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Modeling Diffusion of Information in an Increasingly Complex Digital Domain

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Author Note: Cadet Daniel Provaznik is a senior in the United States Military Academy's Class of 2018. CDT Provaznik will graduate in May of 2018 with a Bachelor of Science in Systems Engineering with a minor in terrorism studies. Upon commissioning as a Second Lieutenant into Army Aviation, he will pursue a Master's degree in Technology and Public Policy at the Massachusetts Institute of Technology. Major Jillian Wisniewski serves as advisor to CDT Provaznik for this Honors thesis as well as his capstone research.

Abstract: Offering entertainment, discussion, and information, social media provides users with a stimulating online experience. Within the last five years, it has also become an increasingly popular medium for the consumption of news. News outlets publish articles and reports through social media, and by doing so influence their users in a way that corresponds with the outlet's political leaning. Because social media outlets provide users with tailored content, the prevalence of biased news reporting reinforces the user's political values and polarizes their beliefs. This thesis attempts to examine the relationships that give rise to this political polarization in social media and discusses possible opportunities to mitigate it.

Keywords: Left-Wing, Right-Wing, Personalization, Tailored Content, Bias, Political Leaning, System Dynamics

1. Introduction

This paper will use the system dynamics modeling process as outlined by John Sterman of MIT: articulating the problem, formulating a dynamic hypothesis, formulating a simulation model, testing that model, formulating effective policies, and evaluating those policies (Sterman, 2000).

2. Problem Articulation

In today's world, personalization has become a cornerstone of the online experience. Social media giants, in particular, create individualized experiences for their users based on their expressed preferences, historical trends, and predicted interests (Van Dijck, 2013). When applied to politics, these environments inundate users with similar or related information that reinforces their current political beliefs. This inundation isolates users from alternative opinions and viewpoints, polarizing their perspective. This polarizing isolation effect is commonly referred to as the "echo chamber" or "filter bubble" (Karsten, 2016). The challenge addressed in this paper to illuminate the relationships that give rise to this political polarization in social media and to discuss possible opportunities to mitigate it.

2.1 Variables

The variables within the echo effect model include: User Political Interests, Personalization Algorithms, Media News Reporting, Right-Wing Beliefs, Left-Wing Beliefs, Proportion of Right-Wing Beliefs, Proportion of Left-Wing Beliefs, Flow of Right-Wing Tailored Content, and Flow of Left-Wing Tailored Content. See Table 1 for their definitions. Media content not derived from social media is not considered in this model.

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Table 1. Key Variable Table

VARIABLE	DESCRIPTION	UNITS
Right-Wing Articles Consumed	The number of Right-Wing articles read by user	Articles
Proportion of Right-Wing Beliefs	Ratio of Right-Wing Beliefs to the overall user political beliefs	Dimensionless
Flow of Right-Wing Tailored Content	Articles with a purposeful Right-Wing slant	Articles/Day
Left-Wing Articles Consumed	The number of Left-Wing articles read by user	Articles
Proportion of Left-Wing Beliefs	Ratio of Left-Wing Beliefs to the overall user political beliefs	Dimensionless
Flow of Left-Wing Tailored Content	Articles with a purposeful Left-Wing slant	Articles/Day
User Political Beliefs	The combination of Right-Wing and Left-Wing ideologies	Articles
Media News Reporting	Political articles on exogenous events	Articles/Day
Personalization Algorithms	Programs that use user political preferences as inputs and suggest correspondingly biased information to the user as outputs	Dimensionless

2.2 Expected Behavior

As depicted in the reference mode in Figure 1, an individual is estimated to become politically polarized sometime within the first 500 days. It is important to note that the rate at which this polarization process happens is dependent on the assumed number of articles that the user is exposed to per day. For the reference mode depicted, the higher the number of Media News Reporting articles viewed per day, the faster the polarization.

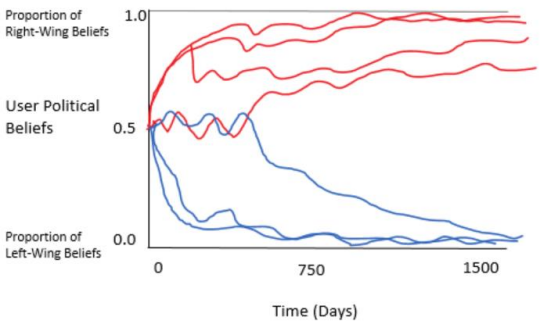

Figure 1: Reference Mode of Proportion of Right-Wing Beliefs

3. Dynamic Hypothesis Formulation

The structure responsible for this system behavior is depicted in the Stock and Flow Diagram in Figure 2. User Political Beliefs are governed by a Polya process with path dependence. This path dependence is driven by opposing reinforcing and balancing feedback loops, including: the Polarization Effect Cycle, the Right-Wing Ideology Repression Cycle, and the Left-Wing Ideology Repression Cycle. In this model, Left-Wing Ideology is defined as the complement of Right-Wing Ideology, allowing the Proportion of Left-Wing Beliefs and the Proportion of Right-Wing Beliefs to sum to one.

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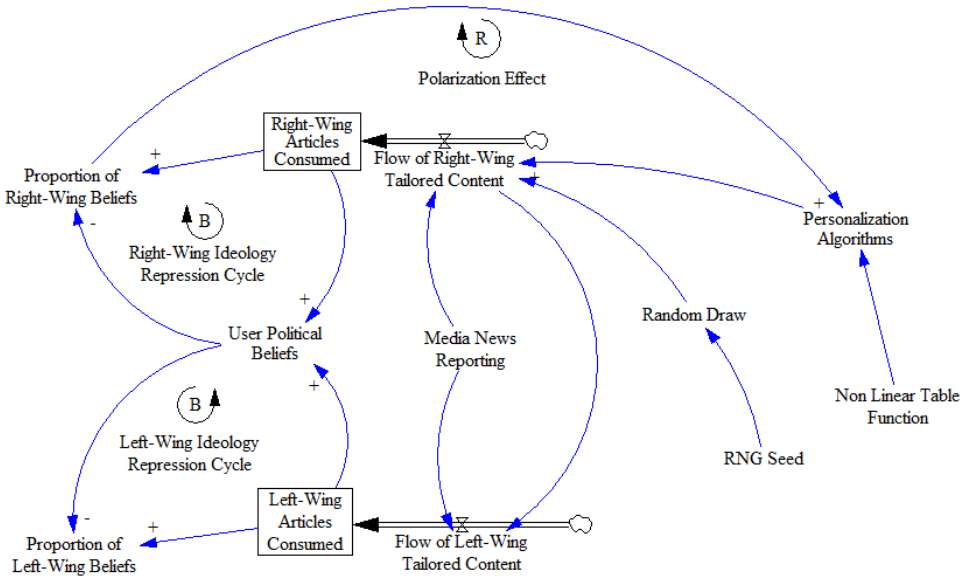

Figure 2: Stock and Flow Diagram

4. Formulation of a Simulation Model

Table 2 depicts each variable, its description, units, associated equation, initial value, and supporting logic.

Table 2: Key Variable Descriptions, Units, Equations, Initial Values, and Supporting Logic

VARIABLE	DESCRIPTION	UNITS	EQUATION	INITIAL VALUE	SUPPORTING LOGIC
Right-Wing Articles Consumed	The degree to which one adheres to Right-Wing Ideology	Articles	=INTEG(Flow of Right-Wing Tailored Content)	10	Individuals fall along a spectrum of political beliefs: Left-Wing to Right-Wing
Proportion of Right-Wing Beliefs	Ratio of Right-Wing Beliefs to the overall user political beliefs	Unit-less	= (Right-Wing Beliefs)/(User Political Beliefs)	N/A	An individual's beliefs represents some portion of both Left-Wing and Right-Wing beliefs
Flow of Right-Wing Tailored Content	Flow of information with a purposeful Right-Wing slant	Articles/Day	= IF THEN ELSE(Random Draw<= Personalization Algorithms, Media News Reporting, 0)	N/A	As Personalization Algorithms decide which content to reinforce, biased content will populate the user's news feed.
Left-Wing Articles Consumed	The degree to which one adheres to Left-Wing Ideology	Articles	=INTEG("Flow of Left-Wing Tailored Content")	10	Individuals fall along a spectrum of political beliefs: Left-Wing to Right-Wing
Proportion of Left-Wing Beliefs	Ratio of Left-Wing Beliefs to the overall user political beliefs	Unit-less	=(Left-Wing Beliefs)/(User Political Beliefs)	N/A	An individual's beliefs represents some portion of both Left-Wing and Right-Wing beliefs

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Flow of Left-Wing Tailored Content	Flow of information with a purposeful Left-Wing slant	Articles/Day	= Media News Reporting - "Flow of Right-Wing Tailored Content"	N/A	As Personalization Algorithms decide which content to reinforce, biased content will populate the user's news feed.
User Political Beliefs	The combination of Right-Wing and Left-Wing ideologies	Articles	="Left-Wing Articles Consumed"+"Right-Wing Articles Consumed"	N/A	This is a user's cumulative beliefs of both Left and Right-Wing ideologies.
Media News Reporting	Political commentary on exogenous events	Articles/Day	N/A	5	A user is subject to the political echo chamber of social media and exposed to other media throughout the day.
Personalization Algorithms	Programs that use user political preferences as inputs and suggest correspondingly biased information to the user as outputs	Unit-less	=Non Linear Table Function("Proportion of Right-Wing Beliefs")	N/A	As users indicate their political beliefs, social media provides individualized content that matches expressed beliefs

5. Testing

The two variables manipulated were the Random Number Generator (RNG) Seed and Media News Reporting. These two variables fed values into the other functions within the model, impacting on the resulting behavior. The first variable addressed was the RNG Seed. The RNG Seed variable feeds into the Random Draw function, which dictates the effectiveness of the personalization algorithms. The RNG Seed has a range between 0 and 50 and must be a whole number. For the extreme condition testing, our team varied the RNG Seed value within this range and compared it to a baseline middle value of 25. Below is a graph of the resulting behavior our team observed in the proportion of Right-Wing Beliefs.

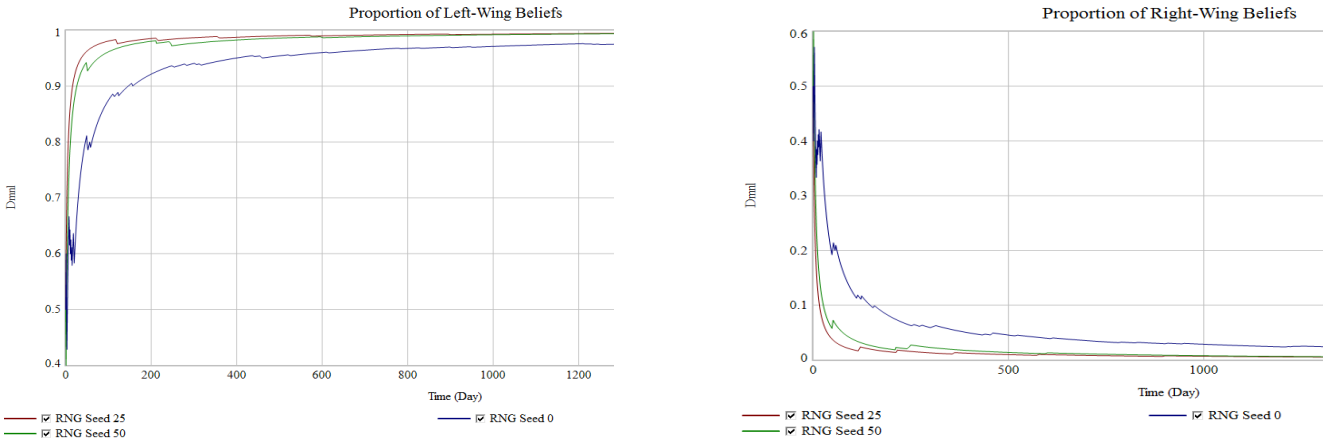

Figure 3: Effects of RNG Seed Extreme Conditions Testing on Proportion of Left and Right-Wing Beliefs

As seen in Figure 3, as the RNG Seed is varied from 0 to 25 and from 25 to 50, the proportions of Left and Right-Wing Beliefs do not exhibit any significant change. Under close inspection, there is no clear relationship between the RNG Seed number and the Proportion curve, since an RNG Seed of 0 has the slowest polarization, but an RNG seed of 50 is actually slower than an RNG Seed of 25. The RNG Seed only feeds numbers to the Random Draw equation, which then randomly

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selects numbers to input into the Flow of Left-Wing Tailored Content and Right-Wing Tailored Content functions. Thus, there is no clear relationship.

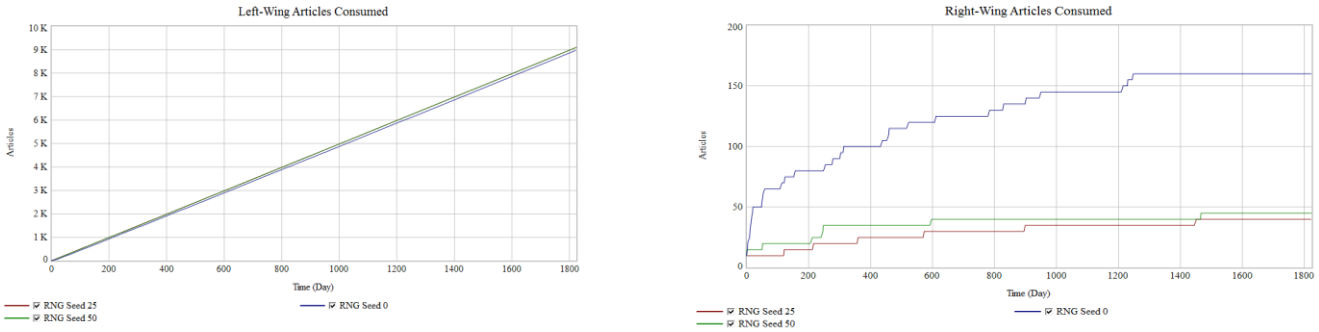

Figure 4: Effects of RNG Seed Extreme Conditions Testing on Left-Wing and Right-Wing Articles Consumed

As can be seen in Figure 4, despite the RNG Seed value used, a linear trend of Left-Wing Articles Consumed increasing over time still exists. This indicates that the RNG Seed number has no significant effect on the long-term behavior of Left-Wing Articles Consumed. This behavior is similar in Right-Wing Articles Consumed as well, however, the number of Right-Wing Articles Consumed is far fewer than the number of Left-Wing Articles Consumed.

The Media News Reporting variable feeds both the Flow of Left-Wing Tailored Content and Flow of Right-Wing Tailored Content, controlling the number of articles a user internalizes and is measured as Articles/Day. Preliminary testing of this variable showed that the approximate range for this variable was between 0 and 15, as increases above 15 negligibly affected the speed to which a user becomes polarized. So for extreme conditions testing, Media News Reporting was varied between 0 and 15. Figure 5 depicts the relationships between Media News Reporting and the Proportion of Left-Wing Belief sand the Proportion of Right-Wing Beliefs.

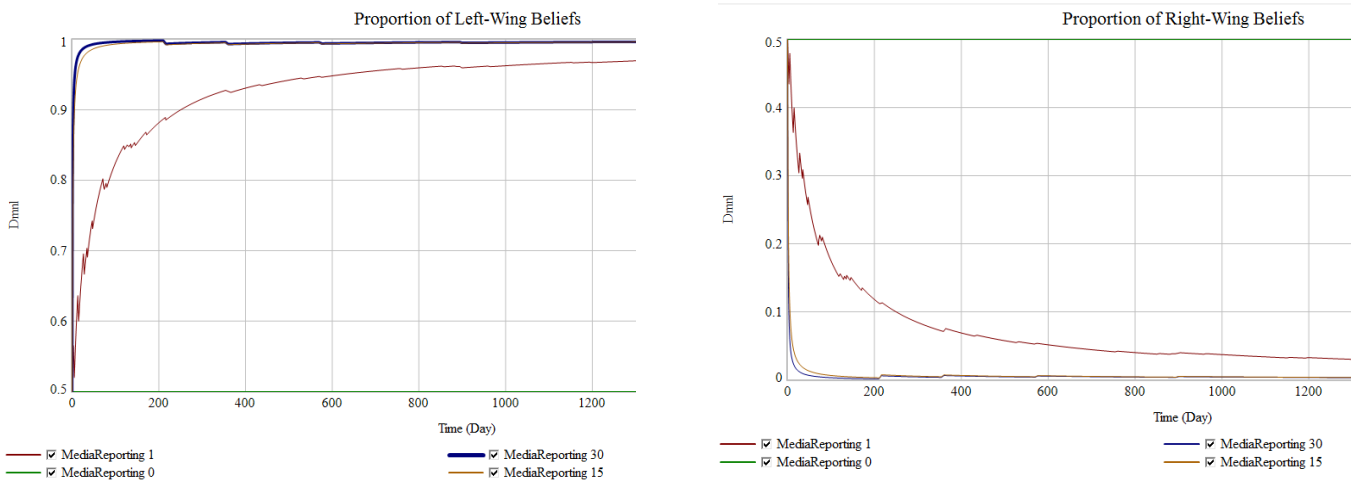

Figure 5: Effects of Media News Reporting Extreme Conditions Testing on the Proportion of Left-Wing Beliefs and the Proportion of Right-Wing Beliefs

Figure 5 shows that the number of Articles per Day a user consumes dictates how quickly that individual polarizes. When considering that on average, a user internalizes 0 articles per day, they remain completely neutral. However, as an

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individual internalizes closer to 30 articles per day, he or she polarizes very quickly, in this case in less than 100 days. The same behavior is observed with the Proportion of Right-Wing Beliefs.

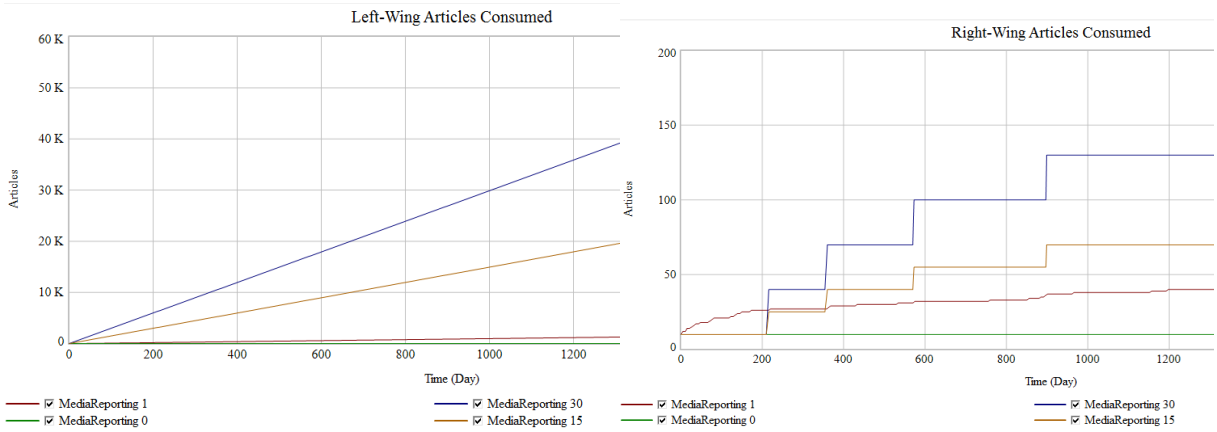

Figure 6: Effects of Media News Reporting Extreme Conditions Testing on Right-Wing Articles Consumed

Figure 6 shows that as the Media News Reporting value increases, the number of Left-Wing Articles and Right-Wing Articles Consumed increases over time at rates similar to those previously depicted.

5.3 Sensitivity Analysis

After extreme conditions testing, sensitivity analysis was conducted on the same variables outlined in the extreme conditions testing, but within a smaller range to observe changes in behavior. The first variable tested was the RNG Seed. The RNG Seed variable feeds into the Random Draw function, which dictates the effectiveness of the personalization algorithms. The RNG Seed has a range between 0 and 50 and must be a whole number. For the sensitivity analysis, our team varied the RNG Seed value within the confines of this range. We chose to use RNG Seed values of 0, 10, 20, 30, 40, and 50. Below is a graph of the resulting behavior our team observed in the proportion of Right-Wing Beliefs.

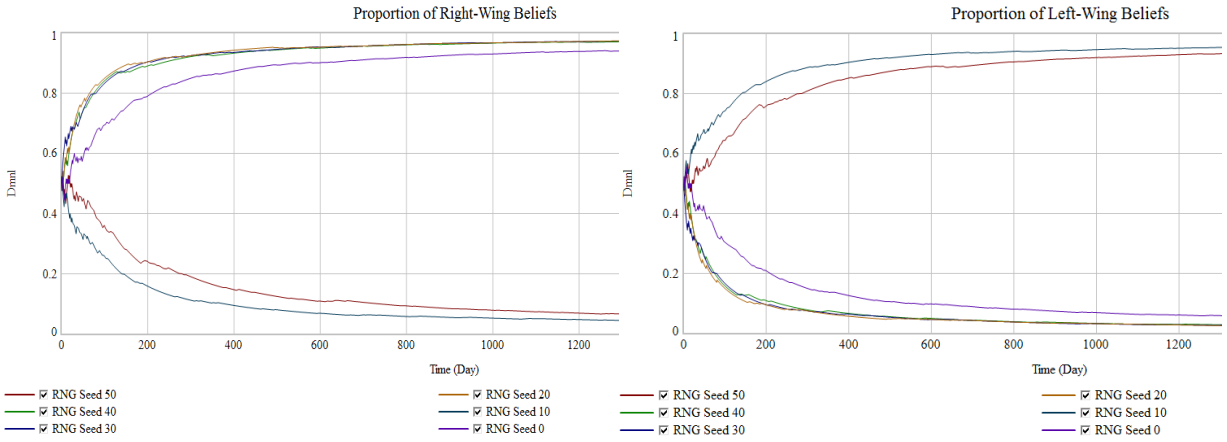

Figure 7: Proportion of Left-Wing Beliefs and Proportion of Right-Wing Belief RNG Seed Sensitivity

As can be seen in the graph, there is no clear relationship between the RNG Seed value and the resulting behavior of the Proportion of Right-Wing Beliefs. This is consistent with our findings outlined in the extreme conditions testing section.

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This similar behavior can be observed in the complementary graph for Proportion of Left-Wing Beliefs, which is depicted below. The next indicator analyzed was Articles Consumed.

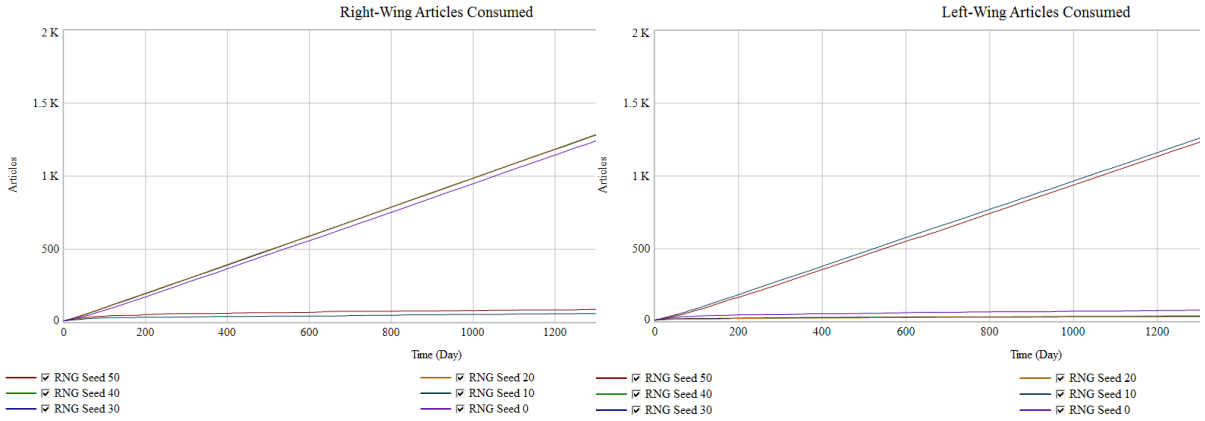

Figure 8: Right-Wing Articles Consumed RNG Seed Sensitivity

Figure 8 depicts how the RNG Seed number affects the number of Left-Wing Articles Consumed and Right-Wing Articles Consumed over time. As noted with the proportion graphs, the RNG Seed value shows no distinct relationship between RNG Seed and articles consumed over time.

The Media News Reporting variable feeds both the Flow of Left-Wing Tailored Content and the Flow of Right-Wing Tailored Content. This variable helps control the number of articles a user internalizes and is measured as Articles/Day. The approximate range for this variable is between 0 and 15. The Media News Reporting value was changed within this range. Figure 9 depicts the relationship between the Media News Reporting and the Proportion of Right-Wing Beliefs.

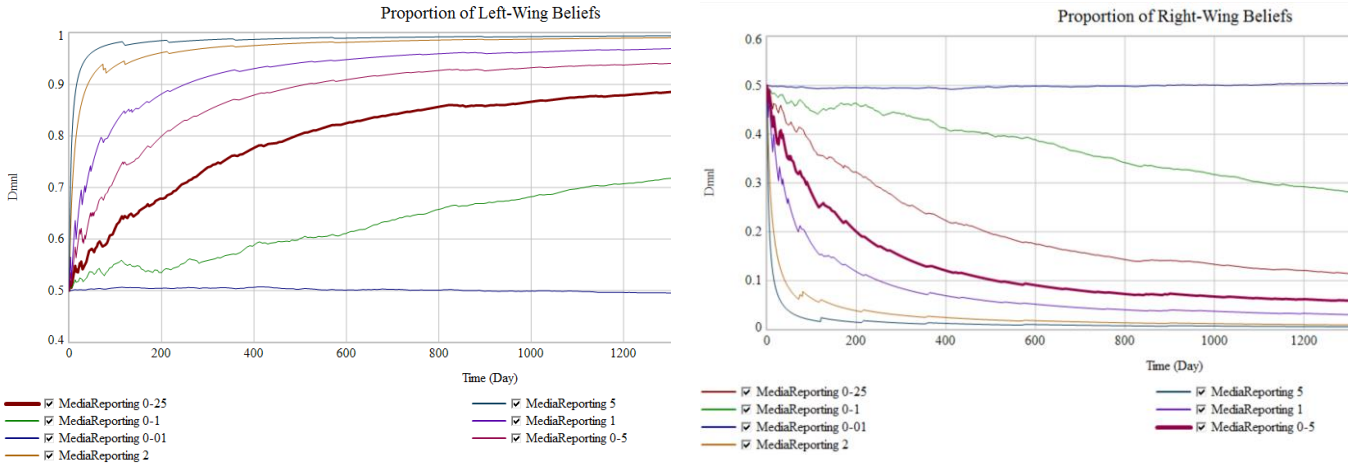

Figure 9: Proportion of Left-Wing Beliefs and Right-Wing Beliefs Media News Reporting Sensitivity

The relationship seems to be most acutely sensitive between the values of 0 and 2, with subsequent values after 2 not having as significant of an effect. This behavior is also reflected in the Proportion of Left-Wing Beliefs, depicted below. Next the effects of Media News Reporting on the number of Left-Wing and Right-Wing Articles Consumed were analyzed. As evident in Figure 10, the relationship seems to be most sensitive between the values of 2 and 5.

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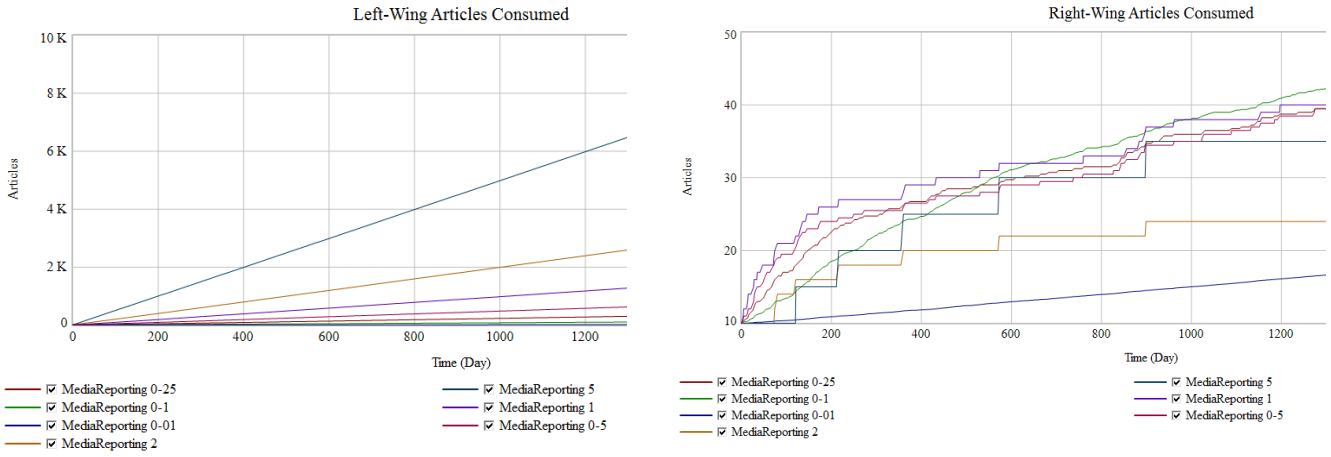

Figure 10: Left-Wing Articles Consumed and Right-Wing Articles Consumed Media News Reporting Sensitivity

6. Policy Design and Evaluation

The first proposed policy recommendation is to institute a federal restriction capping the effectiveness of personalization algorithms. This artificially imposed cap would force social media giants to either allow or feed media news reporting of the opposite bias to their users.

The second proposed policy recommendation mandates that social media giants include a time delay within their personalization algorithms. This time delay would ultimately delay the polarization process, allowing users to experience more varied media news reporting in the newly available time through their own exploration. This additional time for extra exposure would cause the personalization algorithms to introduce less polarized material to their users.

7. Conclusion

The model demonstrates that polarization does occur. This follows the principles of the Polya process and path dependence. Therefore, it passes a general common sense test for expected model behavior. This modeled polarization is important for consumers to understand because it not only affects the information they receive, but also has the potential to alter their political opinions and thereby their decisions and actions. Consumers of social media should diversify their intake of information to reduce the effect of polarization and promote a political alignment that is uninfluenced by social media giants. Both proposed policy recommendations have the potential to facilitate that intake diversification, promoting a less polarized—and hopefully more open, educated, and well-rounded population.

8. References

Healy, W. (2017, January 25). Journalism Quality and Partisanship Guide 2017. Retrieved December 03, 2017, from http://www.pigscast.com/2017/01/25/journalism-quality-partisanship-2017-guide/.

Karsten, J., & West, D. M. (2016, December 09). Inside the Social Media Echo Chamber. Retrieved March 07, 2018, from https://www.brookings.edu/blog/techtank/2016/12/09/inside-the-social-media-echo-chamber/.

Sterman, J. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. New York: McGraw-Hill Higher Education.

Van Dijck, J., & Poell, T. (2013). Understanding social media logic.

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