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

Contact author:

Hyunjin Song
Department of Communication
University of Vienna

Rathausstraße 19/1
1010, Vienna, Austria
hyunjin.song@univie.ac.at
+43-1-4277-49922

January 28, 2017

Accepted for publication in *Journal of Communication*

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.

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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; Berelson, Lazarsfeld, & McPhee, 1954; Delli Carpini, Cook, & Jacobs, 2004; 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 opinions (Stroud, 2010), and the recent proliferation of partisan news sources and the rise of online social networks as transmitters of news arguably made it easier to do so. In consequence, studies revealed that reliance on attitude congruent 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 and the consequences 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; also see Boomgaarden, 2014; Schmitt-Beck, 2003). 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. The present study develops an integrated theoretical framework, combining insights from literature on information processing and effects with prior contributions on selective exposure to information while taking into consideration the conditionality of these processes based on the extent and nature of interpersonal discussion networks. First, this study investigates a *mutually reinforcing spiral model* (Slater, 2007: hereafter denoted as RSM) within the context of attitude congruent (partisan) selective exposure and attitude polarization, aiming to advance a more nuanced understanding of the cumulative effects and consequences of media choice behaviors for individual- and system-level ramifications. 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 in longitudinal perspective, the ABM approach allows formalizing such dynamics, facilitating robust causal inference. 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; Neiheisel & Neibler, 2015; Schmitt-Beck, 2003), we also address the *role of interpersonal agreement and disagreement* as a core explanatory mechanism of a positive feedback process that may lead to more extreme outcomes. While the RSM framework has been mainly concerned with the question of reinforcement and maintenance of media selection and 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 these 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 reinforcing spirals. Accordingly, as an exemplary case of such contextual variations, we consider 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 on dynamic relationships between attitude congruent media exposure, political discussion, and attitudinal polarization, the ABM provides a parsimonious, yet highly generalizable representation of a complex reality. The general approach advanced in the present study therefore can be easily extended and applied to other substantive domain of interest, such as environmental (e.g., global warming) or health-related beliefs and behaviors, while overcoming the typical generalizability concern from observational and/or experimental data that are bounded to the particular context of a study. 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, contributing to refining theoretical notions of and empirical approaches to understanding information effects in political contexts and beyond.

Reinforcing spirals between partisan selective exposure and attitudinal polarization

Although "the most likely 'effect' of communication … is further communication" (Chaffee, 1986, p. 76), so far scholars pay relatively scant attention to this possibility. Explicitly

stating this dynamic perspective, Slater (2007; also Slater, 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 (selective exposure), which in turn reciprocally influences such media use over time (media influence). Although more direct evidence supporting core assertions of the RSM is limited to a few studies (e.g. Feldman et al., 2014; Zhao, 2009), the model provides a valuable starting point to formulate the dynamic relationship between selective media use and attitudinal polarization.

Based on a cognitive dissonance framework, the 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). Indeed, studies have found the consistent evidence of attitude-congruent media selectivity both on outlet-level (e.g., CNN vs FOX News: Stroud, 2010) and story selection-level (i.e., selection of specific news items based on their valence: Garrett & Stroud, 2014). Such exposure patterns, in turn, are thought to cause more extreme and polarized attitudes (Iyengar & Hahn, 2009; Stroud, 2010) either based on cognitive (Stroud, 2010; Zaller, 1992) or affective mechanisms (Iyengar et al., 2012). Attitude polarization therefore denotes "the strengthening of one's original position or attitude" following selective exposure to politically congenial information (Stroud, 2010, p. 557). In sum, previous studies convincingly suggest that partisan selective exposure leads to extreme attitudes, which in turn should increase such exposure. This

implies reciprocal dynamics unfolding over time as advanced in the RSM (Slater, 2007).

Empirical investigations of the RSM within the context of 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 the RSM. Using a three-wave panel study, Schemer's (2012) 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 media use. While theoretical frameworks and some scattered empirical evidence suggest spiral processes, it needs to be noted that this evidence is rather suggestive. Given limitations in data one can hardly speak of actual tests of reinforcing *spirals*, since only a small fraction of what could be a spiral usually is investigated. Furthermore, little is known about how interpersonal communication as a competing information source would affect spiral dynamics and what may be the contextual boundaries in which such spirals to occur.

Political discussion network as a "filter" of partisan media influence

It is generally acknowledged that the effect of mass media exposure is conditional in nature (Boomgaarden, 2014; McLeod, Kosicki, & McLeod, 2008), 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). That is, citizens do not encounter political information without social context. Rather, they are embedded within a rich array of social networks, channels through which such information can be gleaned and interpreted (Huckfeldt, Johnson, & Sprague, 2004). Therefore, it is imperative to *simultaneously* consider two distinctive

sources of political information – mass media exposure and political discussion network – when evaluating the reciprocal impacts of media and attitudes. Yet, studies addressing the role of political discussion for media effects are, surprisingly, virtually non-existent when it comes to interactions of interpersonal discussion and reinforcing spirals of media selection and effects. Prior studies are mainly concerned with the impact of political discussion on knowledge or participation (e.g., Eveland & Hively, 2009; Mutz, 2006), but have paid little attention to the conditioning effects on media selectivity or on attitude (de)polarization (Boomgaarden, 2014).

Literature to date suggests that everyday political discussions within one's social network are "pervasive" (Klofstad, 2011, p. 131) and "everywhere" (Kim & Kim, 2008, p. 62). People talk politics with their friends and families, exchange their ideas and change their opinions. Prior studies have therefore conceived that political discussion significantly influences one's opinions and attitudes both theoretically (Delli Carpini et al., 2004; Kim & Kim, 2008) and empirically (Eveland et al., 2011). For instance, studies suggest that political conversation directly enhances quality of opinions and attitudes by providing relevant arguments and reasons (Hucfeldt et al., 2004; Kim, Wyatt, & Katz, 1999) and by triggering more in-depth processing of relevant information (Eveland, 2001).

In addition to its direct effect on attitudes, the *composition* of one's immediate social environment may moderate the influence of mass media exposure (e.g., Schmitt-Beck, 2003; Southwell & Yzer, 2007). Earlier research on media and interpersonal discussion, particularly from the foundational work of the Columbia school scholars (Berelson et al., 1954; Katz & Lazarsfeld, 1955), postulated that networks of interpersonal communication may bolster or alter the direct impact of the mass media messages. According to this notion of "the filter hypothesis" (Schmitt-Beck, 2003, p. 237), individuals in homogenous social networks receiving political

information that is consistent with their preferences are likely to strengthen their initial attitudes (Southwell & Yzer, 2007). By contrast, media influences would diminish when citizens surrounded by such homogeneous environments receive dissonant messages. Those who are surrounded by heterogeneous environments, however, are less likely to be resistant to such dissonant political message (Neiheisel & Neibler, 2015). Hence, the composition of individuals' discussion networks may either inhibit or reinforce the effect of mass media conditional on the congruent or dissonant nature of the message (Berelson et al., 1954; Katz & Lazarsfeld, 1955).

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 et al., 2004; Southwell & Yzer, 2007). It creates one-sided vs. two-sided message flows, 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 et al., 2004; Schmitt-Beck, 2003). In sum, prior perspectives undoubtedly suggest that information flows from attitudinally congruent and/or dissonant media are fundamentally conditioned by one's political discussion network.

The ebb and flow of message reception: The role of 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, 2013). Indeed, it is often theorized that interest and attention to relevant information and more effortful and deliberative processing of such information yield stronger and more 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., 2013). 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). As the opportunity for being exposed to attitude-congruent channel and/or content increases, those who are highly interested in politics (and those who are more likely to attend such news) would engage higher degrees of pro-attitudinal exposure as a function of individuals' choice. This may further imply that impact of attitude-congruent media exposure on subsequent polarization may be higher for those who

are more interested in politics (Arceneaux, Johnson & Cryderman, 2013; Levendusky, 2013).

This ebb and flow of attention to and interest, and subsequent reception of relevant messages, may have an important implication for the RSM in that it explicates the boundary conditions under which RSM processes, conditioned by interpersonal discussion, may take place. During heightened periods of media attention (such as during election), increased attention to (and reception of) attitude-congruent media is logically expected to yield stronger impact, either through the activation of latent partisan 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 as a function of increased attention and interest level. Yet as the attention and interest gradually decreases (such as after elections), positive feedback loop would be restabilized to its original homeostatic status. Likewise, if 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

Each of the aforementioned factors – attitude-congruent media exposure, informal political discussion, and contextual variations in which such processes are unfolding – address important aspects of reinforcing spiral regarding how attitudes and opinions are dynamically updated and maintained over time. Integrating these factors into a more comprehensive yet parsimonious model, we present a brief formalization of our expectations in Figure 1 below. We pay particular attention to how the relationships between pro- and counter-attitudinal exposure, the nature of the interpersonal discussion networks, contextual variations, and political attitudes over time are integrated to a larger process of a reinforcing spiral framework, focusing on key

moderating mechanisms that amplify or inhibit reinforcing spirals.

[Figure 1 About Here]

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

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) in determining one's attitudes, as illustrated in (a) path in Figure 1. Yet such an autoregressive effect of prior attitudes is subject to decay over time (Krosnick & Petty, 1995; Petty & Cacioppo, 1996), thus the impact of prior attitudes on current attitudes becomes gradually weaker. Yet we would expect the specific decay value to be contingent on different kinds of attitudes, such that some constructs (such as political ideology or partisan identification) are more stable and resistant to new information than others (e.g., new policy preferences). In light of our model, we would expect strong attitudes to (a) exhibit much more stability over time, and (b) more likely to drive selective exposure, yet (c) the influence of attitude-congruent media and discussion on attitude would be smaller. The consequences of such stable, resistant attitudes would be that polarization over time as a function of media exposure and political discussion is less likely than with more malleable attitudes (see additional material in Appendix).

Selective exposure to attitude congruent media. Advances in selective exposure research consistently document that attitude congruent media exposure is quite substantial (Levendusky,

2013; Stroud, 2010), yet at the same time, counter-attitudinal exposure still appears to be common (Garret & Stroud, 2014). Therefore, while we expect that citizens would have a *de facto* preference for attitude-consistent media, we also consider a not-so-trivial degree of counter-attitudinal media exposure, although the amount of such exposure would always be lower than that of pro-attitudinal media exposure. This relationship is conceptually depicted in (b) path in Figure 1, such that prior attitude serves as determinant of subsequent media exposure.

As a parsimonious, generalizable representation of reality, we refer to "partisan media exposure" (or "attitude-congruent media exposure") as a general construct, such that one can address different kinds of selective exposure (e.g., selection of *media outlet* vs. *specific information/story*) as well as its contextual boundaries -- such as when supply of partisan media outlets are limited (as in European cases) vs. one can allow more degree of selectivity (as in U.S cases) – within the model. Yet regardless of its particular context, our expectation is that exposure to attitude congruent or dissonant media message, *irrespective 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 (Zaller, 1994) and experimental studies of pro- and counter attitudinal exposure (Arceneaux et al., 2013; Levendusky, 2013) generally support this perspective.

While literature suggests that *avoidance* is a much weaker motivational force than the selective approach (Garrett, 2009; Garrett & Stroud, 2014), it is nevertheless possible that citizens are likely to selectively avoid counter-attitudinal media exposure at first place, or at least they can "resist" such messages given exposure. Research on motivated reasoning (Taber & Lodge, 2006) suggest that counter-arguing (i.e., disconfirmation bias) is pronounced for those

with strong attitudes (Levendusky, 2013) or with high political interest (Arceneaux et al., 2013). Also, it is plausible to assume that those who are more interested in politics (and therefore holding strong attitudes) are more likely to engage in "selective" exposure at first place than those with less political interest. We additionally examined this possibility by incorporating the disconfirmation bias (selective avoidance) and interaction between interest and media selectivity (i.e., confirmation bias) into the model (results are presented in the Appendix), yet the results and general conclusions presented below remain by-and-large unchanged. [2]

Political discussion network. Before we postulate a moderating impact of the partisan composition of individuals' discussion network on the reciprocal relationship between selective exposure and attitude change (i.e., "social influence"), we must address the question of how individuals "construct" their discussion network at first place ("social selection"). Literature suggests that similarity of attitudes, or the principle of attitude "homophily," drives the selection of potential discussion partners (McPherson et al., 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 exchange opinions and relevant information regarding politics. During such exchange, they perceive the distribution of opinion from their network, which serves as one determinant of their attitude, the (e) path in Figure 1. In addition to the distribution of their neighbors' opinion, an individual also perceives

the extent of networks political agreement and disagreement (Eveland & Hively, 2009). One consequence of homogenous versus heterogeneous networks is the moderating influence on the impact of media exposure, as postulated by the filter hypothesis framework (Schmitt-Beck, 2003; Southwell & Yzer, 2007). This relationship is represented in (f) path in Figure 1.

Effect of exposure context. We expect that attention to and the reception of political information generally increase during certain contexts (Dilliplane, 2014; Strömbäck & Johansson, 2007), such as during election periods, crisis, or during high impact societal events (e.g., referendums), while politically disinterested selectively drop out from selective exposure-polarization spirals (Prior, 2013). We also expect that the degree of selective exposure and attitudinal homophily in discussion network would also be increased, which leads us to expect a stronger impact of attitudinally congruent media exposure in such contexts. Coupled with the amplification effect of interpersonal network and stronger effects of attitude stability, this heightened impact of attitudinally congruent media would lead to increased polarization. In contrast, when attention gradually decreases, such feedback processes would restabilize.

Our formalization of the 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 pro- and counter-attitudinal 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 based on their political interest. At the start of a simulation run, individuals are randomly assigned a "political interest" value between 0 and 1 (following a normal distribution with a mean of 0.5), which subsequently determines the strength of agents' initial attitudes. That is, those who score higher than 0.7 on the political interest scale (i.e., "highly interested in politics") are set to have "strong" to "moderate" attitudes (e.g., -3, -2, +2, or +3 attitude value). Those who are between 0.3 and 0.7 on the political interest scale (i.e., "moderately interested in politics") are set to have "moderate" to "weak" attitudes (e.g., -2, -1, 0, +1, or +2 attitude value). Finally, those who score less than 0.3 on the political interest scale (i.e., "not interested in politics") are set to have "weak" to "no" attitudes (e.g., -1, 0, or +1 attitude values). We treat an agent's political interest as being exogenous to media exposure and political discussion. Since one's political interest appears to be exceptionally stable and robust over extended periods of time (Prior, 2010), political interest is not influenced by other factors in our model rather than driving changes in such factors.

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 the R package *RNetlogo* to implement the ABM.[3]

In line with theoretical considerations discussed above, we assume that agents have a *de facto* preference for attitudinally consonant (partisan) media, and also generally prefer to interact with others whose attitude falls within a certain range of similarity. Here, we define attitude to be "similar" when it falls within a ± 1 range of the focal agent's attitude.[4] Agents selectively choose to interact with attitudinally similar neighbors, up to the point at which 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.[5]

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:

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

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 favors an issue or a position (for instance, an agent identifies as "liberal"), 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 (McGraw et al., 2003;

Kim & Garrett, 2011), above three "considerations" are summed into a running tally. The tally is compared to previous attitudes, and agents increase (or decrease) their attitude by a scale value of one if the tally is greater (or smaller) than their previously held opinion.[6]

To investigate the RSM and the potentially moderating role of political discussion network heterogeneity and election cycle, we test several scenarios with regard to the core propositions of the 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 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, 2015, for a similar application). Let $\delta_i^{(t)}$ 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:

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

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

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 impacts of media and political discussion on the running tally are set to be increased (Table 1), along with similar changes in agents' propensity for homophilous discussion ties. The ratio of counter-attitudinal exposure is also increased since

pro-attitudinal exposure often *increases* counter-attitudinal 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., 2013). We allow politically disinterested agents (i.e., those at the low one third level of political interest, with a neutral attitude) to randomly 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 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:

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

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 $\left| y_i - y_j \right|$ 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 shows that interpersonal discussion network (dis)agreement (model 2) substantially amplifies the impact of attitude-congruent 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 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 the 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 attitude-congruent media 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 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 a 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).

In sum, we see that in all of our model scenarios, reciprocal dynamics between attitude

polarization and attitudinally congruent partisan media exposure over time critically hinge on the attitudinal composition of one's discussion network and contextual variations in which such media exposure occurs (in this case, election periods). Additional specifications of the parameters as discussed below are presented in the Appendix, where we consider different values of attitude strength, individuals difference (e.g., political interest) in message processing, level of partisan media supply at system-level, information decay and recency effects in media exposure, and indirect ("mediated") exposure to media. By and large, these additional scenarios confirm the general picture presented here, such that limited opportunity of selective exposure at the system level, information decay, and strong attitudes lead to lesser polarization, whereas some of the stable individual difference (political interest) and story-level selection dynamics (via mediated message exposure) leading to similar levels of polarization patterns. Overall, our results points toward a consistent picture regarding the impact of interpersonal discussion network and contextual variations in explaining the reciprocal dynamics between attitude congruent media exposure and attitude polarization.

Discussion and conclusions

Within the context of partisan selective exposure and attitude polarization, the present study attempted to examine core propositions of the RSM, focusing on 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 due to contextual variation. 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 attitudinally congruent 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., 2013). 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 on the impact of media exposure, a theoretical integration (and empirical validation) of interpersonal discussion into mass media effects 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 individual'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 of or confidence in one's judgment, 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 the 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, Johnson, & Sprague, 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.

Considering that contextual variation in terms of heightened interest and attention is not confined to election periods, but may be triggered by external events more generally, it appears that societally salient issues or events that lend themselves for contrasting perspectives may be assumed to lead to more polarization. Taking the 2015 refugee crisis in the European context as an example, our modeling strategy would have predicted stronger polarization of European

populations over refugee and migration issues. Similarly, we add systematic evidence to the role of social context in accentuating or bolstering media effects. While this has been a longstanding tradition (e.g. Katz & Lazarsfeld, 1955; Huckfeldt et al., 2004) and while research has acknowledged the role of interpersonal discussion (Schmitt-Beck, 2003), our simulations show that the field needs to do better in terms of theoretically integrating interpersonal communication into mass media effects. In sum, we thus take spiral dynamics seriously while additionally showing that these processes critically depend on context in terms of interpersonal social settings and issue salience. These will add to our understanding of the conditionality of media effects research (Valkenburg & Peter, 2013) but also of media selection processes in general.

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. As a parsimonious representation of the complex realities, our models and simulations are also able to consider various factors such as attitude strength, individuals difference factors, level of partisan media supply at system-level, and indirect ("mediated") exposure to partisan media – all of which, we believe, are potentially important considerations in understanding real-world cases of attitude polarization and reinforcing spiral process. By formulating a general yet flexible representation, our modeling approach (and computational models such as ABMs in general) can further inform our understanding of the dynamic process and its contingency conditions while addressing the generalizability of our findings. 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).

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, 2015). 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., 2013) 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. Indeed, several prior studies, although anecdotally, suggest that exposure to disagreement within interpersonal political discussion network is likely to be a key moderating mechanism that limit or enhances persuasive (or counter-persuasive) effect of partisan exposure on one's attitudes (e.g., Kim, 2015; Neiheisel & Niebler, 2015), which lends considerable support to the results of our study. To be sure, the system-level generative consequences such as increasing polarization patterns 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, a real-world replication beyond this particular simulation context would provide 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 framework for a study of reinforcing process between selective exposure and polarization.

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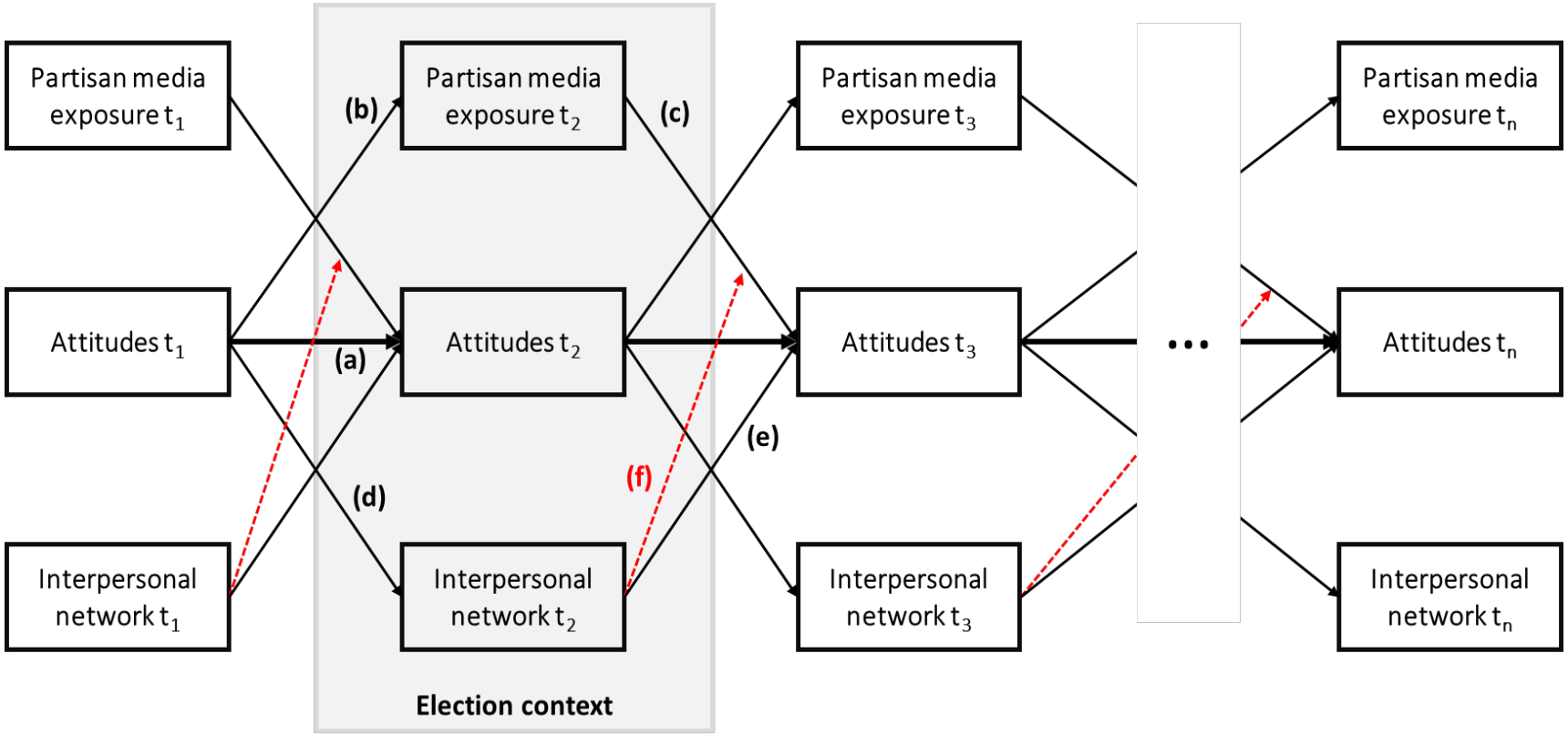
Table 1. The design of simulation experiments and key parameter values

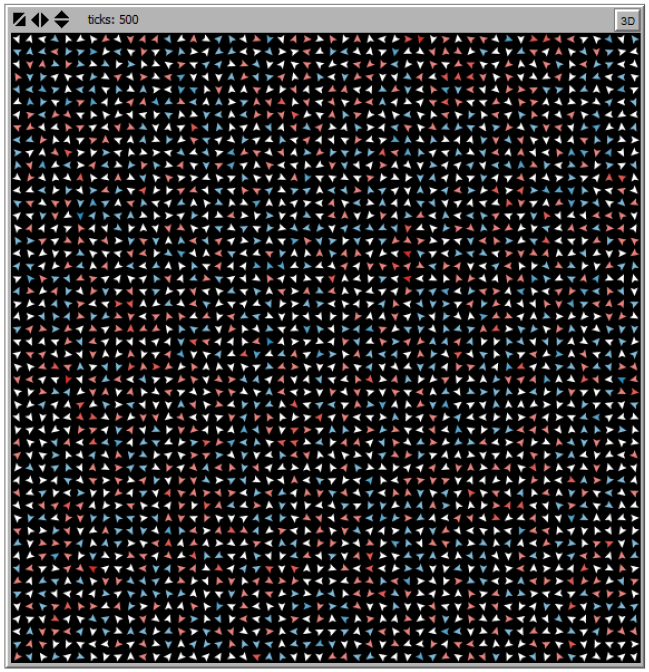
Model settings	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Exposure to agree / disagree	No	Yes	No	Yes	No	Yes
Election cycle	No	No	Yes	Yes	Yes	Yes
Interest in politics	No	No	No	No	Yes	Yes
Parameter values for each model						
Counter- media exposure ratio	0.4	0.4	0.4 → 0.6 → 0.5 → 0.4 (initial value / during election / right after election / off election)			
propensity for homophily	0.4	0.4	0.4 → 0.6 → 0.5 → 0.4			
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)			
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



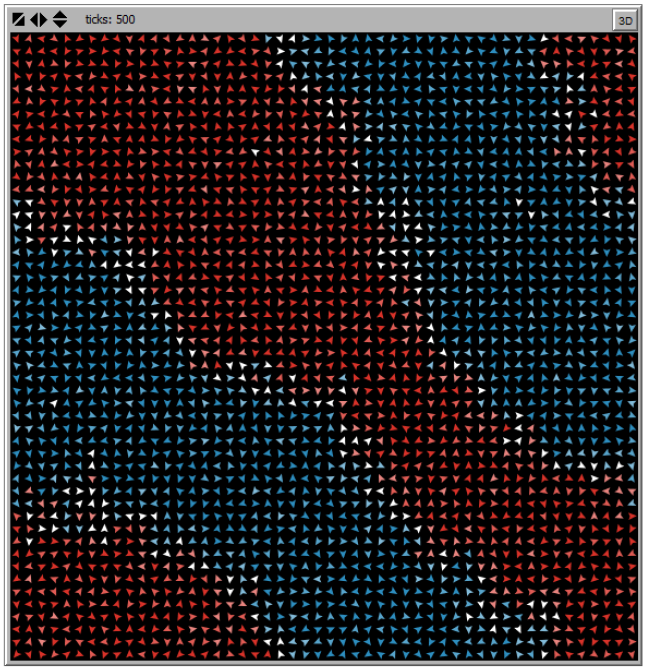
Note: (a) effects of prior attitudes on later attitudes ("attitude stability"). (b) effects of prior attitudes on partisan media exposure ("selective exposure"). (c) effects of partisan media exposure on later attitudes ("partisan media effect"). (d) effects of prior attitudes on selection of discussants in interpersonal discussion network ("attitudinal homophily"). (e) effects of interpersonal discussion network on later attitudes ("social influence"). (f) moderating effects of interpersonal discussion network on impact of partisan media (filter hypothesis).

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



Panel A: Model 1 (random seed = 14562)

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

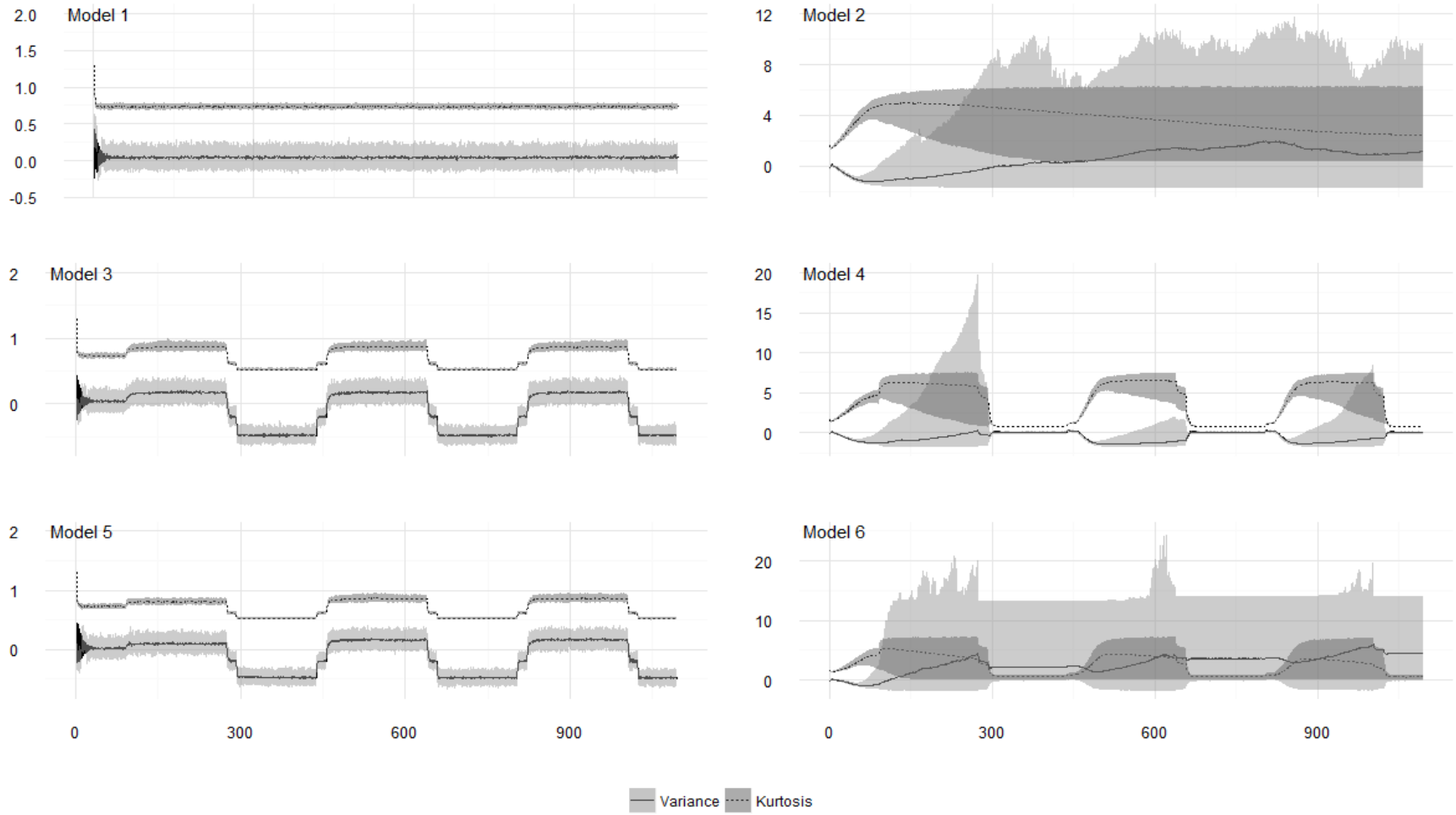


Panel B: Model 2 (random seed = 14562)

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

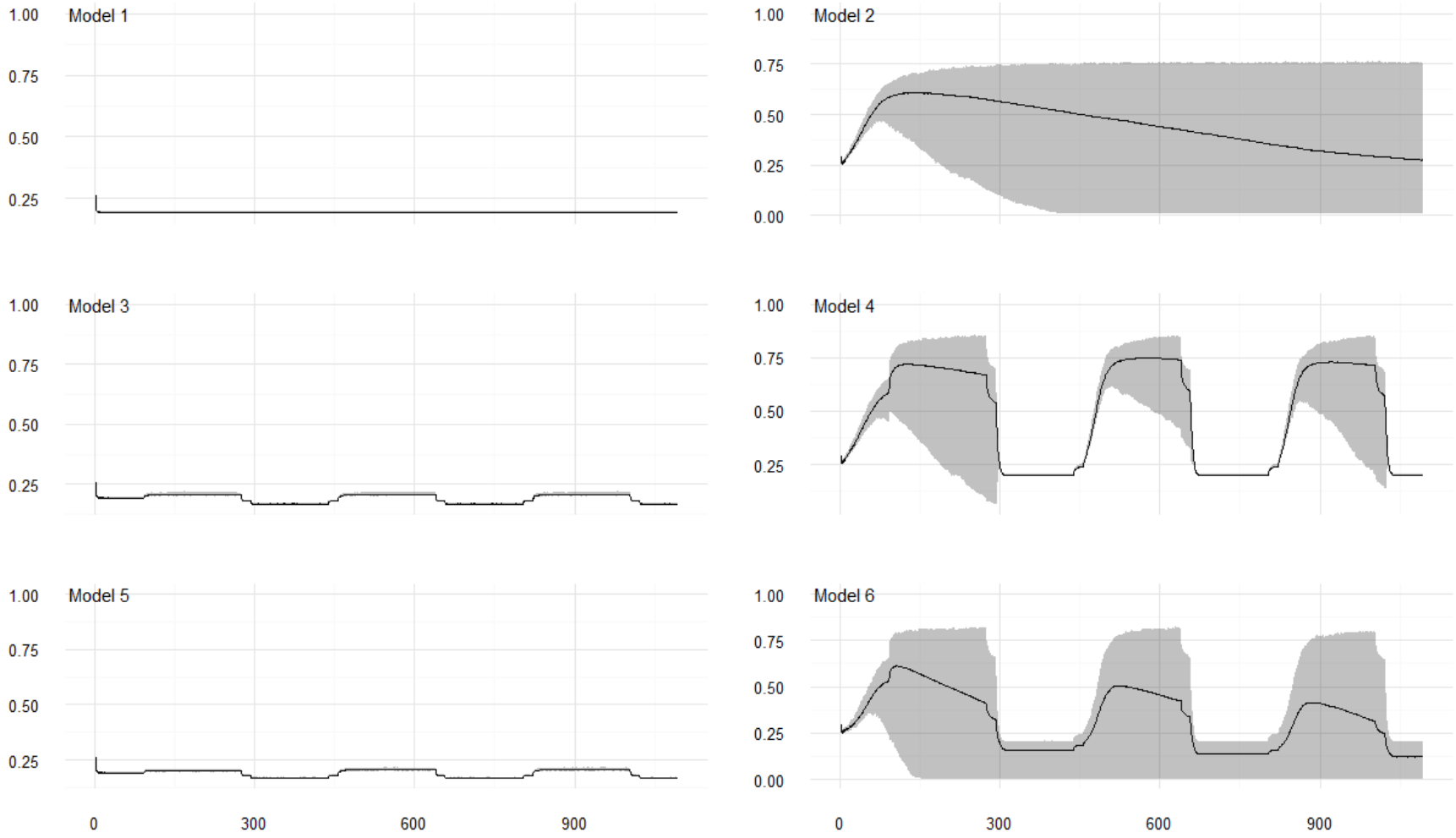
Note: The identical random seed supplied to each model guarantees that initial conditions of each simulation (at *tick = 0*) to be identical across models. As a result, any observed differences between models are attributable to their model specifications (e.g., a uniform impact of partisan news exposure 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.

[1] 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.

[2] We additionally considered and examined various scenarios (presented at Appendix), such as (a) impact of strong attitudes on polarization process, (b) impact of indirect, or "mediated" exposure to partisan information via one's social network, (c) limited opportunity for partisan selectivity at system-level (such as in European cases), (d) moderating effect of political interest in media selectivity along with selective avoidance, (e) and the effect of prior information decay. All of the results did not greatly alter the general patterns and our conclusions.

[3] A set of replication codes for ABM models and statistical analyses are available at http://hyunjinsong.com/research.html

[4] This idea is consistent to the notion of the *latitude of acceptance* (Sherif & Hovland, 1961).

[5] 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).

[6] Therefore, our model is a class of "discrete change" model in one's attitude.

[7] For instance, Iyengar and Hahn (2009) 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 extreme 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 ([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 an "extreme" liberal ("3") at the next tick of a simulation.