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Referenced Information and Belief Update: Evidence from India

Pedro Hemsley[1] & Lynda Pavão[2]

[1] Institute of Economics, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

[2] Department of Economics, State University of Rio de Janeiro, Rio de Janeiro, Brazil

Correspondence: Lynda Pavão, Department of Economics, State University of Rio de Janeiro, Rio de Janeiro, Brazil. E-mail: lynda.pavao@gmail.com

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Abstract

When an individual receives a piece of information, he decides if and how to incorporate it into his set of beliefs. This is particularly important for referenced information, often used by policymakers as a tool to achieve some form of behavior. In this paper, we ask how individuals update their beliefs about Covid-19 mitigation measures when they receive referenced information about vaccine efficacy and the ineffectiveness of treatments like hydroxychloroquine. If individuals follow some form of Bayesian updating process, belief polarization should either decrease or remain unchanged after individuals are presented to the same piece of information. We test this prediction with an online experiment in which participants are randomly assigned to a treatment group that receives referenced information. Our results show that polarization increased in the treatment group, suggesting that belief update does not follow a pure Bayesian process. This finding calls into question the effectiveness of traditional information dissemination in polarized environments.

Keywords: Belief Update, Bayesian Updating, Polarization, Covid-19, Referenced Information, Decision Making

1. Introduction

In recent years, the dissemination of accurate information has been a major component of public health strategies, especially concerning COVID-19 mitigation measures such as vaccination and treatments. Studies have emphasized the importance of clear and factual communication in enhancing public compliance with health guidelines and combating misinformation (Mheidly & Fares, 2020; Kim et al., 2022; Nan, Iles, Yang & Ma, 2022; Rzymski et al., 2021). However, the actual impact of such information on public opinion is complex, often leading to unexpected or undesired results, such as increased polarization. This paper studies the effects of referenced information on public opinion polarization, in the context of COVID-19.

Polarization in public opinion regarding COVID-19 measures has emerged as a significant challenge during the pandemic. Research has shown that polarization can be exacerbated by a variety of factors, including misinformation, social media dynamics, and political affiliation (Allcott et al., 2020; Kerr, Panagopoulos & Van Der Linden, 2021; Hart, Chinn & Soroka, 2020). Referenced information about vaccines and treatments, while relevant for public health responses, can also become a contentious issue, influencing public opinion in unexpected ways (Bargain & Aminjonov, 2020; Muselli, Cofini, Desideri & Necozione, 2021; Lee, Kang & You, 2021; Moehring et al., 2023; Stephenson-Hunter, Yusuf, Larson, Campanella & Gutnick, 2023).

In the end of the day, the impact of referenced information on polarization and behavior depends on the way people incorporate it to their previous set of beliefs. One way to do this is through some form of Bayesian updating process: individuals have some prior belief about a given subject, attach some weight to a new piece of information, and then use it to form a posterior belief. If this is the case, then any piece of common information should either lead to opinion convergence, or have a non-significant impact.

To investigate the impact of referenced information on beliefs and polarization, we conducted an online experiment with 707 participants from India. Participants were randomly assigned to either a control group or a treatment group. The treatment group received referenced information about the efficacy of vaccines and the ineffectiveness of treatments like hydroxychloroquine, while the control group did not receive this information. This experimental design allows us to identify the impact of referenced information on participants' opinions and the degree of polarization within those opinions.

Our findings indicate that referenced information led to significantly higher polarization. This suggests that providing information on contentious issues can sometimes amplify existing divisions. This counterintuitive outcome aligns with previous research showing that referenced information may increase polarization (Fryer Jr, Harms & Jackson, 2019; Baysan, 2022; Andreoni & Mylovanov, 2012; Nyhan & Reifler, 2010). Moreover, there was no direct impact on the average response of participants: referenced information only dispersed opinions around an unchanged average.

The results suggest that individuals do not use new information as in a Bayesian updating model. Instead, our findings highlight the role of emotional responses and identity-driven biases in shaping how information is processed and internalized (for recent discussions, see Bailey et al., 2024 and Malmendier & Veldkamp, 2022) This suggests that public health communication strategies should consider these psychological and social factors to enhance compliance with health guidelines. By examining the effects of referenced information on polarization, we aim to shed light on the mechanisms that drive public opinion in highly polarized environments and offer insights into more effective communication approaches.

2. Sample and Experimental Design

We conducted an online survey on November 4, 2021, with 707 participants from India, recruited from Amazon's Mechanical Turk (MTurk). The reward for participation was set at US$0.15. Respondents were not permitted to participate more than once, and we only accepted workers who had previous experience and had at least a 90 percent approval rating. The questionnaire design and data collection from respondents were conducted through the Qualtrics platform.

The following text was included in the task announcement on MTurk:

"This survey takes around 5 minutes. We will ask questions on a specific subject. Please read them carefully. This survey is completely anonymous, with no collection of personal data. The results will be used only for academic research."

The study began with participants answering socio-demographic questions via an online link. Next, they were informed about the ongoing global health challenges posed by the COVID-19 pandemic. Participants were then randomly assigned to either the treatment or the control group.

The control group proceeded directly to the final question, rating their agreement or disagreement on the efficacy of vaccines and treatments like hydroxychloroquine and ivermectin against COVID-19 on a scale from -8 ("totally disagree") to 8 ("totally agree").

The treatment group was provided with referenced information asserting the effectiveness of vaccines and the ineffectiveness of treatments like hydroxychloroquine and ivermectin in preventing the spread of COVID-19. This information included citations and links to sources for verification, aiming to provide a factual basis for forming opinions. The control group did not receive this referenced information.

At the conclusion of the survey, both groups responded to the same final questions, evaluating their views on the statements:

Y_1 : There are well-established and effective treatments against COVID-19 (for example, ivermectin and hydroxychloroquine).

Y_2: Vaccines are highly effective to avoid infection and the development of severe symptoms of COVID-19.

The dependent variable Y_j represents participants' responses on the effectiveness of treatments against COVID-19 (ivermectin and hydroxychloroquine) and vaccines, measured on the scale from -8 to 8. The appendix presents the complete questionnaire.

Of the 707 respondents, 19 were excluded due to incorrect responses to a verification question, resulting in a valid sample of 688 subjects. Table 1 presents the descriptive statistics of the sample.

Table 1. Summary Statistics

Panel A			
Variables	Mean	Median	SD
Y_1	3.66	5	3.54
$\|Y_1\|$	4.51	5	2.36
Y_2	4.85	5	2.80
$\|Y_2\|$	5.14	5	2.21
Panel B			
Gender (%)	Full Sample	Treatment	Control Group
Female	32.1	30.4	33.8
Male	67.9	69.6	66.2

Age (%)			
29 or Less	28.6	30.4	26.9
30 to 49	67.2	65.5	68.8
50 or more	4.2	4.1	4.3
Education (%)			
Incomplete High School or Less	0.1	0.3	0.0
High School Graduate	1.9	1.8	2.0
College with no degree	1.6	0.9	2.3
Bachelor's Degree	67.3	71.1	63.6
Graduate Degrees	29.1	26.0	32.1
Employment Status (%)			
Employed	83.1	85.7	80.6
Retired	1.3	1.8	0.9
Student	2.6	3.2	4.0
Unemployed	5.2	4.7	5.8
Not Formally Employed	2.3	1.8	2.9
Other/Prefer not to answer	5.4	2.9	5.8
Political Spectrum (%)			
Left	4.5	4.1	4.3
Center	32.6	31.9	33.2
Right	62.9	64.0	62.4
Observations	688	342	346

3. Results

To examine the impact of referenced information on opinion formation about ineffective treatments and vaccines, we ran an Ordinary Least Squares (OLS) regression.

The regression equation is given by:

$$|Y_{ij}| = \beta_0 + \beta_1 \times Info_i + \gamma' X_i + u_i \#(1)$$

Where:

$|Y_{ij}|$ is the absolute value of Y_{ij}, the response of subject i to question j =1,2. It represents how far this opinion is from the center, defined as zero. This is our measure of polarization for subject i. (Note 1)

$Info_i$: Dummy variable equal to one for participants who received the referenced information, and equal to zero otherwise.

X_i: Socio-demographic controls including age, gender, education, employment status, and political position.

Due to the random assignment of referenced information, we may interpret β_1 as the causal impact of referenced information on polarization. Socio-demographic controls were included primarily as a robustness exercise, to check if the treatment effect is stable across different specifications. Since the treatment was randomly assigned, it was unrelated to these controls. Our focus is on the effect of referenced information, rather than on the role of demographic variables, whose causal impact we cannot identify in our experimental framework. (Note 2)

Table 2 reports the results. The estimated value of β_1 is significant and positive in all specifications, for both ineffective treatments (Y_1) and vaccines (Y_2), suggesting that referenced information increased polarization by around 14% of a standard deviation.

Table 2. Regression Results for $|Y_{ij}|$

	Dependent variable:			
	$\|Y_1\|$		$\|Y_2\|$	
	(1)	(2)	(3)	(4)
Info	0.430**	0.349**	0.298*	0.287*
	(0.179)	(0.169)	(0.168)	(0.162)
Constant	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
Observations	688	688	688	688
R^2	0.008	0.130	0.005	0.079

Notes: Robust standard errors in parentheses. *, ** and *** denote statistical significance at, respectively, the 10%, 5% and 1% levels.

The socio-demographic controls (X_i) included in the model did not affect the main effects: the estimated impact of referenced information is similar across specifications. (Note 3 and Note 4) Interaction effects among socio-demographic controls and the treatment were always non-significant, suggesting that no subgroup responded differently to referenced information. (Note 5)

As an additional exercise, one may also ask whether referenced information had a direct impact on the participants' responses Y_{ij}, instead of the polarization measure $|Y_{ij}|$. To answer, we ran the following variation of the previous regression:

$$Y_{ij} = \beta_0 + \beta_1 \times Info_i + \gamma' X_i + u_i \#(2)$$

Table 3 reports the results.

Table 3. Regression Results for Y_{ij}

	Dependent variable:			
	Y_1		Y_2	
	(1)	(2)	(3)	(4)
Info	0.136	0.019	0.277	0.256
	(0.269)	(0.246)	(0.212)	(0.205)
Constant	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes
Observations	688	688	688	688
R^2	0.0004	0.1820	0.0024	0.0065

Notes: Robust standard errors in parentheses. *, ** and *** denote statistical significance at, respectively, the 10%, 5% and 1% levels.

Our findings in Table 3 indicate that referenced information did not significantly alter the average response of participants regarding the effectiveness of vaccines and treatments like hydroxychloroquine and ivermectin.

4. Discussion: Information, Bayesian Updating and Polarization

Formally, Bayesian updating assumes that an individual begins with a prior belief $P(H)$ about a hypothesis or event H – e.g., H may be the event 'vaccines decrease Covid mortality'. When new information E is introduced – such as news about vaccine effectiveness from the World Health Organization –, they update this belief by calculating a posterior probability $P(H \mid E)$, the conditional probability of event H given information E. This combines the prior probability with the likelihood of observing E given H. One may write:

$$P(H|E) = \frac{P(H \text{ and } E)}{P(E)}$$

Bayesian updating has well-established behavioral foundations: Consequentialism and Dynamic Consistency (Ortoleva, 2024). Consequentialism assumes that if an individual is indifferent between two actions conditional on some event E, then they will remain indifferent after learning that E holds. Dynamic Consistency means that an individual prefers some action A to another action B in case E happens if and only if, ex-ante, they prefer any rule that predicts action A conditional on E to a rule that predicts B for all circumstances. Together, these assumptions imply Bayesian updating: individuals incorporate evidence systematically and their updated beliefs guide subsequent decisions. (Note 6)

Theoretical models of Bayesian updating frequently consider that individuals, when confronted with new information, should update their beliefs proportionally to the credibility of the evidence (Kartik, Lee & Suen, 2021; Augenblick & Rabin, 2021). In a simplified way, the actual posterior may be written as a linear combination $\alpha P(H|E) + (1-\alpha)P(H)$ for some $\alpha \in [0,1]$, in which a large α is interpreted as high credibility of evidence E. (Note 7) Hence some common source of information E should either decrease polarization (if α is generally large in a group of individuals) or have little to no effect (if α is small).

Our results, however, suggest that information processing deviates from this Bayesian benchmark: polarization intensifies with the introduction of referenced information. (Note 8)

This counterintuitive outcome relates to the emotional impact of information and the connection between belief formation and group identity. Information related to high-stakes topics like health interventions during a pandemic does not function as neutral data to be assessed; rather, it becomes entangled with the emotional responses and identity-driven biases of the recipients (Suhay, 2015; Esponda, Oprea & Yuksel, 2023). First, if this information contradicts previously-held opinions, it may be met with the same resistance as any source of opposition, leading to an activation of a fight-or-flight response in the brain (LeDoux, 2000). Second, information that contradicts opinions of a trusted network may become a social hazard, if the formation of this network is at least partially determined by such opinions – one may become an outcast for holding a different view about some relevant issue.

Overall, when individuals receive information that aligns with their pre-existing beliefs, it reinforces their views, giving rise to a confirmation bias that strengthens group coherence and individual self-concept (Rabin & Schrag, 1999; Cookson, Engelberg & Mullins, 2023). Conversely, when information contradicts their beliefs, it may be met with cognitive dissonance. To resolve this discomfort, individuals may dismiss, discredit, or rationalize away the discordant

information to maintain internal consistency (Kaaronen, 2018). This selective processing of information is a form of motivated reasoning, as discussed in Ortoleva (2024). Moreover, in highly polarized environments, the same piece of information can be interpreted differently depending on one's pre-existing beliefs and group allegiances, thus not only reinforcing existing divisions but potentially exacerbating them. (Note 9)

The way we presented information in this experiment is typical of media outlets: concise, focused, and referenced. This is seen as an effective method to convey information to the public. However, our findings indicate that this method may increase polarization, while keeping the average opinion unchanged. This suggests that public health communication strategies relying on information may fail to influence belief formation or even have unintended consequences, especially under strong polarization. In these environments, emotional and identity-driven biases are relevant factors in the design of communication strategies.

5. Concluding Remarks

In this paper, we examined how participants formed opinions after receiving referenced information about COVID-19 vaccines and treatments through an online experiment. We found that providing information increased polarization, with treated participants reporting opinions further from the center than the control group. This is at odds with the idea that individuals update their beliefs through some form of Bayesian reasoning when presented with new information. Instead, our results suggest that at least when it comes to polemic issues such as Covid mitigation measures, individuals may not interpret referenced information as a valid source upon which to form their opinions.

These findings have implications for public health communication, particularly in polarized environments. The transmission of information based mostly on factual content may not only fail to reduce divisions but could also exacerbate them. This highlights the need for alternative communication strategies that address the emotional and social dimensions of belief formation.

Although our sample from India is diverse in language, religion, and cultural backgrounds, there are limitations to generalizing these findings to other contexts, as cultural and regional factors may shape responses to public health information differently. While the online platform increased sample diversity compared to in-person experiments, replicating our experiment in other contexts is relevant to establish external validity. Additionally, while our study did not directly measure participants' trust in the information or potential skepticism, these factors could impact how individuals update beliefs, with information fatigue or source credibility affecting polarization. Future research could incorporate measures of trust and skepticism to clarify these influences on belief formation in polarized settings.

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Authors' contributions

All authors conceptualized the study, analyzed the data, and wrote the paper. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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Notes

Note 1. An alternative measure of polarization is the variance of responses. However, the variance puts more weight on response changes far from the center (e.g., from -6 to -7) when compared to changes close to zero (e.g., from +1 to +2). Our focus is not on such a distinction – we give the same weight to opinion changes close or far from the center, making the absolute deviation the appropriate measure.

Note 2. See Athey and Imbens (2017, section 4) for a discussion of controls in randomized experiments.

Note 3. The R^2 coefficient is low, which indicates that the models explain only a small proportion of the variance in polarization. This is not unexpected, since polarization has many drivers. As mentioned in section 2, the focus of this study is on identifying the causal effect of referenced information, rather than explaining the variance of polarization.

Note 4. Using variance as a measure of polarization, the result for ineffective treatments (Y_1) remained unchanged. For vaccines (Y_2), there was no effect under the variance measure as the polarizing effect of referenced information was concentrated around the center of the distribution: indeed, the impact remained positive and significant in the range between -4 and 4 under the absolute deviation measure, but non-significant out of this range. This suggests that referenced information increased polarization more among moderate respondents, where the variance measure puts less weight. Based on our experimental design, we cannot infer whether there is any driver to this difference between Y_1 and Y_2 – it could be a purely random difference.

Note 5. For conciseness, we do not report the results for all variations of our main exercise. Results are available upon

request.

Note 6. It is worth noticing that widely-used game theory equilibrium concepts, such as Perfect Bayesian Equilibrium and Sequential Equilibrium, assume agents update their beliefs according to Bayes' rule.

Note 7. This is the psychology of 'anchoring and adjustment', as discussed in Gabaix (2019). See also Tversky and Kahneman (1974).

Note 8. This is in line with previous research in related fields. See (Fryer et al., 2019).

Note 9. For recent discussions, see Harmon-Jones and Mills (2019) and Epley and Gilovich (2016).

Appendix. Complete questionnaire

Socio-Demographic Questionnaire

1.What is your gender?
Male
Female
Other
Prefer not to answer

2.What is your age?
29 or Less
30-39
50 or more

3.What is your level of education?
Incomplete High School or Less
High School Graduate
College with no degree
Bachelor's Degree
Graduate Degrees (Master, PhD, etc)
Other
Prefer not to answer

4.What is your employment status?
Employed
A Student
Unemployed and seeking work
Not formally employed and not seeking formal employment
Retired
Other
Prefer not to answer

5.How do you classify yourself in the political spectrum in a scale from -8 to 8?
-8: "Very left wing "
-7
-6
-5
-4
-3
-2
-1
0: "Center"
1
2
3
4
5
6

7
8: “Very right wing”

Note: based on the questions above, we built the variables used in our regression in the following way:
Age: variable equal to one for 29 years old or less, to two for 30 to 39 years old, to three for 40 to 49 years old, and four to 50 years old or more.
Gender: variable equal to one if the individual's gender is male and zero otherwise.
Education: variable equal to one for High School or less, to two for High School, to three for College with no degree, to four for Bachelor's degree and to five for Graduate degrees.
Employment status: Employed - variable equal to one if the individual is employed and zero otherwise; Retired - variable equal to one if the individual is retired and zero otherwise; Not Formally Employed - variable equal to one if the individual is not formally employed and zero otherwise.
Political: participant’s self-reported political spectrum, ranging from -8 to 8.

Factual information about the Measures for Controlling the Spread of the Coronavirus *(shown only to participants in the treatment group)*
The COVID-19 pandemic has affected the lives of people all over the world.
Research indicates that there is no effective cure among available treatments, but masks and social distancing are relevant measures to limit the dissemination of the virus that causes the disease. (Reference: World Health Organization).
Moreover, there are currently several vaccines that help avoid infection and the development of severe illness. (Reference: World Health Organization).

We will ask you some questions related to the pandemic.

Verification Question
This is just a verification statement. Please choose option 5.
1
2
3
4
5

Questions Related to the COVID-19 Pandemic
Please choose for each statement below the option that best describes your opinion about COVID-19.

1.There are well-established and effective treatments against COVID-19 (for example, ivermectin and hydroxychloroquine).
-8: “Totally disagree”
-7
-6
-5
-4
-3
-2
-1
0: “Neutral”
1
2
3
4
5
6
7
8: “Totally agree”

2. Vaccines are highly effective to avoid infection and the development of severe symptoms of COVID-19.

-8: “Totally disagree”
-7
-6
-5
-4
-3
-2
-1
0: “Neutral”
1
2
3
4
5
6
7
8: “Totally agree”