequences. In one such laboratory experiment (Chapman et al., 2012), participants engaged in an interactive strategic task in which they had to decide whether to spend points to get vaccinated. Participants were randomly assigned to age roles: For those in the "young" role, vaccination was more effective, in terms of both reducing individual risk of infection and contributing to herd immunity; for those in the "old" role, getting the flu resulted in a more severe point penalty. When the individual's point total determined payment for being in the study, participants behaved in accordance with the self-interested prediction from game theory, with fewer "young" players than "old" players getting vaccinated. In contrast, when participants were paid according to the group's point total, they behaved in accordance with the group optimum solution, with more "young" players than "old" players getting vaccinated. The results from this laboratory task suggest that, if the incentives are set correctly, young people may be willing to get vaccinated prosocially to protect older adults. Thus, for example, young people may be willing to get vaccinated if it is clear that their vaccination will benefit their grandparents and this is an outcome they value.

Böhm, Betsch, and Korn (2017) used a similar laboratory vaccination-game paradigm and found that participants with prosocial (rather than proself) preferences

were more likely to get vaccinated in the laboratory game, and this effect was strongest among those with a positive attitude toward vaccination. The hypothetical scenarios and laboratory-game studies described thus far in this section did not assess actual vaccination behavior. Consequently, they can examine altruism and free riding in hypothetical vaccination judgments or in laboratory choices that have monetary consequences, but these results may not translate to actual vaccination decisions.

Correlational studies of vaccination and intentions. Several studies have examined whether measures of altruistic motives correlated with self-reports of actual vaccination behavior or intentions to vaccinate. Patients' perception of the likelihood of becoming infected and their perception of the likelihood of infecting others each predict unique variance in actual influenza vaccination decisions. However risk to self is much more strongly predictive of receiving a vaccination than is risk to others, at a 3:1 ratio (Shim, Chapman, Townsend, & Galvani, 2012). Thus, to the extent that the relationship between vaccination behavior and perceived likelihood of infecting others captures altruistic motives, we can say that altruism is associated with actually getting vaccinated but plays a minor role relative to self-interest motives. This study was correlational and did not demonstrate a causal link between changes in altruistic motives and getting vaccinated.

Vaccinating boys against HPV has a notable prosocial benefit: It protects the vaccinated boys themselves from HPV-related cancers such as anal and penile cancer, and it also protects the boys' future sexual partners from six HPV-related cancers. Polonijo, Carpiano, Reiter, and Brewer (2016) found that male teenagers were more willing to get the HPV vaccine if they found it important that the vaccine could protect their future romantic partners. Parents of the teens who held the same belief were also more willing to get them HPV vaccine. Furthermore, these prosocial attitudes mediated the relationship between race and willingness to get vaccinated, such that Blacks and Hispanics (vs. Whites) had more prosocial attitudes, and these attitudes were associated, in turn, with higher willingness to get vaccinated. Additional analyses found that perceived benefit to the son, benefit to his future sexual partners, and benefit to the community were all associated with parents' willingness to allow the vaccination and the sons' willingness to get vaccinated (Moss et al., 2015). However, in analyses adjusting for all three beliefs, only protecting the partner was associated with willingness.

In another study, young men gave higher ratings of hypothetical willingness to receive HPV vaccine if they received information on both the benefits to self of vaccination as well as the altruistic benefits to future sexual partners compared with (a) receiving either of these pieces of information in isolation or (b) receiving neither piece of information (a control condition; Bonafide & Vanable, 2015). This study shows a benefit of two pieces versus one piece of information but not necessarily a special role for information on the altruistic benefits of vaccination per se. In contrast, messages emphasizing the social benefits of the MMR vaccine (relative to comparison messages that omit this information) do not increase the intentions of parents to get their infant children vaccinated (Hendrix et al., 2014).

One might expect that health-care workers would be particularly motivated by the prosocial benefits of vaccination. For one thing, health-care workers' contact patterns increase the risk of contracting infectious diseases such as influenza or hepatitis A from patients and of transmitting the infection unknowingly to other patients. In addition, health-care workers presumably have a professional duty to care for patients and protect them from adverse health outcomes, and vaccination provides one route to do that. The evidence indicates, however, that health-care workers' vaccination decisions are not any more motivated by prosocial concerns than are those of other decision makers (Betsch, 2014). A survey study found that health-care workers had higher influenza vaccination coverage than non–health-care workers, but not because of prosocial concerns for patients (Capolongo et al., 2006). The health-care workers perceived a higher risk of infection; had easier access to the vaccine, more knowledge about the vaccine, and stronger pro-Western medical beliefs; and perceived stronger social influence to get vaccinated.

One study examined whether measures of free-riding motives correlated with self-reports of previous vaccination behavior. Free-riding motives were higher among parents who had not gotten the pertussis vaccine for their children (Meszaros et al., 1996).

Intervention studies. In an online study, participants read a prosocial message (about someone who died from the flu because his contacts had not been vaccinated), a control message, or no message (Li, Taylor, Atkins, Chapman, & Galvani, 2016). The prosocial message increased prosocial motives, as measured by willingness to donate to an unrelated cause. Prosocial motives in turn were associated with stated intention to get vaccinated against influenza. The prosocial and control messages did not differ in their effect on vaccination intention, however, and this study did not show an effect on actual vaccination behavior.

In one of the few studies to examine the effect of prosocial motives on actual vaccination behavior (Rothan-Tondeur et al., 2010), health-care workers were

randomized by ward into two conditions; in one, they received a vaccination-message intervention, and in the other, a control condition, they received no message. The message stated that vaccination of health-care workers against influenza benefits patients. The intervention did not affect vaccination coverage, which was equivalent in the two conditions. The messages were delivered via a 2-hour optional information session that health-care workers attended, which may not have been a sufficiently engaging mechanism for delivering the intervention.

A campaign to increase influenza vaccination coverage among health-care workers by emphasizing the prosocial benefits of vaccination to family members and patients had no impact on vaccine uptake (Llupià et al., 2013). Note that in this study, unlike the badge studies described earlier, the prosocial messaging did not have a public-accountability component, which may help to explain the null effect.

Vaccination coverage among health-care workers is often too low, and they are not sufficiently motivated to get vaccinated out of concern for patient safety (Lam, Chambers, MacDougall, & McCarthy, 2010). This has prompted some health-care facilities—particularly academic hospitals in the United States—to institute annual influenza vaccination requirements for health-care workers. Such requirements, sometimes called mandates, communicate a clear injunctive norm that the hospital management views staff vaccination as a priority. The requirements may also circumvent individual motives for vaccination, a topic we return to in Section 4.

Conclusion

Social networks and social norms have powerful influences on health behavior, and some evidence shows that these results extend to vaccination. The social-network literature includes some compelling correlational analyses of large data sets and elegant field experiments, but none of these studies examined vaccination behavior. However, several network models have modeled idealized vaccination behavior under various conditions. Likewise, the intervention studies that provide a clean view of the role of social norms have not examined vaccination, although more multifaceted intervention studies have done so. Studies of vaccination interventions that employ social norms are a clear avenue for future research.

The current literature suggests that free-riding and altruism motivations may influence people's vaccination decisions. The vast majority of studies exploring prosocial motives for vaccination have used hypothetical scenarios, laboratory tasks, or ratings of vaccination intentions. Very few have examined prosocial motives in actual vaccination behavior. Few studies observe actual vaccination behavior and manipulate altruistic or free-riding motives. Furthermore, no studies have compellingly shown that interventions increase vaccination coverage by enhancing prosocial motives. Although these theoretical factors predict behavior in other domains, evidence is required to establish that link in the domain of vaccination. Future research can explore whether vaccination can be enhanced through interventions that encourage social preferences and altruistic motives.

Provider recommendations. The social processes explored in this section provide one class of explanation for why provider recommendations are so strongly associated with patient vaccination behavior. In network terminology, providers are likely to be centrally located in their networks, positioned to influence a large number of people through contagion. Homophily effects on social networks may result in providers being connected to patients who are the most likely to get vaccinated. For example, providers who strongly recommend vaccination attract patients with positive vaccination attitudes (Mergler et al., 2013), even as vaccine-hesitant and vaccine-refusing patients often seek out different providers and complementary and alternative medicines (Frass et al., 2012). Consequently, the strong association between provider recommendation and patient vaccination may be due in part to patient self-selection rather than to a direct causal effect of the recommendation on behavior.

Another reason for the influential role of provider recommendations is that providers can create and communicate injunctive social norms by indicating to their patients, either through explicit recommendations or implicit cues, that they expect patients to get vaccinated. Their recommendations can also communicate descriptive social norms by implying that most other patients get vaccinated or that vaccination is what most previous patients have chosen.

Social media. Social media has become an important force in organizing people in social space. Surprisingly little is known about how social media affects vaccination-related attitudes and behavior (Betsch et al., 2012). Theories reviewed in this section on social processes make interesting predictions—for example, that when people opposed to vaccination connect on social media (homophily), it should further polarize their opinions (contagion; Witteman & Zikmund-Fisher, 2012). Illustrating the value of mining social media for vaccination research, Salathé and Khandelwal (2011) coded 300,000 Twitter messages for sentiments about the H1N1 vaccine and found that sentiments expressed on Twitter in each geographical region corresponded to vaccination coverage. They also

found homophily in the social network. Broniatowski, Hilyard, and Dredze (2016) examined news articles about the Disneyland measles epidemic and predicted which ones would be shared on Facebook. The articles most likely to be shared and most widely shared contained a take-home message (or easily identified gist), shedding light on a psychological construct that is key to information transmission across a network.

Social media likely magnifies the effects of homophily found in other manifestations of social networks, because social media increases the ease of finding like-minded people. To the extent that homophily amplifies contagion effects in social networks, social media would thus also magnify contagion, consequently increasing the polarization of vaccination views. As a result of these enhanced social network dynamics and the speed with which information spreads through social media, social media could serve as the catalyst for a rapid meltdown of the vaccination system and the loss of confidence built up over many years.

Personal stories are some of the most penetrating content spread on social media. The benefits of narrative storytelling favored by antivaccination activists are widely discussed yet poorly quantified (Betsch, Renkewitz, & Haase, 2013; Bruine de Bruin, Wallin, Parker, Strough, & Hanmer, 2017). As mentioned in Section 2, a large body of research in psychological science has demonstrated that anecdotes and personal stories are more influential than base rates and statistics (e.g., Fagerlin, Wang, & Ubel, 2005). Little research has examined what exactly makes antivaccine efforts specifically effective; instead, research has focused on provaccine messages. Recently, provaccination efforts have tried narrative approaches. For example, the U.S. National HPV Vaccination roundtable recently created a series of videos with survivors of HPV-related cancers. The *Someone You Love* documentary (Lumiere, Hefti, & Staurulakis, 2014) follows the stories of five women with cervical cancer, including two who die from the disease. No data are available on how these personal stories affect vaccination behavior, which is an important opportunity for future research.

Priorities for future research include examining the spread of rumors compared with the spread of credible information on social media and how social media affects vaccination attitudes and behavior (Reiter et al., in press). Opportunities for intervention include social-media studies that expose people to social networks with provaccination views. Other avenues for further exploration include examining how citizen activists can use social media to build support for vaccination. Finally, social media has helped antivaccination activists to find one another and to spread their message. Understanding the nature of these messages, and helping provaccination activists to use similar methods, is an important opportunity. Research on the effects of exposing people to social-media information that is at odds with their existing beliefs would be an interesting avenue of investigation. In the near future, the social-network and social-norm effects reviewed in this section are likely to play out on social media at least as much as in interactions that occur in-person.

Section 4: Changing Behavior Directly

Understanding how to change people's thoughts and feelings to motivate them to get vaccinated has received substantial attention. This makes sense given that provision of vaccines requires consent, or at least nonrefusal. It is also increasingly clear that vaccine deliberation is just one part of the story. People who say they are favorably inclined often fail to turn that confidence into actually receiving a vaccination. At the same time, policies can lead people to be vaccinated beyond any effects of their thoughts and feelings. We now turn to individual and situational factors that regulate the relation between what people think and feel about vaccines and their behavior. In line with this emphasis, this section focuses primarily on experimental tests of intervention strategies designed to promote vaccination behavior directly, bypassing any attempt to change what people think and feel.

This section examines three broad groupings of intervention strategies. First, we examine how to close the *intention-behavior gap*, present when people hold favorable vaccination intentions yet fail to act (Sheeran, 2002; Sheeran & Webb, 2016). A variety of strategies have emerged to bridge the intention-behavior gap by building on people's favorable intentions (Fig. 4); these strategies include keeping favorable intentions in mind through reminders, prompts, and primes and reducing barriers through logistics and healthy defaults. We consider whether these strategies can, or have the potential to, help people translate their intentions to be vaccinated into action.

Second, we examine the effectiveness of strategies designed to shape people's behavior without relying on their beliefs about vaccination. We focus on strategies that make salient a new set of outcomes through the use of programs that tie incentives or sanctions to vaccination behavior and strategies that minimize opportunities for deliberation by requiring vaccination to obtain a desired outcome (e.g., access to education or employment). These strategies are particularly interesting given that they may prove to be an effective way to lead people with ambivalent or unfavorable thoughts and feelings to get vaccinated.

Third, we consider new directions in research that could inform the development of new strategies to change behavior directly. Some processes that guide

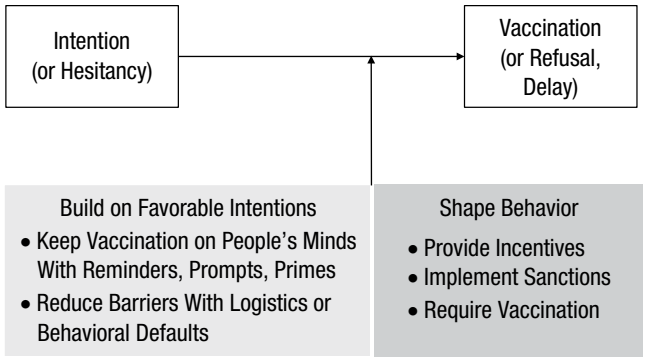

Fig. 4. Influencing vaccination directly, without changing thoughts and feelings.

vaccination behavior operate automatically or outside of conscious awareness (Bargh, 2006; Wood & Neal, 2016). In many behavioral domains, public-health programs have directed considerable effort to help people develop healthy routines such that the desired behavior occurs automatically in response to cues or reminders in the situation (Marteau, Hollands, & Fletcher, 2012; Rothman et al., 2015). For instance, people develop routines to exercise before work each day or to take their medications every evening. In some cases, the routines become habits, such as putting on a seatbelt after entering a car without having to think about it. We consider the implications of whether getting vaccinated can become a behavioral routine and how to render aspects of the underlying behavioral process routine.

In addition to the explicit evaluations that people report regarding a behavior, they may hold favorable or unfavorable implicit evaluations regarding that behavior (Gawronski & Bodenhausen, 2006). Exploring the nature and impact of people's implicit evaluations may offer new insights. For example, people's implicit evaluation of unhealthy behaviors (e.g., smoking, drinking, and drug use) are more favorable than their explicit evaluations, which, in turn, mitigates their stated intentions to reduce an unhealthy behavior (Sheeran, Gollwitzer, & Bargh, 2013). This section applies these ideas to vaccination where such application is promising.

Building on favorable intentions to get vaccinated

People failing to act on their favorable intentions is a common challenge across a range of health domains (Sheeran & Webb, 2016), including vaccination (Brewer et al., 2011; DiBonaventura & Chapman, 2005). Researchers have identified two broad explanations for the intention-behavior gap. First, a person's plan to get vaccinated may be forgotten or fail to come to mind, even when an opportunity to act is available. Second, barriers can emerge that make translating vaccine intentions into action difficult or at least inconvenient. In the subsections that follow, we examine these two classes of explanations with a particular focus on strategies that could increase the likelihood that people consistently act on their intentions to be vaccinated. Given the challenges associated with changing people's beliefs about vaccination, strategies that can maximize the impact of people's preexisting favorable beliefs may be particularly valuable.

Keeping favorable intentions on people's minds. Life's many obligations and distractions may crowd out intentions to be vaccinated. As a result, planning may not receive the attention it needs. People who are not vaccinated as a result of passivity or inaction may find themselves in this state (Robbins et al., 2010). We consider three intervention strategies designed to increase the likelihood that people will keep their favorable intentions in mind: reminder/recall systems, presumptive vaccine recommendations, and primes such as implementation intentions.

Reminder/recall systems. *Reminders* are for people who are due for vaccination (e.g., "Flu season has arrived—Remember that it's time for your flu shot"). Reminders can bring to mind intentions to be vaccinated as well as serve as a cue to action that it is now time to get vaccinated. *Recalls* are reminders for people who are overdue for vaccination. Modes for delivering reminder/recalls include e-mails, postcards, letters, text messages, and phone calls.

Several meta-analyses and systematic reviews have found that systems that provide reminders or recalls increase vaccination coverage (e.g., Briss et al., 2000; Groom et al., 2015; Jacobson Vann & Szilagyi, 2018; Stone et al., 2002; Szilagyi et al., 2000). Reviews of reminder/recall systems have found them to be effective across populations, types of vaccinations, and mode of delivery (Briss et al., 2000; Jacobson Vann & Szilagyi, 2018). Despite evidence regarding their effectiveness, implementation of these systems is poor; providers grapple with competing demands, including urgent patient needs, limited financial resources, and low organizational capacity (Pereira et al., 2012; Saville et al., 2011; Suh et al., 2012). Even in regions with vaccination registries that give greater capacity to automate reminders, providers implement them variably. Researchers and health agencies have directed considerable effort toward delineating the strategies and resources needed to facilitate the implementation of reminder/recall systems and where to situate those systems (e.g., Kempe et al., 2013, 2015).

Identifying modifiable facets of reminder/recall may help increase their impact. Reminder/recall systems are

likely to be more powerful when it is easier for people to act (i.e., to act on their favorable intentions) in response to the reminder. Telephone-based systems that allow people to schedule an appointment when they receive the reminder are the most effective mode for delivering reminders (Jacobson Vann & Szilagyi, 2018), and allowing people to choose the method for contacting them increases the impact on vaccination coverage (Kempe et al., 2016). People are more responsive to a reminder/recall that comes from a source that is familiar and trusted (Kempe et al., 2013), but reminder/recalls are most effective when a centralized infrastructure such as the regional health department manages them and includes the endorsement by the patient's practice (Kempe, Saville, et al., 2015). With regard to content, the message should clearly state that it is time to get vaccinated and provide information about how to take action (Hawe, McKenzie, & Scurry, 1998). However, patient privacy laws may limit how specific such messages can be, depending on mode of delivery. Finally, it is not clear whether reminders and recalls elicit different psychological responses (e.g., a recall may remind recipients that someone is monitoring their behavior and knows they are late).

Presumptive announcements. Another approach to helping people keep their favorable intentions in mind is the use of presumptive provider recommendations. Considerable evidence shows that provider recommendations increase vaccination coverage (Kempe et al., 2016; Schmid et al., 2017; Wheelock, Thomson, & Sevdalis, 2013). Even more powerful are *presumptive announcements* that frame the opportunity to be vaccinated as the default option (e.g., "Your son is due for vaccines against meningitis, HPV cancers, and whooping cough. We'll give them at the end of the visit."). Although providers routinely use presumptive recommendations in many aspects of care, such as ordering tests and prescribing medicines, they typically do not use them for vaccination (Moss, Reiter, Rimer, & Brewer, 2016; Opel et al., 2013; Sturm et al., 2017). Several observational studies have reported that patients are more likely to agree to be vaccinated when the provider's recommendation takes the form of an announcement that assumes readiness for the vaccination (Moss et al., 2016; Opel et al., 2013, 2015). Although promising, these observational findings could mean that physicians more often use a presumptive announcement style with parents who are already inclined to have their children vaccinated. More convincingly, one randomized trial found that training vaccine-prescribing physicians to structure their vaccine recommendations as presumptive announcements led to higher rates of HPV vaccination for 11- and 12-year-olds (Brewer et al., 2017). Further research is needed to determine the degree to which variability in a person's vaccine hesitancy modifies the effectiveness of this strategy.

Why is this strategy effective? A physician recommending vaccination can cue people who are positively inclined toward vaccination to take action. By framing vaccines as routine care, presumptive announcements speed the decision process for people with positive vaccination intentions. For people who are hesitant or opposed to vaccination, the process will slow down, allowing them to ask questions and the provider to ease their concerns. For people who have received vaccines in the past, presumptive recommendations may cue a general inclination toward vaccination (e.g., "I usually get vaccines, and so I'll keep doing it"). Finally, presumptive recommendations may more clearly communicate the clinicians' endorsement of the vaccine, an injunctive norm as discussed in Section 3.

Priming. A third approach to help people keep their favorable intentions in mind involves strategies that prime people's existing intentions regarding the vaccine or that formalize plans for acting on their intentions. Having people merely report on their attitudes and intentions about a health behavior can increase subsequent behavioral performance, a finding called the *question-behavior effect* and the *mere-measurement effect* (Dholakia, 2010; Wilding et al., 2016). In the context of vaccination, Conner, Godin, Norman, and Sheeran (2011) randomized health-care workers to take a survey on their seasonal-flu-vaccine attitudes and intentions. These workers were more likely to get the vaccine than workers who were not sent the survey (42% vs. 36%). Moreover, among workers who completed the survey, those who reported favorable cognitions regarding the vaccine were more likely to get vaccinated than those with less favorable cognitions. The researchers replicated the mere-measurement effect in an RCT with patients in a general medicine clinic, although the effect was small (77% vs. 75%; Conner et al., 2017). Research suggests that mere measurement amplifies underlying intention (Morwitz & Fitzsimons, 2004). Thus, a person planning not to get vaccinated would become even less likely to do so after a mere-measurement intervention, and the overall impact of such an intervention across the population would depend on the percentage of people who did and did not intend to get vaccinated.

Another strategy that can help people keep their favorable intentions in mind is to have them formulate *implementation intentions* or if-then plans that delineate what they need to do and when to fulfill their intentions (Gollwitzer & Sheeran, 2006). Forming an if-then plan helps people develop a mental link between a situation and the desired response, which, in turn, increases the likelihood that people will perform the desired action when the opportunity emerges. An

if-then plan might take the form of "If I receive a notice about a flu-shot clinic, then I will immediately schedule an appointment." Implementation intention interventions can have a substantial impact on behavior (overall $d = 0.65$ (Adriaanse, Vinkers, De Ridder, Hox, & De Wit, 2011; Bélanger-Gravel, Godin, & Amireault, 2013; Gollwitzer & Sheeran, 2006).

A large implementation-intentions RCT that prompted employees at a U.S. firm to specify a date and a time for their next influenza vaccination increased vaccination coverage (from 33% to 37%; Milkman, Beshears, Choi, Laibson, & Madrian, 2011), but having people specify the date alone had no effect. Likewise, in an implementation-intentions trial, Dutch men who have sex with men were instructed to indicate where, when, and how they would make an appointment, and hepatitis B vaccination increased from 9% to 21% (Vet, de Wit, & Das, 2014). The intervention excluded people who intended to not get vaccinated, and its impact was equally strong among people with weak and strong intentions. However, people with strong intentions were more likely to form complete if-then plans, which, in turn, was correlated with getting a vaccination. Finally, forming implementation intentions (specifying what, where, and when) led to higher seasonal-influenza vaccination among Thai adults (84% vs. 90%), a difference that was not statistically significant in this underpowered quasi-experiment (Payaprom, Bennett, Alabaster, & Tantipong, 2011). One plausible mechanism to explain the impact of implementation intentions is an improvement in prospective memory (Chen et al., 2015). Like the mere-measurement effect, implementation intentions are designed to help people to act rather than change their intentions. Consistent with this premise, studies in other behavioral domains show that implementation intentions increase behavior by eliciting higher rates of action from individuals who hold favorable attitudes or intentions toward the behavior (Sheeran, Webb, & Gollwitzer, 2005).

Reducing barriers. Even when people's intentions to get vaccinated are at the top of their minds and not forgotten, they may not lead to behavior because *barriers*—real or perceived—may emerge that make taking action difficult (Gerend, Shepherd, & Shepherd, 2013; Kimmel, Timko Burns, Wolfe, & Zimmerman, 2007). Situational barriers include lack of transport, inadequate maternity leave or childcare, multiple competing priorities, inconvenient clinic opening times, service or vaccine cost, or lack of vaccine availability (Falagas & Zarkadoulia, 2008; Hollmeyer, Hayden, Poland, & Buchholz, 2009; Holman et al., 2014). Their health-care provider may recommend a delay in vaccination because of a sick child or may not take opportunities to vaccinate at sick visits (Smith, Marcuse, Seward, Zhao, & Orenstein, 2015). Language barriers as well as disabilities (e.g., deafness) can make it difficult for people to interact with care systems or obtain information, potentially leaving them unaware that a vaccination is due (Fiscella, Franks, Doescher, & Saver, 2002; McKee, Barnett, Block, & Pearson, 2011). Finally, some people may experience judgment or discrimination from providers (Trivedi & Ayanian, 2006; but see Hausmann, Jeong, Bost & Ibrahim, 2008) or fear that vaccination will be painful (Falagas & Zarkadoulia, 2008; E. Mills, Jadad, Ross, & Wilson, 2005). Taken together, these factors can impede action, creating a gap between people's inclination to be vaccinated and their behavior. Logistical strategies that can blunt the effect of these barriers should enable people to act on their favorable intentions, thereby increasing vaccination coverage.

On-site vaccination. Provision of free seasonal-influenza vaccine clinics at schools, workplaces, or community centers addresses barriers related to cost and access. On-site vaccination increases seasonal-influenza vaccination (Briss et al., 2000), but this approach is more difficult to implement for other vaccines (e.g., Hayes et al., 2013; Watson, Shaw, Molchanoff, & McInnes, 2009). Even when vaccines are available on site for no cost, vaccination coverage can remain modest, even among those who express favorable intentions to get vaccinated. It would seem that when people want to be vaccinated, they are surprisingly slow to commit to a specific time to do so. This tendency may be exacerbated as a result of choice overload when clinics offer a large array of dates and times for vaccination (Scheibehenne et al., 2010; Schwartz, 2004).

Defaults. Given the challenges people face in turning their intentions into action, researchers have started to test strategies that reframe the decision process in ways that might make action easier or, at least, might make people perceive it to be easier (Li & Chapman, 2013). One important aspect of the decision process is whether performing the behavior is construed as the default response. In settings without strong norms or requirements, the default state is not being vaccinated. Being vaccinated requires one to schedule an appointment or specify a time and place (i.e., it is an opt-in choice). An intriguing approach is to reframe vaccination as an opt-out choice, where the default response is to obtain the vaccine. This is what may be happening when clinical recommendations regarding vaccination during a clinic visit take the form of a presumptive announcement (Brewer et al., 2017; Moss et al., 2016; Opel et al., 2013, 2015). It may also be the reason why standing orders for vaccination are a highly effective method for increasing vaccination coverage (Community Preventive Services Task Force, 2016a). Standing orders authorize nurses,

pharmacists, and other health-care personnel to assess a client's immunization status and administer vaccinations according to a previously approved protocol, without the need to interact with or receive a direct order from the attending physician at the time of vaccination. Standing orders may create a similar presumptive expectation of vaccination in which the process is aborted only if the parent or patient asks to speak to a provider or expresses concerns regarding vaccination.

Note that health-care providers may also benefit from systems that make it easier for them to act on their intention to vaccinate their patients. Providers randomized to use of a modified electronic health record that made them actively accept or cancel an order for seasonal-influenza vaccine had higher vaccination orders and coverage than those who used a standard electronic health record (Patel et al., 2017). In this case, the default involved having to make a choice about whether to order the vaccine. However, electronic-records prompts can be misunderstood and become ineffective over time as providers tire of seeing them or receive too many prompts (Szilagyi et al., 2015; Zazove et al., 2017).

Other strategies can frame getting vaccinated as the default option. One lab study among U.S. participants used hypothetical vaccination behavior, and the researchers found that framing seasonal-influenza vaccination as an opt-out choice elicited greater interest in the vaccine than an opt-in choice; however, the finding was not present among Korean participants (Böhm et al., 2016). Another online lab experiment using hypothetical vaccination behavior found parents had greater interest in the HPV vaccine for their sons when it was provided with two other vaccines than when provided on its own, what the authors described as a "soft default" (Reiter, McRee, Pepper, & Brewer, 2012). However, another manipulation of a "hard default" (whether the son's school automatically gave the vaccine) found that the opt-out condition elicited less interest in vaccination. One explanation for the unexpected finding is a *default rejection* because of a perceived limitation in choice (Jachimowicz, Duncan, Weber, & Johnson, 2017), consistent with reactance (Brehm, 1966).

In a field RCT, Chapman, Li, Leventhal, and Leventhal (2016) explored whether automatically scheduling people for seasonal-influenza vaccination would increase uptake. Specifically, outpatients were randomly assigned to receive one of two letters about the clinic (in a third condition, participants received no letter). In the opt-in condition, which reflected the clinic's current communication strategy, patients received a letter about the availability of seasonal-influenza vaccination and could schedule an appointment in the weeks following delivery of the letter. In the opt-out condition, people received a similar letter that provided a prescheduled vaccination appointment at the clinic during the weeks following delivery of the letter, with an option to change or cancel the appointment. People in the opt-out condition were more likely to be vaccinated than those in the opt-in condition (16% vs. 5%), according to their medical records. The provision of an appointment rendered getting the vaccine the default state and created a commitment to being vaccinated at a given date and time. Although some people needed to change the prescheduled appointment, this approach meant that people did not need to take the time and effort to schedule an initial appointment, eliminating a real barrier, albeit modest, to action. A previous RCT showed similar results (45% vs. 33%; Chapman, Li, Colby, & Yoon, 2010). An RCT with health-care workers found an effect of similar size (28% vs. 16%) for default appointment scheduling, but it was not statistically significant, possibly because of insufficient power (Lehmann, Chapman, Franssen, Kok, & Ruiter, 2016).

Reframing vaccination as the default behavioral response has intriguing promise as a strategy to address the intention-behavior gap. One might hypothesize that providing a prescheduled appointment would be most effective if targeted toward individuals who already hold a favorable attitude and intention toward the vaccine, although this was not examined by Chapman et al. (2016). Moreover, this approach could be integrated into a reminder/recall system in which people were not only informed that they were due for a vaccine that they had received previously but also were given a prespecified appointment for the vaccination.

Shaping the behavior

Among strategies that do not try to change thoughts or feelings about vaccination, an alternative to focusing on helping people act on their intentions is to focus on behavior. One class of strategies is designed to provide people with an additional set of reasons to get vaccinated. Specifically, incentive programs can provide either rewards or penalties that are contingent on people's vaccination behavior. The reward or penalty is devised to make it worth the person's while to get vaccinated without changing their beliefs about the vaccine. The second class of strategies is designed to sidestep people's beliefs about the vaccine by minimizing or restricting the degree of choice people have about their vaccination behavior. This approach primarily involves the imposition of vaccination requirements that determine access to work, school, or area of residency. In the following subsections, we examine the effect these two alternative approaches have on vaccination behavior as well as potential downstream

implications for how they might influence people's thoughts and feelings about vaccines.

Incentives and sanctions. Incentive and sanction programs have emerged as a potential strategy for shifting people's analysis of the costs and benefits of engaging in a desired pattern of behavior. *Incentive* programs provide people with monetary or nonmonetary rewards contingent on the performance of a specified behavior (e.g., being vaccinated), whereas *sanction* programs enact monetary or nonmonetary penalties contingent on the failure to perform the behavior (for overviews, see Giles, Robalino, McColl, Sniehotta, & Adams, 2014; Kane, Johnson, Town, & Butler, 2004).

Given this framework, incentives and sanctions offer the most practical value in contexts in which people are not engaging in the desired behavior at a sufficient rate. A key feature of these programs is that they target a set of outcomes that are distinct from the thoughts and feelings about vaccination that are traditionally targeted by intervention programs. Thus, this intervention strategy can be effective without having to change people's underlying thoughts and feelings about the vaccine.

To date, programs for vaccinations have either provided an incentive (e.g., a cash payment) for engaging in the behavior or have implemented a sanction by limiting an existing benefit for failing to engage in a behavior (e.g., reducing a government payment). However, the overwhelming majority of the programs provide an incentive for obtaining a vaccine; thus, this will be the primary focus of this section.

Incentive programs have focused primarily on promoting childhood vaccination (e.g., Banerjee, Duflo, Latif, Glennerster, & Kothari, 2010; Bond, Davie, Carlin, Lester, & Nolan, 2002; Browngoehl, Kennedy, Krotki, & Mainzer, 1997; Kerpelman, Connell, & Gunn, 2000; Mantzari, Vogt, & Marteau, 2015; Minkovitz et al., 1999) and influenza vaccination for adults (e.g., Bronchetti, Huffman, & Magenheim, 2015; Moran, Nelson, Wofford, Velez, & Case, 1996). However, incentives have also been used to promote hepatitis B vaccine in adult subpopulations (e.g., injection drug users: Seal, 2003; Topp et al., 2013; Weaver et al., 2014). The reviews of incentives diverge in their recommendations: Some assert that this approach is an effective strategy for promoting vaccination (Community Preventive Services Task Force, 2015, 2016a, 2016b); others contend that the evidence for effectiveness is inconclusive (Adams et al., 2015). A consistent theme across these reviews is the heterogeneity in the nature and quality of the underlying studies, which makes it difficult to draw any strong conclusions regarding this intervention strategy. For instance, many tests of incentive programs have been conducted in combination with other intervention strategies, making it difficult to isolate the effect of the incentive. Furthermore, the incentives used in these programs vary considerably in size, by whether they are monetary or nonmonetary, and by whether they provide a fixed reward or variable reward (e.g., a lottery ticket). Currently, investigators have little guidance regarding how to set the magnitude of the incentive, whether it matters if the reward is fixed or variable, or whether the reward should involve monetary or nonmonetary outcomes. A more thorough understanding of how features of the program affect people's behavioral decisions could help policymakers optimize incentives to make them more effective and efficient (Burns et al., 2012).

Only a small number of programs have tested the effect of introducing a sanction for not receiving a vaccination. In these cases, the focus has been on childhood vaccination programs, and the sanction involved a reduction in the financial support that families would otherwise receive from the government. Thus, the potential adverse outcome is the absence of a benefit rather than the imposition of an additional cost. Although Kerpelman et al. (2000) found that the potential loss of benefits led to higher rates of compliance with childhood vaccination schedules, Minkovitz et al. (1999) found that a similarly structured program had no effect on vaccination coverage. The introduction of a system to link vaccination requirements and certain exemptions to receipt of government payments was associated with increased vaccination coverage in Australia (Lawrence, MacIntyre, Hull, & McIntyre, 2004). The questions raised regarding incentive-based reward programs are relevant here as well. For instance, whether the proposed sanction is sufficiently averse to motivate the behavior requires careful consideration. To date, no study has tested the effectiveness of a program in which the sanction involved imposing an additional cost for failing to be vaccinated, which might be experienced as a more aversive outcome.

Moving forward, analyses of incentive-program effectiveness should also consider the broader consequences of linking an incentive to vaccination behavior. A prevailing concern regarding incentive programs is that they have the potential to undermine people's intrinsic motivation for the incentivized behavior. To date, this has not been shown to be an issue when using incentives to motivate healthy behavior (Promberger & Marteau, 2013). Given that incentive programs are not designed to change how people think and feel about vaccines, there is little reason to believe that providing an incentive for one vaccine will increase the likelihood

that people will obtain other vaccines. In fact, if anything, it may alter what people expect to receive in exchange for being vaccinated, making them less responsive to calls for vaccinations that do not provide incentives.

Consideration should also be given to what the implementation of an incentive program for vaccination might inadvertently communicate about vaccines (Connelly, Certo, Ireland, & Reutzel, 2011). On the one hand, an incentive program may affirm the importance of vaccination. People may think that paying people to take action or penalizing them for inaction signals the value of this behavior. On the other hand, the program may signal that presently people are not choosing to perform the behavior, creating or reinforcing the impression that obtaining the vaccine is not normative (Section 3). Moreover, the observation that people need to be paid (or potentially penalized) in order to agree to be vaccinated could be taken to imply that the case for vaccination, on its own, is not sufficient to motivate action. These latter inferences may serve to undermine people's interest in the vaccine (Gneezy, Meier, & Rey-Biel, 2011).

An interesting question is for whom an incentive program might be most effective. Given that an incentive is designed to improve people's cost-benefit analysis of performing the behavior, it may provide limited added value when offered to people who already hold favorable beliefs about the vaccine. However, it seems well suited for people with ambivalent or unfavorable beliefs about the vaccine because the incentive serves as a counterweight to these beliefs. For instance, Bronchetti et al. (2015) observed that providing an incentive for getting the seasonal-influenza vaccine had a more pronounced effect on the behavior of students who had not gotten the vaccine in the prior year.

Finally, the acceptability and feasibility of implementing an incentive program to promote vaccination are important considerations. Several studies have observed that people express discomfort with the notion of paying people to take care of their health (Adams et al., 2015). Regarding feasibility, incentive programs are likely to be viable only within care systems that have the resources to cover the costs of the incentive. Healthcare systems could also build incentives into quality-metrics programs. Finally, checklists are available for thinking through how to make incentive programs acceptable and effective (Glasziou et al., 2012).

Requirements. Another strategy to shape behavior is creating requirements that share some qualities with defaults and sanctions. Requirements clearly set vaccination as a default and impose a sanction or penalty on those who want to opt out. Some jurisdictions have policies that require vaccination as a precondition for access to resources or activities tied to school or work or, in some cases, even residency. In this manner, vaccination requirements are similar in structure to sanction programs that impose penalties for failing to take action. Most requirements are instantiated through legal action by national or regional governments, although some come from employers and providers. All have exemptions for people medically contraindicated for vaccination, and some provide other exemptions relating to personal beliefs or religion. The level of difficulty in attaining these exemptions varies.

Requirements also vary considerably between jurisdictions. Australia requires parents to have their children fully vaccinated or to have obtained an approved exemption (medical or otherwise). The personal-belief or so-called conscientious-objection option was removed from the eligible exemptions in 2016 (Leask & Danchin, 2017). Some Australian states have vaccination requirements for childcare entry, not for school attendance, but legislation enables exclusion of unvaccinated children during an outbreak in both school and childcare. Other countries, such as Slovenia, have highly comprehensive programs, including requiring vaccination against nine diseases; people can submit medical-exemption requests to a committee. Philosophical exemptions are not allowed, and failure to comply results in a fine (Walkinshaw, 2011). Other countries have more modest or disease-specific immunization requirements. Belgium, for example, requires polio vaccination but has not had to enforce the policy because of extremely high rates of vaccination (Walkinshaw, 2011). In 2017, Italy began requiring 12 vaccines. The World Health Organization currently has no official recommendation on vaccination requirements.

The United States requires immigrants to have 14 vaccines but requires no vaccines of travelers and temporary visitors. People infected while outside the United States are responsible for most domestic measles cases (CDC, 2011). All U.S. states require evidence of vaccination against at least some diseases as a condition of school entry or access to childcare (Barraza, Schmit, & Hoss, 2017), but states vary considerably in the vaccines that they require and ages or grade levels to which the policies apply. All U.S. states grant medical exemptions, which are for individuals who have a medical condition that is a contraindication to a vaccine. Forty-eight U.S. states and the District of Columbia offer religious exemptions from school vaccine requirements (Diekema, 2014; Yang & Silverman, 2015), and 20 U.S. states allow philosophical or religious exemptions, which often require only that an individual declare a personal belief opposing vaccination. Only three U.S. states, West Virginia, Mississippi, and California, have laws specifically excluding religious or philosophical exemptions from vaccination requirements.

Vaccination requirements can also be policies that private institutions enact. Most U.S. universities require vaccination in some form and limit exemptions (Noesekabel & Fenick, 2017). Hospitals may require workers to receive certain vaccines as a condition of employment. Physicians may also enforce a form of requirement by refusing to treat children who do not get recommended vaccines (Flanagan-Klygis, Sharp, & Frader, 2005).

Effectiveness of requirements. Vaccination requirements are effective in increasing coverage for the targeted vaccines (Community Preventive Services Task Force, 2016b; Lee & Robinson, 2016; Lytras, Kopsachilis, Mouratidou, Papamichail, & Bonovas, 2016) and may have spillover effects for nontargeted vaccines (Moss, Reiter, Truong, Rimer, & Brewer, 2016). Studies of school vaccination requirements in the United States have consistently found that when policies allow for philosophical and religious exemptions, vaccination coverage is lower than when such exemptions are not allowed (N. R. Blank, Caplan, & Constable, 2013; Feikin et al., 2000; Omer et al., 2006, 2008; Safi et al., 2012; J. W. Thompson et al., 2007). Making exemptions more difficult to obtain, such as by requiring a doctor's permission or requiring counselling, can limit their use (Omer et al., 2018). As would be expected, people with vaccine exemptions are more likely to contract vaccine-preventable diseases such as measles, with estimates of 22 to 35 times greater risk compared with vaccinated people (CDC, 2004; Salmon et al., 1999), and pertussis, with estimates of 6 times greater risk compared with vaccinated people (Feikin et al., 2000; Imdad et al., 2013). Reviews of outbreaks have observed that many affected children had exemptions or were unvaccinated for religious or philosophical reasons and that local area exemption rates are positively associated with measles outbreaks (CDC, 1997, 2013; Zipprich et al., 2015) and pertussis outbreaks (Atwell et al., 2013; Feikin et al., 2000; Imdad et al., 2013; Matthias et al., 2014; Omer et al., 2006, 2008). For example, in a review of U.S. measles outbreaks, 42% of cases for which data were available involved a person with a nonmedical exemption (Phadke et al., 2016).

Requirements for seasonal-influenza vaccination have also been implemented in workplaces, primarily those in health care. In the United States, some states have instituted policies that require health-care workers to be vaccinated, but these policies are quite heterogeneous (Stewart & Cox, 2013). Reviews indicate that requirements are an effective strategy for increasing vaccination coverage among health-care workers (Pitts, Maruthur, Millar, Perl, & Segal, 2014) and can be more effective than other strategies. That requirements are often necessary to reach high vaccination coverage among health-care workers is testimony to the challenges that vaccination-promotion programs face.

When to adopt more restrictive requirements. Requirements can be highly effective, but depending on the prevailing reasons for undervaccination in a population, it may be sufficient or more advisable to apply other less coercive measures. We review several issues related to adopting requirements, but conclusions for any jurisdiction require a careful consideration of the potential effects (Leask & Danchin, 2017; Opel et al., 2017).

Some argue that vaccine requirements for the general public are best used when vaccination coverage is very high and most other interventions have been deployed. The problem of sticky social norms means that mandates that stray too far from existing behavior may be rejected (Kahan, 2000). This reaction may be particularly likely to emerge among people who hold ambivalent or unfavorable beliefs about vaccination (Betsch & Böhm, 2016). Confidence in the safety and effectiveness of vaccination will also need to be high (Opel et al., 2017). People who feel their freedom to act has been curtailed may react with anger (Brehm, 1966), reject the vaccine requirement, and become more susceptible to antivaccination messages. In two U.S. jurisdictions with laws that require HPV vaccination for school entry, people frequently opt out. This makes the laws ineffective and can also reduce uptake of other vaccines for adolescents, perhaps because people learn the behavior of rejecting vaccines (Moss et al., 2016). This finding may reflect the specific complexities around the HPV vaccine. Requirements for other adolescent vaccines increased uptake of those vaccines as well as the HPV vaccine (Moss et al., 2016).

Requirements can provide an opportunity for people to engage with their health-care provider or system, which can increase the likelihood that they will obtain other vaccines (Moss et al., 2016). However, the imposition of financial penalties and policies that limit access to care systems could also reduce some families' access to care. Adoption of requirements should take this into account along with complex array of other practical and ethical issues (National Vaccine Advisory Committee, 2008), a review of which is beyond the scope of this work (Colgrove, 2006; Verweij & Dawson, 2004). One final practical issue is that implementing new vaccine requirements and restricting existing exemptions generate substantial media attention, and often controversy, and can use up the time of vaccination-program staff. It is important to assess the political will to weather resistance and resources within the vaccination program to address critics.

Emerging perspectives

Vaccination as a routinized behavior. A key element of initiatives designed to improve people's health is that they rely on people initiating changes in their behavior (e.g., diet, physical activity, substance use) and maintaining those changes. Yet, the development of strategies that can elicit sustained changes in behavior has proven challenging (Rothman, Baldwin, Hertel, & Fuglestad, 2011; Rothman, Sheeran, & Wood, 2009). However, some people can maintain the behavior over time, and for them, the behavior becomes a routinized response to a cue or condition in the environment (Wood & Neal, 2016; Wood & Rünger, 2016). In some cases, routinized, repeated behaviors seem to occur with little conscious thought (e.g., putting on your seatbelt every time you drive a car), whereas in other cases, completing the behavior may take conscious thought, but the initial sequence of action is triggered by cues in the environment (e.g., seeing athletic shoes next to the bed in the morning can prompt people to exercise).

To be up to date with the recommended vaccine schedule, people must receive a large number of vaccinations, which may require multiple doses or annual repetition. Successfully navigating this complex set of behaviors can be challenging, yet some people regularly obtain all of the vaccines available to them. People who successfully obtain all, or nearly all, available vaccines may have turned vaccination into a routinized, repeated behavior (Gierisch et al., 2010) that takes limited deliberation.

Consistent with the view that regular vaccination can become routinized, people's vaccination behavior shows consistency. In particular, prior vaccination behavior is one of the strongest predictors of future uptake of the same vaccine or another vaccine for oneself and one's children (Schmid et al., 2017). Although the predictive value of prior vaccination behavior would suggest that people have the potential to develop a vaccination routine, several aspects of vaccination behavior are likely make it difficult for a routine to emerge. First, vaccination is not fully under one's own control; one must receive the vaccine from a provider. Second, the time period between vaccination events is highly variable and in many cases can be quite long, which may make it difficult to form a consistent routine. Third, a routine is more likely to develop when a behavior is repeated under similar conditions (e.g., running first thing in the morning on every weekday). However, the conditions under which vaccinations are obtained are often heterogeneous and vary in their timing, setting, and provider; this is particularly likely across different types of vaccines because one might get a seasonal-influenza vaccine at work but a shingles vaccine in a doctor's office.

The observation that prior vaccination behavior is a strong predictor of subsequent vaccination may offer important insights into the factors that regulate this behavior and have the potential to support the development of a vaccination routine. A history of prior vaccination behavior may be a marker for individual-level factors that support vaccination, such as the beliefs that underlie vaccine confidence, trust in the health care system, and a perception of vaccination as the normative behavioral response. A prior history may also be a marker for the presence of structural factors that support vaccination, such as the availability of resources or services provided through one's workplace or health care system. Thus, consistent vaccination behavior may represent the persistent presence of factors that support vaccination behavior each time the opportunity arises.

To the extent that prior vaccination history serves as a marker for the presence or absence of these supportive conditions, it may provide an opportunity for investigators to deploy intervention resources more effectively and efficiently. People who do not have a history of vaccinations may need to be persuaded of the value of a given vaccine and thus are more responsive to intervention strategies that provide information about, or explanations for, vaccination. On the other hand, people with a history of prior vaccinations may not need to be convinced about the value of vaccination, and thus it would be sufficient to rely on intervention strategies that provide reminders or put in place structural changes that make it easier to access vaccination services.

Leveraging the effect of implicit or nonconscious beliefs on vaccination. Research on the psychological determinants of vaccination behavior has focused almost exclusively on the explicit (conscious) thoughts and feelings that people report regarding vaccination (e.g., appraisals of risk, confidence in vaccination). This focus on conscious thoughts and feelings is consistent with prevailing models of health behavior (Conner & Norman, 2015; Rothman & Salovey, 2007), and compelling evidence shows that experimentally elicited changes in conscious thoughts and feelings can elicit changes in behavior (e.g., Sheeran et al., 2016, 2014). Yet because the observed magnitude of these effects have proven modest, investigators have begun to explore the hypothesis that people also hold implicit (or nonconscious) thoughts and feelings about behavior that may affect their behavioral decisions (Marteau et al., 2012; Sheeran et al., 2016; Sheeran et al., 2013). As noted earlier, these implicit thoughts and feelings are associated in memory with the behavior, but they are not readily available to conscious awareness.

Research on implicit processes has focused on the determinants of addictive or hedonic behaviors such as

smoking, drinking, drug use, and unhealthy dietary choices (see Sheeran & Bosch, 2016). This work has been guided by the premise that people may explicitly report that they hold unfavorable thoughts or feelings toward cigarettes, beer, or doughnuts, but at the same time hold implicit thoughts or feelings that are more favorable. Moreover, under certain conditions (e.g., times of stress, reductions in executive function or self-control), these implicit beliefs can have a more pronounced influence on behavior (Strack & Deutsch, 2004).

A similar discrepancy may exist between people's explicit and implicit thoughts and feelings about vaccination. People's explicit thoughts and feelings may indicate a favorable evaluation of vaccination, whereas their implicit thoughts and feelings may reveal a more unfavorable or ambivalent evaluation of the behavior. For people whose thoughts and feelings are marked by this discrepancy, their favorable (explicit) thoughts and feelings should guide their behavior when they have sufficient time and mental energy to make decisions. However, their more unfavorable (implicit) thoughts and feelings should guide their behavior when they are under stress or other conditions that constrain the time and energy they can direct toward their decisions. This pattern of predictions might help elucidate the factors that underlie inconsistencies in people's vaccination behavior over time. Formative research is needed to examine people's implicit and explicit thoughts and feelings regarding vaccination, their relation to each other, and the conditions under which they are predictive of vaccination behavior.

If evidence emerges in support of the predicted, differential influence of implicit and explicit thoughts and feelings on vaccination behavior, investigators may want to pursue the development of strategies that can mitigate the adverse effect of people's implicit thoughts and feelings. These strategies could take one of two approaches. One would be to develop strategies that support the activation and use of people's (more favorable) explicit thoughts and feelings about vaccination, especially when they are under stress or are grappling with multiple demands on their time. Another would be to develop strategies that inhibit the influence of implicit thoughts and feelings on vaccination behavior. For example, the formation of if-then plans to promote the use of deliberation in situations in which people might typically react impulsively has been shown to reduce the predictive effect of implicit attitudes on behavior (Webb, Sheeran, & Pepper, 2012). In either case, these approaches should increase the likelihood that people's vaccination behavior is more likely to be consistent with their (favorable) explicit beliefs regarding the vaccine.

Conclusion

Interventions to encourage vaccination are remarkably effective when they intervene on behavior directly without trying to change individuals' thoughts and feelings about vaccination or the social context in which vaccination occurs. Vaccinating is often a passive act, even in high-income countries (Robbins et al., 2010). For example, in Australia, which has 93% vaccination coverage for children under age 5, passive undervaccination accounted for ~60% of the undervaccinated, and the remaining ~40% was probably due to active undervaccination (Beard et al., 2016). Strategies designed to facilitate or prompt action have considerable potential.

One cluster of strategies that bridges the gap between positive intention and behavior are promising. They are likely to be effective with people who have favorable vaccination intentions. Strategies to close the intention-behavior gap include reminders, primes, defaults, and implementation intentions. The observation that people fail to act on their favorable intentions is but one example of situations in which people's actions are out of sync with their beliefs. In some situations, people take action despite holding ambivalent or unfavorable beliefs about a behavior. To date, the prevailing way to engage with people who hold ambivalent or unfavorable beliefs about a vaccine is to try and change how they think and feel about the vaccine. Several taxonomies of vaccination behavior identify a group of individuals as "reluctant but persuadable" (Benin et al., 2006; Gust et al., 2005). Yet, as noted earlier, persuasive communications can be challenging to implement and are limited in their effectiveness.

Another cluster of strategies focuses more on the behavior. These strategies may increase vaccination among people with a range of intentions. Strategies that focus on the behavior include incentives, sanctions, and requirements. Research is needed to establish whether these approaches are effective for people who are opposed to vaccination or have ambivalent attitudes about vaccination. Several strategies in this section frame or reframe vaccination behavior as the default behavioral response. Strategies that target individual-level or structural factors that support this conceptualization may prove to be a valuable way to help people transform vaccination into a routinized, repeated behavior.

Provider recommendations. Consistent with the discussions in previous sections, health-care provider recommendations are strongly associated with vaccination behavior. Physician recommendations may be effective because they serve as a cue to action, but several additional factors may contribute to their effectiveness. First, to the extent that the

recommendation can be acted on immediately, it sidesteps several of the logistical challenges associated with obtaining the vaccine (e.g., scheduling an appointment; making arrangements to get to the clinic). Second, a recommendation from a health-care provider may affirm or augment people's perceptions of the value and safety of the vaccine. Third, with the recommendation, the health-care provider may lead the patient to construe vaccination as the default.

Provider recommendations are especially effective when they take the form of presumptive announcements. Such recommendations may be successful, at least in part, because of their direct effect on patient behavior. Specifically, they have the potential to make vaccination the default response or to serve as a strong prime or reminder that activates the favorable intentions patients already have. Whether recommendations are beneficial for all patients may depend on why physician recommendations are effective. For example, if recommendations increase vaccination coverage because they serve as a reminder or cue to action, they should be effective for people who already hold favorable attitudes or intentions regarding the vaccine but may show limited benefit for people with unsure or ambivalent attitudes or intentions. If recommendations instead increase vaccination coverage because they increase confidence or communicate a social norm, they may be particularly effective when directed toward people who are unsure or ambivalent regarding the vaccine.

The most promising avenues for policy implementation come from the literature reviewed in this section. Improving vaccination coverage is likely to necessitate some combination of reminders, defaults, incentives, and requirements, and other similar programs.

Section 5: Leveraging the Psychology of Vaccination

Our review of the psychology of vaccination is organized around three themes. People's thoughts and feelings about vaccines are consistently associated with vaccination behavior, but intervention strategies designed to change thoughts and feelings to increase vaccination have a surprisingly limited impact or rest on a surprisingly weak evidence base. Experimental evidence about how to influence thoughts and feelings about vaccination is also sparse. Likewise, although vaccination occurs in a social context and social-norm interventions have proven effective in influencing other behaviors, intervention strategies that target these social processes do not yet have a proven track record of facilitating vaccination (e.g., Bronchetti et al., 2015). In contrast, the strongest evidence for increasing vaccination comes from intervention strategies designed to build on already favorable intentions and directly shape behavior.

What should policymakers, immunization managers, and vaccination providers do with the insights offered by our review? This final section of our article summarizes our findings and considers their application to vaccination policies and programs. We begin by outlining some limitations of our review and of the literature; summarize the main psychological principles and their effect on vaccination; apply these interventions to the three pressing problems in vaccination (inadequate coverage, delay, and instability); and offer directions for further research. Although recommendations for how to increase vaccination are common (Politi, Jones, & Philpott, 2017), we argue that such recommendations will have the greatest impact if they take into account psychological theory and behavioral findings.

Scope of evidence

Readers may come to our article looking for the magic trick that will dramatically increase vaccination uptake. None exists. Although many interventions fail, and those that work typically have small effects, this process is a normal part of science; the field is still young. With strong caveats stated, many of the approaches we describe are complementary and can be rolled out together or by starting with interventions that are least costly or least likely to elicit pushback. Implementing multiple strategies is likely to produce the largest effect. This premise suggests new research on how to integrate approaches and whether particular combinations are more effective under specific conditions.

Our review builds on a solid foundation of theories from psychological and behavioral science, although many theoretical mechanisms have never been tested in the domain of vaccination. Nevertheless, the findings we review are based on high-quality studies of vaccination behavior. We offer several caveats to people looking to use our review to inform policy and practice. First, this is a narrative review focused on conceptual themes and their empirical support. We relied on systematic reviews where possible, conducting additional reviews of the supporting studies, and we conducted a series of new reviews across several literatures. We do not claim to have located every study on a topic. That said, the main assertions of our article are firmly grounded in theory and multiple streams of evidence.

Second, in some areas, the available evidence is limited in quality or quantity, or the most compelling evidence concerns behaviors other than vaccination. Furthermore, the large majority of studies of vaccination are cross-sectional, so it is difficult to make inferences

about the causal effect of beliefs on behavior. Evaluations of interventions have focused primarily on outcomes, and attention to specifying the mechanism underlying the effect has been limited. Many interventions are composed of multiple components, but their evaluations were not designed to isolate the effectiveness of specific strategies. Much of the relevant research comes from the United States or Europe, where specific programmatic and funding contexts may limit the generalizability of some findings to other settings. We attempt to identify these shortcomings in our summary of findings in Table 4. Increasingly, researchers are conducting cross-continent studies that have found that, for example, vaccine acceptance is generally high (Sundaram et al., 2016), challenges to vaccine confidence are global (H. J. Larson & Schulz, 2015), motivators of vaccination are surprisingly similar across countries (Kwong, Pang, Choi, & Wong, 2010), the influence of some social factors on vaccination varies across cultures (Böhm et al., 2016), and interventions to increase vaccine demand result in improved vaccine coverage in low- and middle-income countries (Johri et al., 2015).

Third, our review focuses on contexts in which vaccines are available and affordable because this is where psychological science may have the most to offer. Even theoretically sound and empirically supported interventions should be applied to vaccination programs with care. An intervention should be the right match for the problem, grounded first in an understanding of barriers facing a population and the suitability of that intervention to the context. If, for example, the main reason for a region's low vaccine coverage is that services are not readily accessible or that cost is a barrier, requirements with sanctions would be inappropriate.

General psychological principles

The literature supports three general psychological principles that motivate getting a vaccination, but all do not apply equally to efforts to increase vaccination coverage. One principle is that what people think and feel motivates whether they choose to be vaccinated. These constructs include risk appraisals, such as perceived risk and fear of the infectious agent, as well as confidence in vaccination. Despite the widely demonstrated correlation of thoughts and feelings with vaccination behavior, the intervention strategies currently used to modify what people think and feel are minimally effective or unreliable in increasing vaccination. Communication is an essential element of vaccination programs, and the alternative of not communicating about vaccination is likely to end badly. However, the literature shows that most of the recommended messages about vaccines that have been put forward by major relevant clinical organizations have a striking lack of evidence regarding their effect on vaccination coverage. We suspect that the poor performance of communication interventions reflects a reliance on a generally weak intervention approach that is grounded on interventionists' misplaced confidence that facts are persuasive and an underestimation of the impact of affect-eliciting messages such as personal testimonials.

A second principle is that social processes such as contagion, social norms, altruism, and free riding also motivate vaccination behavior. A sizable literature of correlational studies or experiments using hypothetical scenarios or laboratory paradigms points to the influence of social networks and social preferences on health behavior. However, few field studies of actual vaccination behavior have examined whether interventions that change social processes affect vaccination coverage. We see this area as promising for future intervention development.

A third principle is that the most potent ways to increase vaccination coverage rely on changing behavior directly. This finding is in some ways unexpected because vaccination typically involves some degree of deliberation and choice. One approach to changing behavior directly is to build on people's favorable intentions to get vaccinated, for the most part without changing what they think, feel, or experience socially. These interventions include reminders, defaults, and planning prompts. Another approach to changing behavior directly is to shape behavior through incentives, sanctions, and requirements, again without trying to change what people think, feel, or experience socially. The findings on incentives and requirements are robust across various health behaviors and many are well-developed for use with vaccination, including in low- and middle-income countries.

What implications do these findings have for psychological science? Vaccination represents a set of behaviors in an applied setting and thus is not the domain of any single psychological theory. As we have summarized, the current evidence indicates that interventions designed to change thoughts and feelings are less effective at altering vaccination behavior than those targeting behavior directly. It is difficult to say whether this finding has implications for the psychological processes that drive vaccination behavior (i.e., that behavior is less driven by cognition and attitudes than we might initially believe) or reflects more the particular interventions that have been tried and the difficulty of changing strongly held vaccination values. Social processes appear to be a promising avenue for vaccination behavior change, and yet few intervention studies in this area have been conducted. Thus, vaccination offers a relevant high-stakes test bed for psychological theory.

Table 4. Likely Impact of Interventions to Increase Vaccination Coverage Based on Available Evidence

Article section	Intervention	Likely impact	Especially effective when...	Amount of evidence: Any behavior	Amount of evidence: Vacc	Amount of causal evidence: Vacc	Amount of causal evidence: Vacc in LMICs
2	Messages that increase disease risk appraisals	○	People have low disease-risk appraisals or have become complacent about disease risk	2	2	1	1
2	Education campaigns that increase confidence	○	People have low confidence that vaccination is effective and safe	2	2	1	1
2	Decision aids	○	People initially do not agree to vaccination because they have questions	2	1	1	0
2	Motivational interviewing	○	People initially express ambivalence about vaccination	2	1	1	0
3	Descriptive norm messages	◎	People are unsure or misunderstand what others are doing	2	2	0	0
3	Social network interventions that build on contagion	◎	People are at least minimally connected to a social network	2	0	0	0
3	Messages that change altruism or free-riding beliefs	○	People have low altruism or high free-riding motivation	2	2	0	0
2, 3, 4	Healthcare provider recommendations	●	People have favorable, ambivalent, or unfavorable intentions	2	2	2	0
4	Presumptive health-care provider recommendations	●	People have favorable or ambivalent intentions	2	1	1	0
4	Reminders and recalls	◎	People have favorable intentions but do not get vaccinated	2	2	2	1
4	Implementation-intention interventions	◎	People have favorable intentions but do not get vaccinated	2	1	1	1
4	Mere-measurement interventions	◎	People have favorable intentions but do not get vaccinated	2	1	1	0
4	On-site vaccination	●	People have favorable intentions but do not get vaccinated	2	2	2	2
4	Default appointments	●	People have favorable intentions but do not get vaccinated	2	1	1	0
4	Incentives	●	People have favorable, ambivalent, or unfavorable intentions	2	2	2	2
4	Vaccination requirements	●	Vaccination rates are already high; most people affected by requirement support it	2	2	1	0

Note: Vacc = vaccination coverage; LMICs = low- or middle-income countries; ○ = little or no impact; ◎ = modest impact; ● = substantial impact; 0 = no evidence; 1 = some evidence; 2 = substantial evidence. Conclusions about evidence are based on consensus among authors who considered the available evidence, including the number of available studies, evidence for causal association, the quality of the studies, and the size of the effect. See the relevant section of the article for more information on the interventions.

The three principles that we present in this review may be more related to one another than the current evidence indicates. Interventions that act on behavior directly are the most effective at eliciting behavior change. A sizable enough behavior change on a group scale, however, would alter the descriptive norm. The shift in social norms may perpetuate the behavior change and may also lead to changes in thoughts and feelings. This potential feedback cascade is an interesting area for future research.

The psychological mechanisms we reviewed have other implications as well. For example, future research

is needed to uncover the mechanisms underlying the potent effects of health-care-provider vaccine recommendations. Our taxonomy suggests that recommendations may change patients' risk appraisals or vaccine confidence, they may communicate an injunctive norm supporting vaccination, or they may serve as a cue to action. All of these are plausible explanations. However, the lack of process-oriented research in this area leaves this as an intriguing open question. Given the large impact of recommendations, an important area for future research is to identify effective means for encouraging providers to recommend vaccination to their patients.

Addressing the three main vaccination problems

As we have noted, our review identified numerous interventions that build on insights from psychological science to address persistent problems facing vaccination. Our review can be useful for programs that have limited budgets, that have a reasonable understanding of the barriers to uptake, and that must prioritize a limited set of interventions. These constraints necessitate that programs usually must select only one or a few interventions to implement. In addition, the APEASE criteria specify six areas to consider when developing interventions: affordability, practicability, effectiveness and cost effectiveness, acceptability, side effects/safety, and equity (Michie, Atkins, & West, 2014).

Researchers have proposed that the most relevant psychological principles to apply and the most suitable interventions to implement will depend on the particular vaccination problem. The four-C model (complacency, convenience, confidence, and costs) suggests tailoring the intervention to the needs of the population (Betsch et al., 2015). For people who are complacent, the model suggests that the goal is to increase perceived risk and confidence, establish social norms, and emphasize altruistic motives. For people low in confidence, the goal is to debunk myths. For people facing problems of convenience, the goal is to reduce barriers, strengthen self-control, and increase confidence. Finally, for people inclined to calculate the costs and benefits of receiving a vaccination, the goal is to increase risk appraisals, debunk myths, stress social benefit and add incentives.

We suggest a somewhat simpler heuristic of considering people's inclination toward getting vaccinated. Choice of intervention and its likely effect may vary depending on whether people are favorable to, ambivalent about, or opposed to vaccination. We use this premise to make recommendations in Table 4 for when a particular strategy might be especially effective. For example, when people have positive intentions but do not always follow through, we can support those intentions with reminders, implementation intentions, and healthy defaults. Even when people are ambivalent, we can shape behavior with incentives and requirements if the context is suitable. By delineating how an intervention strategy is designed to work, researchers are better able to make recommendations regarding the conditions under which a specific strategy will be most effective (Sheeran, Klein, & Rothman, 2017). For instance, health-care-provider recommendation would appear to be a particularly powerful intervention strategy, but our limited understanding of the mechanisms through which it works constrains our ability to specify when this strategy will be maximally effective.

Increasing coverage. Most intervention approaches that we suggest are suitable for people inclined toward or perhaps ambivalent about getting vaccinated. One of the most promising tools for addressing low overage is the use of health-care-provider recommendations because they are so strongly associated with vaccination, but the specific approach to recommendations matters. Physicians should use presumptive announcements about vaccination at the outset, reserving open-ended conversations for addressing questions if parents raise them. Other tools that may be effective in raising coverage are those reviewed in Section 4 for closing the intention-behavior gap, such as the use of reminders and recalls or removing barriers to vaccination by providing standing orders. Harnessing social processes is an intriguing potential tool that merits exploration but remains poorly understood. Building provaccination descriptive and injunctive social norms among vaccine recipients and health-care professionals may increase coverage.

For people disinclined to get vaccinated, approaches include respectful engagement, such as offering decision aids and using motivational interviewing. Neither approach has evidence showing that it can increase vaccination coverage, but both build on the principle of patient empowerment, which may be meaningful for people whose opposition to vaccination is likely to generate disapproval from health-care providers. Likewise, self-affirmation can make people more receptive to risk communication (Harris & Epton, 2009; McQueen & Klein, 2006). Vaccination requirements are increasingly popular for childhood and adolescent vaccines, but they are not yet in place for adults other than health-care workers. Requirements may also be most practical if used only after most other approaches have been exhausted.

Interventions that address thoughts and feelings may offer a small impact, such as communication campaigns focused on vaccine effectiveness, vaccine safety, and the harms of not getting vaccinated, with the goal of

increasing motivation. We suspect that their impact is most meaningful in early phases of a program or for rollout of a new vaccine, when awareness of a vaccine is low, and when the campaign can reach people who are already most inclined to get vaccinated. Some data suggest that educational campaigns may be effective in low- and middle-income countries but not in high-income countries (Harvey, Reissland, & Mason, 2015).

Very few evidence-based methods are available to aid clinicians in convincing hesitant parents and patients to get vaccinated. Surveys of primary-care providers demonstrate their frustration in perceiving that what they are currently doing is not very effective (Kempe, O'Leary, et al., 2015). Clearly, to better address the concerns of parent and patients about vaccines, providers need more evidence-based tools and vaccination programs need more evidence-based interventions that are practical in primary care, given time and resource constraints. Some of the methods that show promise in other medical contexts (e.g., motivational interviewing) may be difficult to incorporate into clinical practice given the amount of time required for training and use (Lundahl et al., 2013; Söderlund, Madson, Rubak, & Nilsen, 2011).

Increasing timeliness. Even when parents have their children fully vaccinated, they may delay or spread out the vaccines such that the child does not complete the entire vaccination schedule by the recommended age. School requirements increase timeliness. Because parents who delay but do not refuse vaccination presumably have reasonably favorable vaccination intentions, reminders and recalls may be quite effective with this group. Default automatic appointments are also effective at bringing patients in at the desired time.

Establishing a social norm for timely vaccination may be promising, although little evidence is yet available to show how such an approach might work. Social-marketing efforts may be useful, especially if led by vaccine advocates who can counter the promotion of delay by health-care providers (e.g., the author of a popular parenting book; see Sears, 2011). As with encouraging vaccine uptake, communication is likely to be a weak tool. However, national campaigns could reinforce social-promotion efforts. If so, they should emphasize the risks of waiting to get vaccinated. Of course, one-on-one counseling by health providers remains an option, as does use of decision aids, which reduced delay in one trial.

Increasing robustness of vaccine coverage. In the past century, vaccination has eradicated one human disease (smallpox), and two others are close to eradication (polio and guinea worm). At the same time, three other disease-eradication programs experienced setbacks, in part because of the erosion or collapse of support from policymakers and challenges to vaccine confidence (Taylor, 2009). Understanding why policymakers adopt effective policies and maintain their support is an area with little evidence. It is likely that policymakers and everyday citizens are subject to similar psychological processes.

Vaccination takes place within a larger system of healthy policy, industry production, government oversight, and program delivery. Vaccination of individuals is important, as is support for national vaccine policies. Such public support can lead to stable vaccination coverage and make the national vaccination system more resilient when facing vaccine scares or spikes in anti-vaccination sentiment. Although risk appraisals and confidence are weak motivators of behavior, they may be important for generating and maintaining support of vaccination policies and programs (Petrescu, Hollands, Couturier, Ng, & Marteau, 2016). So while public education and communication efforts are weak interventions when targeted toward behavior, they may be useful when all else fails, and they may generate support for vaccination policies and programs and may be especially important during a safety scare. Other potentially viable approaches rely on social processes by strengthening vaccination social norms and developing provaccination activist networks. Other key areas for future research include developing methods for intervening through social media to address vaccination concerns, thereby increasing the robustness of vaccine coverage.

Conclusion

Vaccination is one of public health's greatest achievements, saving millions of lives each year. Support for vaccination is high, especially for children, yet vaccination programs face persistent challenges. The interventions we identified, through analyzing the psychological processes involved and reviewing the evidence, can aid policymakers and program managers as they work to improve vaccination coverage. Our review suggests why and for whom they are likely to be most effective. A local program manager may be faced with a small budget for improving vaccination coverage, and developing a leaflet may be an attractive option, but it is unlikely to offer any actual improvement in vaccination coverage. In contrast, changes to systems and policies may provide more substantial and enduring changes. At the same time, vaccination provides a high-stakes, real-world test bed for evaluating a broad array of theories in psychological science. An understanding of the

psychology behind vaccination behavior can inform both theoretical development and facilitation of evidence-based vaccination policy and practice.

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