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Evaluation of behavioral economic strategies to raise influenza vaccination rates across a health system: Results from a randomized clinical trial

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ABSTRACT

Influenza vaccination rates are low. Working with a large US health system, we evaluated three health system-wide interventions using the electronic health record's patient portal to improve influenza vaccination rates. We performed a two-arm RCT with a nested factorial design within the treatment arm, randomizing patients to usual-care control (no portal interventions) or to one or more portal interventions. We included all patients within this health system during the 2020–2021 influenza vaccination season, which overlapped with the COVID-19 pandemic. Through the patient portal, we simultaneously tested: *pre-commitment messages* (sent September 2020, asking patients to commit to a vaccination); *monthly portal reminders* (October – December 2020), *direct appointment scheduling (*patients could self-schedule influenza vaccination at multiple sites); and *pre-appointment reminder messages* (sent before scheduled primary care appointments, reminding patients about influenza vaccination). The main outcome measure was receipt of influenza vaccine (10/01/2020–03/31/2021). We randomized 213,773 patients (196,070 adults ≥18 years, 17,703 children). Influenza vaccination rates overall were low (39.0%). Vaccination rates for study arms did not differ: Control (38.9%), pre-commitment vs no pre-commitment (39.2%/38.9%), direct appointment scheduling yes/no (39.1%/39.1%), pre-appointment reminders yes/no (39.1%/39.1%); $p > 0.017$ for all comparisons (p value cut-off adjusted for multiple comparisons). After adjusting for age, gender, insurance, race, ethnicity, and prior influenza vaccination, none of the interventions increased vaccination rates. We conclude that patient portal interventions to remind patients to receive influenza vaccine during the COVID-19 pandemic did not raise influenza immunization rates. More intensive or tailored interventions are needed beyond portal innovations to increase influenza vaccination.

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1. Introduction

Influenza virus causes substantial hospitalizations, deaths, and illnesses (Grohskopf et al., 2020). The Advisory Committee on Immunization Practices (ACIP) recommends yearly influenza vaccination of all United States (US) residents ≥6 months of age (Grohskopf et al., 2020; Grohskopf et al., 2018), and the US Healthy People 2030 national goal is over 70% influenza vaccination coverage (Office of Disease Prevention and Health Promotion, n.d.). However, influenza vaccination rates in the US are low. During 2020–21 (when this study was conducted), only 38% of 18–49 year-olds, 50% of 50–64 year-olds, and 75% of those over 65 years received a vaccinate (Centers for Disease Control and Prevention, n.d.).

Studies have identified three types of barriers for vaccination: patient factors such as inconvenience, access barriers, and vaccine hesitancy; provider factors such as missed opportunities for vaccinations at existing visits and suboptimal office workflow; and health system factors such as the lack of population-wide effort to raise rates (Szilagyi et al., 2008; Thomson et al., 2016).

The US Task Force on Community Preventive Services recommends using multiple parallel strategies to overcome barriers (Briss et al., 2000). Yet few studies have evaluated multi-component interventions at health system level to address all three types of barriers (Stokley et al., 2021; Fiks et al., 2021). We implemented and evaluated a scalable, health system-wide, multi-component intervention targeting patient, provider, and health system barriers simultaneously, capitalizing upon advances in the electronic health record (EHR).

We focused our intervention on the patient portal – a secure internet platform connected to the EHR and accessed online or via an application for healthcare providers and patients to communicate with each other (Anthony et al., 2018). Portals are used widely (Anthony et al., 2018), particularly since the rise in telehealth visits during the pandemic (Bakken, 2020), and have promise for increasing influenza vaccination rates (Cutrona et al., 2018; Milkman et al., 2021; Wijesundara et al., 2020; Ueberroth et al., 2021). Our prior studies found that generic influenza vaccine portal reminders alone (Szilagyi et al., 2020a); messages tailored to patient age (e.g., older adults) or patients with diabetes-who are at high risk from influenza; and message framing (positive or negative) all had minimal or no impact on raising influenza vaccination rates among adults (Szilagyi et al., 2021a). However, tailored messages raised influenza vaccination rates substantially for the second vaccination among children needing two doses (Lerner et al., 2021), suggesting vaccine hesitancy plays a role in responses to messaging.

For this study during the COVID-19 pandemic (fall 2020 through spring 2021), we postulated that psychological messages from behavioral economics that worked in other settings to drive behaviors, plus strategies to reduce access barriers, might be effective in raising vaccination rates, particularly since the population was focused upon COVID-19 vaccination and less on influenza vaccination.

We performed a health system-wide, multi-arm (using a nested study design) randomized clinical trial to simultaneously test the effect of usual-care versus four portal-based reminder interventions. First, we tested a *request for pre-commitment*- asking patients in September to pre-commit to influenza vaccination. Pre-commitment is used as a behavioral nudge for farsighted and discretionary behaviors (Cialdini, 2009), giving patients time to develop a plan to get a flu vaccination (Rogers et al., 2015; Milkman et al., 2011). We felt this was important because of disruption from the pandemic. Second, we tested the impact of monthly *portal reminders* containing multiple psychological constructs known to direct people toward specific behaviors and emphasizing the importance of influenza vaccination during the pandemic. Third, we tested *a direct appointment scheduling system* allowing patients to schedule their own vaccination appointment at their primary care practice or other convenient health system practices, facilitating vaccine access. Fourth, we tested a *pre-appointment portal reminder message* sent just before any scheduled primary care appointment to eligible patients, reminding patients about their need for an influenza vaccination and setting patients' expectation for vaccination at the upcoming visit to reduce missed vaccination opportunities (Jaca et al., 2018).

2. Methods

2.1. Study design

This study was approved by the Institutional Review Board at the University of California, Los Angeles (UCLA), with a waiver of patient consent. The study involved the entire UCLA Health System, with 67 primary care internal medicine, medicine-pediatrics, family medicine, and pediatric practices across west Los Angeles. The study period was 10/1/2020–3/31/2021, during the pandemic when public focus was on COVID-19 vaccines.

The study design (Fig. 1) was a two-arm randomized controlled trial (RCT), and a 2 × 2 × 2 nested factorial design within the treatment arm. Patients were randomized *within* primary care practices to a control group (usual care, no reminders from the health system except for UCLA employees sent a reminder), or one of the interventions depicted in Fig. 1. The health system emailed all patients in the treatment arm up to three nearly identical portal reminder messages – in October, November, and December 2020 – about the importance of influenza vaccination.

All patients in the treatment arm were randomized into either direct appointment scheduling or no direct appointment scheduling. Within these two treatment sub-groups, patients were further randomized into pre-commitment messages or no pre-commitment messages, and into pre-appointment reminders or no pre-appointment reminders. This study design allowed us to compare the effectiveness of being sent monthly portal reminders overall plus the added effectiveness of pre-commitment, pre-appointment reminders, and direct appointment scheduling.

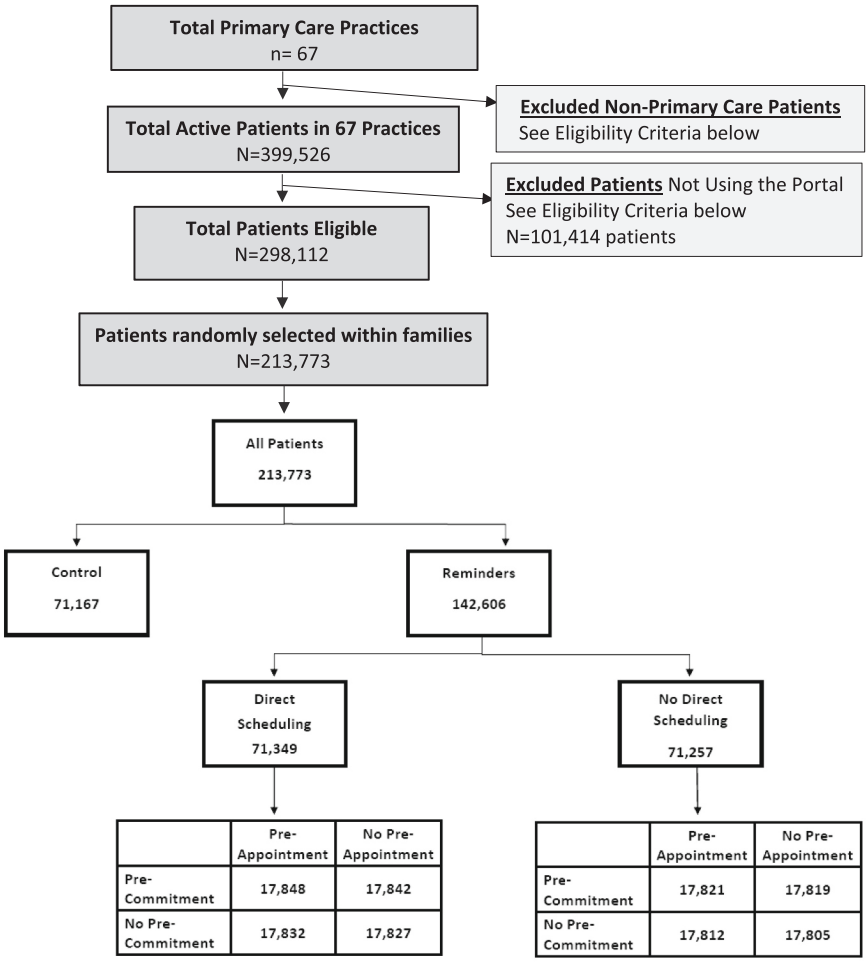
2.2. Study participants

All UCLA-Health System practices used *Epic*™ EHR and its patient portal. We included all primary care patients (Fig. 1) age six months or older. UCLA Health identifies "primary care patients" if they have (a) ≥2 visits to primary care providers (PCPs) within three years, or (b) ≥1 PCP visit with a preventive service code within one year, or (c) enrolled in managed care and assigned to UCLA Health (regardless of visits). Next, we identified the primary care practice the patient most recently visited within three years. We identified family clusters using algorithms matching patients' phone numbers, addresses, insurance member numbers, and patient guarantor identifiers. Finally, we defined an active portal user as a patient or portal proxy (for children, elderly, or disabled persons) who logged into the portal at least once during the prior 12 months, not including the initial portal login; this encompassed 75% of all primary care patients. These steps established the denominator of family clusters.

Statisticians randomly selected one index patient per family who was an active portal user. All other study personnel and healthcare providers were blinded to patient allocation. We excluded patients who were not active portal users and family members of index subjects. Index subjects were then randomly allocated to one of the study arms. Two-thirds of index subjects were assigned to receive portal messages. Among those receiving messages, index subjects were further randomized using a 2x2x2 factorial design to determine which combination of our direct scheduling, pre-commitment and pre-appointment reminder interventions they would receive. Family members of index subjects were sent the same portal reminders as the index family member to prevent confusion within families; we analyzed data for index subjects only.

2.3. Intervention: Portal messages (Appendix 1)

We used principles from the Health Belief Model (Becker and



Eligibility Criteria
Eligibility as a primary care patient of the Health System and active Portal user: • At least 6 months old • Primary care patient of the Health System per the Health System's criteria: (a) >2 visits to a primary care provider (PCP) within the past 3 years, or (b) ≥1 visit to a PCP with a preventive service in past 12 months, or (c) registered as a UCLA Health System ACO patient. • Active Patient Portal user (≥1 login over last 12 months, not including their initial account login) **Ineligibility:** • Not a primary care patient within the Health System • Not an active Patient Portal user

Fig. 1. Consort diagram.

Maiman, 1975), social psychology (Cialdini, 2009), behavioral economics (Jenssen et al., 2019; Thaler and Sunstein, 2021) lessons from our prior portal studies (Szilagyi et al., 2020a; Szilagyi et al., 2021a; Lerner et al., 2021) and the literature on health literacy (Kim and Xie, 2017) to develop portal messages: (a) *pre-commitment messages* sent in September, (b) *monthly messages* sent in October, November, and December 2020 (without or with a link to the *direct appointment scheduling* portal platform, depending on randomization), and (c) *pre-appointment reminders* sent prior to scheduled primary care appointments between 10/1/2020–12/31/2020.

Statisticians kept track of patient allocation and sent files to the health system's EHR team defining which portal message to send per round of reminders. Patients were notified that they had "A message from your doctor" on the patient portal via email or portal phone application notification, depending on their pre-specified portal account and individual phone application preferences. Patients logged into the portal to read portal messages.

2.3.1. *Pre-commitment messages*

We sent messages to adults/proxies, reminding them that due to COVID, doctors expected high demand for flu vaccines (psychological constructs of *social proof and scarcity* (Cialdini, *2009*)). Messages asked them to respond: (1) whether they planned to get a flu vaccine that season, and if they did, (2) where (UCLA, retail pharmacy, etc.), and (3) in which month; messages suggested they save their vaccine plan information in their calendar.

2.3.2. *Monthly reminder messages (no direct appointment scheduling)*

Messages were addressed to the patient's first name (*personalization*), reminding patients (or proxies) to make an appointment for a flu vaccine before the arrival of flu season. They stated that we anticipated high demand for flu vaccine (*scarcity* and *social proof)* (Cialdini, *2009*). We reminded patients they could receive a vaccination at a UCLA practice, pharmacy or other setting; we included links to other informational websites (*reducing small transaction costs* (Thaler and Sunstein, 2021)).

We asked patients to "Please call today for a flu vaccine appointment before flu arrives" and included a "click-to-call link" with a central phone number for an appointment (facilitating vaccine appointment scheduling for patients accessing the portal by cell phone (*reducing small transaction costs (*Thaler and Sunstein, 2021*)*). We also used terminology that included the psychological constructs (Cialdini, 2009; Brown et al., 2010) of *omission bias* ("choosing to get a flu vaccine") and *social good* ("avoid spreading flu to your loved ones"); and reminded patients that "influenza vaccination is especially important during the COVID-19 pandemic." The message was signed "Your UCLA Health Team" with a carbon copy ("cc") to the patients' doctor's name (*appeal to authority and personalization*) (Cialdini, 2009). Identical portal reminders were sent in October, November, and December 2020 if no vaccination was identified in the EHR one week prior to the scheduled portal reminders; the December 2020 reminder stated "this is your last reminder" (*urgency*) (Cialdini, 2009).

2.3.3. Direct appointment scheduling

Monthly portal messages instructed patients to "Click here to schedule your flu vaccine appointment online." We created a new nurse appointment called "Flu Vaccine Only," visible to patients on the portal direct scheduling system. Appointments were available at all primary care offices and other offices. Patients clicked on the link within the monthly reminder, directing them to all available sites for a Flu Vaccine Only appointment. Patients clicked on an available day and time to schedule their own appointment.

2.3.4. Pre-appointment reminder messages

These were added to existing health system's pre-appointment portal message reminding patients of an upcoming visit and sent 2–4 days prior to scheduled visits. The added vaccine reminder expressed concern that high demand could lead to a flu vaccine shortage and encouraged recipients to ask their doctor for their flu vaccine "while supplies last" to increase their chance of staying healthy (*scarcity, urgency*). If the upcoming appointment was by telemedicine or phone, the message also reminded patients about the availability of vaccinations at pharmacies.

2.3.5. Messages for parents of children

Messages were addressed to "Parent of [Child's First Name]-" same content as messages for adults except stating UCLA doctors and the American Academy of Pediatrics recommend the flu vaccine (*personalization, appeal to authority (*Cialdini, *2009*)), and including sentences about consequences of choosing not to vaccinate the child and the benefits of choosing to vaccinate the child during the pandemic (trying to overcome omission bias (Ritov and Baron, 1990) by turning the decision to not vaccinate into an act of *commission (*Brown et al., *2010;* Asch et al., *1994*)).

All system-generated messages were in English, below 7th-grade reading level per Flesch-Kincaid analysis and included primary care physician names. We piloted messages with multiple UCLA patients for content and construct validity and worked with the EHR team to optimize their appearance.

3. Measures

3.1. Patient characteristics

Patient characteristics from the EHR (Table 1) were: age, sex, insurance at latest primary care visit, race, ethnicity, and influenza vaccination within two years.

3.2. Influenza vaccination data

The EHR contains dates and locations of influenza vaccinations at any UCLA Health site. UCLA clinicians or nurses can manually enter outside vaccinations into the EHR. Further, the health system receives data about outside influenza vaccinations from: (1) Surescripts (a pharmacy benefits manager), (2) the California Immunization Registry (CAIR), and (3) Care Everywhere (Epic's information exchange application). UCLA clinicians can manually accept these outside vaccination data. Finally, patients/proxies can enter self-report vaccination data into the EHR via the portal. We integrated all these available data sources prior to the analyses and accepted all outside data irrespective of whether UCLA clinicians manually accepted vaccination records.

Monthly portal message sent to each patient randomized to any of the intervention groups contained a web link through which patients could enter vaccinations they received outside of UCLA into the EHR.

Table 1
Demographic characteristics of the study sample by demographics during the 2020–2021 influenza vaccination season.

	Total N (%)	Control N (%)	Reminder Groups[a] (all combined) N (%)
	N = 213,773	N = 71,167	N = 142,606
Age			
<18	17,703 (8.3)	5849 (8.2)	11,854 (8.3)
18–64	156,835 (73.4)	52,375 (73.6)	104,460 (73.3)
65+	39,235 (18.4)	12,943 (18.2)	26,292 (18.4)
Gender			
Female	121,587 (56.9)	40,517 (56.9)	81,070 (56.9)
Male	92,186 (43.1)	30,650 (43.1)	61,536 (43.2)
Primary Insurance[b]			
Private	181,724 (85.0)	60,482 (85.0)	121,242 (85.0)
Public	28,545 (13.4)	9487 (13.3)	19,058 (13.4)
Other/unknown	3504 (1.6)	1198 (1.7)	2306 (1.6)
Race			
Asian	20,513 (9.6)	6750 (9.5)	13,763 (9.7)
Black/African-American	9906 (4.6)	3332 (4.7)	6574 (4.6)
Other/multiple races/ unknown	67,815 (31.7)	22,525 (31.7)	45,290 (31.8)
White	115,539 (54.0)	38,560 (54.2)	76,979 (54.0)
Ethnicity			
Hispanic or Latinx	22,249 (10.4)	7400 (10.4)	14,849 (10.4)
Non-Hispanic/other/ unknown	191,524 (89.6)	63,767 (89.6)	127,757 (89.6)
Influenza vaccine History[c]			
No prior vaccination	87,954 (41.1)	29,283 (41.2)	58,671 (41.1)
Prior vaccination	125,819 (58.9)	41,884 (58.9)	83,935 (58.9)

[a] Patients in the reminder groups were randomized to one of eight groups (see Fig. 1).
[b] Public insurers included Medicaid, Medicare, and Tricare. If patients had Medicare + supplemental private Medigap coverage they were labelled as having private insurance.
[c] Notation of an influenza vaccination within the EHR during either of the prior 2 influenza seasons.

3.3. Outcome measures

3.3.1. Primary outcome

The primary study outcome was any influenza vaccination between 10/01/2020–03/31/2021 as documented in the EHR after merging the above sources, but *not including* vaccinations self-reported by patients *in response to the portal reminders* since the control group didn't have equal opportunity for self-report (eliminating differential ascertainment). The primary outcome represents a conservative bias because portal reminders could have encouraged some patients to obtain influenza vaccinations at other locations (e.g., pharmacies, workplaces) for which

vaccination data are not merged into the EHR.

3.3.2. Subgroup outcomes

We determined influenza vaccination in pre-determined subgroups who might be more likely to use the portal or respond to the interventions: age (<18, 18–64, 65+ years old), sex (male, female), primary insurer (public, private, other), race (Asian, Black, Other/Multiple/Unknown, White), ethnicity (Hispanic, Non-Hispanic), and influenza vaccination within two years (any, none).

3.3.3. Secondary process measures

We assessed (1) sources of influenza vaccination data – external or patient/proxy update through normal portal processes or in response to portal reminders, and (2) whether patients opened the monthly portal or pre-commitment letters.

3.4. Power calculation

Power was conservatively estimated for the evaluation of each of our three sub-interventions (pre-commitment prompt, direct scheduling, and pre-appointment reminders) averaging over the other interventions, within the treatment arm. A sample size of 71,258 patients per arm provides >90% power to detect a small, but clinically meaningful 2-percentage point improvement in vaccination. This assumes a chi-squared test, a control group rate of 50% (most conservative), and a significance level of 0.017 (3-fold Bonferroni correction for simultaneous evaluation of each intervention).

3.5. Statistical analysis

We report descriptive statistics for patient characteristics. Primary analyses compared vaccination rates between study arms using mixed-effects Poisson regression with robust standard errors. Models included main effects for assignment to any treatment, to direct scheduling, pre-commitment prompt, and pre-appointment reminders, as well as random practice effects, and controls for patient characteristics (age, sex, race, ethnicity, insurance, and prior vaccination). Secondary subgroup analyses were performed by fitting separate models for each subgroup.

For the primary analysis, we used a significance level of 0.017 (adjusting for multiple comparisons). In all other analyses, we considered *p*-values below 0.05 as statistically significant.

As secondary outcomes, we report rates of external vaccinations, self-reported vaccinations, and opening the portal-based reminders and pre-commitment prompts in the respective treatment arms.

Statistical analyses used SAS v. 9.4 (SAS Institute Inc., Cary, NC).

4. Results

4.1. Practice and patient characteristics (Table 1)

We randomized 213,773 patients including children ($N = 17,703$) and adults ($N = 196,070$), (Fig. 1). Most were female, White, and non-Hispanic. Most had private or Medicare insurance and had an influenza vaccination within the two prior years (59%).

4.2. Process measures and influenza vaccination rates

Altogether, 16,643 of 83,362 (20.0%) influenza vaccinations noted in the EHR were from outside UCLA Health. An additional 12,698 influenza vaccinations were exclusively self-reported in response to the patient portal reminders. Among patients sent a monthly portal reminder ($N = 142,636$), 81,215 (56.9%) opened any of three possible messages. Among patients sent a pre-commitment message ($N = 71,330$), 21,780 (30.5%) opened it. We did not assess vaccination rates among these groups because the overall findings showed no impact and positive effects within a subgroup would reduce but not eliminate any overall impact.

4.3. Influenza vaccination rates (primary outcome) by study group

The influenza vaccination rate in the control group was 38.9% (Table 2). Vaccination rates did not differ by intervention arms for pre-commitment Yes/No (39.2%/38.9%), direct appointment scheduling Yes/No (39.1%/39.1%), pre-appointment reminders Yes/No (39.1%/39.1%), or only monthly reminders (38.7/38.9); $p > 0.05$ for all comparisons using adjusted Poisson models.

Table 3 shows risk ratios (95% confidence intervals) comparing the effect of pre-commitment, direct appointment scheduling, and pre-appointment reminders on influenza vaccination rates. There was not statistically or clinically significant impact of any of the three strategies on influenza vaccination rates.

Table 3 also shows adjusted risk ratios for receiving a vaccination for the pre-specified subgroups. Individuals had lower vaccination rates than their counterparts if they were > 17 years of age, male, had public or other/unknown insurance, were Black or race being Other/Multiple/Unknown, non-Hispanic, or hadn't received a vaccination within two

Table 2
Influenza vaccination rates (2020–2021 vaccination season) for all patients across the health system and by patient characteristic, by intervention strata.[a]

Patient characteristic	Control	Intervention groups					
		Pre-commitment		Direct Appt scheduling		Pre-Appt reminder	
		Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
All patients	38.9	39.2	38.9	39.1	39.1	39.1	39.1
Age (y)							
<18	56.8*	57.8	58.4	57.8	58.4	57.7	58.5
18–64	40.9	41.4	41.2	41.3	41.3	41.4	41.2
65+	22.5*	22.0	21.3	22.0	21.4	21.3	22.0
Gender							
Female	39.4	39.6	39.4	39.6	39.5	39.5	39.6
Male	38.1	38.7	38.3	38.4	38.6	38.5	38.5
Primary insurance							
Private	41.0	41.3	41.1	41.2	41.2	41.2	41.2
Public	25.6	26.7	25.6	26.3	26.1	26.1	26.3
Other/unknown	35.1	34.2	33.8	33.7	34.3	33.1	34.9
Race							
Asian	48.1	48.6	47.9	48.5	47.9	48.2	48.2
Black	31.5	33.7*	31.9	32.8	32.8	33.1	32.5
Other/multiple/unknown	37.6	37.8	37.9	37.9	37.8	38.3	37.4
White	38.6	38.9	38.5	38.6	38.7	38.4	39.0
Ethnicity							
Hispanic	41.5	42.0	41.5	41.0*	42.5	42.2	41.3
Non-Hispanic/unknown	38.5	38.9	38.6	38.9	38.7	38.7	38.8
Vaccine History[b]							
No prior vaccination	20.5	21.3	20.9	21.3	20.9	21.1	21.1
Prior vaccination	51.6	51.7	51.6	51.4	51.9	51.6	51.7

These results exclude vaccinations self-reported by patients in response to the portal influenza reminders.

[a] All intervention groups were sent 3 monthly portal reminder messages until vaccination was documented in the EHR.

[b] Prior influenza vaccination in the past 2 years.

* $p < 0.05$ using multivariable Poisson models; asterisks in control column refer to comparisons between the reminder and control conditions; asterisks in other columns refer to comparisons between those receiving v. not receiving a further intervention within the reminder condition (e.g., pre-commitment yes v. pre-commitment no).

Table 3
Adjusted rates and risk ratios (95% Confidence Intervals)[a] using a Poisson regression model, comparing the risk of receiving an influenza vaccination (2020–2021 vaccination season) by intervention arm and by patient subgroups.*

	Adjusted rate (95% CI)	Adjusted RR (95% CI)
Reminder letters		
No	28.1 (26.8, 29.5)	- REF -
Yes	28.3 (27.0, 29.7)	1.01 (1.00, 1.02)
Direct appointment scheduling		
No	28.2 (26.9, 29.6)	- REF -
Yes	28.2 (26.9, 29.6)	1.00 (0.98, 1.01)
Pre-commitment		
No	28.2 (26.8, 29.5)	- REF -
Yes	28.3 (27.0, 29.7)	1.00 (1.00, 1.01)
Pre-appointment reminder		
No	28.3 (26.9, 29.6)	- REF -
Yes	28.2 (26.9, 29.6)	1.00 (0.99, 1.01)
Age		
<18 years	42.8 (40.5, 45.2)	- REF -
18–64 years	33.9 (32.7, 35.2)	**0.79 (0.76, 0.83)**
65+ years	15.5 (13.9, 17.2)	**0.36 (0.32, 0.40)**
Gender		
Female	28.6 (27.3, 30.0)	- REF -
Male	27.8 (26.5, 29.2)	**0.97 (0.96, 0.98)**
Primary insurer		
Private	30.0 (28.7, 31.5)	- REF -
Public	27.7 (26.6, 28.8)	**0.92 (0.90, 0.94)**
Other/unknown	27.0 (25.1, 29.1)	**0.90 (0.85, 0.95)**
Race		
White	28.9 (27.6, 30.2)	- REF -
Asian	31.4 (29.9, 33.1)	**1.09 (1.07, 1.11)**
Black	26.2 (24.9, 27.7)	**0.91 (0.88, 0.94)**
Other/multiple/unknown	26.6 (25.3, 28.0)	**0.92 (0.91, 0.94)**
Ethnicity		
Non-Hispanic/unknown	27.2 (26.0, 28.5)	- REF -
Hispanic	29.2 (27.8, 30.8)	**1.07 (1.05, 1.10)**
Prior influenza vaccination**		
No	17.4 (16.4, 18.4)	- REF -
Yes	45.8 (43.8, 47.8)	**2.63 (2.54, 2.72)**

These results exclude vaccinations self-reported by patients in response to the portal influenza reminders.
The model controls for all items shown in the table.
* Bolded values indicate $p < 0.05$.
** Within 2 years.

years.

4.4. Secondary outcomes: Influenza vaccination among subgroups

4.4.1. Univariate subgroup analyses

Patients receiving pre-commitment reminders had higher influenza vaccination rates than those not receiving these reminders among Black patients (33.7% vs 31.5%, $p < 0.05$) and publicly insured patients (26.7% vs 25.6%, $p < 0.05$). For direct appointment scheduling and pre-appointment reminders, none of the treatment arm subgroups had statistically higher vaccination rates than those not receiving the interventions. Patients with prior influenza vaccinations had much higher vaccination rates in the current season, although the portal interventions didn't have significant effects in this subgroup.

5. Discussion

This study found that four health system-wide interventions within the EHR's patient portal, designed to nudge patients toward influenza vaccination or improve access to influenza vaccinations (i.e., a pre-commitment message, monthly reminders, direct appointment scheduling, and pre-appointment reminders), did not raise influenza vaccination rates during the 2020–2021 influenza vaccination season, the first full influenza season within the pandemic.

Our rationale for testing the patient portal as the mechanism to deliver influenza vaccine reminders was based upon high use of the portal in this health system (75%) and nationwide and the potential for scalability across health systems with favorable results in smaller studies (Cutrona et al., 2018; Wijesundara et al., 2020; Ueberroth et al., 2021). However, portal messages can only be effective if they are opened. Studies are needed to improve the engagement with portal messages—perhaps by making messages similar to items that appear on people's cell phones. Interestingly, another study the same season in two other health systems found that pre-appointment *text message* reminder messages raised influenza vaccinations (Milkman et al., 2021). Portal reminders require extra clicks and log-ins to access the message; whereas text messages are immediately available. Patients may be more likely to read a text message requiring a single click to open than portal messages that require a greater investment in time and effort (Stokley et al., 2021; Stockwell et al., 2013; Stockwell et al., 2012); an unread message cannot influence behavior. Text messages using behavioral economic-informed messages have worked for other preventive measures (Huf et al., 2020; Bhochhibhoya et al., 2021). Studies comparing patient portal-based reminders (via email) versus text message reminders are needed, analogous to studies that compared text versus mailed or auto-dialer reminders (Szilagyi et al., 2020b; Gurfinkel et al., 2021).

Patient vaccine hesitancy may have contributed to the lack of impact of our portal reminders (Cialdini, 2009). Interestingly, a study of text message-based patient reminders for COVID-19 vaccinations conducted within our health system in January–February 2021 noted short-term impact (within 4 weeks) for eligible older adults on scheduled appointments for COVID-19 vaccination, although overall appointment rates were below 20% (Dai et al., 2021). Perhaps patient reminders are effective among patients who strongly desire a vaccine, as was the case for COVID-19 vaccines. Patient reminders may now be less effective than previously noted (Jacobson Vann et al., 2018), even if coming from healthcare providers (Szilagyi et al., 2021b) and using psychological principles. More targeted interventions may be needed to nudge (Wolf et al., 2022) patients who are amenable to vaccination but are not yet vaccinated.

A third likely factor contributing to the lack of impact of our interventions is the pandemic. Many people were focused on COVID-19 vaccines rather than influenza vaccines, many were reluctant to make medical visits, and news media were highlighting how the influenza season was extremely light that year. Perhaps in a more normal season these types of interventions might be more effective.

Our study had several strengths. We implemented the interventions across an entire health system, using a large, pragmatic trial; we randomized patients within primary care practices to minimize unmeasured confounders. We also had good capture of influenza vaccinations by obtaining data from pharmacies, outside practices, and the state registry.

Study weaknesses include a single health system with lower vaccination rates than national coverage. This influenza season coincided with the COVID-19 pandemic. After having shut down temporarily (except for urgent or emergent visits) in the spring of 2020, the health system was encouraging in-person visits by October 2020, but many patients still used telehealth visits for care and were afraid to attend in-person visits. In addition, COVID-19 vaccination began in December 2020 for individuals 65 years of age and older, and simultaneous vaccination with both COVID-19 vaccine and influenza vaccine was not recommended. These novel barriers to influenza vaccination may have contributed to lower vaccination rates (Szilagyi et al., 2020a; Szilagyi et al., 2021a) and lack of response to interventions.

When portal messages are sent, patients see a generic notification that they have a portal message but are not able to see the content of the message unless they take the extra step of logging into the portal and reading the message. As noted by the many unread portal messages, any information technology-based intervention can only work if it is actually delivered. At this time there is no ability for end-users to directly access a portal message immediately as they do with text messages. Interventions

are needed to improve patient engagement with portal messages. Further, we did not test text messages which might have more impact. Finally, the EHR was missing data about race and ethnicity for many patients.

We conclude that within a large health system within Los Angeles, during the pandemic, patient portal reminders for influenza vaccinations that included messages containing psychological nudges did not raise influenza vaccination rates. Three interventions designed to increase vaccination motivation and follow-through – patient pre-commitment messages, direct patient appointment scheduling, and pre-appointment reminders – also were not effective in raising influenza vaccination rates. More work is needed to identify sustainable methods to increase uptake within vaccine hesitant communities.

Author contributions

PS, AC, AKD, MO, SV, ST, CA, SG, CF and CL contributed to the literature search, study design, overseeing aspects of the fieldwork, data interpretation, drafting and editing of the manuscript. SV and CT performed data analyses. SE and MS contributed to the fieldwork. MR, C-HT and JB contributed to data interpretation, drafting and editing. SF contributed to the literature search, fieldwork, data interpretation, drafting and editing. PS had full access to all data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

All text, tables and figures are original and have not been previously published.

Non-author contributions

The following individuals work in the UCLA Health system and provided assistance with obtaining data from the electronic medical records and sending the patient portal messages. They did not receive compensation.

- Ashley Elizabeth Turner BA, UCLA Health
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- Ilona Chakarian, UCLA Health
- Michael Ricanor, UCLA Health
- Michael Sloyan MPH, UCLA Health
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- Vickie Reid, UCLA Health

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Institutional review board approval

The UCLA IRB approved this study.

UCLA-IRB approved trial protocol

The trial protocol is included in supplemental materials entitled "UCLA IRB Snapshot- Protocol and SAP – Approved 10.9.2019. This document contains the protocol for 3 RCTs. The current manuscript refers to RCT #3. RCT #1 is referenced as Reference #16 in the manuscript. RCT #2 is Reference # 17 and #18.

Credit author statement

Peter G. Szilagyi, MD MPH: Data curation, funding acquisition, investigation, methodology, supervision, writing original draft.

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Dr. Szilagyi had full access to all data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Declaration of Competing Interest

Dr. Humiston is a consultant to Sanofi Pasteur. Dr. Humiston's employer gets grant money for her work sponsored by the Pediatric Infectious Diseases Society Foundation, a not-for-profit organization, which is funded for the project through unrestricted joint educational grants from Sanofi Pasteur US, Merck & Co., Inc., Pfizer, Inc., GlaxoSmithKline, and Seqirus USA, Inc.

All other authors have no conflicts of interest to report.

Trial Registration: This trial was registered with ClinicalTrials.gov (NCT04533685).

Data availability

Raw data underlying this article were generated from the UCLA Health System; restrictions apply to the availability and release of data. Please contact the author (PS) for requests for data.

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