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Analyzing the Effect of the Application of Behavioural Insights to Immunization Reminder Postcards in the Fraser Health Region

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Background & Purpose

In the Fraser Health region of B.C., vaccine coverage rates range from 71-77% over the past few years for up-to-date (UTD) immunizations at 2 years of age, far below the national target of 95%.[1] As a result, outbreaks of infection can occur, such as in 2014 when the Fraser Valley experienced the largest measles outbreak in BC in over 30 years.[2] There are multiple barriers to achieving immunization targets and reducing the risk of disease spread. Some parents may be vaccine-hesitant due to complacency, lack of confidence, and/or utility calculations based on personal evaluations of risk. [3,4] Other parents may intend to vaccinate their children but fail to act on their intentions due to inconvenience, busy schedules, or other barriers. Behavioural insights (BI) have been employed to help individuals experiencing this gap between intention and action.[4, 9-15]

BI is the 'application of behavioural science to policy and practice'.[5] BI incorporates the idea that people have two different, but often collaborative, systems for processing information and making decisions – the automatic system: quick, intuitive and unconscious, and the reflective system: slower, rational, and conscious.[6] Because our behaviours are often more automatically processed in response to our environments, we can alter aspects in the presentation of information and potentially have a significant impact on decision-making behaviour.[7] Nudges, a type of BI intervention, encourage people toward certain decisions while still protecting their freedom to choose other decisions. Nudge-interventions are "liberty-preserving approaches that steer people in a particular direction."[8] Thus, nudges may be a useful tool for encouraging vaccination.

Nudge techniques including social comparisons have been used to increase immunization.[6] For example, a vaccine message sharing that "80% of your community members support COVID-19 vaccination" uses descriptive social norms to indicate that vaccination is more common than people may realize.[6] Because vaccination requires immediate effort (book and attend a vaccination appointment) for a delayed reward (protection from disease), people may be likely to procrastinate.[9] Nudges that help people overcome procrastination can be helpful. For example, implementation intentions are self-formulated plans that help create plans to overcome the intention-behaviour gap.[4,6] An example of such prompt would be "if your child has not received their immunizations, then go to this website to book your appointment today. If your child has received their immunizations, then update their records." Incentivization (e.g., providing small monetary rewards for getting vaccinated) and defaults (e.g., automatically scheduling vaccination appointments) are other nudges that have been effective for increasing immunizations among adults.[6,13,15]

In Ontario, the Ministry of Health and Toronto Public Health provide another example of how BI can be applied to immunization. They sought to identify a solution for increasing HPV vaccination coverage among students. To understand the population, they identified that a student's divided attention may interfere with their ability to extract important information from the immunization reminder letters they receive at school. Additionally, they may not understand their susceptibility to vaccine-preventable disease and illnesses and, with a natural preference for actions that result in short-term rewards, vaccination may not a priority. To find a solution, they conducted a randomised control trial in which they applied various nudge techniques, such as applying a time-limit and addressing risk misperceptions, to their immunization reminder letters. They found that the addition of these behavioural insights resulted in a two-fold increase in the likelihood of vaccination among recipients compared to the original reminder letter.[18] While not exhaustive, this summary provides an understanding of how BI can be applied to immunization.

From surveying parents in the Fraser Health region, we understand that being busy, procrastination, and a lack of awareness that their child is behind schedule are significant barriers to achieving up-to-date (UTD) immunizations at 2 years of age.[1] The need for an enhanced reminder system has been recognized.[1] A literature review was conducted to gain an understanding of how applying BI to immunization interventions can increase vaccination rates. The studies included were large scale randomized control trials that focused on either influenza vaccinations in adult and older adult populations, childhood vaccinations and parents, or COVID-19 and adults. The most prominent finding is that immunization reminders are an effective strategy for increasing vaccination rates as the increase in vaccination rate among intervention groups ranged from 0.4 to 10.5 percentage points compared to controls among the mentioned populations.[9-14] Efforts to enhance reminder effectiveness by using various additional BI such as framing, planning prompts, or persuasion through education, vary in success.[9-14] The literature reveals the importance of contextually understanding why a BI could be effective at increasing vaccinations in one population but not another. For instance, Levine et al.'s (2021) study in a low-income community in Northern Ghana utilized micro-incentives to motivate individuals to prioritize childhood vaccination and overcome logistical barriers, and increased vaccination coverage by 49.5 percentage points compared to control. However, the same strategy in a high-income community with high availability and access to vaccines might have a different effect. In a study by Milkman et al. (2011), implementation intentions proved to be effective in increasing vaccination rates by 1.5 to 4 percentage points, but Yokum et al. (2018) found they had no effect compared to the control. Milkman et al.'s study population involved individuals who had access to workplace vaccination clinics, whereas Yokum et al.'s study population was scattered across the country. As a result, the implementation intentions were more logistically precise for Milkman's study population and were more effective in dismantling mental hurdles to set an action plan whereas in Yokum et al.'s study, clinic availability and accessibility may have been bigger barriers.

In this project, Fraser Health sought to increase the immunization rate among children due for their two-year-old vaccinations. We identified barriers including procrastination, a multi-step process, and missing information.[1] To help overcome the intention-action gap, Fraser Health sends reminders to the families of children turning 17 months old. Previous research suggests that deadlines can create a sense of urgency that encourages people to take action and stop procrastinating (BIG, 2021). Research also suggests that checklists that break complex, multi-step processes into a small number of simple steps can make it easier for people to take action (Gawande, 2009). As such, Fraser Health designed four different immunization reminder postcards that were sent to the families of children turning 17-months-old, as shown in Figure 1. The two nudges were tested for their effectiveness in increasing 2-year-old immunization coverage in a quasi-randomised control trial using a 2 (reminder: yes vs. no) x 2 (checklist: yes vs. no) factorial design.

Methods

To guide the development of research questions for the analysis, the PICOT framework was applied to the study. The framework identifies the study population, intervention, control, outcomes, and time period.

Population: Families of children turning 17 months of age in the Fraser Health region who are eligible for immunization.

Intervention and control: 1 of 4 postcards designed with different behavioural insights were sent to families of children turning 17 months of age on one date each month from January to April 2022 to remind the guardian that their child was due for immunizations. As shown in Figure 1, the intervention groups include: 1) Control, the standard reminder postcard; 2) Deadline, a postcard emphasizing the immunization due date as well as more detailed contact information; 3) Checklist, a postcard with a checklist to indicate the steps for booking and preparing for an immunization appointment; and 4) Deadline plus checklist, a postcard including both the deadline and checklist.

Figure 1. Images of the front and back of the postcard in each condition: Control, deadline, checklist, and deadline plus checklist.

Control

Deadline

Checklist

Deadline + Checklist

Outcomes:

O1. If a child received booster and is up-to-date (UTD)

O2. If a child received any immunization

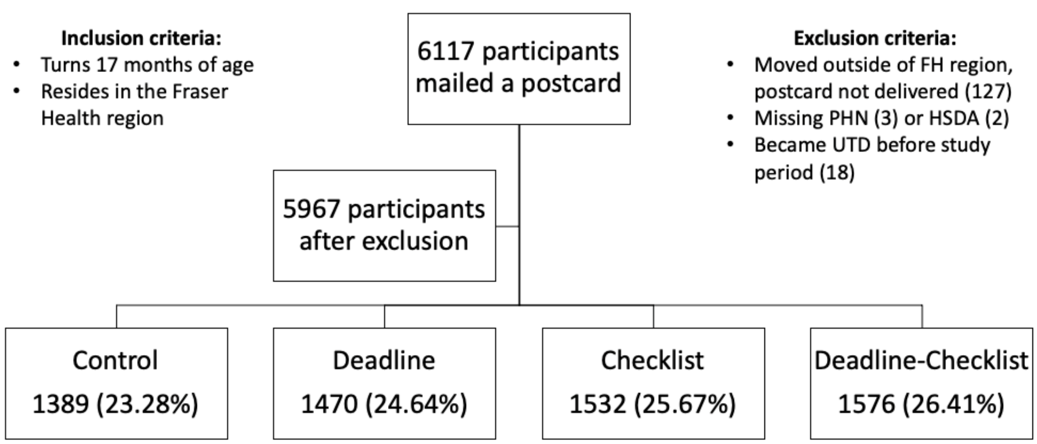
The following research questions were developed:

- (RQ1a) Does the use of behavioural insights in the design of immunization reminder post cards have an effect on immunization uptake and (RQ1b) whether or not a child is up-to-date in the Fraser Health region?
- (RQ2) Which postcard design was most effective? We hypothesized that the deadline plus checklist postcard will be most effective in achieving these outcomes because it places the most emphasis on the urgency of the behaviour while also providing actionable steps to completing it.

Time period: We conducted two analyses to enable us to examine two time points. First, we were primarily interested in immunizations that occurred between the immunization reminder date and the 21-month birthday. This is when the 21-month recall is performed by Fraser Health to notify guardians via telephone that their child is behind on immunizations. Identifying immunizations administered before the 21-month recall allows for us to better determine if the immunization received was prompted by the 17-month reminder, as opposed to the 21-month recall. This analysis is referred to as the 21-month analysis. In the second analysis, we included all immunizations performed up to 24 months of age so we could capture immunizations that may have occurred closer to the "deadline" of 2 years of age, which will be referred to as the 24-month analysis.

The study population included 6,117 children who were sent one of these postcards; however, 127 children were lost to follow up because the postcard was never delivered, the child moved out of the region, or the postcard was returned and they were too old to be re-mailed. Another two children were excluded due to improper health unit identification, and another three due to missing personal health numbers (PHN). Additionally, 18 children had become fully UTD on their immunizations before the study period began. Since the postcard reminder is designed to remind parents to get their child immunized with the 18-month booster immunization that will make them fully UTD, we excluded these 18 children as the postcard was irrelevant for them. This resulted in a sample of 5,967 children.

Figure 2. Assessment of eligibility and intervention distribution.



The study was conducted as a quasi-randomized control trial in which children were assigned to an intervention based on their birthdate. An overview of how randomization was conducted can be found in the cohort postcard schedule (Appendix 2). The different postcard designs were fairly evenly distributed as 1389 (23.3%) children received the control postcard, 1470 (24.6%) received the deadline postcard, 1532 (25.7%) received the checklist postcard, and 1576 (26.4%) received the deadline plus checklist postcard. The postcards and postcard variations were distributed fairly evenly across health units in the Fraser Health region, proportional to their population size.

To evaluate the impact of each intervention postcard in comparison to the control postcard on each of the outcomes, a binary logistic regression was conducted adjusting for Health Service Delivery Area or HSDA (which infers the client's residence), sex, and mail-out cohort (cohort). For the 24-month analysis, we also adjusted for receipt of the 21-month recall reminder. Regression-adjusted analysis for each outcome was conducted to control for the confounding potential of each predictor variable that may have an effect on the outcomes. Immunization coverage rates and vaccination attitudes and beliefs differ across each HSDA which may result in differential effects of each postcard within each area.[1] Sex was controlled for due to its importance for clinical significance. Receipt of 21-month recall was controlled for because as a second reminder for immunization it may have a significant effect on immunization uptake. We controlled for the cohort, which are the groups of participants classified by their birth month and who are sent the postcard on the same day. Cohort 1 was mailed on January 19th with their observation window ending in the month of May for the 21-month analysis and in August for the 24-month analysis, depending on their birthdate. Cohort 2 was mailed on February 16th with observation until June and September. Cohort 3 was mailed on March 16th with observation until July and October. Finally, Cohort 4 was mailed on April 20th with observation until August and November. Differing external factors may have influenced immunization decision-making dependant on the month of postcard delivery. This will be expanded on in later sections. The distribution of these predictors across each intervention arm is displayed in Table 1.

Table 1. Demographics of the study population

Variable	Chi-Square Test of Independence	Study Group				
		All (n=5967)	Control (n=1389)	Deadline (n=1470)	Checklist (n=1532)	Deadline-Checklist (n=1576)
Age		17 mo	17 mo	17 mo	17 mo	17 mo
Sex	$X^2(3, N=5967)=10.9593, p=0.0119$					
Female		2936 (49.20%)	671 (48.31%)	696 (47.35%)	738 (48.17%)	831 (52.73%)
Male		3031 (50.80%)	718 (51.69%)	774 (52.65%)	794 (51.83%)	745 (47.27%)
HSDA	$X^2(6, N=5967)=12.3625, p=0.0544$					
Fraser North		2001 (33.53%)	439 (31.61%)	472 (32.11%)	514 (33.55%)	576 (36.55%)
Fraser East		1080 (18.1%)	259 (18.65%)	268 (18.23%)	264 (17.23%)	289 (18.34%)
Fraser South		2886 (48.37%)	691 (49.75%)	730 (49.66%)	754 (49.22%)	711 (45.11%)
21 mo Recall	$X^2(3,N=5967)=9.5382,p= 0.0229$					
Yes		1810 (30.33%)	404 (29.09%)	493 (33.54%)	448 (29.24%)	465 (29.51%)
No		4157 (69.67%)	985 (70.91%)	977 (66.46%)	1084 (70.76%)	1111 (70.49%)
Mail Out Cohort	$X^2(9, N=5967)= 68.7070, p= <.0001$					
Cohort 1 (January)		1547 (25.93%)	340 (24.48%)	361 (24.56%)	364 (23.76%)	482 (30.58%)
Cohort 2 (February)		1538 (25.78%)	422 (30.38%)	352 (23.95%)	389 (25.39%)	375 (23.79%)
Cohort 3 (March)		1481 (24.82%)	320 (23.04%)	442 (30.07%)	363 (23.69%)	356 (22.59%)
Cohort 4 (April)		1401 (23.48%)	307 (22.10%)	315 (21.43%)	416 (27.15%)	363 (23.03%)
21 Month Analysis						
Fully UTD (O1)	$X^2(3,N=5967)=0.3105,p=0.9580$	3935 (65.95%)	918 (66.09%)	962 (65.44%)	1009 (65.86%)	1046 (66.37%)

Any immunization (O2)	X^2(3,N=5967)=0.3329,p=0.9537	4347 (72.85%)	1013 (72.93%)	1063 (72.31%)	1117 (72.91%)	1154 (73.22%)
24 Month Analysis						
Fully UTD (O1)	X^2(3,N=5967)=1.7349,p=0.6292	4494 (75.31%)	1054 (75.88%)	1110 (75.51%)	1135 (74.09%)	1195 (75.82%)
Any immunization (O2)	X^2(3,N=5967)=1.0752,p=0.7831	4961 (83.14%)	1161 (83.59%)	1227 (83.47%)	1261 (82.31%)	1312 (83.25%)

The regression model was built using a purposeful sampling technique which is a non-probability sampling technique in which variables are chosen for inclusion by the judgement of the researcher. To begin building the regression model, a univariable analysis was conducted to explore the unadjusted association between the predictor variables and the outcome. This was performed by conducting a logistic regression for each predictor variable and each outcome. Variables with a p-value smaller than 0.25 were kept in the model, as supported by literature,[16] and those with larger values did not contribute and were eliminated. The only variable that remained in the model despite having a p-value larger than 0.25 is the sex variable due to clinical significance. Two multivariable models were fitted for each outcome, one that included all predictor variables, and another smaller one that eliminated the variables that did not contribute to the model (those with a p-value greater than 0.25). The change of coefficients (Δβ) was compared between the smaller model and the original model. A change in coefficients of less than 20% indicated that the eliminated variable would remain out of the model (as indicated in Tables 2-3 as a missing input) and if the change was greater than 20%, the variable was kept.[16] The goodness of fit was assessed using the Hosmer and Lemeshow Goodness-of-Fit statistic.

Results

The predictor variables were fairly evenly distributed across study groups. However, a pattern was observed between the cohort and the study groups. Cohort 1 had a greater proportion of participants within the deadline plus checklist study group than the other study groups by roughly 6%. Cohort 2 had a greater proportion of those in the control group by roughly 5%, Cohort 3 had a greater proportion of those in the deadline group by roughly 6%, and Cohort 4 had a greater proportion of those in the checklist group by roughly 4%. Additionally, with 33.54% of the study group having received a recall reminder, the deadline study group had a greater portion of participants who received the recall than the other study groups and the overall sample. The chi-square test of independence for each predictor variable (sex, HSDA, received recall, and cohort) indicated rejection of the null hypothesis since each p-value fell below the threshold of 0.05, therefore indicating a statistically significant association between each predictor variable and the study groups (X^2(3, N=5967)=10.9593, p=0.0119; X^2(6, N=5967)=12.3625, p=0.0544; X^2(3, N=5967)=9.5382, p=0.0229; X^2(9, N=5967)=68.7070, p=<.0001, respectively). The chi-square tests were not indicative of a statistically significant association between the outcome variables for the 21-month analysis and the study groups (X^2(3, N=5967)=0.3105, p=0.9580; X^2(3, N=5967)=0.3329, p=0.9537). The same goes for the 24-month analysis (X^2(3, N=5967)=1.7349, p=0.6292; X^2(3, N=5967)=1.0752, p=0.7831).

The multivariable logistic regression results for each outcome are presented in Tables 2a and 3a for the 21-month analysis, and Tables 2b and 3b for the 24-month analysis. The results for each of the postcards are in reference to the control, and HSDA's Fraser North and Fraser East are compared to Fraser South, as this HSDA represents the largest proportion of our sample.

Table 2a. Effect of reminder postcard on UTD immunization at 21 months of age

	Outcome 1: UTD including Booster				
Predictor Variables	β coefficient	SE	OR	P value (α=0.05)	95% CI
Control (reference)	-	-	-	-	-
Deadline	-0.0374	0.0799	0.963	0.6398	(0.824, 1.127)
Checklist	-0.0175	0.0791	0.983	0.8247	(0.841, 1.148)

Deadline-checklist	0.00299	0.0789	1.003	0.9697	(0.859, 1.171)
Fraser South (reference)	-	-	-	-	-
Fraser North	-0.0996	0.0628	0.905	0.1130	(0.800, 1.024)
Fraser East	**-0.7549**	**0.0733**	**0.470**	**<.0001**	**(0.407, 0.543)**
Male (reference)	**-**	**-**	**-**	**-**	**-**
Female	0.0149	0.0553	1.015	0.7883	(0.911, 1.131)
Cohort 1 (reference)	-	-	-	-	-
Cohort 2	**-0.1958**	**0.0776**	**0.822**	**0.0116**	**(0.706, 0.957)**
Cohort 3	-0.1315	0.0786	0.877	0.0943	(0.752, 1.023)
Cohort 4	**-0.2326**	**0.0791**	**0.792**	**0.0033**	**(0.679, 0.925)**

Table 2b. Effect of reminder postcard on UTD immunization at 24 months of age.

	Outcome 1: UTD including Booster				
Predictor Variables	β coefficient	SE	OR	P value (α=0.05)	95% CI
Control (reference)	-	-	-	-	-
Deadline	0.0957	0.0994	1.100	0.3356	(0.906, 1.337)
Checklist	-0.1279	0.0979	0.880	0.1914	(0.726, 1.066)
Deadline-checklist	0.00927	0.0980	1.009	0.9247	(0.833, 1.223)
Fraser South (reference)	-	-	-	-	-
Fraser North	-0.00536	0.0784	0.995	0.9454	(0.853, 1.160)
Fraser East	**-0.6953**	**0.0897**	**0.499**	**<.0001**	**(0.418, 0.595)**
Male (reference)	-	-	-	-	-
Female	0.0673	0.0685	1.070	0.3259	(0.935, 1.223)
No Recall	-	-	-	-	-
Received Recall	**-2.2938**	**0.0697**	**0.101**	**<.0001**	**(0.088, 0.116)**
Cohort 1 (reference)	-	-	-	-	-
Cohort 2	0.1144	0.0961	1.121	0.2341	(0.929, 1.354)
Cohort 3	**0.2375**	**0.0976**	**1.268**	**0.0150**	**(1.047, 1.535)**
Cohort 4	**0.2284**	**0.0985**	**1.257**	**0.0204**	**(1.036, 1.524)**

There were 3935 participants (65.95%) who were fully UTD at 21 months and 4494 (75.31%) at 24 months. The regression-adjusted results for both analyses show that none of the postcard intervention had a statistically significant effect (p-value>0.05) on a child being UTD for their immunization. HSDA had a significant effect on the outcome as the odds of a child being fully UTD decreased for those residing in Fraser East compared to Fraser South by 53% (OR=0.470, 95% CI [0.407, 0.543] for the 21-month analysis, OR=0.499, 95% CI [0.418, 0.595] for the 24-month analysis). In both analyses, the cohort had a significant effect on a child being fully UTD.

For the 21-month analysis, the odds of being UTD decreased for all cohorts in comparison to Cohort 1, but only Cohort 2 and Cohort 4 were statistically significant. The decrease in odds associated with Cohort 2 was roughly 18% and for Cohort 4 roughly 21% (OR= 0.822, 95% CI [0.706, 0.957]; OR=0.792, 95% CI [0.679, 0.925], respectively). For the 24-month analysis, the direction of the effect of the cohorts on the outcome differed. The odds of being UTD increased for all cohorts in comparison to Cohort 1, but only Cohort 3 and Cohort 4 were statistically significant. The increase in odds associated with Cohort 3 was roughly 27% and for Cohort 4 roughly 26% (OR=1.268, 95% CI [1.047, 1.535]; OR=1.257, 95% CI [1.036, 1.524], respectively). Factoring in whether or not the participant received the reminder recall at 21 months was only relevant for the 24-month analysis which showed that the odds of being fully UTD decreased by roughly 90% if they had received the recall (OR=0.101, 95% CI [0.088, 0.116]). This does not mean receiving a recall reminder will deter parents from getting their child immunized. The recall reminder is delivered to those who are already not UTD or are behind on their immunizations. Not being UTD is an inclusion criterion for receiving the 21-month recall. Therefore, receiving the recall did not result in the child not being UTD, rather they received the recall because they were not UTD by 21 months.

Table 3a. Effect of postcard on receiving any immunization at 21 months of age.

	Outcome 3: Any Immunization				
Predictor Variables	β coefficient	SE	OR	P value (α=0.05)	95% CI
Control (reference)	-	-	-	-	-
Deadline	-0.0393	0.0853	0.961	0.6451	(0.813, 1.136)
Checklist	-0.00670	0.0846	0.993	0.9369	(0.842, 1.173)
Deadline-checklist	0.00812	0.0844	1.008	0.9233	(0.854, 1.189)
Fraser South (reference)	-	-	-	-	-
Fraser North	-0.0712	0.0682	0.931	0.2961	(0.815, 1.064)
Fraser East	**-0.8615**	**0.0759**	**0.423**	**<.0001**	**(0.364, 0.490)**
Male (reference)	-	-	-	-	-
Female	-0.00251	0.0591	0.997	0.9661	(0.888, 1.120)
Cohort 1 (reference)	-	-	-	-	-
Cohort 2	**-0.1442**	**0.0835**	**0.866**	**0.0841**	**(0.735, 1.020)**
Cohort 3	-0.1129	0.0844	0.893	0.1812	(0.757, 1.054)
Cohort 4	**-0.2753**	**0.0841**	**0.759**	**0.0011**	**(0.644, 0.895)**

Table 3b. Effect of remainder postcard on receiving any immunization at 24 months of age.

	Outcome 3: Any Immunization				
Predictor Variables	β coefficient	SE	OR	P value (α=0.05)	95% CI
Control (reference)	-	-	-	-	-
Deadline	0.1230	0.1146	1.131	0.2830	(0.903, 1.416)
Checklist	-0.0993	0.1131	0.906	0.3801	(0.726, 1.130)
Deadline-checklist	-0.00834	0.1129	0.992	0.9411	(0.795, 1.237)
Fraser South (reference)	-	-	-	-	-
Fraser North	-0.0321	0.0914	0.968	0.7249	(0.810, 1.158)
Fraser East	**-0.9144**	**0.1008**	**0.401**	**<.0001**	**(0.329, 0.488)**
Male (reference)	-	-	-	-	-
Female	0.0381	0.0789	1.039	0.6295	(0.890, 1.213)
No Recall	-	-	-	-	-
Received Recall	**-2.5807**	**0.0847**	**0.076**	**<.0001**	**(0.064, 0.089)**
Cohort 1 (reference)	-	-	-	-	-
Cohort 2	0.2064	0.1123	1.229	0.0660	(0.986, 1.532)

Cohort 3	**0.2906**	**0.1133**	**1.337**	**0.0103**	**(1.071, 1.670)**
Cohort 4	0.1931	0.1127	1.213	0.0867	(0.973, 1.513)

A total of 4347 participants (72.85% of sample) and 4961 participants (83.14% of sample) received an immunization during the study period within 17-21 months of age and 17-24 months of age, respectively. In line with previous outcomes, there is no statistically significant effect of the postcards on this outcome for either analysis. Fraser East decreased the odds of having received an immunization compared to control (OR=0.423, 95% CI [0.364, 0.490] for the 21-month analysis, OR=0.401, 95% CI [0.329, 0.488] for the 24-month analysis). For the 21-month analysis, the odds of having received an immunization decreased for all cohorts in comparison to Cohort 1, but only Cohort 2 and Cohort 4 were statistically significant. The decrease in odds associated with Cohort 2 was roughly 14% and for Cohort 4 roughly 26%. (OR=0.866, 95% CI [0.735, 1.020] and OR=0.759, 95% CI [0.735, 1.020], respectively). For the 24-month analysis, the direction of the effect of the cohorts on the outcome differed. The odds of having received an immunization increased for all cohorts in comparison to Cohort 1, but only Cohort 3 was statistically significant. The odds increased by roughly 34% for Cohort 3 (OR=1.337, 95% CI [1.071, 1.670]). Having received the reminder recall at 21 months decreased the odds of having received an immunization by roughly 94% (OR=0.076, 95% CI [0.064, 0.089]).

Table 4. UTD rates and immunization rates by cohort.

	Cohort 1	Cohort 2	Cohort 3	Cohort 4	Total
O1. UTD					
21 Months	0.69	0.65	0.66	0.64	0.66
24 Months	0.76	0.75	0.75	0.74	0.75
O2. Received Immunization					
21 Months	0.76	0.73	0.73	0.70	0.73
24 Months	0.84	0.84	0.83	0.82	0.83

To aid in the interpretation of the impact of the cohort on each outcome, Table 4 displays the UTD rates and immunizations rates within each cohort. As expected, for both outcomes the rates increase from the 21-month analysis to the 24-month analysis within each cohort and in the total sample. For both outcomes, cohort 1 has the highest rates by 21 months and 24 months, however, the differences between rates among the cohorts lessens by 24 months.

Discussion

Our findings do not indicate that the application of a deadline and/or checklist to immunization postcard reminders had an effect on immunization uptake or the UTD status of children compared to the control postcard.

While none of the postcards produced results that were statistically significant, the change in the direction of the effect of the deadline postcard between analyses is of interest. Results from the 21-month analysis suggest the deadline postcard may decrease the odds of being UTD (Table 2a, OR=0.963, 95% CI [0.824, 1.127]) and having received an immunization (Table 3a, OR=0.961, 95% CI [0.813, 1.136]), whereas by 24 months the deadline postcard may increase these odds (Table 2b, OR=1.100, 95% CI [0.906, 1.337] and Table 3b, OR=1.131, 95% CI [0.903, 1.416]). The regression results from the 21-month analysis may be more indicative of the effects of each behaviourally-informed strategy than the 24-month analysis due to its proximity to the postcard delivery and absence of a second reminder to get immunized. However, the emphasis of a deadline on the postcards may have led to a non-significant delay in parents getting their child immunized; in other words, parents were less likely to get their child immunized between 17 months and 21 months and more likely to get their child immunized between 21 months and 24 months. This may point to the importance of sending the reminder closer in time to the deadline: Learning that they had six months until the deadline may have prolonged procrastination. This effect may be partly explained by the anchoring bias which is the tendency for people to most heavily focus on the first prominent piece of information given to them for subsequent decision making and actions.[17] Parents may have focused on the first date given to them, at 2 years of age, instead of noting that they should be immunized BEFORE this time. We speculate that a reminder and deadline that are closer in time may be more impactful. For example, the deadline could emphasize the 18-month birthday to get children immunized with their 18-month booster.

Another interesting result was the effect of the cohort on both outcomes. In the 21-month analysis, cohorts 2, 3 and 4 had a decreased odds of being UTD and having received an immunization compared to cohort 1 as observed in Table 2a and Table 3a. However, by 24 months the effect reversed and cohorts 2, 3 and 4 had an increased odds compared to cohort 1, as observed in Table 2b and Table 3b. While the UTD rate and immunization rate remained highest for cohort 1, cohorts 2, 3, and 4 had a greater increase in rates (9-12%) compared to cohort 1 (7-8%) between 21 months and 24 months and the rates across all cohorts became within 1% of each other. One possible explanation is that those in cohorts 2, 3 and 4 may have had a longer wait time to access an appointment or may have a had a preference for an appointment later in the spring. This would have resulted in immunizations not being given by 21-months, despite intentions to be vaccinated.

A statistically significant finding from the analysis was the impact of the Health Service Delivery Area (HSDA) on immunization. For both the 21-month analysis and the 24-month analysis, residing in Fraser East significantly decreased the odds of having received an immunization (58-60% reduction) and the odds of being UTD (50-53% reduction). This draws attention to the importance of accounting for contextual factors when selecting behaviourally informed strategies. Consideration should be given to the behaviours and attitudes most common and the availability and accessibility of childhood immunization resources within each HSDA so that future messaging can be designed with community-centred behavioural strategies that address specific barriers.

Despite the statistically non-significant results observed among the postcards, there are many lessons to be learned from this study.

Procrastination, forgetfulness, and logistical barriers are common reasons why children in the Fraser Health region are behind in their immunizations.[1] This is especially true when children are due for their 12- and 18-month visits because, by this age, parents have likely gone back to work and immunizations may become a lower priority.[1] The postcards used in our study were designed with these barriers in mind to help parents maneuver the intention-behaviour gap. Our findings indicate that the checklist, intended to ease the process of scheduling an appointment, and emphasis of a deadline did not have an impact over and above the control reminder postcard. Among those who got immunized, it is possible that the reminder itself was enough to encourage vaccination as the intent was already present. For the present study, we do not have the data to determine the effectiveness of the postcard reminder alone on increasing immunization uptake compared to not receiving a postcard reminder. However this consideration is supported by previous research that indicate reminders are an effective strategy for increasing vaccination rates among adults for influenza and COVID-19.[9-14] For example, this finding is comparable to Yokum et al.’s (2018) study that looked at using implementation intentions and other BI strategies in their reminders to older adults for influenza vaccination.[11] They found the reminder, regardless of the BI strategy used, significantly increased vaccination compared to receiving no reminder.[11] They hypothesize that the reminder was sufficient because this high risk, older population was already intent on vaccinating due to encouragement from their physicians.[11] To increase immunization among those still to be vaccinated, perhaps more of our efforts need to be concentrated on other factors influencing the convenience of childhood immunization, such as accessibility, rather than simply altering the ways we remind parents.

Individuals who did not get immunized or become UTD within the study period may represent parents with greater vaccine hesitancy or a larger intention-behaviour gap. With parents who are complacent and perceive the risk of vaccine preventable diseases to be low or lack confidence in vaccines, the intent to immunize their child may be weaker or not present. In a report on the use of behavioural insights in healthcare, Perry et al. (2015) note that the existing intention of an individual to enact a particular behaviour is a very important factor that determines the effectiveness of planning prompts[6]. For such individuals with weak intentions to vaccinate, strategies need to address this lack of intention. Similarly, Clayton et al. (2021) noted that their use of pro-vaccine descriptive social-norms and myth and facts messages was not more effective in encouraging childhood vaccination in their study population of parents compared to receiving no information or a standard public health message, but the effect may be different with a population who is more vaccine-hesitant.[14]

This study adds to the currently limited research on the use of behavioural insights in promoting childhood immunization. The current body of research focuses primarily on adults and older adults for immunizations such as influenza and COVID-19.[9-12, 15] For example, Milkman et al. (2011) investigated the use of implementation intention prompts to encourage influenza vaccination in adults over the age of 50 and demonstrated the effectiveness of this strategy.[12] However, the checklist strategy in our study population of parents was not effective. Vaccine hesitancy may play a larger role when deciding whether or not to immunize their child compared to when making decisions about oneself. Several studies investigating vaccine hesitancy have noted considerations unique to parents, such as scrutiny about health care decision-making for the family from peers and society and the fear of inflicting undue harm to their child.[19-24] Additionally, there are differences in the perceived risks associated with influenza immunization and infection compared to childhood immunizations and diseases. These complexities may help to explain the non-significance of our behaviourally informed strategies in increasing childhood immunizations, despite similar strategies being effective in some studies with other populations and immunizations.[12] Expanding the body of evidence through rigorous study designs such as this quasi-randomized controlled trial is critical for identifying effective BI strategies for increasing childhood immunizations.

Moving forward, it is important to identify strategies that increase the convenience of childhood immunization. One potential strategy could be the use of default, automatically-scheduled appointments, which can increase appointment uptake as people are more likely to stick with an existing appointment rather than reschedule.[7] Chapman et al. (2016) found that patients who received a pre-scheduled appointment had an influenza vaccination rate that was 11% higher than patients who were informed they could book an appointment and 14% higher than patients who did not receive any information.[15] This strategy may also be helpful for providing external reasons to vaccinate for complacent individuals.[4] However, consideration should be taken to ensure or maintain a positive perspective on immunization as there is a risk of people feeling coerced.[15] Another important consideration is that pre-scheduled patients may not show up to appointments or cancel, resulting in wasted time and space in a clinic's schedule, so it is important to consider plans to mitigate such effects.[15] With a schedule already in place to guide childhood immunizations, this strategy could be effective in ensuring that children are UTD and immunized on time. Additionally, Fraser Health currently requires childhood immunizations to be scheduled through the phone. Providing an alternative method for scheduling appointments and reminding parents may improve convenience, such as an online booking platform that can be shared through a QR code on the reminder postcards or distributed via text messages. Moving to an electronic-based strategy may be more in line with today's patterns of media consumption and communications.

Strengths & Limitations

The use of public health information systems allows for comprehensive documentation of public health administered immunization. However, immunizations provided by community vaccine providers such as family physicians may be incomplete in these systems. This is because of the reliance for any immunizations performed outside of the public health units to be submitted to Fraser Health for documentation in public health systems. However, our study timeline should have provided sufficient time for this documentation to be submitted. Due to randomization, this limitation should be evenly spread across intervention arms and is not of major concern. Additionally, with the extension of the analysis to 24 months of age, there were 299 additional immunizations captured. Not all of these immunizations occurred after the 21-month mark however, as this analysis should have accounted for any delays in record submission. Furthermore, the 24-month analysis is aligned with the provincial standards on calculations for UTD immunization status at 2 years of age.

Fraser Health's Spring Immunizations Campaign, which took place from March 7th to May 17th 2022, was occurring alongside this study to help catch children up in the immunization schedule who had fallen behind due to the pandemic. This campaign may have provided more opportunities for this population to get immunized than what is normally available and may have affected each cohort differently. The online-appointment booking system offered during this campaign may have streamlined appointments as well. However, this campaign was not directed towards the 17-month age group and we have adjusted for the potential confounding effect of the different cohorts in the analysis, therefore it unlikely to have had as great of an influence on the outcomes of this study.

The postcards were only designed in English which presents a limitation. The diverse population of the Fraser Health region is home to many immigrants who speak a variety of different languages and may not be skilled in reading English. As of the 2021 census in Surrey, where Fraser Health's central office is located and the most populous area in the Fraser Health region, roughly 35% of the population mostly or only speak a language other than English or French at home.[26] The most common non-official languages spoken at home are Punjabi, Hindi, Mandarin languages, Tagalog (Filipino), and Cantonese.[26] Additionally, with the analysis stretching as far as 7 months past the delivery of the postcard, we cannot be confident the impact of the postcard persisted until these later months.

The COVID-19 pandemic is another limitation to consider. Jurisdictions across Canada have reported reductions in UTD coverage rates. For example, a recent study from Ontario revealed that during 2020, overall UTD coverage for all children dropped as much as 5.7%.[26] The COVID-19 pandemic interferes with a child's UTD status and appointment attendance by limiting opportunities for childhood vaccinations or presenting new barriers for families to start their child on their immunization.

Finally, these results may be generalizable to other regions that also provide publicly funded vaccinations, have similar immunization communication strategies, and have a population with similar vaccine attitudes and behaviours. Further studies are needed to examine the effects of behavioural insights applied to alternative strategies such as text-message reminders or online appointment booking systems.

Conclusion

Our research did not indicate that the application of behavioural insights in the form of a deadline and/or checklist were effective in increasing childhood immunization uptake or UTD coverage. While the checklist and deadline strategies used in our study did not increase vaccination rates more than the control postcard, it is possible the reminder itself was enough to encourage vaccination among those who got immunized. We suggest effort be focused on improving the convenience of childhood immunization. However, this cost-effective and rigorous study contributes to the limited body of research on the use of behavioural insights for increasing childhood immunizations.

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Appendix 1. Experiment Protocol

Overview

Currently, an average of 74% of children in the Fraser Health Authority receive their 18-month immunizations (i.e., immunizations against diphtheria, tetanus, pertussis, polio, and Haemophilus influenza type b). Each month Fraser Health sends postcards to approximately 1,400 families informing them that their 17-month-old child will soon be due for immunizations.

Methods

Over the course of four months from January to April 2022, we will send immunization reminder postcards to approximately 5,600 families with children turning 17 months old. We will use a quasi-randomized controlled trial (RCT) where children are assigned to condition based on their birthdate. Each month for four months, the days are divided into four cohorts and each cohort will receive a specific postcard design (control, deadline, checklist, or deadline + checklist, see Table 1). All postcards will be mailed on the same day each month.

We've chosen to assign children to postcard conditions based on their birthdate cohort because true randomization is not feasible due to the manual mail-out system. Additionally, this will prevent multiple-birth children (e.g., twins) from being in different postcard groups, which would create contamination where some parents are potentially exposed to multiple conditions. Because the study will only be in the field for four months, it is highly unlikely any families will have children in multiple cohorts (i.e., care for multiple children turning 17 months old on different days within four months).

By mailing out all postcards on the same day, we will eliminate history effects that might be present if we mailed out postcards cohort-by-cohort (e.g., a change in the severity of the COVID-19 pandemic affecting the likelihood of different cohorts receiving immunization).

By rotating the postcard each cohort is assigned to each month, we will reduce the impact of systematic differences between cohort (such as children born early in the month being different from children born later in the month, or the deadline working better for children whose immunizations due dates are closer).

Table 1. Cohort Postcard Schedule

Cohort	January 2022	February 2022	March 2022	April 2022
	Postcard Design			
Children with birthdate on the 1st through 7th	Control	Deadline	Checklist	Deadline + Checklist
Children with birthdate on the 8th through 14th	Deadline	Checklist	Deadline + Checklist	Control
Children with birthdate on the 15th through 21st	Checklist	Deadline + Checklist	Control	Deadline
Children with birthdate on the 22nd through 30th/31st	Deadline + Checklist	Control	Deadline	Checklist

Data Plan

The key independent variable (IV) is postcard condition (control, deadline, checklist, or deadline + checklist). Participants will be randomly assigned to condition by their birthdate cohort (per Table 1).

The key dependent variable (DV) is whether a child receives their required 18-month immunization. This will be recorded by Fraser Health.

The data team will be able to connect the IV and DV because they will be linked by the child's birthdate.

Ethical Considerations

This experiment design does not inform families that they are taking part in an experiment. This should not pose an ethical concern because 1) families already receive reminder postcards; 2) the intervention is relatively light touch (i.e., changes to postcard wording and design); 3) no additional data is collected; and 4) no identified data will be shared and only aggregate data will be reported.

Procedure for Each Month

1. The Central Immunization Admin Team gets cohort postcard schedule for the current month from Rebecca Haber (see Table 1).
2. Central Immunization Admin Team pulls information from PARIS for all children turning 17 months.
3. Central Immunization Admin Team organizes list by birthdate to separate the children into four cohorts (see Table 1).
4. Central Immunization Admin Team prints address stickers for each child.
5. Central Immunization Admin Team affixes stickers to postcards according to cohort postcard schedule for the current month.
6. All postcards are mailed on same day (across all versions of the postcard).
7. Central Immunization Admin Team saves list of children who received postcards each week (excel file).

Appendix 2. Cohort birth dates, mailing dates, and postcard design

Cohort	**January 2022** Mail Jan 19	**February 2022** Mail Feb 16	**March 2022** Mail Mar 16	**April 2022** Mail Apr 20
	Birthdate & Postcard Design			
Cohort 1 Children with birthdate on the 1st through 7th	August 1-7 2020 Control	Sept 1-7 2020 Deadline	Oct 1-7 2020 Checklist	Nov 1-7 2020 Deadline + Checklist
Cohort 2 Children with birthdate on the 8th through 14th	August 8-14 2020 Deadline	Sept 8-14 2020 Checklist	Oct 8-14 2020 Deadline + Checklist	Nov 8-14 2020 Control
Cohort 3 Children with birthdate on the 15th through 21st	August 15-21 2020 Checklist	Sept 15-21 2020 Deadline + Checklist	Oct 15-21 2020 Control	Nov 15-21 2020 Deadline
Cohort 4 Children with birthdate on the 22nd through 30th/31st	August 22-31 2020 Deadline + Checklist	Sept 22-30 2020 Control	Oct 22-31 2020 Deadline	Nov 22-30 2020 Checklist