



TEXAS A&M UNIVERSITY

Mays Business School

Humana®

Humana - Mays
2021 Healthcare Analytics
Case Competition

Humana members' Covid-19 vaccination propensity prediction

Team Govax!

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Agenda

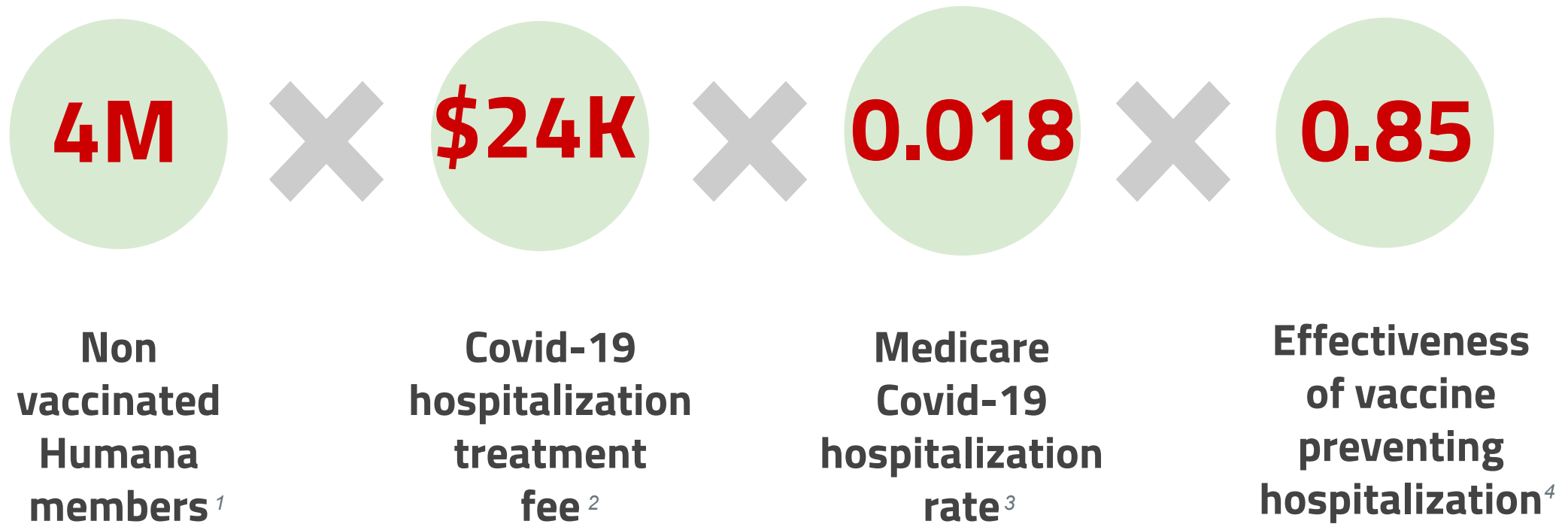
- **Social and business background**
- **Modeling approach**
- **Business recommendations**



We need to get vaccinated as soon as we can so we can prevent the spread of COVID-19, which will also prevent the emergence of variants. It's a race between vaccination and variants.

<https://www.yalemedicine.org/news/herd-immunity>

Full vaccination to all members will save Humana \$1.5B



1. Total Medicare members * fully vaccination rate (March 2021)

2,3 [Centers for Medicare and Medicaid Services \(CMS\) Report](#)

4. CDC's average effectiveness preventing hospitalization for Pfizer, Moderna and Johnson & Johnson

Our recommendations are:

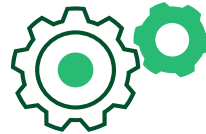
- 1 At home vaccination**
- 2 Telehealth**
- 3 Community engagement**
- 4 Health providers connection**

Three step iterative modeling approach:



Data ingestion and cleaning

- Customized data imputation method for most important features



Research and Feature Engineering

- Segment important features, and regroup unrepresentative categorical features



Model Selection and Hyperparameters Tuning

- Early stopping technique to cross validate 7 hyperparameters - improved efficiency



Data ingestion and Cleaning

Dataset information

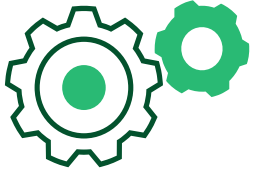
- 970k member records in training dataset
- 360+ features

Data cleaning and pre-processing

- Handle data type inconsistency
- Impute missing values with customized methods to reduce bias introduced

Analyze and cluster features

- Research on original features
- Aggregate, and segment features based on research



Research and Feature engineering

Regroup unrepresentative categorical features in one-hot encoding

- Reduce noise and resolve collinearity

Subset and segment the important features into 3 categories

- Population demographics (eg. age, income)
- Resource accessibility (eg. nearby vaccination site)
- Pharmaceutical claims (eg. spendings on drugs)

Generate 2500 + new features

- Feature transformation, feature combination
- Attempt: AutoFeat, FeatureTools



Model selection and Hyperparameters tuning

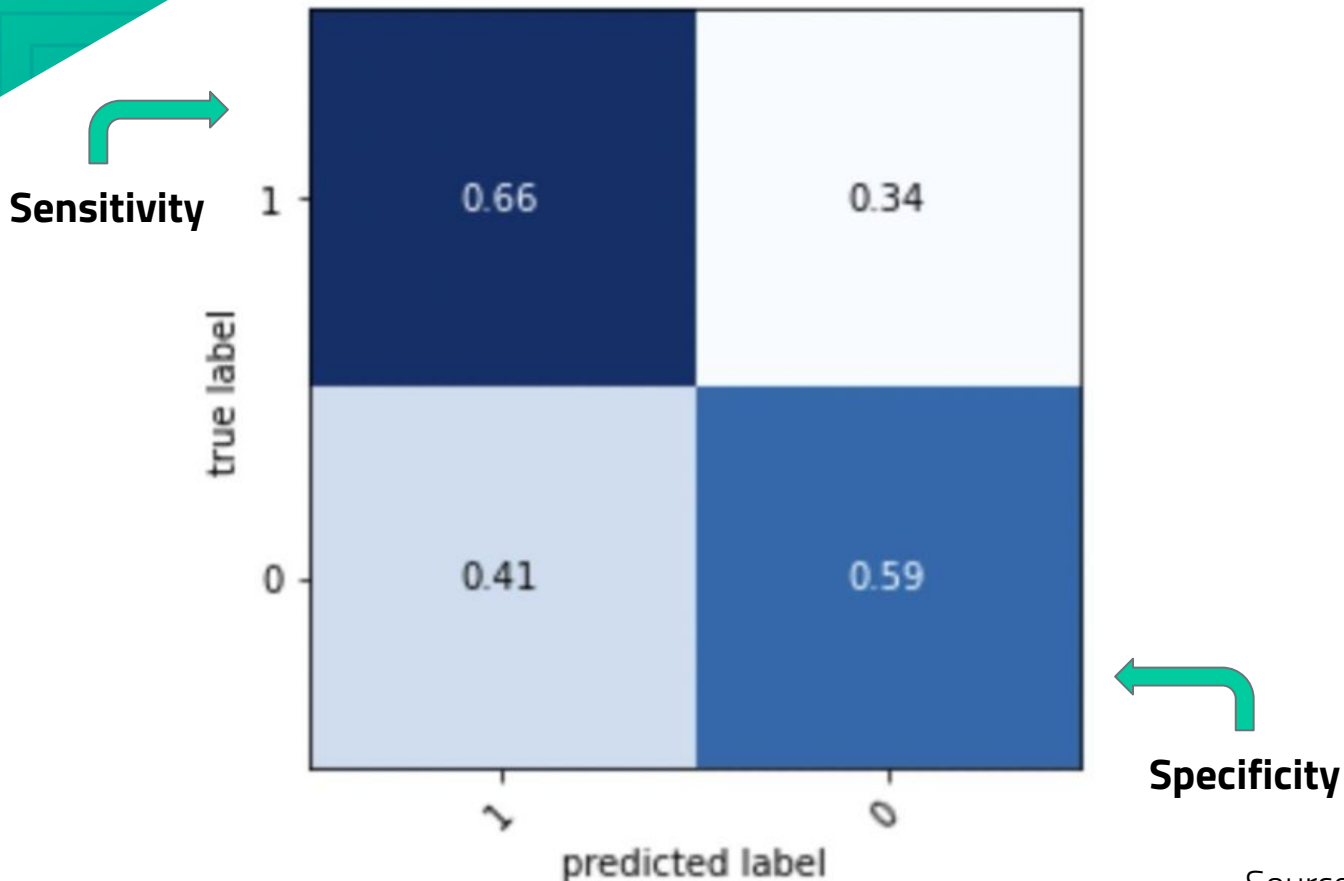
Final model - XGBoost

- Clever tree-based penalization, extra randomization parameter, captures non-linear relationships
- Vast amount of tuning parameters
- Automatic feature selection - from 3000+ down to 200+
- Compared against Random forest, lasso regression, logistic regression

Fine tuning hyperparameters

- Max depth, gamma, reg alpha, reg lambda, colsample by tree, min child weight, n estimators
- Early stopping technique to improve efficiency
- Improved model AUC score by **10%**

Average model performance and insignificant disparity across races



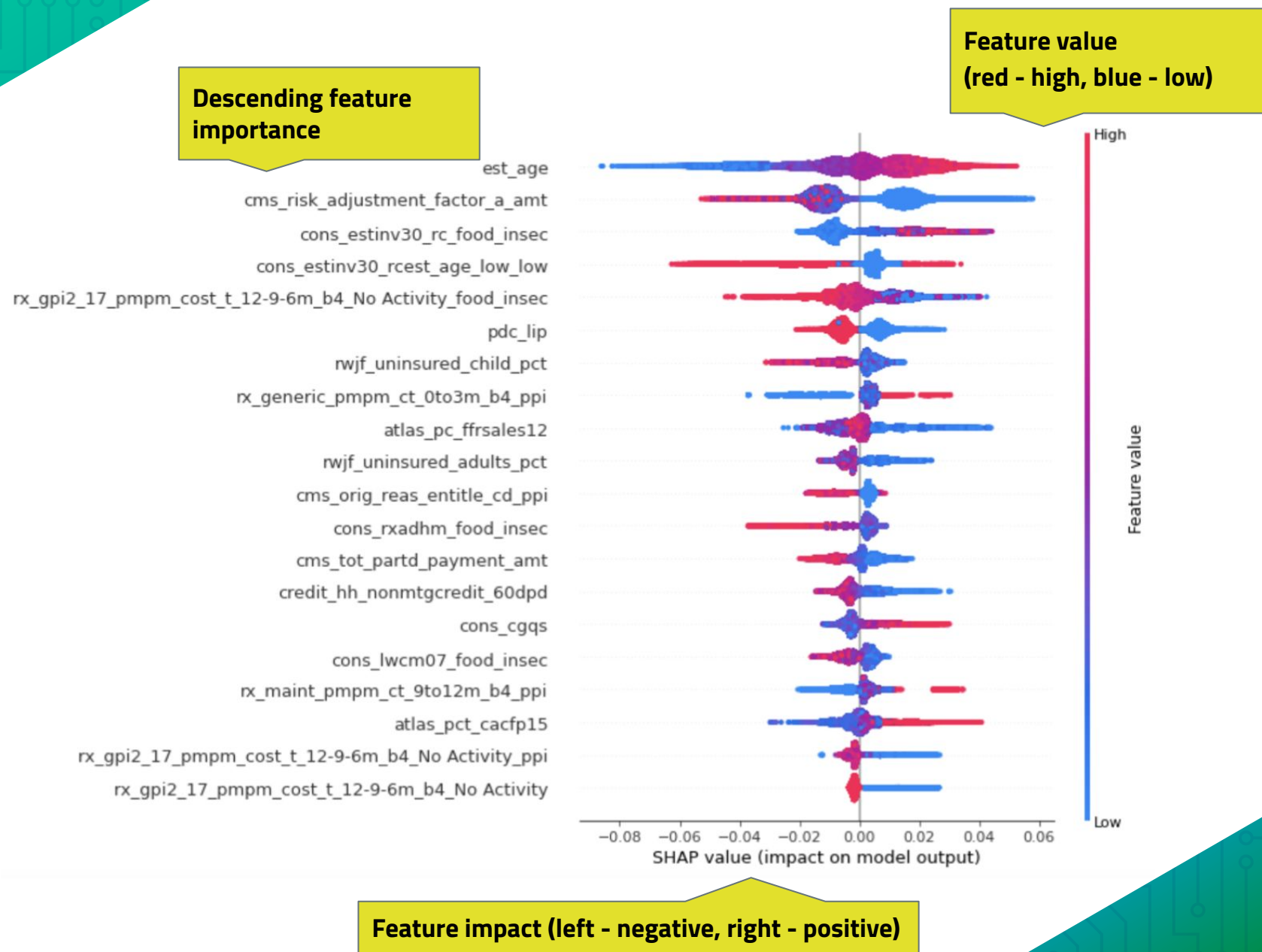
Average predictive power

- AUC score of 0.67
- Average sensitivity and specificity
- Room for improvement

Low model disparity

- Disparity ratio of 0.99
- Model output suggests insignificant difference between racial and gender groups

The SHAP summary plot shows top important features and feature effects...



...which reveals the characteristics of unvaccinated members

Young and disabled

58% of members younger than 67 are disabled, and most of them are unvaccinated



High health risk

If a member already has high health risks, they will be more reluctant to get Covid vaccinated



Living in highly uninsured areas

Populations living in highly uninsured areas are more unlikely to receive Covid vaccination



Fewer household assets

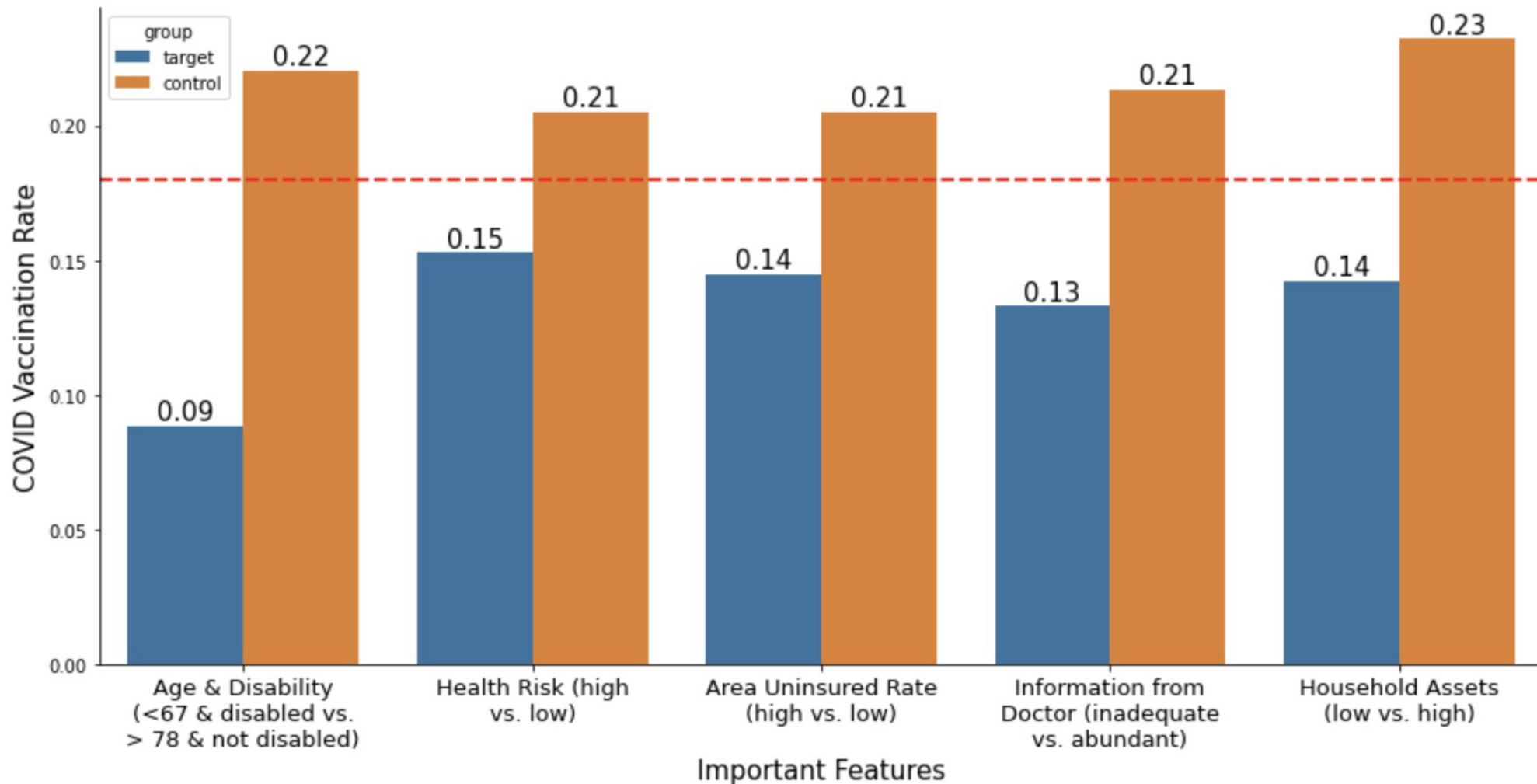
People with low household investable assets will be hesitant in receiving vaccination



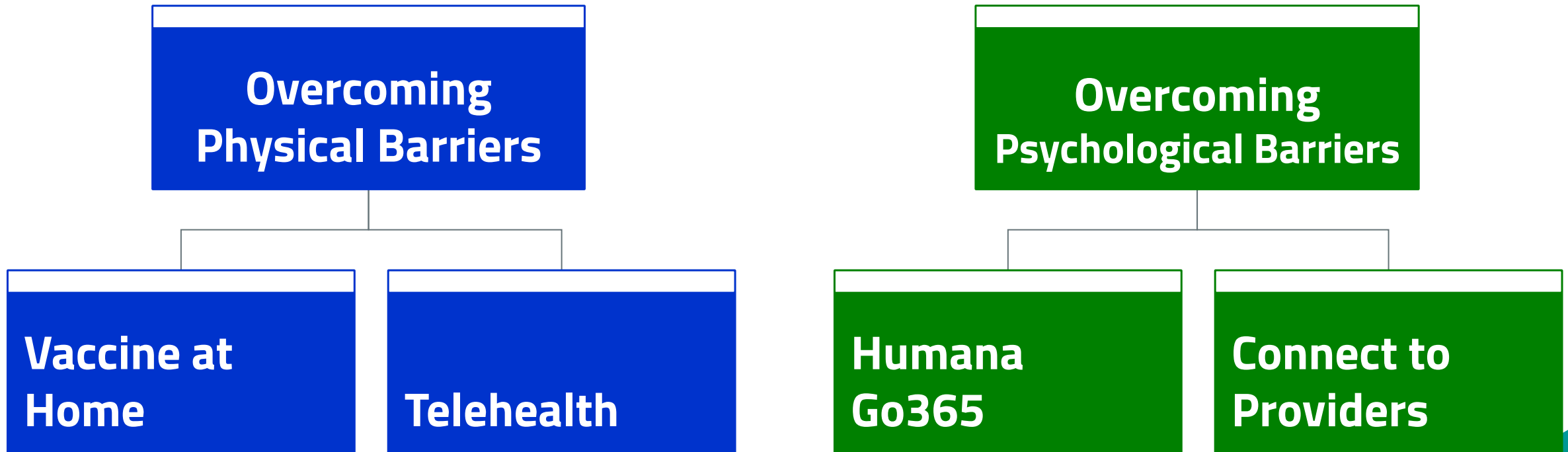
Infrequent use of doctors' information

If individuals are reluctant to use doctor/physician as a primary source for medical information, they won't be likely to get vaccinated

A closer statistical look at Covid vaccination rate for our top 5 important features



There are two categories for recommendations to overcome vaccine hesitancy



People with disabilities can overcome physical barriers by **Vaccine at Home**

Vaccine at Home

Who People with disabilities
— **25%** among members

Where At Home
By **Visiting Caregivers**

How Contacting members
Making reservations



Internal values



\$37M Net Savings per 100K people

Costs: \$150 per person for in home vaccine

Savings: \$375 per person as preventable reimbursements

External values



Strong **government support**



Satisfy medical facilities-avoidant customer

Future work: Vaccine at home costs \$70 more than vaccine at medical facilities.

→ Eligibility matters, and it can be combined with Telehealth to reduce costs.

Telehealth enables outreaching reluctant members and provides improved access at lower costs

MyHumana Mobile App

Find vaccine-available providers
Push alert

Virtual Visits

Check side effects
Offer virtual visits

Personalized Nudge

Recommendations
Complications based on member's health status

Further Application

Apply to other immunizations
Lifelong Vaccine Map

Expected values



Easier access and continuous care^{1, 2}
→ Customer Satisfaction



Virtual visit costs **50% less** per visit¹
→ benefit members with **lower assets**



Telehealth Industry is growing rapidly

Annual revenue growth **8.3%** (2020-2025)³

Estimated smartphone users **311M** (2025)

Aging and chronic diseases in Medicare

1. Health Affairs, 2017, average cost of virtual visits: \$79, office visits: \$146
2. 2021 ACSI Survey, Quality & Reliability of mobile app
3. IBIS, Statista

Humana Go365 can increase members' willingness to get the vaccine

Rewards on COVID-19 Vaccination

Higher vaccine hesitancy &

Higher risk members

(risk factor, chronic disease, obesity)¹

→ **Incentive to get vaccine** by rewards

Community Activities

Vaccine Representatives

Advertisement in Go365 activities

→ **Engaging communities**

Expected values



Reach out to members at **Higher Risk**

\$24,000 – Hospital Stay (Covid treatment cost)

\$115,497 – With ICU or Ventilator²



Vaccination rates increased by **8%**

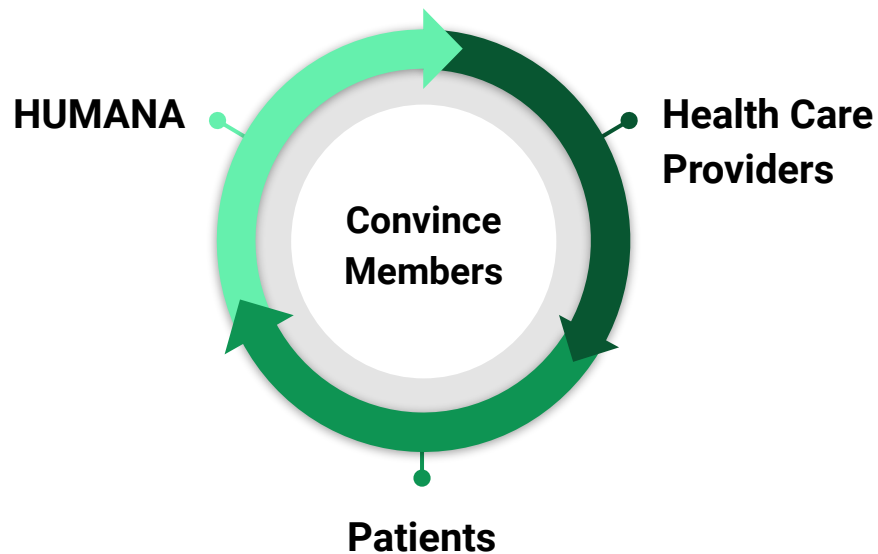
– lottery, gift cards, vouchers (by CDC study)³



Decisions to vaccinate **were influenced by social circles' action** (by flu study)⁴

1. CDC
2. Fair Health Study:
3. CDC, Community Preventive Services Task Force conducted a systematic review 2015
4. Building Vaccine Confidence Through Community Engagement 2020

Doctors' direct recommendations can boost vaccine acceptance



Members with High Risk & Living in Uninsured Areas

- Campaign for doctors
- Suggest members talk to doctors

Expected values



Patients using **doctors as a primary source** for medical information are **more vaccinated**



Providers' recommendations were significantly associated with influenza vaccination ¹



82% of reasons for vaccine hesitancy is related to **side effects, safety, mistrust** ²

→ Relieve members' concerns

1. Association of provider recommendation and offer and influenza vaccination

2. Medicare Current Beneficiary Survey (MCBS) COVID-19 Fall 2020

Summary

XG Boost model



**Identify important Covid
vaccine hesitancy
characteristics**

- 1 At home vaccination**
- 2 Telehealth**
- 3 Community engagement**
- 4 Health providers connection**

THANK YOU



Appendix

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Appendix 1

Index	Subject	Number	
A	Fully Vaccination rate (March 2021)	13.04	
B	Number of Humana Medicare Advantage Members (2020)	4,600,000	
C	Number of Fully Vaccinated Members	600,000	$A*B$
D	Number of Not Fully Vaccinated Members	4,000,000	$(1-A)*B$
E	Average Medicare fee-for-service COVID-19 hospitalizations	\$24,000	
F	Medicare Covid Hospitalizations per 100K	1,825	
G (*)	Effectiveness of full vaccination for preventing hospitalization	0.85	
H	Preventable Costs of Unvaccinated COVID-19 Patients	\$1,489,200,000	$D*E*G*(F/100,000)$

A. CDC, The New York Times

E, F. Centers for Medicare and Medicaid Services (CMS) Medicare COVID-19 Data Snapshot Overview, April 2021

G. CDC Morbidity and Mortality Weekly Report, August 2021

*Among adults aged ≥ 75 years, the effectiveness of full vaccination for preventing hospitalization was 91% for Pfizer-BioNTech, 96% for Moderna, and 85% for Johnson & Johnson COVID-19 vaccines(CDC). We will use 85%, the lowest.

Appendix 2

Customized data cleaning and imputation example

Z	Description	Importance	Categories	Need to ask again	Data type	Percentage of Missing Value	Filling Method
lang_spoken_cd	Preferred language for member	high	Demographics	language	object	74.18	drop?
mabh_seg	MAPD behavioral segment - text categories	high			object	64.93	drop?
hedis_dia_hba1c_ge9	Binary flag without applying all Diabetes HEDIS eligibility criteria indicating if evidence for HBA1C test is greater than or equal to nine in the past one year		Lab claims	Diabetes	object	32.03	0/1
cons_hhcomp	Household Composition	high	Demographics		object	20.48	0/1
cons_rxmaint	RX Maintenance Meds				object	20.47	mean
cons_mobplus	Mail Order Buyer				object	20.47	0/1
bh_ip_snf_net_paid_pmpm_cost_9to12m_b4	net paid cost per month for behavioral health claims related to skilled nursing inpatient facilities in the past ninth to twelfth month prior to the score date		Medical Claim	IP	object	16.18	median
bh_ip_snf_net_paid_pmpm_cost_3to6m_b4	net paid cost per month for behavioral health claims related to skilled nursing inpatient facilities in the past third to sixth month prior to the score date		Medical Claim	IP	object	3.72	drop
total_med_allowed_pmpm_cost_9to12m_b4	allowed cost per month for non-behavioral health claims in the past ninth to twelfth month prior to the score date		Medical Claim		int64	16.22	median
rwjf_resident_seg_black_inx	Social and Economic Factors - Residential segregation - black/white	high	Demographics		int64	7.98	median
atlas_veg_acrespth12	Vegetable acres harvested/1,000 pop		Consumer	farm	int64	6.09	median
atlas_farm_to_school13	Farm to school program		Consumer	farm	int64	1.70	0/1

Appendix 3

XGBoost Hyperparameters Glossary

- **Max_depth**: the maximum depth of each tree in the model. This is usually one of the most common and important hyperparameters in tree-based models as high values are often associated with overfitting, and it's also a measure of model complexity.
- **Gamma**: the minimum error or loss reduction for a leaf node to develop into new branches. The larger gamma is, the more conservative the algorithm will be, and the fewer depth each tree would develop.
- **Reg_alpha**: an L1 regularization term on weights (similar to Lasso regression). Can be used to reduce high dimensional data and as a form of feature selection in the model. A high alpha would result in a more conservative model.
- **Reg_lambda**: L2 regularization term on weights (similar to Ridge regression). Similar to alpha, lambda can be used to regularize the model.
- **Colsample_bytree**: a subsampling hyperparameter that occurs whenever a tree is constructed, which takes the subsample ratio of columns.
- **Min_child_weight**: the minimum sum of weights of all observations required in a child. It's a threshold to prune branches from a large tree. This is a regularization hyperparameter used to control overfitting and generalize the model.
- **N_estimators**: the number of trees in each model. A large number of trees for the model could lead to a longer training time but lower variance.

Appendix 4.1: Feature explanations

Important Features	Explanation
est_age	Member age {calculated using est_bday, relative to score/index date}
cms_risk_adjustment_factor_a_amt	Risk Adjustment Factor
rx_generic_pmpm_cost_6to9m_b4_food_insec	`Cost per month of prescriptions related to generic drugs in the past sixth to ninth month prior to the score date` / `Household food insecurity (% , three-year average), 2013-15: mean`
cons_estinv30_rcest_age_low	Estimated Household Investable Assets (< the first quartile) + est_age (< the first quartile)
rx_gpi2_17_pmpm_cost_t_12-9-6m_b4_No Activity_food_insec	`The trend of cost per month of prescriptions related to VACCINES drugs in the past sixth to the ninth month versus ninth to the twelfth month` / `Household food insecurity (% , three-year average), 2013-15: mean`
pdc_lip	Proportion of days covered for prescriptions related to hyperlipidemia in the past one year
rwjf_uninsured__child_pct	Clinical Care - Percentage of children under age 19 without health insurance
rwjf_uninsured_adults_pct	Clinical Care - Percentage of population under age 65 without health insurance
rx_generic_pmpm_ct_0to3m_b4	Count per month of prescriptions related to generic drugs in the past three months prior to score date
cons_lwcm07	The probability of the individual being less likely to use doctor/physician as a primary source for medical information

Appendix 4.2: Feature explanations

Important Features	Feature Explanation	Ratio Calculation	Results
Age < 67 with Disability	`est_age` < first quartile value (67) and `cms_orig_reas_entitle_cd` ==1	12951 / (12951 + 133850)	8.82%
Higher Health Risk	`cms_risk_adjustment_factor_a_amt` >= third quartile value (0.756000)	35851 / (198957 + 35851)	15.27%
Area with Higher Uninsured Rate	`rwjf_uninsured_adults_pct` >= third quartile value (0.171413)	34738 / (34738 + 205319)	14.47%
Inadequate Information from Doctor	`cons_lwcm07` >= third quartile value (0.28487)	25767 / (25767 + 167959)	13.30%
Less Household Assets	`cons_estinv30_rc` < first quartile value (2500)	38820 / (38820 + 233961)	14.23%

Appendix 4.3: Feature explanations

Important Features	Feature Explanation	Ratio Calculation	Results
Age>78 without Disability	`est_age` > third quartile value (78) and `cms_orig_reas_entitle_cd` !=1	51097 / (51097 + 180783)	22.04%
Lower Health Risk	`cms_risk_adjustment_factor_a_amt` <= first quartile value (0.000000)	89029 / (89029 + 344986)	20.51%
Area with Lower Uninsured Rate	`rwjf_uninsured_adults_pct` <= first quartile value (0.087093)	89036 /(89036+ 345017)	20.51%
Proper Information from Doctor	`cons_lwcm07` <= first quartile value (0.186320)	43863 / (43863 + 161851)	21.32%
More Household Assets	`cons_estinv30_rc` > third quartile value (375000.000000)	52233 / (52233+ 172804)	23.21%

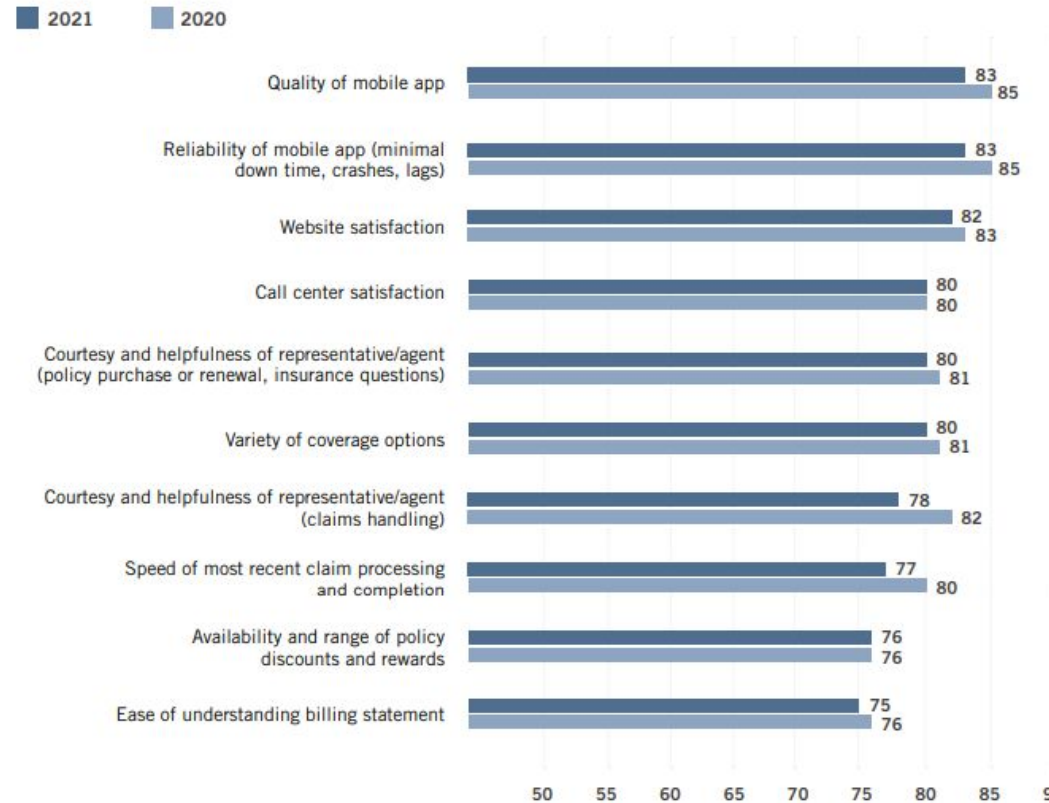
Appendix 5

Medicare COVID-19 Vaccine Shot Payment(CMS)

- Approximately \$40 to administer each dose of the COVID-19 vaccine, including additional doses and booster doses
- Effective on August 24, 2021, Medicare pays the additional payment amount (approximately \$35 per dose administered)

ACSI Survey

PROPERTY & CASUALTY INSURANCE Customer Experience Benchmarks Year-Over-Year Industry Trends



Appendix 6

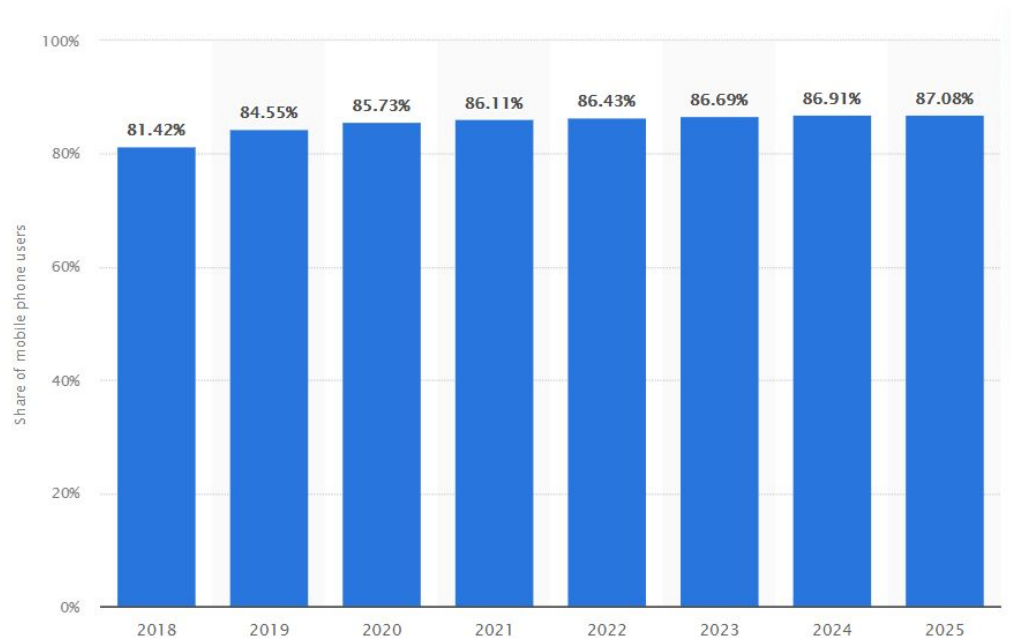
Number of Smartphone Users

Number of Smartphone Users in the U.S: **294.15M** (2020)

Smartphone penetration rate in the U.S: **85.7%** (2020)

Estimated Number of Smartphone Users in the U.S: **311M** (2025)

Estimated smartphone user penetration rate: **87%** (2025)



Medicare Beneficiary Survey(MCBS)

Forgone Care

- **8%** of Beneficiaries needing health care reported **forgo due to pandemic**
- The most commonly reported type of forgone care was a **regular check-up(36%)**
- The most common reason the beneficiary decided to forego care **was not wanting to risk being at a medical facility(49%)**

Virtual visits

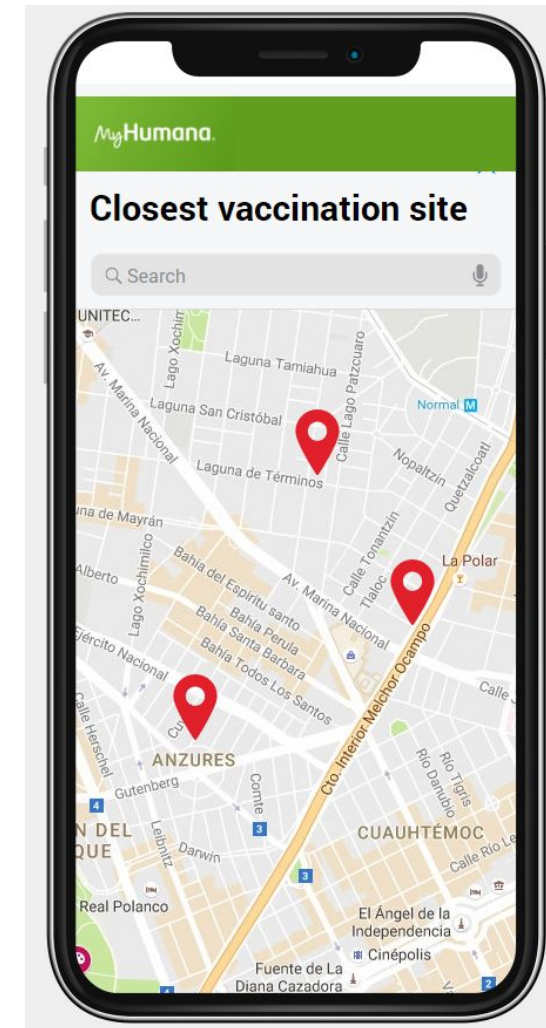
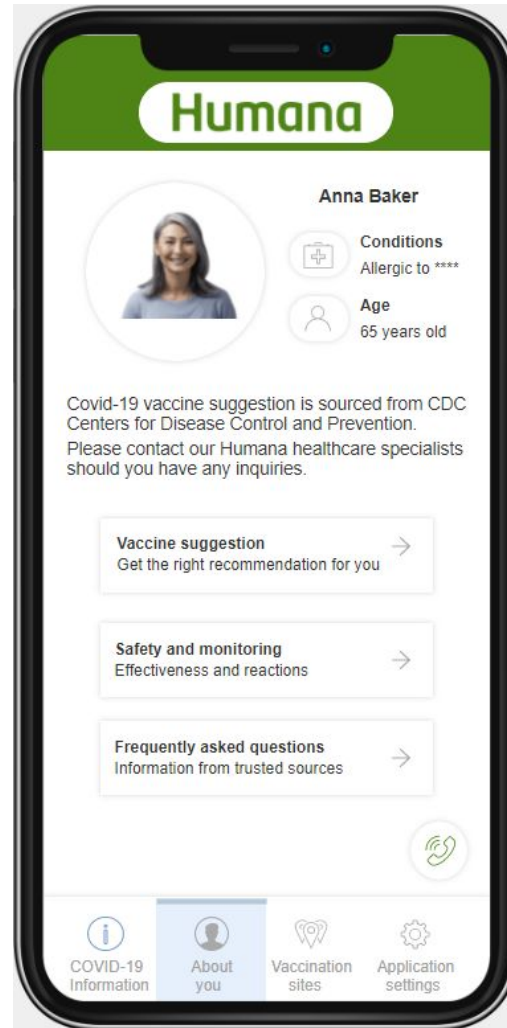
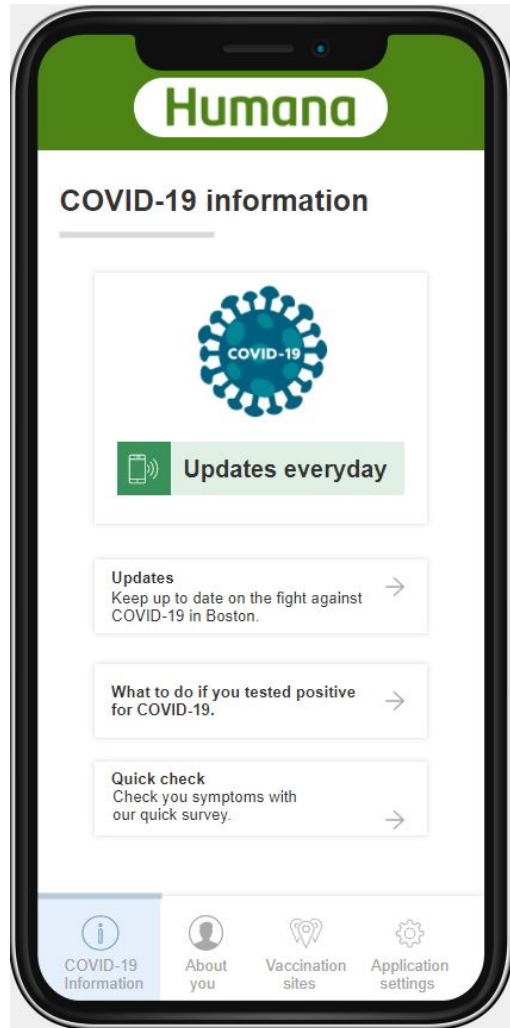
- **61%** reported that their provider offers **both telephone and video appointments**
- **48%** reported their provider **replaced to telemedicine appointment**

Access to technology

- **83%** of beneficiaries reported having **access to internet**
- **Smartphones are the most commonly used type** of technology among beneficiaries(**70%**)

Appendix 7

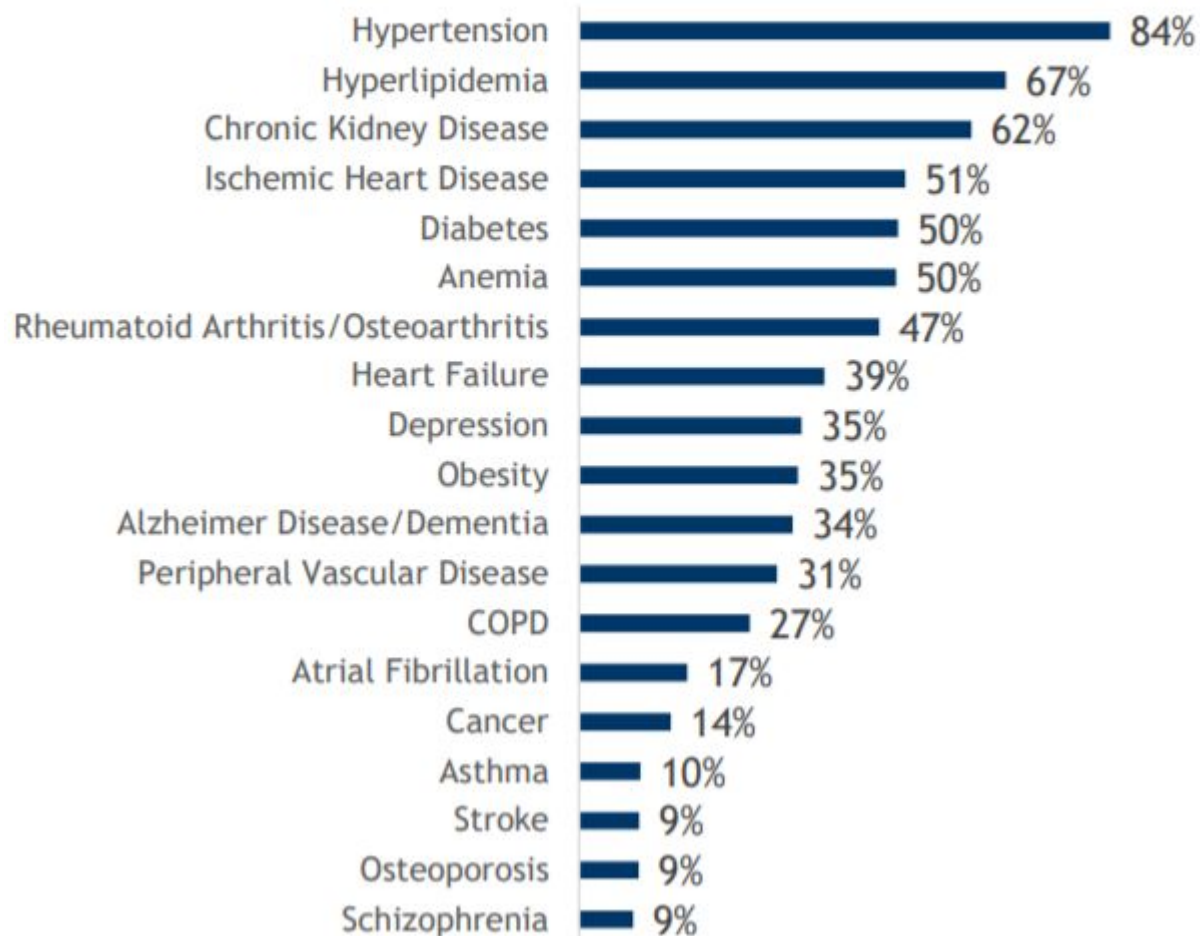
Visualization of Mobile app



Appendix 8

People more likely to get severely ill from COVID-19

Chronic Condition Prevalence Among Fee-for-Service COVID-19 Hospitalized Beneficiaries



CDC

- Older adults are more likely to get severely ill from COVID-19. More than 81% of COVID-19 deaths¹ occur in people over age 65.
- The risk of severe COVID-19 increases as the number of underlying medical conditions increases in a person
- Cancer
- Chronic Kidney Disease
- Chronic Lung Disease
- Diabetes
- Obesity

Appendix 9

Office of Inspector General - Vaccine Rewards

Would the offer or provision of cash, cash-equivalents, or in-kind incentives or rewards to Federal healthcare programs beneficiaries who receive COVID-19 vaccinations during the public health emergency violate OIG's administrative enforcement authorities?

In the limited context of the COVID-19 public health emergency, a health care provider, supplier, or managed care organization **offering or providing a reward or incentive in connection with the beneficiary receiving the COVID-19 vaccine (either one or both doses) would be sufficiently low risk under the Federal anti-kickback statute and Beneficiary Inducements CMP if the following safeguards were met:** (1) the incentive or reward is furnished in connection with receiving a required dose of a COVID-19 vaccine (which could include either one or two doses, depending on vaccine type); (2) the vaccine is authorized or approved by the Food and Drug Administration as a COVID-19 vaccine and is administered in accordance with all other applicable Federal and State rules and regulations and the conditions for the provider or supplier receiving vaccine supply from the Federal government; (3) the incentive or reward is not tied to or contingent upon any other arrangement or agreement between the entity offering the incentive or reward and the Federal health care program beneficiary; (4) the incentive or reward is not conditioned on the recipient's past or anticipated future use of other items or services that are reimbursable, in whole or in part, by Federal healthcare programs; (5) the incentive or reward is offered without taking into account the insurance coverage of the patient (or lack of insurance coverage) unless the incentive or reward is being offered by a managed care organization and eligibility is limited to its enrollees; and (6) the incentive or reward is provided during the COVID-19 public health emergency.

Reasons for vaccine hesitancy (MCBS)

