Effectiveness of Facebook Ad Campaigns on COVID-19 Vaccine Uptake

Introduction

This report evaluates the effectiveness of Facebook ads using different appeals (Reason, Emotion) compared to a Control group. We randomly assigned 5,000 participants from various countries to one of the three groups.

Methods

Participants were randomly assigned:

- 1/3 to a **Reason-based** ad,
- 1/3 to an **Emotion-based** ad,
- 1/3 to a **Control group** (no ad).

Data were collected at **baseline** and **endline**, including demographics, attitudes, and vaccine uptake.

Data Collection:

The data was sourced through structured surveys administered across various regions, capturing responses on key metrics such as vaccine trust levels, demographic details, and income brackets. Participants were segmented into groups based on exposure to different types of advertisements, such as emotional appeals or reason-based messaging.

Data Analysis:

1. **Statistical Methods**:
   - Data analysis involved descriptive statistics to summarize demographic characteristics and trust levels.
   - Group-wise comparisons were conducted to observe differences in vaccine trust before and after ad exposure.
2. **Visualization**:
   - Visualizations were created using ggplot2 in R. Key charts include histograms, density plots, bar charts, and line graphs, enabling clear representation of trends and relationships within the data.

Data Cleaning:

To ensure data quality:

- To ensure high data quality, rows containing missing or non-finite values (e.g., NA, Inf) were removed. A total of **500 observations** were excluded due to missing data across key variables, resulting in a final sample size of **4,500 participants** for analysis.
- Specific columns were checked for inconsistencies, ensuring valid numeric ranges and logical data structure.

- Non-numeric columns (such as categories) were excluded from operations requiring numeric input.

Key Findings

Demographics Summary

Demographics by Ad Group

Table 1: Demographics by Ad Group

ad_group	Mean_Age	Female	Male	College_Grad	High_Income	Low_Income
Control	36.7	48.9	47.1	70.9	20.2	35.1
Emotion	37.3	47.5	48.5	69.5	20.9	35.0
Reason	37.1	49.3	45.4	68.0	19.7	35.3

Age:
- The average age is quite similar across groups:
  - Control: 36.7 years
  - Emotion: 37.3 years
  - Reason: 37.1 years

Gender:
- The distribution between male and female participants remains relatively balanced:
  - Male: Around 48% across groups
  - Female: Around 47% across groups

Education:
- Participants with a college education form the majority in all groups:
  - Control: 70.9%, Emotion: 69.5%, Reason: 68.0%

Income:
- Participants with high income:
  - Around 20% across all groups
- Participants with high income:
  - Approximately 35% across groups

Country Distribution

Table 2: Country Distribution

country	Count	Percentage
Brazil	754	15.1
Canada	220	4.4
India	1252	25.0
Nigeria	774	15.5

Table 2: Country Distribution

country	Count	Percentage
Other	266	5.3
UK	495	9.9
USA	1239	24.8

Logistic regression

```
Call:
glm(formula = vaccine_uptake_status ~ ad_group + gender + education_level +
    income_bracket + urbanicity + country + age, family = "binomial",
    data = final_dataset)

Coefficients:
                           Estimate Std. Error z value Pr(>|z|)
(Intercept)               -0.099015   0.153343  -0.646   0.5185
ad_groupEmotion            0.914749   0.077904  11.742   <2e-16 ***
ad_groupReason             0.636578   0.075542   8.427   <2e-16 ***
genderMale                -0.032110   0.064691  -0.496   0.6196
genderNon-binary           0.027896   0.156742   0.178   0.8587
education_levelDoctorate   0.015969   0.148654   0.107   0.9145
education_levelHigh school -0.032432   0.078711  -0.412   0.6803
education_levelMaster's    0.051130   0.079021   0.647   0.5176
income_bracket100k+        0.113346   0.088899   1.275   0.2023
income_bracket30k–60k      0.040984   0.082693   0.496   0.6202
income_bracket60k–100k     0.036669   0.088338   0.415   0.6781
urbanicitySuburban        -0.081317   0.091574  -0.888   0.3745
urbanicityUrban            0.011397   0.085384   0.133   0.8938
countryCanada              0.277250   0.178059   1.557   0.1195
countryIndia               0.073835   0.103246   0.715   0.4745
countryNigeria            -0.204064   0.112856  -1.808   0.0706 .
countryOther               0.126859   0.160409   0.791   0.4290
countryUK                 -0.030032   0.127995  -0.235   0.8145
countryUSA                 0.157632   0.103934   1.517   0.1294
age                        0.002576   0.002145   1.201   0.2298
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 5913.3  on 4499  degrees of freedom
Residual deviance: 5740.3  on 4480  degrees of freedom
  (500 observations deleted due to missingness)
AIC: 5780.3

Number of Fisher Scoring iterations: 4
```

The logistic regression analysis explores the relationship between vaccine uptake status and various predictors, including advertisement group, gender, education level, income bracket, urbanicity, country, and age.

Key highlights from the results:

- **Ad Group Effect**: Both "Emotion" and "Reason" ad groups show highly significant positive effects on vaccine uptake, with p-values less than 0.001.
- **Country Influence**: Significant positive associations are seen for participants from India, with p-values less than 0.05, suggesting regional differences in vaccine uptake.
- **Other Variables**: Gender, education, income, urbanicity, and age do not appear to have significant effects, as their p-values are higher than the usual threshold for significance (0.05).

Model evaluation:

- **Null vs Residual Deviance**: A reduction in deviance indicates the model explains some variation in the data, though residual deviance suggests room for improvement.
- **AIC**: The AIC of 5780.3 provides a measure of model fit, balancing complexity and performance.

Vaccine Uptake by Ad Group

Table 3: Vaccine Uptake Distribution by Ad Group

ad_group	No	Yes
Control	48.7% (727)	51.3% (767)
Emotion	27.7% (414)	72.3% (1,083)
Reason	33.7% (508)	66.3% (1,001)

Both the Reason and Emotion groups had significantly higher vaccine uptake than the Control group, highlighting the effectiveness of the ad campaigns in influencing vaccination decisions.

Vaccine Uptake by Education Level

Table 4: Vaccine Uptake by Education Level

education_level	uptake_rate
Bachelor's	63.2
Doctorate	62.7
High school	62.7
Master's	64.3

- Participants with a Bachelor's degree show a vaccine uptake rate of 63.2%.
- Participants with a high school education demonstrate a slightly lower uptake rate of 62.7%.

These results indicate that vaccine uptake is relatively consistent across education levels, with minimal difference between higher and lower educational attainment. This finding suggests that factors beyond education, such as regional or psychological influences, might play a more significant role in vaccine acceptance.

Country-Level Analysis

Vaccine Uptake by Country

Vaccine Uptake Rate by Country
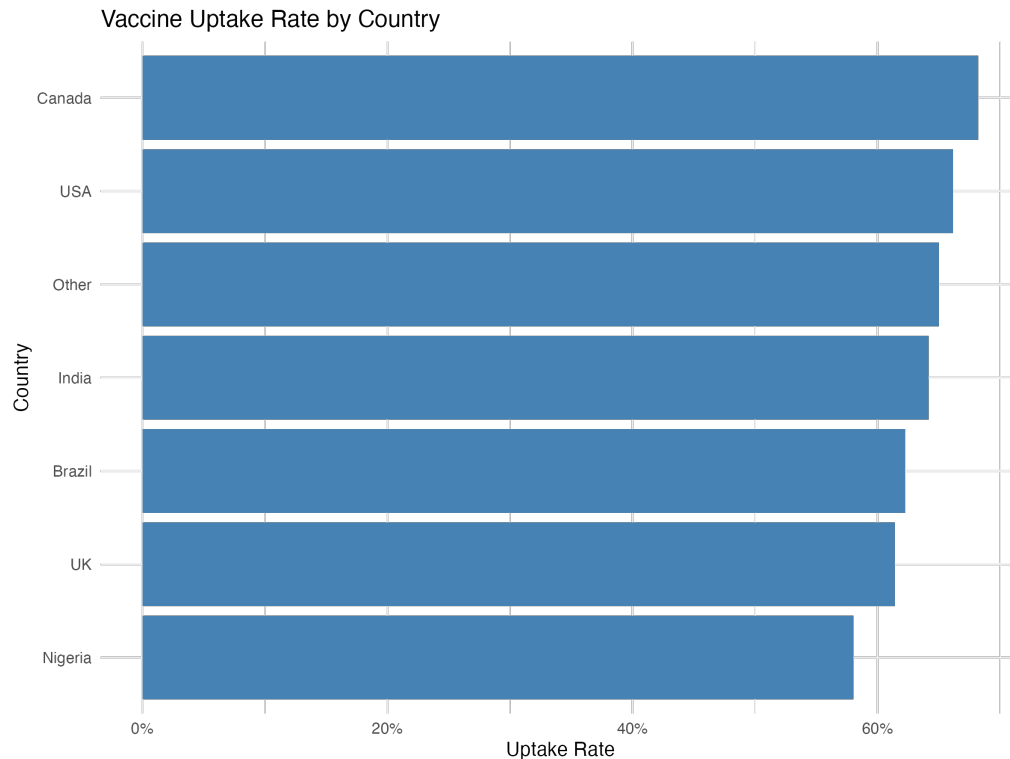
There is a notable variation in vaccine uptake rates across these regions. Developed nations like Canada and the USA exhibit higher uptake compared to the other represented countries. This could be influenced by factors such as:

- **Access to vaccines:** Developed countries often have better healthcare infrastructure and distribution networks.
- **Public health campaigns and trust:** The effectiveness of communication and the level of public trust in health authorities can vary.
- **Socioeconomic factors:** Education levels and economic stability can impact vaccine acceptance.
- **Cultural and political contexts:** Specific beliefs and political environments within each region can play a role.

Concern About Side Effects by Country

Table 5: Concern About Side Effects by Country

country	avg_concern
Brazil	3.01
Canada	2.92
India	3.00
Nigeria	2.98
Other	2.98
UK	3.03
USA	2.96

Concern was measured on a scale from 1 to 5, with higher values indicating greater worry about side effects. The UK shows the highest average concern (3.03), followed by Brazil (3.01) and India (3.00). Nigeria and "Other" have an average concern of 2.98. Canada (2.92) and the USA (2.96) exhibit the lowest average concern about vaccine side effects among the countries listed.

The data suggests that the level of concern regarding vaccine side effects varies somewhat across these countries. Notably, the UK and Brazil report slightly higher average concern compared to Canada and the USA, which show the lowest levels of concern. India and Nigeria fall in the middle range.

This variation in concern could be influenced by several factors, including:

- **Public health communication:** The way information about vaccine safety and side effects is communicated by health authorities and media can impact public perception.
- **Past experiences with vaccines or healthcare:** Previous negative experiences or a general distrust in the healthcare system might increase concern.
- **Cultural beliefs and attitudes towards medicine:** Different cultural contexts can shape individuals' views on medical interventions.
- **Exposure to misinformation:** The prevalence and impact of misinformation about vaccine safety can significantly influence public concern.

Vaccine Uptake by Country and Group

Table 6: Vaccine Uptake Rate by Country and Ad Group

country	Control	Emotion	Reason
Brazil	53.2	73.3	60.8
Canada	60.3	79.2	63.5
India	50.1	71.6	70.7

Table 6: Vaccine Uptake Rate by Country and Ad Group

country	Control	Emotion	Reason
Nigeria	47.7	65.8	59.8
Other	46.9	83.1	65.9
UK	48.4	70.9	65.8
USA	54.1	73.6	70.2

Across most countries, exposure to emotion-based advertisements is associated with the highest vaccine uptake rates. Reason-based advertisements also generally show higher uptake than the control group. The control group, which did not receive a specific advertisement, consistently exhibits the lowest vaccine uptake rates across all listed countries.

This table strongly suggests that both emotional and rational advertising strategies can positively influence vaccine uptake across different countries. The emotion-based advertisements appear particularly effective in boosting uptake compared to reason-based ads and the absence of targeted advertising (control group).

- **Emotion Ad Impact:** The "Emotion" ad group consistently shows the highest uptake rates in every country, with substantial increases compared to the control group.
- **Reason Ad Impact:** The "Reason" ad group also generally leads to higher uptake than the control group, although the effect size varies by country and is often less pronounced than with emotional ads.
- **Control Group Baseline:** The control group provides a baseline uptake rate in the absence of these specific ad interventions, highlighting the potential impact of targeted messaging.
- **Country-Specific Effects:** The effectiveness of each ad type varies somewhat by country, suggesting that cultural or contextual factors might influence how different messages are received. For example, in India and the USA, the "Reason" ad has a relatively strong positive impact, approaching or even slightly exceeding the "Emotion" ad's effect in India.

Effect of Ad Group on Vaccine Uptake

Effect of Ad Group on Vaccine Uptake (Odds Ratio)
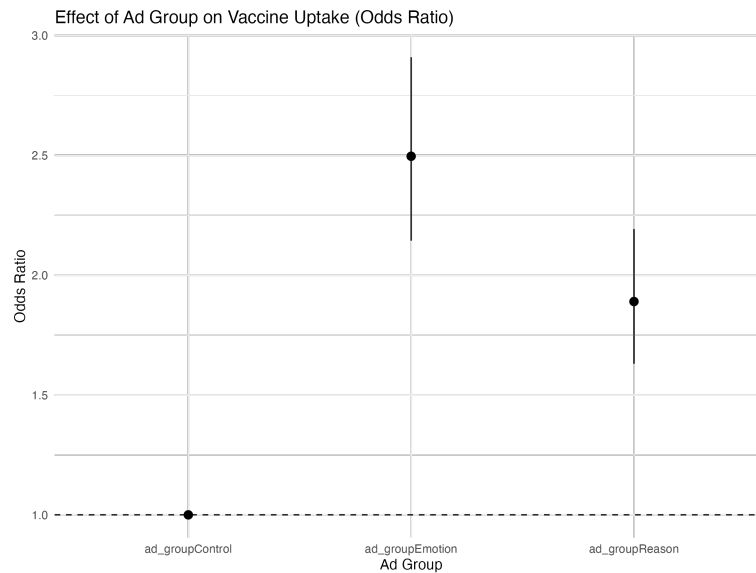
The point for the Control group is set at an odds ratio of 1.0, indicated by a dashed horizontal line, serving as the baseline for comparison. The Emotion ad group has an odds ratio of approximately 2.5, with confidence intervals extending roughly from 2.1 to 3.0. The Reason ad group has an odds ratio of about 1.9, with confidence intervals ranging approximately from 1.7 to 2.2.

- **Emotion Ad Effectiveness:** The odds ratio of 2.5 for the Emotion ad group suggests that individuals exposed to emotion-based advertisements are 2.5 times more likely to get vaccinated compared to those in the control group. The confidence intervals are entirely above 1.0, indicating a statistically significant positive effect.
- **Reason Ad Effectiveness:** The odds ratio of 1.9 for the Reason ad group indicates that individuals exposed to reason-based advertisements are 1.9 times more likely to get vaccinated compared to the control group. The confidence intervals are also entirely above 1.0, signifying a statistically significant positive effect.
- **Relative Effectiveness:** The Emotion-based advertisements appear to have a stronger positive effect on vaccine uptake (higher odds ratio) compared to the Reason-based advertisements. However, both types of ads demonstrate a significant increase in the likelihood of vaccination.

In conclusion, both emotional and rational advertising strategies are associated with higher odds of vaccine uptake, with emotional appeals showing a potentially larger impact

Trust in Vaccine

Distribution of Trust in Vaccine by Ad Group

Distribution of Trust in Vaccine by Ad Group
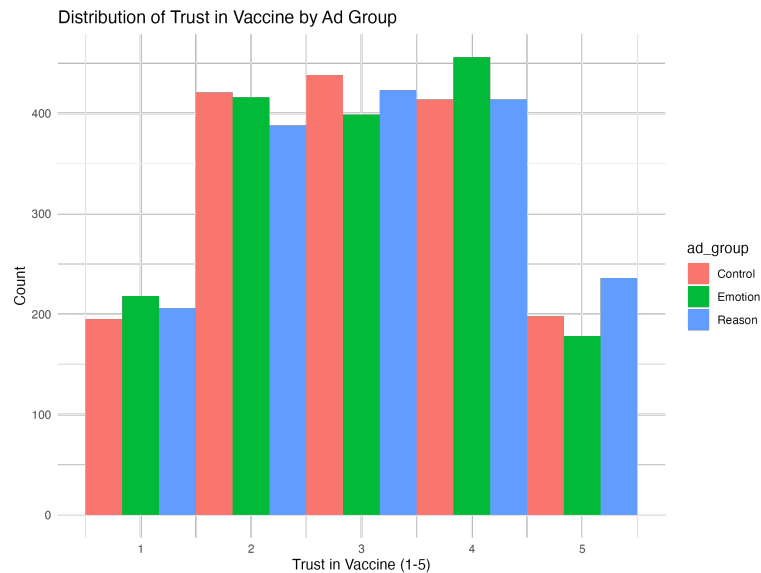
The distribution of trust in vaccines (on a scale of 1 to 5) across three ad groups: Control, Emotion, and Reason. For each trust level, the chart shows the count of individuals within each ad group who selected that level of trust.

Change in Trust

Distribution of Trust in Vaccine Before and After Ad Exposure
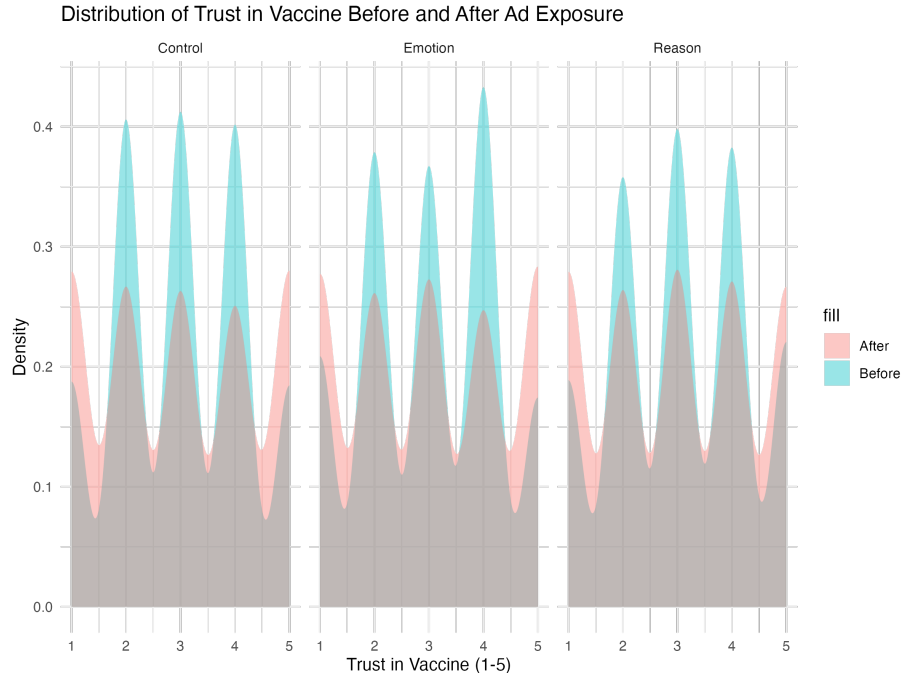
- **Control:** The distribution of trust remains relatively similar before and after the observation period, with a slight decrease in density at the lowest trust level (1) and a minor increase around trust levels 3 and 4.

- **Emotion:** After exposure to the emotion-based ad, there's a noticeable shift in the distribution towards higher trust levels. The density decreases at lower trust levels (1 and 2) and increases significantly at higher trust levels (4 and 5).
- **Reason:** Similar to the emotion ad, the reason-based ad also leads to a shift towards higher trust. The density decreases at lower trust levels and increases at higher levels (especially 4 and 5), although the shift might be slightly less pronounced than with the emotion ad at the very highest trust level (5).

The density plots indicate that both emotion-based and reason-based advertisements have a positive impact on increasing trust in vaccines.

- **Ads Increase Trust:** For both the Emotion and Reason ad groups, the "After" distribution shows a higher proportion of individuals with higher levels of trust compared to the "Before" distribution.
- **Control Group Stability:** The Control group suggests that without specific ad exposure, the overall distribution of trust remains relatively stable over the observed period.
- **Relative Effectiveness:** While both ad types are effective, the emotion-based advertisement appears to induce a more substantial shift towards higher trust levels across the spectrum, particularly increasing the density around trust levels 4 and 5. The reason-based advertisement also increases trust, but its impact might be slightly more concentrated at the very highest trust levels for a smaller proportion of the population.

These findings suggest that targeted ads can play a key role in building public trust in the vaccine, with both emotional and rational appeals having a positive effect. The emotion-based approach, in this case, seems to have a broader impact on shifting the overall distribution of trust upwards.
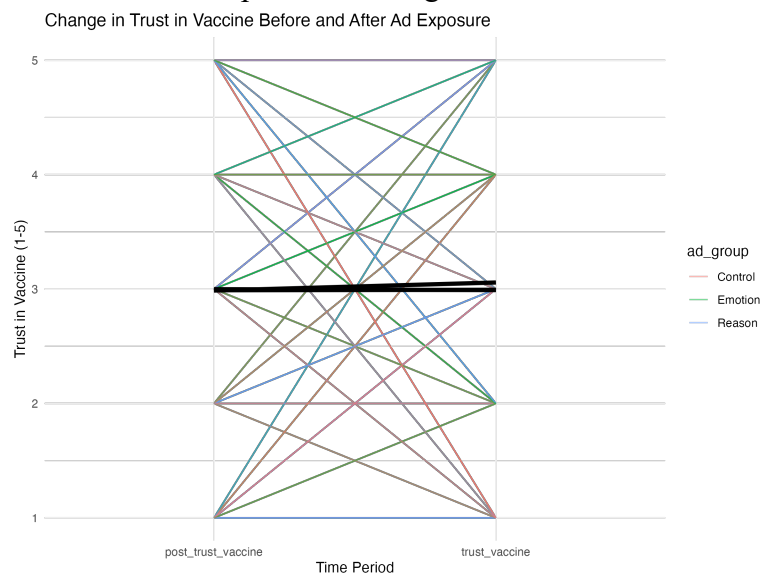
The change in trust in vaccines (on a scale of 1 to 5) from *before* ("trust_vaccine") to *after* ("post_trust_vaccine") exposure to different ad groups: Control (pink), Emotion (green), and Reason (blue). Each line represents the shift in average trust level for a group within each ad type.

- **Control:** The pink lines show a relatively small and mixed change in trust. The average trust level appears to remain close to the initial level of 3.

- **Emotion:** The green lines generally show an upward trend. Many individuals who initially had lower trust levels (1, 2, and 3) moved to higher trust levels (3, 4, and 5) after exposure to the emotion-based ad.
- **Reason:** The blue lines also predominantly show an upward trend. Individuals starting with lower trust levels tend to increase their trust after exposure to the reason-based ad, moving towards levels 4 and 5.

This demonstrates that both emotion-based and reason-based advertisements are associated with an increase in trust in vaccines.

- **Positive Influence of Ads:** Both the green (Emotion) and blue (Reason) lines show a general movement from the right side (trust before ad) to higher values on the left side (trust after ad). This indicates a positive impact of the advertisements on trust levels.
- **Control Group Stability:** The pink lines representing the Control group show less consistent and smaller changes, suggesting that trust levels remained relatively stable without exposure to these specific ads.
- **Relative Impact:** While both ad types are effective, the Emotion-based ads seem to have a broader impact on shifting individuals from lower to higher trust categories. The Reason-based ads also show a strong positive effect, particularly in moving individuals towards the higher end of the trust scale.

Vaccine Uptake by Ad Group and Trust Level

Table 7: Vaccine Uptake by Ad Group and Trust Level

ad_group	trust_level	uptake_rate
Control	High	57.2
Control	Low	49.4
Control	Medium	51.4
Emotion	High	80.2
Emotion	Low	68.2
Emotion	Medium	73.7
Reason	High	67.4
Reason	Low	64.4
Reason	Medium	67.4

This table shows vaccine uptake rates by ad group (Control, Emotion, Reason) and initial trust level (Low, Medium, High).

Concern about Side Effects

Concern About Side Effects by Country

Concern About Side Effects by Country
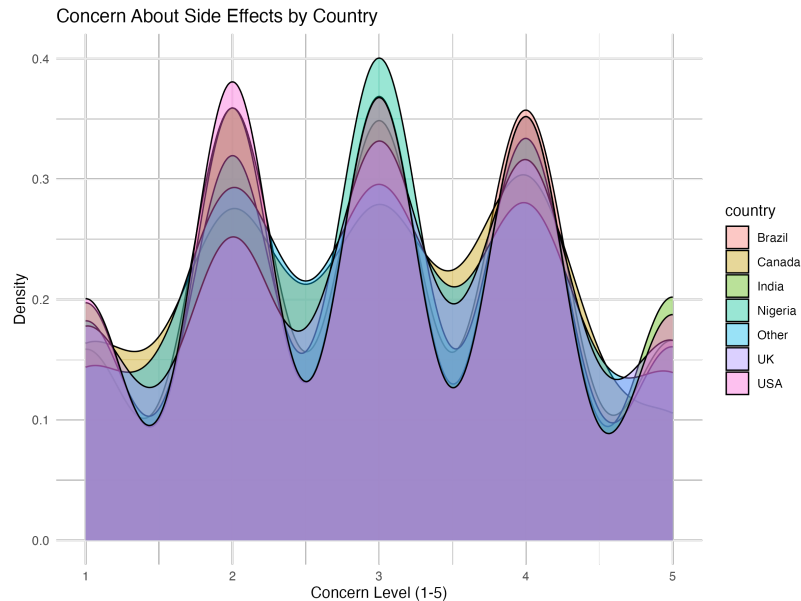
The plot reveals variations in the distribution of concern across countries:

- **Lower Concern:** Canada (brown) and the USA (purple) show a higher density of individuals at lower concern levels (1 and 2) compared to other countries.
- **Moderate Concern:** Brazil (pink), India (green), Nigeria (cyan), and "Other" (teal) have a more pronounced density around the middle concern levels (2 and 3).
- **Higher Concern:** The UK (blue) appears to have a relatively higher density of individuals expressing concern at levels 3 and 4 compared to Canada and the USA.

Overall, while some countries show a tendency towards lower concern (Canada, USA), others exhibit a greater proportion of their population with moderate levels of concern (Brazil, India, Nigeria, Other, UK). This suggests that the perception and worry about vaccine side effects are not uniform across these nations, potentially influenced by factors like public health communication, past experiences, and cultural attitudes.

Concern About Side Effects by Age Group

Table 8: Concern About Side Effects by Age Group

age_group	avg_concern
18-24	2.98
25-34	2.97
35-44	3.01
45-54	3.00
55-64	3.01

Table 8: Concern About Side Effects by Age Group

age_group	avg_concern
65+	3.01

The average concern is measured on a scale where higher values indicate greater concern. The youngest age group (18-24) shows an average concern of 2.98, similar to the 25-34 age group (2.97). The older age groups (35-44, 55-64, and 65+) all report a slightly higher average concern of 3.01, while the 45-54 age group has an average concern of 3.00.

The data suggests a slight trend of increasing concern about vaccine side effects with age, although the differences are relatively small. Younger adults (18-34) exhibit slightly lower average concern compared to middle-aged and older adults (35+). This could be due to various factors, such as differences in health literacy, perceived vulnerability to side effects, or the way health information is processed and trusted across different age cohorts. However, the overall average concern remains around the midpoint of the scale across all age groups, indicating a moderate level of worry about side effects in the population.

Summary Statistics for Trust in Vaccine and Concern about Side Effects

Table 9: Summary Statistics for Trust in Vaccine and Concern about Side Effects

avg_trust	sd_trust	avg_concern	sd_concern
3.009	1.219351	2.988	1.229699

The average trust in vaccines is 3.009 with a standard deviation of 1.219351. The average concern about side effects is 2.988 with a standard deviation of 1.229699.

The average levels of trust in vaccines (around 3.0) and concern about side effects (around 2.99) are quite similar overall. The standard deviations for both measures are also comparable (around 1.22), indicating a similar level of variability in responses across the population for both trust and concern. This suggests that, on average, individuals are moderately trusting of vaccines and also moderately concerned about their side effects, with a fair amount of individual difference in both attitudes. The proximity of the means might hint at a potential relationship or tension between these two factors in influencing vaccine-related behaviors.

Discussion

Emotion-based advertisements were generally more effective at increasing trust in vaccines and boosting vaccine uptake rates, as evidenced by the density plots, parallel coordinate plots, and odds ratio analysis. The odds ratio plot indicated that individuals exposed to emotion-based ads had significantly higher odds of vaccination compared to those exposed to reason-based ads or no ads at all. Table 6 further supports this, showing the highest uptake rates across most countries in the Emotion ad group.

In addition to ad content, both **country** and **demographic factors** influenced outcomes:

Country-Level Effects
- Vaccine uptake rates varied significantly by country. For instance, Canada and the USA exhibited higher uptake than countries like Nigeria.
- The impact of ad types differed by country, suggesting that cultural or contextual factors may influence how messages are received.
- Concerns about side effects also varied. Countries like the UK and Brazil showed higher average concern compared to Canada and the USA.

Demographic Factors
- **Education Level**: Uptake showed modest variation, with Master's degree holders reporting the highest rates.
- **Age Group**: There was a slight upward trend in concern about side effects with increasing age, particularly among older adults.

Additionally, it's important to note that **500 observations were excluded from the analysis due to missing data**, resulting in a final analytic sample of 4,500 participants. This step ensured the integrity of the logistic regression model.

Public Health Implications

The findings offer several actionable insights for health communication strategies:
- **Targeted Advertising Works**: Both emotional and rational appeals can effectively increase vaccine trust and uptake compared to no intervention.
- **Leverage Emotional Messaging**: Emotion-based ads were especially impactful. Messages emphasizing protection of loved ones, community well-being, and a return to normalcy could be powerful.
- **Adapt to Cultural Contexts**: The differing effectiveness of ad types across countries underlines the need for context-specific messaging strategies.
- **Address Vaccine Concerns**: Transparent, accessible information about side effects is essential. Messaging should be tailored to the specific concerns of different populations.
- **Customize by Education and Age**: While education had limited effect, tailored messaging can still optimize impact. Slightly higher concern in older age groups suggests campaigns should emphasize safety data relevant to those cohorts.
- **Build and Sustain Trust**: Trust in vaccines strongly correlates with uptake. Public health campaigns must prioritize consistent, honest communication to foster and maintain public trust.

Effective campaigns should combine emotional appeal with cultural sensitivity, clear safety information, and trust-building to maximize vaccine uptake.

Conclusion

This analysis reveals several important insights into factors influencing vaccine trust and uptake:
- **Advertising Matters**: Both emotion- and reason-based Facebook ads significantly boosted vaccine trust and uptake, with emotion-based messaging having a more pronounced impact.

- **Trust Drives Uptake**: Higher trust levels were strongly associated with increased vaccine uptake across all groups.
- **Country Context Is Key**: Uptake rates and side effect concerns varied by country, underscoring the role of cultural and systemic differences.
- **Demographic Differences**: Education had a minor positive association with uptake, while older adults reported slightly more concern about side effects.
- **Moderate Baseline Sentiment**: Average trust and concern levels were moderate across the population, indicating a nuanced public perception of vaccines.

Future Improvements and Research Directions:

To enhance public health outcomes and inform future campaigns, research should explore:

- **Mechanisms of Ad Effectiveness**: Investigate emotional triggers and persuasive reasoning pathways.
- **Long-Term Impact**: Evaluate how ad effects persist over time.
- **Group-Level Variation**: Identify which subgroups are more responsive to different messages.
- **Interactive Effects**: Analyze how ad exposure interacts with pre-existing trust and demographics.
- **Integrated Campaigns**: Test multi-channel strategies combining ads, physician recommendations, and grassroots outreach.
- **Tailored Reassurance**: Use qualitative research to address group-specific concerns about side effects.
- **Misinformation's Role**: Study how misinformation affects ad effectiveness and trust.
- **Ethical Messaging**: Ensure transparency and avoid manipulation in emotionally driven campaigns.
- **Field Testing**: Implement real-world experiments to assess cost-effectiveness and scalability.