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Shifting the Demand for Vaccines: A Review of Strategies

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Abstract

Vaccines prevent millions of deaths, and yet millions of people die each year from vaccine-preventable diseases. The primary reason for these deaths is that a significant fraction of the population chooses not to vaccinate. Why don't people vaccinate, and what can be done to increase vaccination rates besides providing free and easy access to vaccines? This review presents a conceptual framework, motivated by economic theory, of which factors shift the demand for vaccines. Next, it critically examines the literature on these demand shifters and interventions that target these demand shifters. The review concludes with offering directions for future research and lessons for public health decision making.

INTRODUCTION

Vaccines prevent millions of deaths from infectious diseases every year (18). At the same time, millions of people die from vaccine-preventable diseases (80). While a small portion of those deaths may be among the vaccinated, who are imperfectly protected by vaccines, the dominant reason why people die from these diseases is that a significant fraction of the population does not receive recommended vaccines. This problem transcends traditional socioeconomic considerations such as affordability of and access to vaccinations (12). As seen presently with vaccinations to protect again severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease 2019 (COVID-19), high-income countries that provide free vaccinations demonstrate less-than-ideal vaccination coverage (38).

Low population-level vaccination coverage has both personal and social consequences. At the individual level, a person who is not vaccinated is susceptible to the disease prevented by the vaccine. At the societal level, higher vaccination coverage provides several positive spillover effects even for those who are unvaccinated. Higher vaccination coverage means lower disease spread, and social contact with vaccinated individuals confers a lower risk of infection. A secondary positive spillover effect, seen with an infection such as COVID-19, which affects many aspects of society, is that lower disease spread allows the resumption of normal life, which will likely have important effects on the well-being of both vaccinated and unvaccinated populations.

In this article, we review aspects of the demand for vaccination. The initial demand curve in **Figure 1** demonstrates how vaccination coverage changes as one lowers the monetary and non-monetary costs of receiving the vaccine. This demand curve is derived by aggregating individuals' demand for vaccines. At the individual level, we can define a person's decision to vaccinate as the point when the sum total of expected benefits exceeds the monetary and nonmonetary costs of vaccinating. Even though we do not know all the considerations that go into individuals' decisions, the demand curve can nevertheless measure the fraction of the population whose expected net benefits from vaccination exceed a certain cost threshold. For example, a fraction *d1* of the population gets vaccinated when the monetary and nonmonetary costs of vaccination are *c1*.

In general, two types of strategies are used for increasing the demand for vaccines. The first is to lower the monetary and nonmonetary costs of receiving the vaccine. These costs may be reduced by subsidizing financial costs, by reducing travel and wait time costs by providing more convenient vaccination sites, or by sending reminders to reduce the cognitive costs of

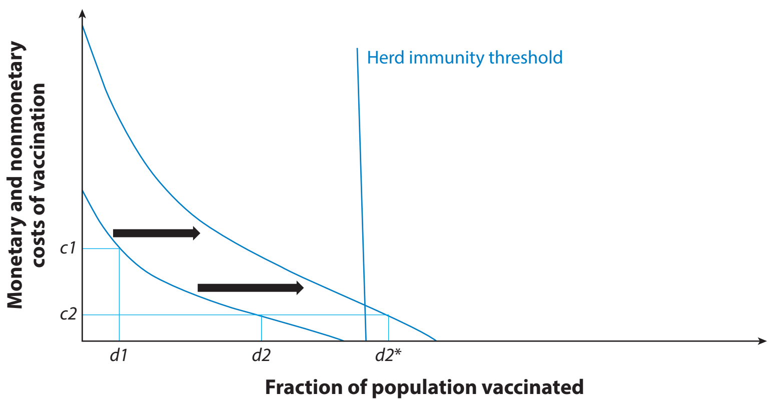

Figure 1

Demand curve for vaccine and herd immunity threshold.

remembering appointments. For example, lowering the monetary and nonmonetary costs of receiving vaccines from *c1* to *c2* increases the demand from *d1* to *d2*. However, as shown in **Figure 1**, population vaccination coverage may still be below the herd immunity threshold even when monetary and nonmonetary costs are zero (or even below, as with subsidies or rebates). In this situation, the second strategy, shifting the demand curve out, is the only strategy for increasing vaccination coverage beyond the threshold.

In standard economic theories, shifting of the demand curve happens whenever the good (in this case, the vaccine) becomes more desirable at any cost, which can happen through multiple channels. The demand curve for vaccines can shift out if the vaccine is perceived as more beneficial (for example, if one's social contacts get vaccinated, which increases the social benefits of vaccination) or, alternatively, if the costs of not being vaccinated increase, for example, if variants seem to spread and cause more severe disease or if incomes increase (this may be more relevant where the monetary cost of getting vaccinated is positive, such as in many non-US contexts).

This article focuses on factors that shift the demand curve out. We first present a model that provides a theoretical framework for factors that may shift the demand curve. Next, we critically review the empirical literature on key factors that shift the demand for vaccines. We then evaluate the literature on interventions that may shift the demand curve for vaccines by influencing these key factors. We conclude by providing directions for future research and lessons for policy makers and public health professionals.

CONCEPTUAL MODEL

Figure 2 presents our conceptual framework of the decision to vaccinate against an infectious disease. One consideration for an individual deciding whether to vaccinate includes how their lives would change as a result of vaccination. An unvaccinated person would face some probability, say r, of contracting an infectious disease with severity S. If we assume that the perceived effectiveness of the vaccine is e, then the perceived probability of a vaccinated person getting the infection is

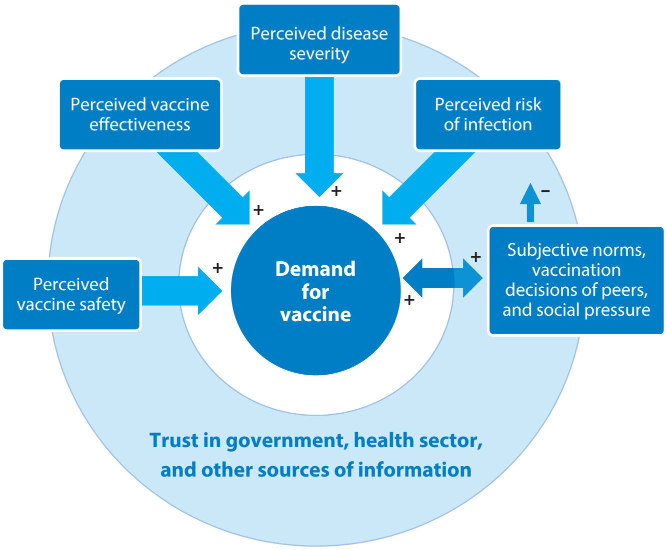

Figure 2

Conceptual model of the decision to vaccinate against an infectious disease.

$(1 - e)r$. Therefore, the perceived benefit of vaccination, operating through its ability to lower the risk of infection, is erS. Thus, the perceived benefit of vaccination is an increasing function of perceived effectiveness of the vaccine, disease risk, and disease severity. One would need to subtract all relevant costs (including considerations such as perceived side effects) to yield the net perceived benefits of vaccination.

This perceived net benefit of vaccination would vary across individuals because they may have different sources of information on vaccine effectiveness, vaccine safety, disease risk, or disease severity. However, even if they had the same information, different individuals might form different beliefs depending on their personal weighting of risk information. The information on vaccines or disease risk is surrounded with uncertainty, especially for newer and evolving diseases or vaccines. Individuals who trust or believe that they have reliable information on vaccine effectiveness, vaccine safety, disease risk, and severity may be more likely to act on the information. Individuals who do not trust their source of information may choose inaction and not vaccinate. Thus, trust in the government, in the formal health care system, or in other official sources of information may play an important role in influencing decisions about vaccination. Similarly, increasingly positive provider recommendations may play an important role for individuals who perceive providers as a trusted source of information (45).

An individual's decision to get vaccinated may also depend on the decisions made by others in the community and peer group to get vaccinated. The vaccination decisions of others may influence one's vaccination decision through multiple pathways (5). First, if others in the community get vaccinated, then it reduces one's own disease risk by reducing disease prevalence, thus potentially reducing the perceived cost of remaining unvaccinated. In other words, increasing community vaccination creates an incentive to free ride and reduces individual demand for vaccination. Second, and in contrast, if others in the community are being vaccinated, then it might create social incentives to vaccinate. For example, if vaccination is the social norm, people may want to get vaccinated to reduce dissonance with their peers. Third, people may want to follow the wisdom of the crowds. That is, if most others in the community are vaccinating, then it must be a good decision.

This conceptual framework has important implications for public policy related to vaccines and for predicting disease dynamics. First, an important insight from this model is that the relationship between disease risk and vaccinations is bidirectional and cyclical. An increase in disease risk will spur greater demand for vaccines. The greater demand for vaccines in turn will reduce future disease prevalence, which in turn would reduce the demand for vaccines. Thus, the demand for vaccines is temporally related, and the initial success of a vaccination campaign today will reduce the demand for vaccines tomorrow (53). Second, with conforming and nonconforming peer effects, the demand for vaccines may be unstable with multiple possible equilibria that depend on initial conditions (5). For example, if initial conditions favor vaccination, then a certain fraction of the population will get vaccinated initially. Then conforming peer effects would encourage others to copy the behavior of those who vaccinated early, resulting in a high vaccination equilibrium. On the other hand, if initial conditions favor not vaccinating, then most of the population will not get vaccinated initially. Then others would copy the decision not to get vaccinated, resulting in a low vaccination equilibrium. Third, if society is in a high vaccination equilibrium, then vaccine subsidies or public intervention to increase vaccination may not be required as private vaccination decisions may already be above the threshold for herd immunity. However, if society is in a low vaccination equilibrium, then even small subsidies or modest public efforts to increase vaccination rates might be successful in moving vaccinations above herd immunity as long as conforming peer effects are strong and dominate the incentives to free ride.

We follow this conceptual framework in developing a review of demand shifters and strategies that may shift the demand curve for vaccines, as these strategies are particularly salient in an era where achieving high vaccination rates carries large public health benefits, beyond the benefits to individuals. The impetus for this review is the importance of increasing COVID-19 vaccination coverage. At the same time, the literature on shifting COVID-19 vaccination coverage is nascent. We focus on influenza vaccinations because the shared epidemiologic and clinical features of both diseases and their vaccines make lessons from influenza relevant for guiding COVID-19 policies. We expand our review for other vaccines when few or no studies were found for a particular demand shifter for influenza. We conclude by summarizing principal lessons from the literature on drivers and interventions for shifting the demand curve for vaccines.

RESULTS

Review of Studies into Drivers of Shifting Demand for Vaccines

We reviewed the empirical literature on the drivers identified in our conceptual framework. We summarize the main findings below, and additional studies and details are included in **Supplemental Table 1**.

Supplemental Material >

Vaccine effectiveness and safety. In the United States, the Food and Drug Administration (FDA) provides scientific and regulatory guidance to vaccine developers (19). Using evidence from clinical trials, the FDA conducts a review of vaccine effectiveness and safety before a vaccine is approved (19). Concerns about vaccine safety and effectiveness remain a barrier to uptake among a substantial portion of the population.

Vaccine effectiveness. The literature we identified suggests that perceived vaccine effectiveness is broadly influential for vaccine uptake and acceptance of the H1N1 and seasonal influenza vaccines. This relationship has been studied among adult populations in the United States, Malaysia, Hong Kong, Taiwan, and Slovenia. The odds ratios (ORs) in these studies ranged from 2.39 to 4.27 for uptake and 6.91 to 18.29 for vaccine acceptance (26, 30–32, 35, 44). Porter et al. (56) studied military members in the United States and found an association between perceived effectiveness and acceptance of the H1N1 vaccine [OR 1.20, 95% confidence interval (CI) (1.04–1.38)]. Matsui et al. (41) studied residents of a rural community in Japan and found that perceived effectiveness was associated with uptake among <18-year-olds [OR 10.5, 95% CI (2.68–41.7)], 18–64-year-olds [OR 8.85, 95% CI (4.61–16.9)], and ≥65-year-olds [OR 19.9, 95% CI (8.28–48.0)].

Vaccine safety. Concerns about vaccine safety are typically due to the fear that vaccines may cause adverse reactions, contain harmful ingredients, or may cause illness more severe than the disease against which the vaccine is intended to protect (14). Unease about vaccine safety, including reactions or side effects, is associated with highly variable (consistently lower) uptake or acceptance in many populations. Fear of side effects was associated with lower odds of H1N1 vaccination uptake among Chinese adults [OR 0.05, 95% CI (0.03–0.06)] and lower acceptance among German adults (OR 0.76, 95% CI not reported) (51, 62). The belief that the H1N1 vaccine is unsafe was associated with lower vaccine uptake among adults in the United States [OR 0.2, 95% CI (0.1–0.5)] (60). Finally, de Perio et al. (13) found that school employees in the United States were less likely to have received the seasonal influenza vaccine if they believed that it would make them sick (45% compared with 77% among those who did not hold this belief).

Conversely, a perceived high level of safety is associated with higher vaccine uptake and acceptance. Several studies have found that perceived safety is associated with higher uptake for H1N1 and seasonal influenza vaccines among general adult populations in countries such as the United States, Germany, and Slovenia (OR range 3.04–9.5) (31, 32, 55, 76, 81). Perceived safety was also associated with higher uptake of the seasonal influenza vaccine among parents of young children in Australia [OR 3.0, 95% CI (1.7–5.5)] (46). Another study of 50–64-year-olds in the United States reported that respondents who did not believe they could contract influenza by receiving the seasonal influenza vaccine had higher odds of vaccine uptake compared with those who believed they could contract influenza from the vaccine [OR 2.4, 95% CI (1.9–3.1)] (67).

Trust in government, health care sector, and other sources of information. The relationship between vaccination and trust in the government, health care practitioners, or other sources of information such as the media has been considered in multiple studies. Trust in health care providers is particularly notable among these studies.

Trust in authorities. Several studies have found that trust in (any) authorities is associated with higher uptake of the seasonal influenza vaccine and H1N1 vaccine among adult populations (OR range 1.05–1.8) (3, 7, 66, 79). Prati et al. (57) studied the association between trust in several different authorities and vaccine acceptance among Italian adults. Trust in the institutional response to the outbreak, trust in the media, and trust in the Ministry of Science were all associated with higher odds of vaccine acceptance. Odds ratios for these associations fell within a narrow range (1.3–1.4) (57).

Trust in the health care system. Trust in the health care system was also examined by several studies and was shown to be associated with higher odds of vaccine uptake and acceptance of H1N1 and seasonal influenza vaccines. Study populations were diverse and included adults in Sweden and the United States, mothers of adolescent females (11–14 years old) in the United States, and outpatients (≥50 years old) receiving care in Veteran Affairs clinics (42, 61, 65, 77). Odds ratios in these studies ranged from 1.30 to 2.28. Boggavarapu et al. (6) studied the association between trust and H1N1 vaccine uptake among 50–68-year-old African American churchgoers in Georgia, United States, in the presence and absence of perceived discrimination. Trust in health care providers was associated with vaccine uptake in the absence of perceived discrimination [OR 14.83, 95% CI (3.68–58.93)] but was not significant in the presence of perceived discrimination.

Trust in the government. Trust in the government was examined by many studies, but its association with H1N1 or seasonal influenza vaccine uptake is unclear. Quinn et al. (58) studied adults in the United States, oversampled for African American and Hispanic adults, and did not find a significant association between trust in the government and H1N1 vaccine uptake. Similarly, Nyhan et al. (48) did not find an association among college students at a public university in the southeastern United States. One study conducted in Taiwan found that trust in the government is associated with higher H1N1 vaccine acceptance [OR 1.35, 95% CI (1.16–1.57)] (11).

Subjective norms, vaccination decisions of peers, and social pressure. As discussed in the conceptual framework, peer effects can be conforming and nonconforming. Social influence from friends and family or subjective norms, which are the beliefs that one's social circle will support or approve of a particular behavior, may increase vaccine uptake or other personal health behaviors (32). However, some individuals may want to free ride on the vaccination decisions of peers as an increase in vaccine uptake among peers reduces disease risk for the individual.

Subjective norms and social influence. Most studies have found that the subjective norm or social influence favoring vaccination is associated with higher uptake and acceptance. Kumar et al. (32)

studied adults in the United States and found that having the majority of friends or family members receive the H1N1 vaccine was associated with higher odds of vaccine uptake [OR 8.31, 95% CI (4.75–14.55)]. Many studies had similar findings, but there was variation in the estimated effect sizes across studies. For example, in a study of child care center employees in the United States, the odds ratios of vaccination for H1N1 and seasonal influenza were 4.05 and 4.93, respectively, among those where social norms favored vaccination (13). However, another study of college students in the southeastern United States found that odds ratios of vaccinating were 1.78 and 1.73, respectively, among those with greater social network support for vaccinating (48). Normative support for vaccination during pregnancy was also associated with seasonal influenza vaccine uptake among minority pregnant women in Georgia, United States (OR 3.41) (22). However, two other studies also conducted in Georgia did not find an association between norms and vaccine uptake or acceptance (21, 23).

Free-riding behavior. Free-riding behavior in the context of vaccinations refers to individuals who deliberately choose not to vaccinate while benefiting from the protection conferred by others who are vaccinated (27). Few studies have assessed this demand shifter using an epidemiological approach. Ibuka et al. (27) studied undergraduate students in the United States and found that having a high proportion of the population vaccinated was associated with decreased odds of seasonal influenza vaccine uptake (OR 0.40). Few other studies have examined this demand driver empirically (8).

Perceived risk perception. Perceived risk of infection and perceived disease severity also play an important role in determining the demand for vaccines. Both factors increase the cost of remaining unvaccinated and thus are associated with an increase in demand for vaccines.

Perceived risk of infection. Perceived risk of infection was examined across several studies and populations. Many studies examined this demand shifter among adults in countries such as the United States, Israel, Malaysia, France, and Australia (37, 44, 71–73). These studies found that perceiving a high risk of infection was associated with increased vaccine uptake and acceptance for both H1N1 and seasonal influenza vaccines (OR range 1.30–4.66) (37, 44, 71–73). Kumar et al. (32) studied adults in the United States and oversampled for African American and Hispanic adults. They found that perceived risk of infection was associated with higher odds of H1N1 vaccine uptake [OR 2.27, 95% CI (1.81–2.84)] and acceptance [OR 3.72, 95% CI (2.28–6.07)]. Porter et al. (56) studied military service members in the United States and found an association with H1N1 vaccine acceptance [OR 1.33, 95% CI (1.12–1.57)]. Finally, a study examining police officers in the United Kingdom also found an association with H1N1 vaccine acceptance [OR 5.08, 95% CI (1.44–17.93)] (4).

Perceived disease severity. Perceived severity of the disease and its ability to interfere with daily life were examined across numerous studies. The association between perceived disease severity and vaccine uptake or acceptance among adults was examined in the United States, Hong Kong, Taiwan, and Australia. These studies found that perceiving the disease to be severe or to have a great impact on daily life was associated with uptake and acceptance of H1N1 and seasonal influenza vaccines (OR range 1.44–2.03) (11, 17, 26, 30, 34, 35, 40). The association between this demand shifter and vaccine uptake or acceptance was also examined across other populations. For example, a study examining police officers in the United Kingdom found that disease severity was associated with higher odds of vaccine acceptance [OR 2.86, 95% CI (1.14–7.15)] (4). A study of essential community workers in Spain also found an association between disease severity and vaccine uptake [OR 3.8, 95% CI (2.1–6.7)] (9). Matsui et al. (41) studied residents of a rural community in Japan and found that disease severity was associated with higher odds of vaccine uptake among <18-year-olds [OR 2.65, 95% CI (1.02–6.93)] and 18–64-year-olds [OR 2.86, 95% CI (1.46–5.59)].

Common study designs and limitations. The large majority of studies examining these demand shifters used multivariate logistic regression models and cross-sectional data to examine the association with vaccination demand. A major limitation of these studies is that they do not establish a causal relationship between the demand shifter and vaccine uptake. These studies likely suffer from omitted variable or reverse causation bias. For example, trusting individuals might differ from those who do not trust health care establishment along multiple dimensions. Some of these dimensions or factors can be controlled for in a multivariate regression, but others might be unobserved to the researcher. Some of these unobserved factors could influence the demand for vaccines. Thus, the observed negative association between trust in health care and vaccine uptake could be because of trust in health care or some other demand shifter that is correlated with trust in health care. Similarly, those who choose to get vaccinated might justify their decision by reporting high perceived safety or effectiveness of vaccines. This reverse causation would mean that the observed association between vaccine uptake and perceived effectiveness and safety is an upper bound of the true causal effect of perceived safety or effectiveness on vaccine uptake. Similarly, the observed positive association between social norms and vaccine uptake does not establish a causal link because it is possible that individuals with similar social norms choose to associate with each other, which would imply an upward bias in the estimates.

To truly measure the causal effect of a demand shifter on vaccine uptake we need experimental or quasi-experimental variation in the demand shifter. Three different approaches have been used to estimate causal effects of demand shifters. The first approach relies on natural experiments or quasi-experimental variation in a demand shifter to estimate the causal effects of a demand shifter on vaccine uptake. For example, a recent paper utilizes quasi-experimental variation in trust in health care to estimate its effect on vaccine uptake. Specifically, the paper uses exposure to medical campaigns organized by the French colonial government in sub-Saharan Africa to generate quasi-experimental variation in trust in health care (39). These medical campaigns that spanned the period 1921–1956 targeted areas with sleeping sickness and forcibly gave dubious treatment to millions of villagers with severe and sometimes fatal side effects. The authors argue that exposure to these campaigns had a long-lasting effect on trust in health care and that exposure to these campaigns was unrelated to other factors that may influence the demand for vaccines. They next show that areas that had high historical exposure to these campaigns have low vaccination rates for childhood diseases today (39). Others have exploited disease outbreaks to generate quasi-experimental variation in perceived risk of disease. These studies find that an outbreak of a vaccine-preventable disease in a previous year leads to increased vaccine uptake (50, 52, 68). Another paper uses random assignment of students to dorms as a natural experiment to estimate the effects of peers on beliefs and influenza vaccination decisions. Their results suggest that an individual's perceived value of vaccines increases as more of their peers are immunized. The authors also find strong evidence of conforming peer effects: A student is 8.3 percentage points more likely to be vaccinated if an additional 10% of her friends receive the flu vaccine (59).

Another set of literature identifies the causal effect of demand shifters by asking about vaccination decisions under hypothetical scenarios that vary a particular demand shifter. For example, Romley et al. (64) asked a large sample of US adults about their willingness to receive an Ebola vaccine and found that respondents expressed a greater inclination to use the vaccine in a hypothetical scenario with a high community vaccination rate. In particular, an increase in the community vaccination rate from 10% to 90% had the same impact on reported vaccine uptake as a nearly 50% reduction in out-of-pocket cost. Similarly, Ibuka et al. (27) use a computer simulation game to ask participants about vaccination decisions. In the game, participants could observe the vaccination decisions of others in the group. The authors found that a higher observed vaccination rate within the group during the previous round of the game decreased the likelihood of an individual's vaccination acceptance, indicating the existence of free-riding behavior. Diks et al. (15) provide a systematic review of studies using hypothetical choice experiments. They note that duration of protection from vaccine, vaccine effectiveness, and vaccine risk significantly influenced vaccination decisions (15).

The advantage of the hypothetical choice experiment approach over natural experiments is that the variation in demand shifter is, by design, exogenous or unrelated to other demand shifters. In natural or quasi experiments, one cannot completely rule out bias from unobserved confounders. However, a major limitation of hypothetical choice experiments compared with natural experiments is that they study stated preferences for vaccines, which might be different from true or revealed preference for vaccines. In other words, vaccination intentions in hypothetical choice experiments might differ from vaccination decisions in real life.

Pragmatic experiments or trials offer an advantage over both these approaches. They randomly assign an intervention that targets one or more demand shifters and then study how vaccination decisions differ among participants who receive the intervention (treatment group) versus participants who do not receive the intervention (control group). However, it is important to note that pragmatic trials can identify the causal effect of a demand shifter only if the intervention is successful in changing the demand shifter. Pragmatic trials are also important because they help identify interventions that can shift demand for vaccines. The next section reviews the literature on interventions targeting demand shifters.

Review of Studies of Interventions for Shifting the Demand for Vaccines

In this section, we discuss interventions that provide information on vaccine safety, vaccine efficacy, disease risk, and disease severity. We study these demand shifters together rather than individually because, in our review, interventions bundle these informational aspects. Next, we discuss interventions that intend to increase vaccine uptake by improving trust. Finally, we discuss interventions related to norms, the decisions of peers, and social effects.

Informational interventions. Informational interventions were the most readily identified type of intervention. They include interventions that provide information about vaccines and/or disease risk. The assumption is that providing information about the vaccines and/or disease would increase the perceived net benefits of vaccination, and these changes in underlying beliefs would increase vaccine uptake.

The evidence on the effectiveness of providing information on increasing vaccine uptake is mixed. Several studies show that educational interventions can increase vaccination rates. Roca et al. (63) found that an education program in Spain, delivered via surface mail, consisting of information regarding the effectiveness and safety of the influenza vaccine, increased vaccination rates for influenza [OR 1.31, 95% CI (1.04–1.65)]. Scott et al. (70) found that parents who received in the waiting room an educational handout containing information about influenza disease that was based on local or national data (compared to the usual care) had greater odds of child influenza vaccine receipt by the end of the season [adjusted OR (aOR) 1.68, 95% CI (1.06–2.67)]. Similarly, Ho et al. (25) studied the impact of informational flyers and posters carrying key messages about the benefits of vaccination at the point of care for patients aged 65 and older in Singapore. They found that patients who visited the clinic during the intervention period were more likely to receive influenza vaccination than were those who visited the clinic during the control period [aOR 1.43, 95% CI (0.99–2.07)]. In a review, Abdullahi et al. (1) found that health education improved human papillomavirus (HPV) vaccine uptake compared with usual practice [relative risk (RR) 1.43, 95% CI (1.16–1.76), 3 studies]. Kaufman et al. (28) reviewed seven studies (3,004 participants) on face-to-face interventions to inform and educate parents about early childhood vaccination and found that the intervention increased vaccination rates [RR 1.20, 95% CI (1.04–1.37)]. Leung et al. (36) studied the impact of three-minute face-to-face presentations by medical students with two additional minutes for questions paired with a pamphlet regarding influenza compared to usual care in an outpatient clinic in Hong Kong and found that intervention increases vaccination [adjusted RR 1.34, 95% CI (1.04–1.72)].

Stuck et al. (78) used health risk assessment (HRA) as an intervention. HRA usually entails some form of a questionnaire, risk calculation depending on the answers, and feedback. They found that 66% of individuals in the treatment arm and 59% in the control arm had influenza vaccinations in the past year when individuals were followed for 2 years after the intervention [OR 1.35, 95% CI (1.09–1.66)]. Shermohammed et al. (74) randomized patients into a control condition (exposure only to standard direct mail or patient portal vaccine promotion efforts) or were told via direct mail, patient portal, and/or SMS that they were at risk for influenza. Individuals who were informed about the risk of influenza were divided into three groups considered to be (*a*) at high risk for influenza and its complications if not vaccinated, (*b*) at high risk according to a review of their medical records, or (*c*) at high risk according to a computer algorithm analysis of their medical records. Patients in the 3 treatment conditions were 5.7% more likely to get vaccinated during the 112 days postintervention, on average, than were those in the control group. Notable observations about the effect sizes of these informational interventions are their consistency and that they are smaller than the effect sizes implied by the observational studies.

Although several educational interventions have succeeded, others have failed despite changing beliefs about the benefits of vaccination. Williams et al. (82) studied the impact of an educational intervention that used video and written information to target vaccine-hesitant parents. They found that attitudes of vaccine hesitancy declined among participants in the intervention group compared with the control group, but there was no difference in on-time receipt of vaccines at 12 weeks. Gottvall et al. (24) studied the impact of an educational intervention (a presentation about HPV and vaccines) on Swedish high school students and found that knowledge about HPV improved but that the attitudes about HPV vaccination did not. Kimura et al. (29) found that an educational campaign that clarified misconceptions about influenza and influenza vaccination, and emphasized the seriousness of influenza among long-term care facility residents, did not significantly improve coverage levels compared with no intervention [prevalence ratio (PR) 1.18, 95% CI (0.93–1.50)]. They did find that combining the educational campaign with "Vaccine Day" (a well-publicized day for free vaccinations at the long-term-care facility) was effective in increasing vaccination coverage [PR 1.45, 95% CI (1.24–1.71)]. Frew et al. (20) used persuasive communication interventions on influenza vaccination uptake among pregnant women. They found that neither interventions that utilized affective messages [RR 1.10, 95% CI (0.30–4.01)] nor interventions that utilized cognitive messages [RR 0.57, 95% CI (0.11–2.88)] had a significant impact on influenza vaccine receipt compared with the control group that received an influenza vaccine information statement.

Finally, some studies suggest that providing detailed information on vaccine safety can reduce rather than increase vaccination rates. For individuals who tend to value vaccine safety considerations highly, increasing the salience of adverse effects—even if rare—might lead to greater resistance to vaccinating. For example, in a national survey, Nyhan et al. (47) found that about 40% of respondents believed that influenza vaccine can result in influenza disease. The authors also evaluated how an intervention designed to address this myth affected beliefs and intention to vaccinate. They found that the intervention significantly reduced the belief in the myth but also significantly reduced intent to vaccinate among respondents with a high level of concern about vaccine side effects (47). Other studies that introduced accurate information about the measles, mumps, and rubella (MMR) vaccine and autism found, similarly, that vaccine acceptance may have decreased in some populations following the interventions (16, 49, 54).

Trust. In a systematic review on measuring trust, Larson et al. (33) note that there is a paucity of interventions that examine changes in trust and how interventions that target trust affect vaccine uptake or changes in beliefs. Some studies show that, similar to the literature on educational interventions, providing detailed information on vaccine safety and risks can erode rather improve trust. Scherer et al. (69) tested the possibility that data from the vaccine adverse event reporting system (VAERS) can be used to increase trust that vaccine harms have been adequately researched and disclosed to the public. The authors randomly assigned participants to either summary data or full detailed reports of serious adverse events from VAERS. They found that participants who were educated about VAERS and given summary data about the serious adverse events displayed more trust in the Centers for Disease Control and Prevention (CDC) and greater HPV vaccine acceptance relative to the comparison group. Exposure to the detailed VAERS reports significantly reduced trust in the CDC and decreased vaccine acceptance (69).

Alsan et al. (2) found that information provided by race-concordant health care workers in an in-person setting is more likely to change attitudes toward vaccination for black individuals. The authors found that individuals who were randomly assigned to a black male doctor were 10 percentage points (56%) more likely to agree to the flu shot.

Norms, decisions of peers, and social pressure. As with intervention studies on trust, interventions on social norms are also scant. In a recent paper, Moehring et al. (43) studied the impact of providing descriptive norms (the fraction of their country's population that plan to vaccinate) on vaccine acceptance. The idea is that individuals may have an incorrect belief about the peer norms, and these beliefs are correlated with vaccine acceptance. They found that presenting people with accurate information about what fraction of the population said they will take the vaccine if available increased vaccine acceptance slightly on a five-point scale [0.033, 95% CI (0.021–0.044)]. This represented a 4.9% relative reduction in the fraction of people choosing a response that is "unsure," "probably not," and "no, definitely not." The authors also examined whether the effects of providing information on descriptive norms differed by underlying beliefs about population coverage prior to providing the information. They find a positive and statistically significant effect for those whose underlying beliefs about vaccination coverage were below the peer norm and a statistically insignificant effect for those whose beliefs were above the peer norm (for example, among individuals who thought 90% of their country's peers intended to vaccinate, whereas in reality only 80% did so). However, the difference in effect size between the two groups with underlying beliefs above or below the peer norm was not itself significant.

In a study by Slaunwhite et al. (75), work units were randomly assigned to either champion present or champion absent conditions. Champions were key members responsible for encouraging members of their work units to accept an influenza vaccination and in some cases had the requisite training to administer the vaccine. Results show increased vaccination compliance for groups where a champion was present [10% increase, 95% CI (4.8–13.6%)] compared with control (3% increase, not significant). Chamberlain et al. (10) examined a multicomponent intervention that included vaccine champions and lapel buttons for staff members encouraging immunization in addition to provider-to-patient talking points, educational brochures, posters, and iPads loaded with a patient-centered tutorial. However, the intervention did not have a significant impact on antenatal influenza [risk difference (RD) 3.6%, 95% CI (−4.0–11.2%)] and tetanus, diphtheria, pertussis (Tdap) [RD 1.3%, 95% CI (−10.7–13.2%)] vaccinations.

DISCUSSION

For many, the rapidity with which COVID-19 spread, the severity of the disease, the number of deaths, the social and economic disruptions, and the threat of future waves or related pandemics elevate the stakes in COVID-19 vaccinations. In addition, getting as many people as possible vaccinated, quickly, preferably past the herd immunity threshold, before more transmissible strains have a chance to spread, has obvious public health benefits. Governments that have been able to procure vaccines have responded by providing free and easy access to vaccines, but many individuals choose not to get vaccinated. This naturally raises the question, How is it possible to get more people vaccinated?

Here, we review the evidence supporting the role that different drivers play in shifting the demand for vaccinations. Our review supports several broad conclusions. The literature we reviewed uniformly supports an important role for most of the theoretical demand shifters we identified, including perceived vaccine effectiveness and safety, trust in providers and the formal health care system, and social norms. At first glance, perceived vaccine safety and effectiveness appear as the most important demand shifters, with the largest odds ratios and consistent associations across multiple populations (multiple countries, multiple age groups, rural and urban settings). For example, some of the odds ratios for perceived effectiveness were above 8, and some of the odds ratios for perceived risk of harm from vaccines were below 0.1. However, we note that the studies on the role of these demand shifters were heterogeneous, largely observational, and of varying quality. Some of the differences in effect sizes may also reflect differences in study design and population. The effect sizes for a demand shifter in interventional studies were typically much smaller than the effect sizes for the same demand shifter in observational studies, making it difficult to rule out bias of unclear magnitude in observational studies. We conclude that the putative demand shifters likely matter to vaccine decisions, but the magnitude of their contribution is likely less than that found in many of the studies and is difficult to compare one to another.

Unlike the literature on demand shifters, studies of interventions are nuanced and identify occasionally unexpected direction of effects. First, studies of interventions are scarce relative to the observational literature studying demand shifters, possibly because they are difficult to execute or because of publication bias, as the magnitude of the effects in the intervention studies we identified are smaller than that of the effects in observational studies. To wit, studies assessing vaccine acceptance are easier to find than studies assessing vaccine uptake, pointing to potentially important areas of further investigation. Second, interventions that aim to change perceptions of vaccine effectiveness and safety were the ones most commonly identified in the literature, with relatively few studies examining interventions aimed at changing trust or using social norms. Most studies find a small but significant improvement in vaccine acceptance and uptake with such informational interventions. Third, it remains not entirely clear why these interventions work. Many of the interventional studies focus on vaccine uptake or acceptance only and do not measure change in targeted demand shifters such as perceived safety or effectiveness. Some studies that measure the targeted demand shifter find that the intervention changes the demand shifter without changing vaccine uptake or acceptance. Fourth, some interventions that included information about vaccine safety or tried to debunk myths about harm from vaccines seemed to lead to greater hesitancy among some groups, potentially a result of increasing the salience of vaccine risks.

We conclude by offering some lessons for future research and public health decision making. First, knowledge of ways to shift the demand for vaccinations is very limited. More interventional or quasi-experimental studies that estimate the causal effects of demand shifters on vaccine uptake would be highly beneficial for public health practice. Much of the existing literature identifies associations, and studies of interventions with a causal design cast some doubt on what we can learn from the associational literature. Second, the areas that seem most ripe for research are with interventions that harness peer effects and improve trust. There are strong theoretical groundings and studies suggesting that those effects could be influential, but we have found little strong evidence to support those notions. Finally, interventions need to be tailored to the individual or to a particular local population, and a one-size-fits-all approach may not work or may backfire. At a time when vaccine uptake is a central aspect of public health policy, we hope that this review provides a landscape for what is known and for highlighting which areas are important for further investigation to improve the demand for vaccination.

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