Dynamic spirals put to test: An agent-based model of reinforcing spirals between selective exposure, interpersonal networks, and attitude polarization

Hyunjin Song and Hajo G. Boomgaarden

Department of Communication, University of Vienna

Author Note

Hyunjin Song is a is an assistant professor (postdoc Universitätsassistent) in the Department of Communication, University of Vienna. Hajo G. Boomgaarden is professor for Empirical Social Science Methods with a Focus on Text Analysis at the Department of Communication, University of Vienna.

Correspondence concerning this article should be addressed to Hyunjin Song, Rathausstraße 19/9, 1010 Vienna, Austria. E-mail: hyunjin.song@univie.ac.at

Abstract

Within the context of partisan selective exposure and attitude polarization, this study investigates a mutually reinforcing spiral model, aiming to clarify mechanisms and boundary conditions that affect spiral processes – interpersonal agreement and disagreement, and the ebb and flow of message receptions. Utilizing agent-based modeling (ABM) simulations, the study formally models endogenous dynamics of cumulative processes and its reciprocal effect of media choice behavior over extended periods of time. Our results suggest that interpersonal discussion networks, in conjunction with election contexts, condition the reciprocal effect of selective media exposure and its attitudinal consequences. Methodologically, results also highlight the analytical utility of computational social science approaches in overcoming the limitations of typical experimental and observations studies.

Keywords: Partisan selective exposure, attitude polarization, interpersonal discussion network, mutually reinforcing spiral model, agent-based modeling simulation

Dynamic spirals put to test: An agent-based model of reinforcing spirals between selective exposure, interpersonal networks, and attitude polarization

One of the fundamental prerequisites of healthy, representative democracy is the quality of relevant information that citizens' judgments and opinions are based upon. Media exposure and informal political discussion have long been regarded as keystones on the basis of which citizens' opinions are formed and maintained (e.g. Bartels, 1993; Southwell & Yzer, 2007). Yet decades of research on selective exposure suggests that there is a substantial tendency for citizens to limit their information sources to those that are congenial to their preexisting predispositions (Stroud, 2010), and the recent proliferation of partisan news sources arguably made it easier to do so. In consequence, studies revealed that reliance on partisan news sources leads to attitude extremity and polarization (Iyengar, Sood, & Lelkes, 2012; Levendusky, 2013; Stroud, 2010), although the exact nature of causal links is still subject of scholarly debate (e.g. Prior, 2013). Similarly, scholarly work on informal political discussion is increasingly concerned with the extent of exposure to disagreement in citizen's everyday interactions (Eveland & Hively, 2009; Nir, 2011). Perhaps it comes with no surprise, thus, that the extent of "cross-cutting" exposure - both in terms of media exposure and political discussion alike - has become a central concern for communication scholars (Eveland & Hively, 2009; Mutz, 2006).

What is largely absent in the extant empirical literature, however, is a comprehensive, integrated model that addresses the "the reciprocal nature of [media] selectivity and media effects" (Slater, 2007, p. 283), as well as "the conditional nature of the way both mass media and interpersonal communication affect changes in public opinion" (De Vreese & Boomgaarden, 2006, p. 20; see also Schmitt-Beck, 2003; Southwell & Yzer, 2007). Relying on an agent-based modeling (ABM) framework, this study makes important steps to fill these voids and further extent the literature in the area of political communication, and potentially beyond. First, this study investigates a *mutually reinforcing spiral model* (Slater, 2007, 2015, hereafter denoted as RSM) within the context of partisan selective exposure and polarization, aiming to advance a more nuanced understanding of the cumulative process and effect of media choice behavior for

individual- and system-level consequences. Doing so the study is among the first to take seriously the notion of spiral dynamics in that it formally models endogenous dynamics of media selection and its effect over extended periods of time. While data requirements are hard to meet in typical observational and experimental studies to estimate spiral processes over longer time trends, the agent-based modeling approach allows testing such endogenous dynamics. The outcome will deepen our understanding of mutually reinforcing spiral processes and thus be of interest for any communication research in which such processes are likely to take place.

Second, drawing on what is called the "filter-hypothesis" framework (Berelson, Lazarsfeld, & McPhee, 1954; Schmitt-Beck, 2003), we also address the role of interpersonal agreement and disagreement as a core explanatory mechanism of a positive feedback process that leads to more extreme outcomes. While the RSM framework has been mainly concerned with the question of reinforcement and maintenance of media selection and its effects, this study highlights the role of interpersonal agreement and disagreement potentially *amplifying* the extent of media selectivity and effects. It thereby, to our knowledge, is the first study that extends the RSM with interpersonal discussion effects, thus advancing a coherent theoretical framework integrating political discussion and partisan media influences.

Third, given that we are interested in dynamic developments of RSM, we take contextual variation in which the processes take place into account. As suggested by Slater (2007, 2015), one of the core propositions of RSM is to identify "environmental or other constraints" that limit or amplify the reinforcing spiral process. Accordingly, we introduce election cycles and corresponding varying levels of political engagement to further clarify "when" mutually reinforcing spiral processes may lead to increased polarization.

Although the primary focus of the present study is dynamic relationships between partisan selective exposure, political discussion, and attitudinal polarization over electoral cycles, the general approach advanced in the present study can be easily extended and applied to other substantive domain of interest, such as environmental or science beliefs or misperceptions (e.g., global warming) or attitudes towards health-related behaviors. In sum this study provides a

thorough, albeit highly stylized model of the interplay of the two main information sources and information selectivity in a dynamic model taking into account contextual influences.

Reinforcing spirals between partisan selective exposure and attitude polarization

Although "the most likely 'effect' of communication is ... further communication" (Chaffee, 1986, p. 76), so far communication scholars pay relatively scant attention to this possibility. Explicitly stating this dynamic perspective, Slater (2007, 2015) proposes the idea of a mutually reinforcing spiral. One of the fundamental preposition of the RSM is to regard media use as a dynamic outcome that is motivated by one's belief, interest, self- and group-identity, which in turn influences such antecedent variables over time. Although more direct empirical evidence supporting core theoretical assertions of the RSM is rather limited to a few studies (Feldman, Myers, Hmielowski, & Leiserowitz, 2014; Zhao, 2009), it provides a useful starting point to formulate the dynamic relationship between selective media use and polarization.

Based on a cognitive dissonance framework, a bulk of research on selective exposure suggests that one's partisan self-identity and pre-existing attitudes play a key role in shaping one's media exposure patterns (Knobloch-Westerwick & Meng, 2009; Mutz, 2006; Stroud, 2010). Since attitude-inconsistent information is psychologically discomforting and cognitively more taxing to process (Garrett & Stroud, 2014), individuals generally prefer politically congenial information, although they do not completely isolate themselves from attitude-discrepant information (Garrett, Carnahan, & Lynch, 2013; Garrett & Stroud, 2014; Stroud, 2010). Such exposure patterns, in turn, are thought to cause more extreme and polarized attitudes (Iyengar & Hahn, 2008; Stroud, 2010) either based on cognitive (Stroud, 2010; Zaller, 1992) or socio-affective mechanisms (Iyengar et al., 2012). Attitude polarization denotes "the strengthening of one's original position or attitude" (Stroud, 2010, p. 557) following selective exposure to politically congenial information.[1] In sum, previous studies convincingly suggest that partisan selective exposure leads to extreme attitudes, which in turn increases such exposure. This implies reciprocal dynamics unfolding over time as advanced in the RSM (Slater, 2007).

Empirical investigations of RSM within the context of partisan selective exposure and

attitude polarization are limited. Stroud's (2010) analyses suggests that while selective exposure is related to attitude polarization, there is at least a suggestive evidence that polarization also contributes to selective exposure, providing an indirect support for the notion of RSM. Using a three-wave panel study, Schemer's (2011) latent growth-curve analysis documents that attention to political advertising significantly influenced negative affective responses, whereas enhanced negative affect also prospectively increased the attention to campaign ads. Similarly, Feldman et al. (2014) report conservative partisan news use to decrease global warming belief, and this belief in turn affecting subsequent conservative partisan media use. While theoretical frameworks and some scattered empirical evidence suggest spiral processes, it needs to be noted that this evidence is rather suggestive at best. Given limitations in data points one can hardly speak of actual tests of reinforcing *spirals*, since only a small fraction of what could be a spiral usually is investigated.

Political discussion as a "filter" of mass media influence

It is often theorized that the effect of mass media exposure is conditional in nature (Boomgaarden, 2014), and political discussion has long been regarded as one of the core underpinnings of such contingencies in media effects (Schmitt-Beck, 2003; Southwell & Yzer, 2007). Yet, studies addressing the role of political discussion for partisan media effects are, surprisingly, very scant. Prior studies are generally concerned with the impact of political discussion on knowledge or participation (e.g. Eveland & Hively, 2009; Feldman & Price, 2008; Mutz, 2006), but have paid little attention to the conditioning effects on media selectivity or influences (Boomgaarden, 2014) or on attitude (de)polarization.

It is generally believed that the distribution of opinions within one's political discussion network has a number of direct consequences. For instance, persistent political disagreement may serve as a countervailing source of information that produces ambivalence (Huckfeldt, Mendez, & Osborn, 2004), which attenuates attitude strength (Visser & Mirabile, 2004). In contrast, being embedded in a homogenous network often bolsters preexisting attitudes, leading to a more extreme attitude (e.g. Binder, Dalrymple, Brossard, & Scheufele, 2009; Visser & Mirabile, 2004).

In addition to its direct effect on attitudes, literature suggests that the distribution of opinions within one's political discussion network may also moderate the influence of mass media exposure (e.g. Schmitt-Beck, 2003; Southwell & Yzer, 2007). Indeed, the foundational work of the Columbia school has shown that a homogeneous personal environment may either inhibit or reinforce the effect of mass media, conditional on the affective valence of such a message (Berelson et al., 1954; Katz & Lazarsfeld, 1955). According to this notion of "the filter hypothesis" (Schmitt-Beck, 2003, p. 237; Southwell & Yzer, 2007), the influence of a media message would be amplified when the distribution of political preference in one's network is in line with the media message. In contrast, the media influences would diminish when the distribution of preferences is at odds with the media messages.

There are a number of reasons why this would be the case. First, the reception-accept-sample (RAS) model (Zaller, 1992) states that any new information is evaluated based upon one's pre-existing considerations, with those who holding stronger political predispositions more likely to resist counter-attitudinal messages. Since the filter hypothesis functionally equates citizen's personal environments and the distribution of political opinions therein to one's political predispositions, individuals may conditionally receive mass media messages based upon the opinion of their peers. In addition, the distribution of opinions within discussion networks also provides an additional source of information regarding a given issue (Huckfeldt, Mendez, & Osborn, 2004; Southwell & Yzer, 2007). It creates one-sided vs. two-sided message flow, depending on whether the mass media messages are in line with or at adds with the distribution of opinions. Compared to the one-sided message environment wherein a valence of media message is in agreement with an opinion distribution, those faced with two-sided messages may easily counter-argue and reject dissonant messages to the extent that they are embedded in an attitudinally homogenous political discussion network (Huckfeldt, Mendez, & Osborn, 2004; Schmitt-Beck, 2003).

The ebb and flow of message reception: The role of media attention and political interest

Research on mass media effects suggests mere exposure is not a sufficient condition for media effects. Rather, attention to news, or a cognitive orientation and interest to political affairs, plays a key role determining the patterns of media effects (McGuire, 1989; Strömbäck, Djerf-Pierre, & Shehata, 2012). Indeed, it is often theorized that interest and attention to relevant information and more effortful and deliberative processing of such information yield stronger and lasting effects (Ewoldsen, Rhodes, & Fazio, 2015; Petty & Cacioppo, 1996).

In modern democracies, there is relatively little ambiguity that elections mobilize the general public, in that attention to political media and interest in political affairs generally increase during election periods (Dilliplane, 2014; Strömbäck & Johansson, 2007; Zaller, 1992). As elections near, citizens are more likely to attend to media messages, since they need information to reduce uncertainties regarding their decisions (Downs, 1957).

It is also suggested that one's propensity to attend to political affairs might interact with system-level opportunity structures for selective exposure (e.g Prior, 2013; also see Liu, 2016; Strömbäck et al., 2012). While more politically interested individuals continue to tune into political news, those who are disinterested in politics are no longer *accidentally* exposed to politics as the choice of non-political contents become easier. One consequence of such pattern is the increasing discrepancy between the politically interested and the disinterested in their likelihoods of forming strong, crystalized opinions (Prior, 2013).

This ebb and flow of attention to and interest in political news, and subsequent reception of relevant messages, may have an important implication for RSM. During election periods, the increased attention to (and the reception of) partisan media is logically expected to yield stronger impact, either through the activation of latent political predispositions or the reinforcement of existing political attitudes (Berelson et al., 1954; Dilliplane, 2014). This readily implies that reinforcing processes leading towards attitudinal polarization should be exacerbated during a given election cycle. Yet as the attention and interest gradually decreases after elections, such positive feedback loop would be restabilized to its original homeostatic status. Likewise, if

politically disinterested are tuned out from the political process, the aggregate relationship between selective exposure and attitude becomes stronger since system-level changes accentuate the politically-driven media seeking behaviors among politically interested citizens (Prior, 2013).

An integrated model of reinforcing spiral and interpersonal discussion network influences

The above discussions so far imply that aforementioned factors all would serve as key moderating mechanisms that amplify or inhibit reinforcing spirals leading towards extreme outcomes. In Figure 1, we present a brief formalization of our theoretical expectations regarding the relationships between pro- and counter-attitudinal partisan exposure, the nature of the interpersonal political discussion network, election year context, and political attitudes over time.

[Figure 1 About Here]

We first start with a broad assumption that attitudes are constructed and maintained from several *considerations* (McGraw, Hasecke, & Conger, 2003; Zaller, 1992). Yet we also assume that attitudes are routinely and iteratively updated as any new information is encountered (Kim & Garrett, 2011; McGraw et al., 2003).[2] We hence model attitudes as a function of (1) one's prior attitudes, (2) the degree of exposure to pro- and counter-attitudinal partisan media, and (3) interpersonal network influence from political discussion network.

Effects of prior attitudes

Research suggests that prior attitude serves as one of the strongest predictors of future attitude (attitude strength: Krosnick & Petty, 1995). This further implies that one's prior attitude servers as another "consideration" (just as like media exposure or interpersonal network influence) in determining one's current attitudes, as illustrated in (a) path in Figure 1. Yet such autoregressive effect of prior attitudes is generally subject to decay over time (Krosnick & Petty, 1995; Petty & Cacioppo, 1996), thus the impact of prior attitudes on current attitudes becomes weaker over time.

Selective exposure to partisan media

Advances in selective exposure consistently document that pro-attitudinal news exposure is quite substantial (Levendusky, 2013; Stroud, 2010), yet at the same time, counter-attitudinal

exposure appears to be common (Stroud, 2010). Therefore, we expect that citizens would have a *de facto* preference towards attitude-consistent media, with the amount of pro-attitudinal exposure being proportional to their attitudes (e.g., if a person is a liberal, then he or she watches more liberal media than a conservative media). Yet at the same time, we also consider a not-so-trivial degree of counter-attitudinal media exposure, although the amount of exposure would always be lower than the amount of pro-attitudinal media exposure. This relationship is conceptually depicted in (b) path in Figure 1, such that prior attitude serves the determinants of later partisan media exposure. For pro- and counter-attitudinal media exposure, our expectation is that exposure to partisan media, *regardless of their directions*, will influence one's attitudes towards the direction of such messages (e.g., congruent exposure strengthens initial attitudes, whereas incongruent exposure weakens initial attitudes), as illustrated in (c) path in Figure 1. Both observational (e.g. Zaller, 1992) and experimental studies of pro- and counter-attitudinal exposure (e.g. Arceneaux, Johnson, & Cryderman, 2013; Levendusky, 2013) generally support this perspective.[3]

Interpersonal discussion network

It is often believed that similarity of attitudes drives the selection of potential discussion partners (McPherson, Smith-Lovin, & Cook, 2001). Yet at the same time, political discussion often occurs between people as they routinely interact in their daily social lives regardless of their political similarities (Marsden, 1987; Small, 2013). We therefore expect that citizens generally prefer to interact with others whose attitude falls within a certain range of similarity based on their initial attitudes, while they continue to interact with attitudinally heterogeneous individuals if like-minded discussion partners are not available in their immediate environment. This relationship is represented in (d) path of Figure 1.

Once individuals self-select whom they interact with, they perceive the distribution of discussants' opinion from their interpersonal discussion network, which serves as one determinant of their attitude (i.e., (e) path in Figure 1). In addition to the distribution of discussants' opinion, an individual also perceives the extent of interpersonal agreement and

disagreement (Eveland & Hively, 2009). One important consequence of interpersonal agreement and disagreement within political discussion is its possible moderating influence on the impact of media exposure, as postulated by a filter hypothesis framework (Schmitt-Beck, 2003; Southwell & Yzer, 2007). This relationship is represented in (f) path in Figure 1.

Effect of election context

We expect that attention to and the reception of partisan-laden information generally increases during election periods, while politically disinterested selectively drop out from partisan selective exposure-polarization spirals. We also expect that the degree of selective exposure and attitudinal homophily in discussion network would be increased during election periods. We therefore expect a stronger impact of partisan media during a given election cycle. Coupled with the amplification effect of interpersonal network and stronger effect of attitude stability, this heightened impact of partisan media would lead to increased polarization during election periods. In contrast, when attention gradually decreases after elections, such feedback processes would restabilize.

Our formalization of theoretical expectations regarding conditioning dynamics of the reinforcing spiral process pose unique empirical challenges due to its process-oriented, generative properties of cross-level-of-analysis (Axelrod, 1997), let alone that it is demanding in terms of required data. The Agent-based modeling (ABM) approach provides an ideal observational tool for such a situation. ABMs generally aim to understand complex social systems by modeling adaptive behaviors of social actors, or "agents"(Axelrod, 1997) within a simplified representation of social reality, which is based on assumptions and theoretical expectations in light of an existing framework. ABMs do not aim to achieve a direct translation of previous empirical findings, but rather to provide a "thought experiment" (Axelrod, 1997) by connecting fundamental principles and core assumptions of relevant theories as succinctly as possible. Therefore, ABMs may omit some aspects of relevant theories. In general, simplicity and succinctness is often desired in developing an ABM application (Axelrod, 1997).

Setup of the ABMs

The current ABM consists of 2500 agents situated in a 50 by 50 grid environment, which provides opportunity for partisan media exposure and political discussion with other agents. All agents hold an initial attitude toward a given issue (such as a preference for political candidates, parties or policies) on a 7-point scale (from -3 = strongly disagree, to $+3$ = strongly agree), which is randomly assigned at the start of each simulation. Through each time step, agents interact with other agents (political discussion) and with the environment (media exposure) and iteratively update their opinions (either increase or decrease their attitude value) based on specific algorithms until the tick reaches the final value (*tick = 1095* or 3 years), or either one of two partisan camps completely disappears from the environment as result of attitude changes. The three-year time frame demonstrates the long-term consequences of agents' adaptive behaviors, usually not available in observational or experimental studies. We used *Netlogo* and R package *RNetlogo* to implement the RSM.[4]

In line with theoretical considerations discussed above, we assume that agents have a *de facto* preference towards attitudinally consonant (partisan) media, and also generally prefer to interact with other agents whose attitude falls within a certain range of similarity. Here, we define a discussant's attitude to be "similar" when it falls within a ± 1 range of the focal agent's attitudes.[5] Agents selectively choose to interact with attitudinally similar neighbors, up to the point where a certain proportion of their discussants hold similar attitudes. If such discussants are not available, agents interact with other dissimilar neighbors, with a certain baseline probability of creating discussion ties.[6]

From this setup, an agent iteratively changes his or her attitude as a function of (a) the degree of pro- and counter-attitudinal partisan media exposure (M_t), (b) opinion distribution from political discussion (D_t), and (c) one's prior attitude (Att_{t-1}) as following:

$$\mathbf{Att_t} = f(\mathbf{Att_{t-1}} * \mathbf{C_t}, \mathbf{D_t}, \mathbf{M_t} * \mathbf{C_t})$$

where C_t additionally denotes the extent of exposure to agreement and disagreement in an agent's network, defined as the proportion of those who hold similar and dissimilar preferences (Eveland

& Hively, 2009). For instance, if an agent is strong ("+3") or moderate liberal ("+2"), the extent of political heterogeneity is defined as the proportion of his or her discussants who are liberals (for agreement) and those who are conservatives or independents (for disagreement).

Following the general premise of information processing models (Kim & Garrett, 2011; McGraw et al., 2003), above three "considerations" are summed into a running tally. The tally is compared to previous attitudes, and agents increase (or decrease) their attitude by one if the tally is greater (or smaller) than their previously held opinion.

To investigate the RSM and the potentially moderating role of political discussion network heterogeneity and election cycle, we test several scenarios with regard to core propositions of respective theories, using a set of increasingly complex models as presented in Table 1. Model 1 establishes our baseline, where all of the parameter values are set to their reference value. We assume the baseline ratio of counter-attitudinal to pro-attitudinal exposure is to be 0.4, meaning that on average agents get 40% of counter-attitudinal exposure relative to congruent exposure.[7] Also, we assume the baseline decay value to be 0.2, such that on average 80% of one's prior attitude positively factors into one's running tally, hence an individual's attitude is largely determined by her prior attitude.[8]

[Table 1 About Here]

In model 2, we examine the effect of interpersonal agreement and disagreement on the RSM process. Instead of assuming a monotonic impact, we allow the impact of various considerations on the running tally to be *weighted* by the proportional difference between interpersonal agreement and disagreement (see Sohn & Geidner, 2016, for a similar application). Let $\delta_i^{(t)}$ be the proportional difference of agreeable and disagreeable discussants, $P_{agree} - P_{disagree}$, for each agent (*i*) at time *t*. Then, let the parameters at model 2 (P_{M2}) follow a logistic-like function of $\delta_i^{(t)}$, multiplied by the baseline value (P_{M1}) to produce decreasing (or increasing) marginal returns, such that:

$$P_{(M2|\text{decay or counter exposure})} = P_{M1}\left(\frac{1+e^{-\delta_i^{(t)}}}{l}\right)$$

$$P_{(M2|\text{pro exposure})} = P_{M1}\left(\frac{l}{1+e^{-\delta_i^{(t)}}}\right)$$

where l denotes a normalizing constant for each parameter. We set this constant to be 2 in order for above equations to yield identical parameter values as to model 1 when the proportional difference is equal to zero (i.e., an even-split in the network). These formulations are expected to produce a number of consequences as the distribution of political attitudes in one's discussion network starts to be biased toward agreement or disagreement, as postulated in the filter hypotheses framework. For instance, when an agent is surrounded with a maximally homogeneous network (i.e., no exposure to disagreement), then the decay parameter reduces from 0.2 to 0.13, as one's attitude become more resilient and stronger in such a situation (Levitan & Visser, 2009; Visser & Mirabile, 2004). Likewise, the impact of pro- and counter-attitudinal exposure on the attitude tally changes from the baseline value of 0.4 to 0.58 and 0.27, respectively, effectively amplifying the effect of attitude-consistent media exposure while inhibiting the effect of counter-attitudinal media exposure (Schmitt-Beck, 2003). In contrast, when surrounded with complete disagreement, one's decay parameter value increases from 0.2 to 0.37 (e.g., attitudes become weaker and more susceptible for persuasion), and the relative impacts of pro- and counter-attitudinal exposure on attitude tally change from 0.4 to 0.21 and 0.74, respectively. We expect model 2 to strengthen the positive feedback loop in RSM over time, producing more sharply opposed aggregate distribution of attitudes than does model 1.

In model 3 and model 4, we introduce the election cycle effect (on top of model 1 and 2, respectively) to examine the possible consequences of increasing (decreasing) media attention on the RSM process. During election periods, the impact of media influence and political discussion on the running tally are set to be increased (Table 1), along with similar changes in agents' propensity for homophilous political discussion ties. The ratio of counter-media exposure is also increased during election periods since pro attitudinal exposure often *increases* counter-attitudinal media exposure (e.g. Garrett et al., 2013).

Finally, in Models 5 and 6, we examine possible consequences of a structural change in the

composition of electorates stimulated by interaction between one's political interest and changes in opportunity structure for selective exposure (Prior, 2013; Strömbäck et al., 2012). We allow politically disinterested agents (i.e., those at the low one third level of political interest, with a neutral attitude) to selectively drop out, while those with more interest selectively tune in during election periods (Prior, 2013). We limit the proportion of agents who drop out to be less than 20% of all politically disinterested agents at each time point, while allowing new politically interested agents to come into the system as simulations proceed. We expect this effect to have at least modest influence on the RSM process by strengthening the relationship between partisan selective exposure and attitude polarization over time.

Following DiMaggio, Evans, and Bryson's (1996) seminal conceptualization of "polarization" (also see Fiorina & Abrams, 2008), we examine three key parameters that indicate the existence (or the absence) of attitude polarization for each of the models: (a) *variance* (i.e., the average dispersion) and (b) *kurtosis* (i.e., the degree of the bimodality and polarity between extremes) of attitude distribution, and finally, (c) Esteban and Ray's (1994) *discrete polarization index* (ER index). The ER index simultaneously accounts for the size and number of discrete groups, intra-group homogeneity ("concentration"), and inter-group heterogeneity ("alienation") of the quantity being measured (i.e., attitudes). The ER index is defined as follow:

$$DP(k, a = 1) = k \sum_{i=1}^{N} \sum_{j \neq i} p_i^{1+\alpha} p_j |p_i - p_j|$$

where p_i and p_j are the size of each discrete groups proportional to total population (i.e., liberals, independents, and conservatives), and the term $|p_i - p_j|$ is the pairwise absolute distance based on mean attitudes of groups, and k is the normalizing constant ($= 1.5$ for this case) that the index would run from 0 (= minimum bipolarization) to 1 (= maximum bipolarization). We examine the three parameters at each time step *t*, over the entire simulation time frame. All of the models were repeatedly simulated 100 times with varying random seeds (while setting the identical seed across models within the same simulation run) in order to account for stochastic variations in simulation algorithms. This ensures that any differences in our outcome measures are not affected by any potential differences in their initial conditions.

Simulation results

We first present an exemplary case of model comparison (between Model 1 and 2) in Figure 2, which makes it clear that interpersonal discussion network (dis)agreement (model 2) substantially amplify the impact of partisan media on attitude polarization. At *tick = 500*, the distribution of attitudes in Model 2 appears to be more polarized and concentrated towards the extreme values than in Model 1, and this is indeed reflected in its large and positive variance ($V_{M2} = 5.759$) and negative excessive kurtosis ($K_{M2} = -1.668$) of attitude distribution. Hence, the ER index shows that Model 2 ($ER_{M2} = .701$) is substantially more polarized than model 1 ($ER_{M1} = .193$). We repeated this procedure for every tick in each of the models, replicating for 100 simulation runs, and present time-series trends of our dependent measures (i.e., variance, kurtosis, and ER index) in Figure 3 to Figure 4.

[Figure 2 to Figure 4 About Here]

The first rows in Figure 3 highlight the differences between model 1 and model 2. The distribution of attitudes for Model 1 shows little evidence of increased polarization throughout the simulation time frame. This can be seen in relatively stable and low level of variances ($M = .732, SD = 0.029$) and kurtosis ($M = .042, SD = .102$) of the attitude distributions. In contrast, for Model 2, the attitude distributions generally maintained a high level the variance ($M = 3.661, SD = 2.065$), showing increased polarization over time as a result of selective exposure patterns, providing direct support for the notion of RSM. At the same time, a positive mean excess kurtosis ($M = .542, SD = 2.808$) with negative median excess kurtosis ($= -.452$) of Model 2 indicate that some of simulation runs resulted a situation where the relative size of the majority and the minority is highly imbalanced (e.g., a near-complete homogeneity of opinions) while they maintain sharply opposed attitudes. The ER-index over time subsequently showed a similar pattern (Figure 4), such that the index value was generally higher for Model 2 ($M = .442$) compared to that of Model 1 ($M = .193$), showing higher level of polarization over time. At the same time, there was a greater variability in index values for Model 2 ($SD = .260$) than Model 1 ($SD = .003$), suggesting more variations of actual polarization patterns across simulations.

The second row in Figure 3 present the effects of election cycles with (Model 4) and without (Model 3) the amplification effect of interpersonal (dis)agreement. In general, the increase and decrease in media attention (as modeled in impacts of media exposure on the attitude tally) indeed produced the expected effect for model 3, such that variance (e.g., $M_{t550} = .872, SD_{t550} = .043$) and kurtosis (e.g., $M_{t550} = .174, SD_{t550} = .111$) of attitudes during election periods were much higher than during off-election periods (for variance: $M_{t750} = .523, SD_{t750} = .012$; for kurtosis: $M_{t750} = -.498, SD_{t750} = .083$). With the amplification effect of interpersonal agreement and disagreement (model 4), the distribution of attitudes further polarized towards the extreme during election periods, yet it quickly returned to its homeostasis level after each election periods (e.g., after *tick = 300* or *after tick = 650*). This is indeed more evident in the time-series distribution of the ER-index (Figure 4), where index values of Model 3 were low and stable ($M = .190, SD = .018$) whereas index values of Model 4 are much higher and have greater variability ($M = .482, SD = .250$).

The last rows in Figure 3 and Figure 4 address the last component of model specifications, where we allow politically disinterested citizens to drop out, while more interested citizens selectively tune in to media exposure, again with (Model 6) and without (Model 5) the amplification effect of interpersonal agreement and disagreement. First, Model 5 overall appears to produce largely identical patterns compared to Model 3 in which we do not explicitly consider such varying level of interest. This suggests compositional changes in electorates based on differing level of political interest alone do not appear to accelerate positive feedback loops between partisan selective exposure and polarization. However, Model 6 reveals that overall level of variance (of attitude distribution) gradually declined with seasonality as time progresses while the mean level of excess kurtosis gradually increased (up to the value of 12.58: see Figure 3). This suggests polarization levels during election periods tend to regress back towards previous levels, but not as much lower as had initially been the case. The restabilization after election involves different levels of homeostasis, producing different levels of equilibrium. Figure 4 shows that time-series distributions of mean ER-indices are declining with seasonality as time

progresses, suggesting less polarization over time. However, this is because the ER-index is maximized with bi-polarization, where its maximum value can be obtained with only two distinctive groups with equal sizes holding maximally distanced opinion distributions. When the relative size of the majority and the minority is highly imbalanced (i.e., a near-complete homogeneity), the ER-index gives lower value than maximum bi-polarization. The declining ER index depicted in Figure 3 therefore suggests that compositional changes in electorates (due to declining level of political interest or the decrease in news exposure as a result of such changes) actually homogenize the distribution of political opinions (e.g. Liu, 2016).

Discussion

Within the context of partisan selective exposure and attitude polarization, the present study attempted to examine the core propositions of the RSM, highlighting the system-level consequences of dynamic media selection behavior and its effect. We further specify mechanisms and boundary conditions that affect spiral processes - interpersonal agreement and disagreement, and the ebb and flow of message receptions. Utilizing ABM simulations, this study also highlights the analytical utility of computational social science approaches in overcoming the limitations of typical experimental and observations studies.

Overall, our result suggests that partisan media exposure is likely to be an important factor that contributes to the maintenance and reinforcement of one's political attitudes (Berelson et al., 1954; Dilliplane, 2014; also see Slater, 2015). Especially for model 4 and 6, the macro-level distributions of political attitudes quickly reverted back to less extreme states following the decreases in the impact of media exposure based on declining media attention and political interest (also see Liu, 2016; Prior, 2013; Strömbäck et al., 2012). This highlights the notion, albeit indirectly, that the most likely outcome of partisan news exposure is reinforcement (e.g. Holbert, Garrett, & Gleason, 2010), while the lack of such exposure does not preclude the opportunity for attitude conversion from counter-attitudinal exposure (Dilliplane, 2014).

Although it has become gradually acknowledged that interpersonal discussion may have interactive consequences of on the impact of media exposure, a theoretical integration (and

empirical validation) of interpersonal political communication into mass media effects research is still in its infancy. Our results empirically validate the notion that - especially in model 2, 4, and 6 - attitudinal composition of one's network amplifies the effect of consonant media while diminishing the effect of counter-attitudinal media, therefore serving as an important social "anchor" upon which partisan media exposure is evaluated. Indeed, research suggests that attitudinal composition of one's network strongly affects metacognitions towards one's own attitude (Petty, Briñol, & DeMarree, 2007), such that prevalence of interpersonal disagreement may lower the perceived validity or confidence of one's judgement, whereas homogeneity may bolster them (e.g Levitan & Visser, 2009). This suggests that similar metacognitive processing regarding media messages (based on the attitudinal composition of one's network) would be responsible for the nature of the "filtering" process (e.g. Schmitt-Beck, 2003). While it was shown that political discussion may further polarize initial attitudes (e.g. Binder et al., 2009) and homogeneous groups modify the flow of political information (e.g Huckfeldt, Mendez, & Osborn, 2004), to our knowledge this study is the first to demonstrate that interpersonal discussion networks condition the reciprocal effect of selective media exposure and its attitudinal consequences. Future studies need to acknowledge that investigating RSM processes without simultaneous consideration of interpersonal discussion factors would lead to potentially wrong, or at least incomplete interpretations. Moreover, media effects research in general should take more seriously the postulates of the filter hypothesis to come to more realistic assessments.

Our ABM model vividly highlights the limitations of the prior studies investigating reinforcing spiral processes based on a limited number of data points. Employing multiple simulations over extended time periods with varying setups, our results suggest that actual spiral processes are likely to be subject to contextual variations based on system-level and individual-level moderating factors (e.g., election contexts or changes in composition of electorates). Only using limited data points, most observational or experimental studies cannot get at the actual spiral processes, nor make robust inferences addressing various confounds or possible contextual variations in such processes. Future studies on smaller time frames need to be

aware that different contexts may produce quite different spiral processes, which should bear on the interpretation of the results. Ideally researchers think *ahead* about data requirements and the context for observing spiral processes of media selectivity and its effects over time, rather than employing RSM perspectives *post-hoc* after the data collection.

Methodologically, our results highlight the analytical advantage of a computational social science approach. Many of the empirical social science applications are subject to disjuncture of actual theories and empirical evidence, either data requirements for critical testing of theories are immense, or addressing potential confounding factors in a rigorous manner is often practically impossible. Providing a tool for though experiments and overcoming the limitations of such data requirements, computational social science can facilitate the exploration of robust causal inferences. It also potentially highlights the blind spots of existing empirical evidence, and helps researchers to further develop and refine existing methods and theories. Taking the RSM of selective exposure and attitude polarization as an exemplary case, our analytical approach taken herein further underscores the strengths of computational social science applications to theoretical refinements.

Certainly our approach is not without limitations. First, throughout our simulations, any counter-attitudinal exposure is assumed to weaken one's prior attitude regardless of its specific direction. However, research on motivated reasoning and biased information processing (Taber & Lodge, 2006) suggests that counter-attitudinal partisan media may backlash rather than weaken the prior political convictions. More generally, this further implies that different psychological motivations that underlie pro- and counter-attitudinal media exposure might further condition the reinforcing spiral process (e.g. Mondak, 2010; Valentino, Hutchings, Banks, & Davis, 2008).

Second, we did not allow agents to interact with those who reside outside of their immediate neighbors. Indeed, such setting is fairly common in most ABMs (e.g. Huckfeldt, Johnson, & Sprague, 2004; Liu, 2016), and individuals appear to maintain relatively stable and small (typically three to five) number of discussants (Klofstad, McClurg, & Rolfe, 2009; Marsden, 1987), which is well below the total number of immediate neighbors (= eight) in our

setup. Yet exposure to political (dis)agreement tends to increase with network size (Eveland & Hively, 2009), and ego-network size may be crucial in understanding the emerging patterns of opinion dynamics (Sohn & Geidner, 2016). Although we are confident that the underlying mechanisms postulated here can be scaled up without much modification, it would be fruitful to investigate the effect of various facets of political discussion, including network size, in RSM.

Lastly, we only considered a single-attitude scenario in our simulations. Indeed, Axelrod's (1997) seminal investigation suggests that, when multiple "traits" (i.e., different dimensions, or multiple attitude objects) are present, there is a counterintuitive tendency of global homogenization as the number of traits increases. This suggests that, when a sufficiently large number of attitude dimensions is considered, we might instead observe increased global homogenization rather than polarization, despite the tendency of a single attitude dimension being moderately polarized. Thus, extending and replicating the current RSM to a multiple attitude scenario may further broaden our understanding of complex opinion dynamics.

As opportunities and choices for media contents increase, it is suggested that one's motivations and interest become more important predictors of media choice behaviors (Strömbäck et al., 2012) and its possible consequences (Prior, 2013). Our study not only corroborate such findings, but also suggests that, if anything, individual-level attitudinal compositions of interpersonal environments and various contextual factors also may critically moderate the spiral process between exposure and its attitudinal effect. To be sure, the system-level generative consequences such as increasing polarization patterns over time critically depend on the specific distribution of such factors - which we believe, ultimately, would be an empirical question that requires large scale, detailed real-world data. Therefore, only a real-world replication beyond this particular simulation context would provide more firm evidence on the generalizability of our findings. Yet as a first step, we believe our simulation study provides important groundwork for the theoretical refinement of the RSM perspective and its application as a theoretical framework for a study of reinforcing process between selective exposure and polarization.

References

Arceneaux, K., Johnson, M., & Cryderman, J. (2013). Communication, persuasion, and the conditioning value of selective exposure: Like minds may unite and divide but they mostly tune out. *Political Communication*, *30*(2), 213–231.

Axelrod, R. (1997). The dissemination of culture: A model with local convergence and global polarization. *The Journal of Conflict Resolution*, *41*(2), 203–226.

Bartels, L. M. (1993). Messages received: The political impact of media exposure. *American Political Science Review*, *87*(2), 267–285.

Berelson, B. R., Lazarsfeld, P. F., & McPhee, W. N. (1954). *Voting: A study of opinion formation in a presidential campaign*. Chicago, IL: The University of Chicago Press.

Binder, A. R., Dalrymple, K. E., Brossard, D., & Scheufele, D. A. (2009). The soul of a polarized democracy: Testing theoretical linkages between talk and attitude extremity during the 2004 presidential election. *Communication Research*, *36*(3), 315–340.

Boomgaarden, H. G. (2014). Interpersonal and mass mediated political communication. In C. Reinemann (Ed.), *Political communication* (pp. 469–488). Berlin: Walter de Gruyter.

Chaffee, S. H. (1986). Mass media and interpersonal channels: Competitive, convergent, or complementary? In G. Gumpert & R. Cathcart (Eds.), *Inter/media: Interpersonal communication in a media world* (pp. 62–80). New York: Oxford University Press.

De Vreese, C. H. & Boomgaarden, H. G. (2006). Media message flows and interpersonal communication: The conditional nature of effects on public opinion. *Communication Research*, *33*(1), 19–37.

Dilliplane, S. (2014). Activation, conversion, or reinforcement? The impact of partisan news exposure on vote choice. *American Journal of Political Science*, *58*(1), 79–94.

DiMaggio, P., Evans, J., & Bryson, B. (1996). Have american's social attitudes become more polarized? *American Journal of Sociology*, *102*(3), 690–755.

Downs, A. (1957). *An economic theory of democracy*. New York: Harper Collins.

Esteban, J.-M. & Ray, D. (1994). On the measurement of polarization. *Econometrica*, *62*(4), 819–851.

Eveland, W. P., Jr & Hively, M. H. (2009). Political discussion frequency, network size, and "heterogeneity" of discussion as predictors of political knowledge and participation. *Journal of Communication*, *59*(2), 205–224.

Ewoldsen, D. R., Rhodes, N., & Fazio, R. H. (2015). The MODE model and its implications for studying the media. *Media Psychology*, *18*(3), 312–337.

Feldman, L., Myers, T. A., Hmielowski, J. D., & Leiserowitz, A. (2014). The mutual reinforcement of media selectivity and effects: Testing the reinforcing spirals framework in the context of global warming. *Journal of Communication*, *64*(4), 590–611.

Feldman, L. & Price, V. (2008). Confusion or enlightenment? How exposure to disagreement moderates the effects of political discussion and media use on candidate knowledge. *Communication Research*, *35*(1), 61–87.

Fiorina, M. P. & Abrams, S. J. (2008). Political polarization in the American public. *Annual Review of Political Science*, *11*, 563–588.

Garrett, R. K., Carnahan, D., & Lynch, E. K. (2013). A turn toward avoidance? Selective exposure to online political information, 2004–2008. *Political Behavior*, *35*(1), 113–134.

Garrett, R. K. & Stroud, N. J. (2014). Partisan path to exposure diversity: Differences in pro- and counterattitudinal news consumption. *Journal of Communication*, *64*(4), 680–701.

Holbert, R. L., Garrett, R. K., & Gleason, L. S. (2010). A new era of minial effect? A response to Bennett and Iyengar. *Journal of Communication*, *60*(1), 15–34.

Huckfeldt, R., Johnson, P. E., & Sprague, J. (2004). *Political disagreement: The survival of diverse opinions within communication networks*. New York: Cambridge University Press.

Huckfeldt, R., Mendez, J. M., & Osborn, T. (2004). Disagreement, ambivalence, and engagement: The political consequences of heterogeneous networks. *Political Psychology*, *25*(1), 65–95.

Iyengar, S. & Hahn, K. S. (2008). Red media, blue media: Evidence of ideological selectivity in media use. *Jounral of Communication*, *59*(1), 19–39.

Iyengar, S., Sood, G., & Lelkes, Y. (2012). Affect, not ideology: A social identity perspective on polarization. *Public Opinion Quarterly*, *80*(3), 405–431.

Katz, E. & Lazarsfeld, P. E. (1955). *Personal influence: The part played by people in the flow of mass communication*. New York: The Free Press.

Kim, Y. M. & Garrett, R. K. (2011). On-line and memory-based: Revisiting the relationship between candidate evaluation processing models. *Political Behavior*, *34*(2), 345–368.

Klofstad, C. A., McClurg, S. D., & Rolfe, M. (2009). Measurement of political discussion networks: A comparison of two "name generator" procedures. *Public Opinion Quarterly*, *73*(3), 462–483.

Knobloch-Westerwick, S. & Meng, J. (2009). Looking the other way: Selective exposure to attitude-consistent and counterattitudinal political information. *Communication Research*, *36*(3), 426–448.

Krosnick, J. A. & Petty, R. E. (1995). Attitude strength: An overview. In R. E. Petty & J. A. Krosnick (Eds.), *Attitude strength: Antecedents and consequences* (pp. 1–24). Hillsdale, NJ: Erlbaum.

Levendusky, M. S. (2013). Why do partisan media polarize viewers? *American Journal of Political Science*, *57*(3), 611–623.

Levitan, L. C. & Visser, P. S. (2009). Social network composition and attitude strength: Exploring the dynamics within newly formed social networks. *Journal of Experimental Social Psychology*, *45*(5), 1057–1067.

Liu, F. C. S. (2016). Declining news media viewership and the survival of political disagreement. *International Journal of Public Opinion Research*. doi:10.1093/ijpor/edw004

Marsden, P. V. (1987). Core discussion networks of americans. *American sociological Review*, *52*(1), 122–131.

McGraw, K. M., Hasecke, E., & Conger, K. (2003). Ambivalence, uncertainty, and processes of candidate evaluation. *Political Psychology*, *24*(3), 421–448.

McGuire, W. J. (1989). Theoretical foundations of campaigns. In R. E. Rice & C. K. Atkins (Eds.), *Public communication campaigns* (2nd ed., pp. 43–66). Newbury Park, CA: Sage.

McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology*, *27*, 415–444.

Mondak, J. J. (2010). *Personality and the foundations of political behavior*. New York: Cambridge University Press.

Mutz, D. C. (2006). *Hearing the other side: Deliberative versus participatory democracy*. New York: Cambridge University Press.

Nir, L. (2011). Disagreement and opposition in social networks: Does disagreement discourage turnout? *Political Studies*, *59*(3), 674–692.

Petty, R. E., Briñol, P., & DeMarree, K. G. (2007). The meta-cognitive model (MCM) of attitudes: Implications for attitude measurement, change, and strength. *Social Cognition*, *25*(5), 609–642.

Petty, R. E. & Cacioppo, J. T. (1996). *Attitudes and persuasion: Classic and contemporary approaches*. Boulder, CO: Westview Press.

Prior, M. (2013). Media and political polarization. *Annual Review of Political Science*, *16*, 101–127.

Schemer, C. (2011). Reinforcing spirals of negative affects and selective attention to advertising in a political campaign. *Communication Research*, *39*(3), 413–434.

Schmitt-Beck, R. (2003). Mass communication, personal communication and vote choice: The filter hypothesis of media influence in comparative perspective. *British Journal of Political Science*, *33*(2), 233–259.

Sherif, M. & Hovland, C. I. (1961). *Social judgment: Assimilation and contrast effects in communication and attitude change*. Westport, CT: Westview Press.

Slater, M. D. (2007). Reinforcing spirals: The mutual influence of media selectivity and media effects and their impact on individual behavior and social identity. *Communication Theory*, *17*(3), 281–303.

Slater, M. D. (2015). Reinforcing spirals model: Conceptualizing the relationship between media content exposure and the development and maintenance of attitudes. *Media Psychology*, *18*(3), 370–395.

Small, M. L. (2013). Weak ties and the core discussion network: Why people regularly discuss important matters with unimportant alters. *Social Networks*, *35*(3), 470–483.

Sohn, D. & Geidner, N. (2016). Collective dynamics of the spiral of silence: The role of ego-network size. *International Journal of Public Opinion Research*, *28*(1), 25–45.

Southwell, B. & Yzer, M. C. (2007). The roles of interpersonal communication in mass media campaigns. *Annals of the International Communication Association*, *31*, 419–462.

Strömbäck, J., Djerf-Pierre, M., & Shehata, A. (2012). The dynamics of political interest and new media consumption: A longitudinal perspective. *International Journal of Public Opinion Research*, *25*(4), 414–435.

Strömbäck, J. & Johansson, B. (2007). Electoral cycles and the mobilizing effects of elections: A longitudinal study of the swedish case. *Journal of Elections, Public Opinions and Parties*, *17*(1), 79–99.

Stroud, N. J. (2010). Polarization and partisan selective exposure. *Journal of Communication*, *60*(3), 556–576.

Taber, C. S. & Lodge, M. (2006). Motivated skepticism in the evaluation of political beliefs. *American Journal of Political Science*, *50*(3), 755–769.

Valentino, N. A., Hutchings, V. L., Banks, A. J., & Davis, A. K. (2008). Is a worried citizen a good citizen? Emotions, political information seeking, and learning via the internet. *Political Psychology*, *29*(2), 247–273.

Visser, P. S. & Mirabile, R. R. (2004). Attitudes in the social context: The impact of social network composition on individual-level attitude strength. *Journal of Personality and Social Psychology*, *87*(6), 779–795.

Zaller, J. (1992). *The nature and origins of mass opinion*. New York: Cambridge University Press.

Zhao, X. (2009). Media use and global warming perceptions: A snapshot of the reinforcing spirals. *Communication Research*, *36*(5), 698–723.

1 See Prior (2013) for controversies regarding the proper conceptualization and operationalization of "polarization."

2 Therefore, our theoretical model is broadly consistent with what is called a "hybrid" model of information processing (e.g. Kim & Garrett, 2011), which suggests that both on-line *and* memory-based processing jointly determines one's political attitudes and judgement in a complementary way.

3 Individuals may actively counter-argue or discount counter-information (Taber & Lodge, 2006). Yet such a pattern only appears to be pronounced with substantially strong attitudes (Levendusky, 2013) or with high political interest (Arceneaux et al., 2013).

4 A set of replication codes for ABM models and statistical analyses are available at http://XX  X [masked for peer review, available upon request]

5 This idea is consistent to the notion of the latitude of acceptance (Sherif & Hovland, 1961)

6 The baseline propensity for homophilous discussion ties is set to 0.4, with the probability of creating ties with attitudinally dissimilar neighbor is set to 0.3. This means, on average, 3 out of 10 times agents will create discussion ties with other neighbors even if they have considerably different attitudes, and they are more likely to create discussion ties as their attitudinal similarity increases. From this setup, an agent is expected to have at least 40 % of discussion partners, if available, whose attitudes are similar to their own. Since in *Netlogo* the "neighbors" are defined as other agents in eight surroundings cells, the agent will create discussion ties with 2.4 neighboring agents even if politically similar neighbors are not present. The number of ties then further increases to the extent each additional tie maximizes the proportion of homophilous discussion partners. Most of the prior studies on this topic suggest that core discussion networks of are comprised of up to 3 individuals (see Klofstad et al., 2009).

7 For instance, Iyengar and Hahn (2008) report that the likelihood of Republicans to select liberal media source was only 15% compared to 50% likelihood of choosing them Fox news, and the likelihood of Democrats to select Fox news was about 15% compared to CNN/NPR, which was about 30%. This roughly translates to 0.3 to 0.5 ratio, which we simply took the average value and regard it as a baseline in our study. Knobloch-Westerwick and Meng (2009) also report similar level of likelihood of selecting counter-attitudinal news (about 43%). Also, this value is chosen because the simulated results indicates no polarization patterns empirically.

8 Consider a liberal agent (attitude value of "$+2$") here, who consumed two pro-attitudinal and one counter-attitudinal news, while having discussed politics with two extreme liberals ("$+3$") and one moderate conservative ("-2"). We expect his or her pro-attitudinal exposure increases running tally by 0.8 (= $+2 * 0.4$), and counter exposure decreases the tally by 0.4 (= $-1 * 0.4$). The agent also perceives the average attitude of discussants ($\frac{[3+3-2]}{3} = 1.33$), and this increases the tally by 0.53 (= $1.33 * 0.4$). Lastly, as one's prior attitude will increase the tally by 1.6 (= $+2 * [1 - 0.2]$), the sum of running tally equals 2.53. Since the tally is greater than prior attitude, this agent will increase attitude by one, becoming a "extreme" liberal ("$+3$") at the next tick of a simulation.

Table 1
The design of simulation experiments and key parameter values

Model settings	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Exposure to agree / disagree	No	Yes	No	Yes	No	Yes
Election cycle	No	No	Yes	Yes	Yes	Yes
Interest in politics	No	No	No	No	Yes	Yes
Parameter values for each model						
Counter-media exposure	0.4	0.4	0.4 → 0.6 → 0.5 → 0.4 (initial value / during election / right after election / off election)			
Impact of partisan media	0.4	weighted	Baseline: 0.4 → 0.5 → 0.4 → 0.3 (additionally weighted for Model 4 and Model 6)			
Impact of discussion	0.4	weighted	Baseline: 0.4 → 0.5 → 0.4 → 0.3 (additionally weighted for Model 4 and Model 6)			
propensity for homophily	0.4	0.4	0.4 → 0.6 → 0.5 → 0.4			
Attitude decay	0.2	weighted	0.2	weighted	0.2	weighted
N of agents per time steps	n = 2500	n = 2500	n = 2500	n = 2500	n = 2500	n = 2500
N of time steps	t = 1095	t = 1095	t = 1095	t = 1095	t = 1095	t = 1095
N of replicated simulations	N = 100	N = 100	N = 100	N = 100	N = 100	N = 100

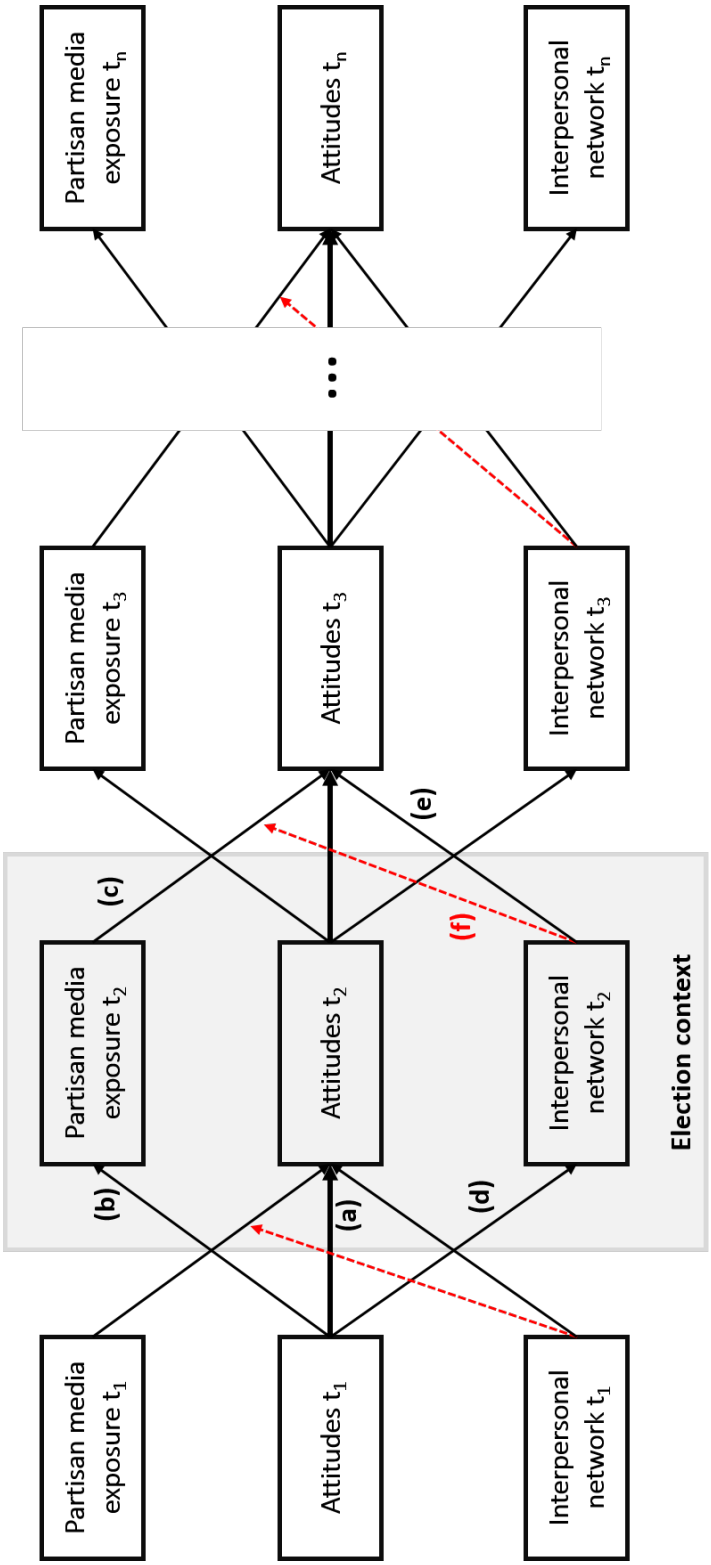
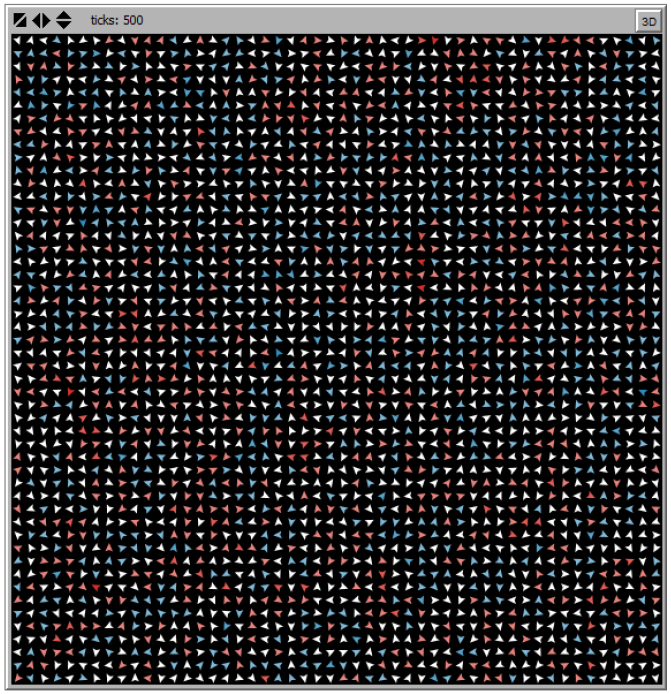
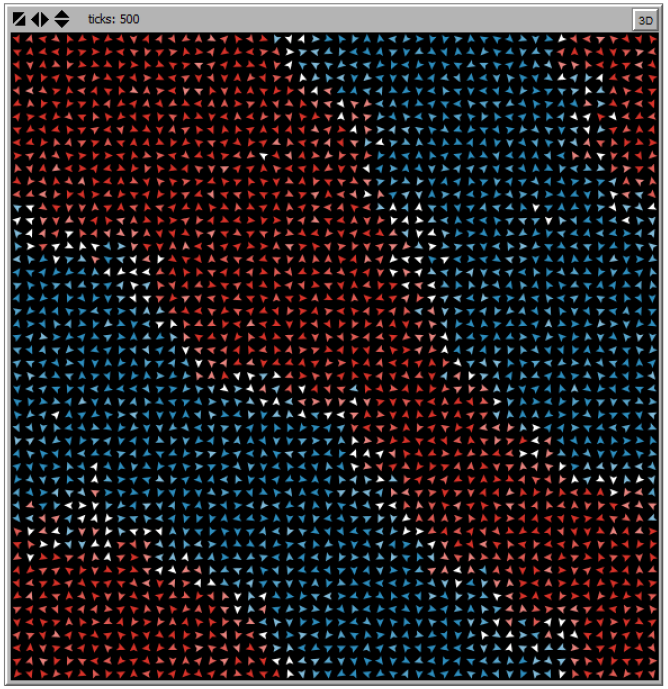


Figure 1. A theoretical model of reinforcing process between selective exposure, interpersonal networks and media effects on attitude polarization



(a) **Model 1 (random seed = 14562)**

Variance = .736 (Mean of attitudes = -.0032)
Excessive kurtosis = .106
ER-index = .193



(b) **Model 2 (random seed = 14562)**

Variance = 5.759 (Mean of attitudes = -.0032)
Excessive kurtosis = -1.668
ER-index = .701

Figure 2. An example comparison of attitude distributions of each model at $t = 500$, simulation #28

Note: The identical random seed supplied to each model guarantees that initial conditions of each simulation (at tick = 0) to be identical across models. As a result, any observed differences between models are attributable to their model specifications (e.g., a uniform impact of partisan news exposure and political discussion vs. the weighted impact based on exposure to interpersonal agreement and disagreement) while excluding the possibility of any differences in their initial starting conditions.

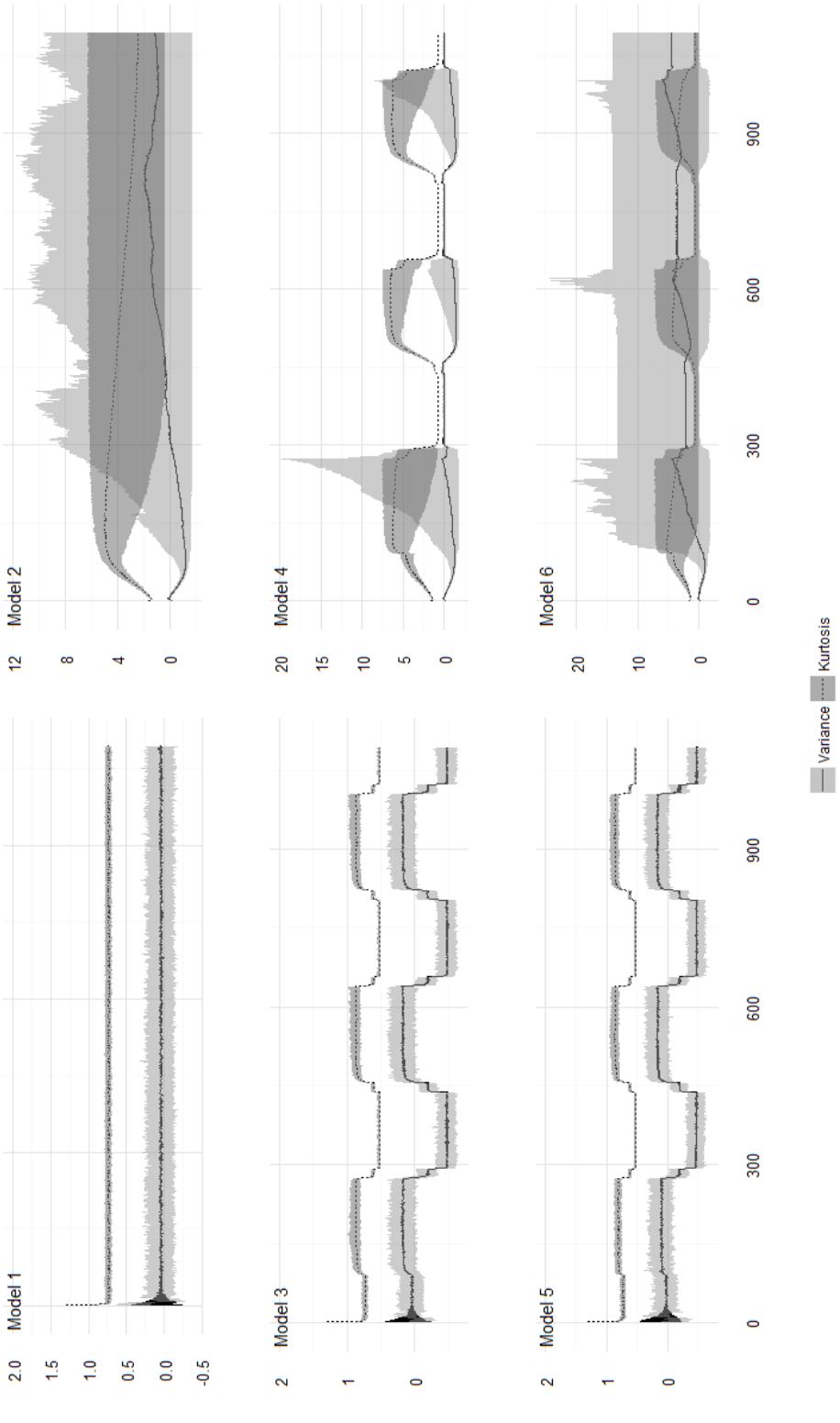


Figure 3. Over-time trends of variance and kurtosis of attitude distributions by model

Note: A solid black line (with light grey area) denote mean variance, and a dashed black line (with darker grey area) denote mean excess kurtosis of the attitude distribution at time *t* across 100 replicated simulations. Light and darker grey areas denote 95% CIs of respective statistics from 100 replicated simulations.

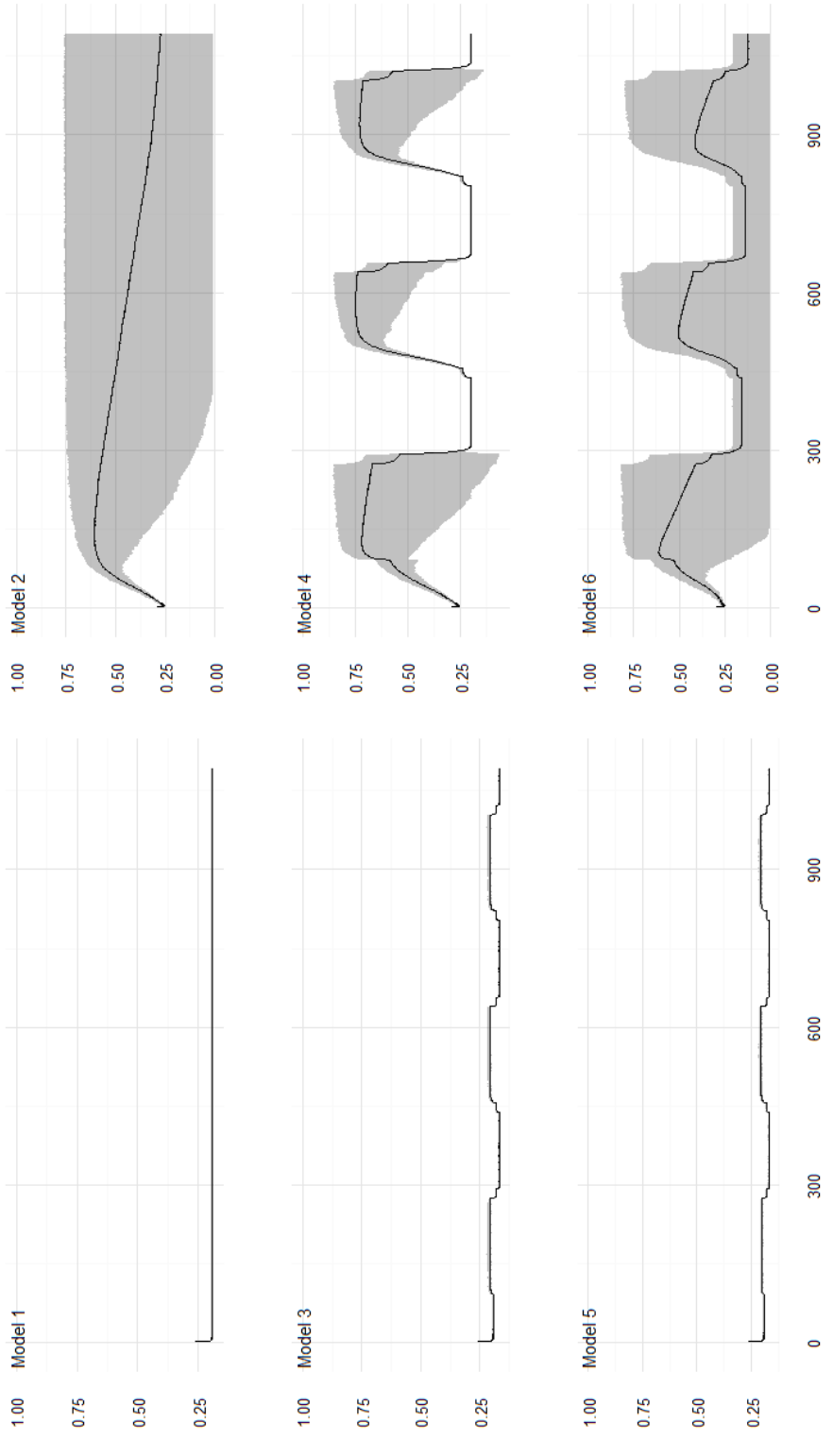


Figure 4. Over-time trends of Esteban and Ray discrete polarization index by model

Note: A think black line represents the mean *ER-index* derived from each cross-sectional attitude distribution at time t across 100 replicated simulations. Darker grey areas denote 95% CIs from 100 replicated simulations.