Dual Attitude Model of Opinion Diffusion: Experiments with Epistemically Motivated Agents

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***Abstract*— Opinion diffusion is often simulated in agent-based models to reveal the perpetuation of norms and beliefs. This paper presents a dual attitude model where agents' interaction, information search, and opinion formation are influenced by the need for cognitive closure (NFCC). Two experiments simulated topic advocacy with either high- or low-NFCC agents. Experiment one initiated societies with unbiased distribution of NFCC levels between advocates of two competing topics, while experiment two initiated biased distributions of NFCC levels between the topics. Results in the unbiased condition showed that the popularity of the majority topic increases over time in high NFCC societies while it decreases over time in low NFCC societies. These results are magnified in the biased context where high NFCC agents provided an NFCC-advantage for their advocaed topic. When high NFCC agents' advocated topic is the majority or equal at initiation, the topic's popularity will increase significantly over time. When high NFCC agents' advocated topic is minority at initiation, these agents resist the assimilative pressures of the majority topic to protect their own topic from popularity losses. Tracking simulations over time revealed different dynamics generated between the two experimental conditions, and showed the roles low NFCC agents and edge-of-cluster agents play in enabling the emergence of such patterns. These results may shed light on the impact NFCC individuals have in within-society and between-societies cultural shifts.**

Keywords*— *Need for Cognitive Closure, Opinion Diffusion, Social Psychology, Political Psychology.

I. Introduction

Several classes of social influence agent-based models (ABM) have shaped our knowledge about opinion diffusion. Ising, voter, and Sznajd models [1, 2, 3], evolutionary game theoretic models [4], culture dissemination model [5], and bounded confidence models [6] are classes with varied levels of complexity and realism. Most of these models tended to take a binary or bipolar approach to the formalization of opinions and had assumptions that were weakly supported by experimental studies [7, 8]. Given Mastroeni's [7] recent search drawing no ABM models from the social psychology domain, there might, thus, be cross-disciplinary benefits for social psychologists to make their ABM work more prominent, and develop models with higher fidelity to established social psychological theories [9].

Jager [10] noted the challenge of identifying an appropriate theory that is also translatable to code, and commented that *till date* "there are no agent architectures that capture the different needs people have, their specific time-dimensionality… and their activation in combination" [Sec 5.6]. Jager's comments seemed appropriate. Except for a few works [e.g., 11, 12, 13], much of social influence ABM models in psychology appeared to be built on model classes from outside the domain. Such models tended to contain assumptions labeled as "theory" or were highly stylized. While assumptions can be seen as just artifacts [14], the greater concern, as Edmonds et al [15] contended, may be the unintended use and misinterpretation of an ABM model.

Our work here answers the call by Jager [10] for more psychological realism in social science ABM, with the aim being a theoretical exposition [15] of the *theory of need for cognitive closure* (NFCC). To do that, a novel ABM model is built, and two experiments are conducted. The first experiment compares the spread of majority topic between societies of high vs. low NFCC. The second experiment explores the evolution of popularity when the majority and minority topics are differentially dominated by agents of high vs. low NFCC. The model, proposed and developed here, links established psychological theories of NFCC, mere exposure effect, just noticeable difference, and bivariate evaluative model of attitude formation, to deconstruct agent interaction as a series of decisions of "*whether to talk*", "*who to talk to*", and "*what to talk about*".

II. Societal Context

NFCC explains human's information search behavior. The theoretical exposition of NFCC is timely given the information tsunami we are in, the varying sources we get information from, and the epistemic insecurities we regularly feel in a globalized world [16]. In politics, conservatives are deemed to have higher levels of NFCC than liberals [17], and in elections, voters do not simply vote base on their position on a continuum, but do hold separate attitudes for each candidate and vote based on the differentials of such attitudes [18, 19]. Voters are also not passive agents who follow the majority in their vicinity, but are active participants in choosing what and who they want to influence [20]. Similarly, when choosing between brands or operating systems (e.g., Android and iOS), consumers note the attributes of their options and evaluate their relative merits. Our model, here, is targeted at such contexts where agents form opinions between two alternatives via repeated interactions with their peers.

III. Need for Cognitive Closure

Need for cognitive closure (NFCC) is both a construct and a theory within the framework of the lay epistemic theory [21]. As a *construct*, it describes human's motivation towards a quick and firm answer, and can be construed as an individual difference (trait) as well as a situationally induced state. It varies on a continuum from low to high NFCC, with high NFCC indicating a greater need for a firm answer and aversion towards ambiguity [22]. As a *theory* it explains how humans move through the epistemic processes of information gathering, hypothesis generation, and answer affirmation.

Epistemic process can be conceptualized as a progression from ambiguity to knowledge, going through a stage of *seizing* information, to a stage of *freezing* on formed opinion/answer. The point separating the two stages is termed the point of belief crystallization [23]. In the seizing stage, an individual acts on his/her urgency tendency to seek out information and form hypotheses to generate knowledge. Once sufficient clarity is gained, an individual will act on one's permanence tendency to maintain position on the subject by reducing information search and avoiding alternative viewpoints [see reviews in 24, 25]. Accordingly, a high NFCC individual will have greater tendencies to seize on early information and form opinions quickly, while a low NFCC individual will form more hypotheses and evaluate more diverse information before coming to a conclusion [22].

A. Need for Cognitive Closure in Opinion Diffusion

The theory of NFCC is chosen to model opinion diffusion because of its strong empirical base and affinity with attitude and social influence. For instance, Pierro et al. [26] found that extensive processing of information led to more persistent attitude change; Kruglanski et al. [27] found motivation for closure to moderate the mere exposure effect; Kosic et al. [28] found that immigrants' acculturation is a function of NFCC and host country conditions, and Tadmor et al. [29] showed that multicultural experiences could unfreeze pre-existing "frozen" beliefs between groups.

Here, we construe NFCC both as construct and theory, and model agents as encapsulating time-invariant levels of NFCC. The relative strength of attitudes for two alternatives combine to derive the information exchange behavior of agents as prescribed by NFCC theory.

IV. Agent Design

Two agent processes are central to the model. First is the determination of an agent's advocacy for a topic (opinion) at a point in time, and second is the interaction process.

A. Dual Attitude Mechanism

Attitude is generally defined as "a person's evaluation of an object on a favorable to unfavorable continuum" [30, p. 300]. While there is agreement that attitude is specific to an object/entity, has an evaluative component, and is the basis for both social cohesion and faultlines; contention remains regarding the number of concurrent attitudes and continuums one can have to derive a holistic evaluation of an attitude-object [31]. Rather than a bipolar construction of attitude, researchers such as Cacioppo et al. [32] have reviewed evidence for the bivariate unipolar construction of attitudes, and in political psychology and consumer decision making it is the relative preference (attitudes) for alternatives that is predictive of actual voting and purchases [33, 34]. Hence as a deviation from past models, we adopt this latter approach to model opinions as the resolution of bivariate unipolar attitudes.

Attitude strengthening. Following the bivariate perspective, our model simulates agents as holding independent attitudes towards two topics, Topic A and Topic B (S_A and S_B). Attitude strengths for each topic are continuous $[0, \infty]$. Changes in an agent's attitude strengths, S_A and S_B, depends on the interaction the agent has at each time period. While there are several theories of attitude change, Zajonc's [35] theory of the Mere Exposure Effect is one theory that is replicated in numerous cultures and contexts. It proposes that the frequency of exposure to an object increases the positive evaluation for the object. Accordingly, we model an agent's attitude strength for a topic to increase when it has "talked" to about a topic. Hence,

$$S_{A\cdot i\cdot t}=\begin{cases} S_{A\cdot i\cdot(t-1)}+1, & \text{if "talked" about Topic A,}\\ S_{A\cdot i\cdot(t-1)}, & \text{else.}\end{cases} \tag{1}$$

$$S_{B\cdot i\cdot t}=\begin{cases} S_{B\cdot i\cdot(t-1)}+1, & \text{if "talked" about Topic B,}\\ S_{B\cdot i\cdot(t-1)}, & \text{else.}\end{cases} \tag{2}$$

Mutual influence. Sharing the same ideas with the Bounded Confidence model [6], *both agents* follow (1) and (2) to update and strengthen their attitude for the topic to which they have just conversed about.

Determining agent advocacy. At each time point, agents determine their preference (advocacy) for each of the two topics based on the *relative attitude strength* (RAS) of each topic. To account for the fact that attitudes are abstract and at times unconscious and hard to detect, the concept of Just-noticeable difference [36, 37] is borrowed. An agent is an advocate of a topic at a point in time only if the topic strength for that topic is larger than the mean attitude strength of the two topic by a *discernible difference D*, which is invariant and similar for all agents. Using the mean attitude strength allows for a symmetric comparison. Specifically, an agent's advocacy, Φ_i, at time t is defined by (3):

$$\Phi_{i\cdot t}=\begin{cases} A_{i\cdot t}, & \text{if} \quad S_A > (1+D)\left(\frac{S_A+S_B}{2}\right);\\ B_{i\cdot t}, & \text{if} \quad S_B > (1+D)\left(\frac{S_A+S_B}{2}\right);\\ U_{i\cdot t}, & \text{else.}\end{cases} \tag{3}$$

Where $A_{i\cdot t}$ and $B_{i\cdot t}$ refers to agent being an advocate for topic A and topic B at time t, respectively. $U_{i\cdot t}$ indicates that the agent is undecided and ambivalent to either of the topic.

B. Integration with Need for Cognitive Closure (NFCC)

Interacting or "talking" with friends and peers involves numerous micro-processes, not least the basic decisions of whether to engage in a conversation, who to talk to, and what to talk about. For agents in our model, these micro-processes are integrated with [23] specifications about individual differences of NFCC. Specifically, NFCC varies on a continuum, is trait-like, and reflects the manner one seeks information and draws conclusion from them.

Determining NFCC Stages. To approach a more realistic representation while maintaining some tractability to better understand the model's simulation, agents can be assigned one of five levels of NFCC, from Low NFCC, Moderately Low NFCC, Mid NFCC, Moderately High NFCC, to High NFCC. Agents' NFCC level is invariant through out the simulation to approximate the trait-like aspect of NFCC.

The theory of NFCC proposes that humans progress from a *seizing stage* to a *freezing stage*, where the motivation to gather information decreases as epistemic clarity is attained [23]. Hence we model agents' NFCC stage as a function of the RAS between the two topics and a freezing-threshold.

As the magnitude of the RAS increases and crosses the freezing-threshold, F, an agent's epistemic need is satisfied and there is a greater likelihood of the agent choosing not to gather further information. Combining this rule with D, yields two sub-stages for NFCC's seizing stage, and one freezing stage. Specifically, an agent's NFCC stage, Π_i, at time t is defined by (4):

$$\Pi_{i\cdot t}=\begin{cases} C1_{i\cdot t}, & \text{if} \quad \max(S_A,S_B) < (1+D)\left(\frac{S_A+S_B}{2}\right); \\ C2_{i\cdot t}, & \text{if} \quad (1+D)\left(\frac{S_A+S_B}{2}\right) < \max(S_A,S_B) < (1+F_i)\left(\frac{S_A+S_B}{2}\right); \\ C3_{i\cdot t}, & \text{if} \quad (1+F_i)\left(\frac{S_A+S_B}{2}\right) < \max(S_A,S_B). \end{cases} \quad (4)$$

Where $C1_{i\cdot t}$ refers to the *first closure stage of seizing* where the agent is ambivalent in its advocacy ($\Phi_{i\cdot t} = U_{i\cdot t}$), and $C2_{i\cdot t}$ refers to the *second closure stage of seizing* where the agent has an advocacy but the RAS is yet to cross the freezing threshold F. $C3_{i\cdot t}$ refers to the *closure stage of freezing*. Hence, (4) requires that $F \geq D$ for all values of F.

Deciding whether to talk. [23] showed that when one reaches the state of closure, one will be less likely to seek out further information that may risk introducing ambiguity or challenging their beliefs. This effect is more pronounced for those with high NFCC than those with low NFCC. Hence, an agent in the final stage of closure (freezing), may choose not to engage in any communication. This likelihood of non-communication is greater for agents with high NFCC.

Deciding who to talk to. The process of determining the conversation partner is guided both by NFCC, homophily, and network location. It is more likely that one picks an interaction partner from those in their first degree, and with those what share the same advocacy. Literature suggests that such likelihood can be influenced by one's stage of closure and NFCC level. Those low in NFCC are more motivated to seek out alternative information, while those high in NFCC will more likely choose those who share similar opinions similar or just take the consensus view in haste [23].

Deciding what to talk about. Choosing people who share similar opinions will likely entail speaking about similar topics and strengthening existing beliefs each holds. However, empirical studies have shown that peope with low NFCC will seek out alternative views to gain epistemic clarity. On the contrary, people with high NFCC will not just refrain from talking to people with different views, but will also try to convert and convince others to adopt their beliefs, hence engaging in conversations about their own advocacy.

Combining the decision to talk, who to talk to, and what to talk about, the following interactions types can be derived.

- No interaction. (Nil)
- Equal probability of speaking to someone of either topic, even if the alter topic is minority. Agents with low NFCC will show this characteristic. (Tk 1)
- Randomly choose a neighor to talk about *that neighbor's topic*. Therefore the probability of speaking about a topic is dependent on the number of topic advocates in the neighborhood. (Tk 2)
- Deliberately choose to talk to a neighbor holding the *neighborhood popular topic*. This is most likely to happen for high NFCC agents as they seek to reduce ambuity in the shortest period of time. (Tk 3)
- Randomly choose a neighbor to talk about *one's own topic*. This is likely to happen for high NFCC agents as they avoid talking about alternative topics. (Tk 4)

With the above rules, the agent goes through the sequence outline in Figure 1. For purposes of investigation, agents in all simulation here are assigned one of five NFCC levels, each with a specific freezing-threshold F (Table 1) and specific probability for each interaction type (Table 2).

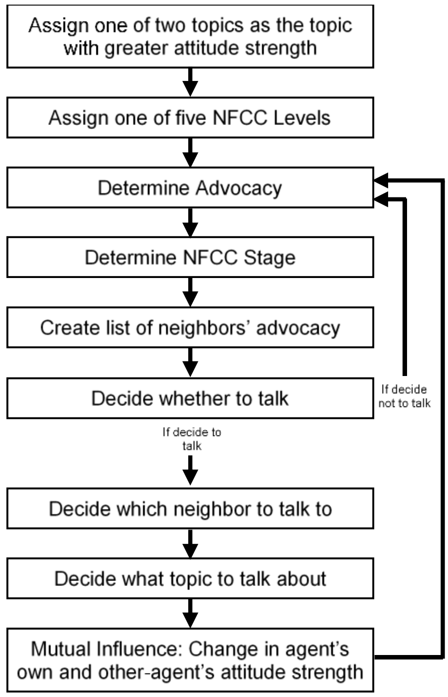

Fig 1. Dual Attitude Agent Process

TABLE I. FREEZING THRESHOLDS FOR DIFFERENT NFCC LEVELS

NFCC Levels	***Low***	***Mod-Low***	***Mid***	***Mod-High***	***High***
F	0.90	0.70	0.50	0.30	0.10

TABLE II. PROBABILITIES OF INTERACTION TYPES

NFCC Stage	***Low NFCC***	***Mod-Low NFCC***	***Mid NFCC***	***Mod-High NFCC***	***High NFCC***
C1 Seize 1	Tk 1: 0.90 Tk 2: 0.10	Tk 1: 0.70 Tk 2: 0.30	Tk 1: 0.25 Tk 2: 0.25 Tk 3: 0.50	Tk 2: 0.30 Tk 3: 0.70	Tk 2: 0.10 Tk 3: 0.90
C2 Seize 2	Tk 2: 0.90 Tk 4: 0.10	Tk 2: 0.70 Tk 4: 0.30	Tk 2: 0.50 Tk 4: 0.50	Tk 2: 0.30 Tk 4: 0.70	Tk 2: 0.10 Tk 4: 0.90
C3 Freeze	Nil.: 0.40 Tk 2: 0.54 Tk 4: 0.06	Nil.: 0.50 Tk 2: 0.35 Tk 4: 0.15	Nil.: 0.60 Tk 2: 0.20 Tk 4: 0.20	Nil.: 0.70 Tk 2: 0.09 Tk 4: 0.21	Nil.: 0.80 Tk 2: 0.02 Tk 4: 0.18

V. EXPERIMENT ONE

The aim of experiment one is to investigate the impact of societal-level differences in NFCC on opinion diffusion via the dual attitude model. Opinion is represented as the advocacy, Φ, adopted by agents, and diffusion is the popularity/proportion of agents, Ω, advocating a topic. Two topics (A and B) are simulated with topic A as the majority topic at initiation. We simulate 1681 agents on a toroidal cellular automata, and monitor topic popularity, time to reach stabilization, and the number of topic clusters. Topic popularity allows us to understand the extent of diffusion, time to reach stabilization allows us to understand the speed of diffusion, and the number of topic clusters allows us to study the extent of local convergence and emergence of faultlines. Agent processes are run in a psuedo-concurrent (parallel) manner.

We *simulate societies of high vs low NFCC* by specifying the proportion of agents at each level of NFCC. Each agent has a probability (as specified in Table 3) to be assigned one of five levels of NFCC at initiation. The exact proportion of agents at each NFCC level for each simulation run is thus stochastic and *unbiased between the topics*. The resultant distribution approximates a beta distribution [2, 4] for low NFCC society, and [4, 2] for high NFCC society. The choice to use five levels of NFCC is to approximate the real-world context of NFCC existing on a continuum, while the use of discrete levels of NFCC, is to allow tractability and better understanding of opinion dynamics across NFCC levels which would otherwise be difficult.

TABLE III. HIGH VS. LOW NFCC SOCIETY NFCC PROPORTIONS

	Low NFCC	***Mod-Low NFCC***	***Mid NFCC***	***Mod-High NFCC***	***High NFCC***
High NFCC Society	2%	8%	17%	45%	28%
Low NFCC Society	28%	45%	17%	8%	2%

For ease of interpretation, we setup the experiment with topic A as the referent topic, and conduct a parameter sweep of starting popularity from 0.55 – 0.95, at 0.10 intervals [0.55, 0. 65, 0.75, 0.85, 0.95]. At initiation, if an agent is assigned to have $S_A > S_B$, then the value of S_B is a random integer between 0 – (S_A-1). The entire assignment process is stochastic, and there can be agents who are ambivalent in their advocacy. Discernible difference, $D = 0.05$, remains invariant through all simulation runs. Simulation ends when the system has stabilized. The rule for stabilization is defined as no change in the number of topic A advocates and no change in the number of topic A cluster for the last 200 ticks. This stringent criteria is used as punctuated equilibriums can be detected for both popularity and cluster even though the system is still evolving to a new state. The agent's network neighborhood here refers to the Moore's neighborhood, and cluster count is defined as the number of agent with all neighbors who are in the same advocacy state.

A. *Results of Experiment One*

Table 4 shows the means and standard deviations (in parentheses) of 200 simulation runs per condition (total of 2000 runs) to investigate the opinion diffusion between high versus low NFCC societies. Table 4A shows that high NFCC societies reach stabilization faster and than low NFCC societies. Notably the five NFCC levels are evenly distributed between advocates of both the majority and minority topics at initiation, and hence the only difference between the topics at initiation are their popularity levels.

Table 4B showed that, in a high NFCC society, popularity for a majority topic will increase, while popularity for the same majority topic will decrease in a low NFCC society. This also means that minority topics will have a better chance of increasing its popularity in a low NFCC than high NFCC society. This result while intuitive on hindsight, is not explicitly coded, and have implications towards understanding the persistence and spread of minority opinion in different cultures and collectives.

Table 4C showed that high NFCC societies tended to have less clusters than low NFCC societies when the simulation ends. Intuitively, high NFCC with greater popularity for the majority topic will lead to greater count of agents surrounded by like-minded agents. Yet graphically, high NFCC society have more "*islets*" of local minorities who are resistant to convert to the advocacy of their surrounding agents, while low NFCC society has more large regions of agents with similar advocacy. Unlike studies generating similar patterns from homophily or strategic regenesis, the pattern here is a result of mutual influence as a function of epistemic motivation for information.

TABLE IV. DIFFUSION UNDER HIGH VS. LOW NFCC SOCIETIES

A: Time to Stability (*t*)

Initial Topic A Popularity (%)	***0.55***	***0.65***	***0.75***	***0.85***	***0.95***
High NFCC Society	771.84	805.32	797.48	686.12	511.64
	(151.36)	(217.07)	(193.27)	(182.37)	(115.07)
Low NFCC Society	1267.20	1517.80	1453.64	1289.88	708.56
	(345.47)	(387.84)	(312.89)	(358.34)	(144.09)

B: End-state Popularity (%)

Initial Topic A Popularity (%)	***0.55***	***0.65***	***0.75***	***0.85***	***0.95***
High NFCC Society	56.04	67.92	79.12	88.19	96.50
	(1.47)	(1.20)	(0.98)	(0.89)	(0.46)
Low NFCC Society	53.13	62.55	72.37	81.94	91.19
	(1.07)	(1.41)	(1.40)	(0.76)	(0.52)

C: Number of Clusters (*n*)

Initial Topic A Popularity (%)	***0.55***	***0.65***	***0.75***	***0.85***	***0.95***
High NFCC Society	24.52	82.84	255.04	587.48	1227.60
	(8.49)	(17.17)	(24.29)	(46.61)	(51.12)
Low NFCC Society	65.44	224.08	540.60	1002.92	1465.04
	(12.37)	(37.09)	(65.33)	(53.07)	(44.42)

VI. EXPERIMENT TWO

The aim of experiment two is to understand opinion dynamics, when NFCC levels are differentially distributed between competing topics (biased distribution). The results will offer insights into the rise/fall of support for a target in the real world (e.g., presidential candidate, religion, fashion brands) when advocates for one topic are dominated by agents with higher/lower in NFCC levels.

Model in experiment one is used with a new initiation setup. Topic A advocates are assigned at initiation with NFCC distribution identical to that of a High NFCC Society, while topic B's advocates are assigned to that of a Low NFCC Society (Table 3). For purposes of exploration, three initiating conditions were created: Topic A as majority (Ω_A = 75%, Ω_B = 25%), topic A as equal (Ω_A = 50%, Ω_B = 50%), and topic A as minority (Ω_A = 25%, Ω_B = 75%). When topic A is the majority, topic B is conversely the minority. Each condition is simulated 200 times. The same stopping rule and simulation outputs are applied. For reporting clarity, agents are referred to as either high or low NFCC as a group in a relative sense, instead of their specific levels.

A. *Results of Experiment Two*

Table 5 and Table 6 report mean values for topic popularity, time to stabilization, and number of clusters.

Time to stabilization. Table 5 shows that when NFCC levels are differentially distributed between topics at initiation, societies with majority topic advocates high in NFCC, takes a longer time to stabilize than systems with majority topic advocates low in NFCC. This means that systems with a *stubborn majority* takes a longer time to stabilize than systems with stubborn minority. Tracking of multiple simulation runs explains this emergent difference.

TABLE V. SPEED OF DIFFUSION AND END-STATE POPULARITY

Initial Conditions		**End-State**		
Topic A High NFCC	***Topic B Low NFCC***	***Time (t)***	***Popularity of Topic A (%)***	***Popularity of Topic B (%)***
25%	75%	740.3	23.87	76.06
50%	50%	1477.14	56.83	42.83
75%	25%	1523.37	90.15	9.65

TABLE VI. CHANGE IN CLUSTER

Initial Conditions		***t* = 1**		**End-State**	
Topic A High NFCC	***Topic B Low NFCC***	***Topic A Clusters***	***Topic B Clusters***	***Topic A Clusters***	***Topic B Clusters***
25%	75%	0.02	84.94	0.36	177.45
50%	50%	2.38	2.44	85.18	6.38
75%	25%	87.84	0.01	900.13	0.01

Principally, low NFCC agents spend more time in the seizing stages and need more interactions to strengthen their advocacy sufficiently to cross the freezing threshold. High NFCC agents, though, are close to the freezing stage or have already frozen and thus have a relatively stable advocacy and reduced likelihood of future interactions.

Hence, in a *low-NFCC-majority society* (*i.e. high-NFCC-minority society*) where low NFCC agents are majority advocates, there are more similar agents around them to reinforce their advocacy. This helps speed up progression from seizing to freezing for them who would otherwise spend much time seizing. For the minority topic advocates who are mostly high in NFCC, they are close to or have reached the freezing stage. Hence even if they have more opportunities to meet dissimilar agents, the reduction in tendency to speak to dissimilar others, reduces the extent of assimilative influence from dissimilar agents, helping these minority agents to maintain their initial advocacy. As such, the peer strengthening of fellow advocates who are also low NFCC agents and the unwillingness of high NFCC agents to interact led to a relatively fast stabilization of the system.

In a *low-NFCC-minority system* (*i.e. high-NFCC-majority society*), the low NFCC agents are minority, and hence are frequently exposed to alternate views. Thus rather than strengthening of their initial beliefs, they go through a lengthy process of first unfreezing, then seizing [23], before they strengthen the advocacy for the new topic. Because of the tendency to sample diverse viewpoints evenly, these agents spend much time in the seizing stage even when there is an abundance of majority topic agents in the neighborhood, hence leading to slower stabilization.

In addition, the greater number of agents for the majority topic gives rise to more homogeneous regions of majority-advocates. This leads to a significant portion of majority topic advocates being distant (> 1 degree apart) from the minority as they are away from the edge of these clusters. Hence despite a numerical advantage, the principle of local influence meant there will not be a proportionate increase in opportunities to influence the minority. As such, the minority agents who are low in NFCC stay in a seizing stage for long periods of time, often alternating between advocacies.

In sum, if there are two competing ideas/topics with one topic being the majority and dominated by high NFCC agents, the minority agents who are low in NFCC stay in a state of indecision for prolong periods of time as they gather diverse information to unlearn their initial advocacy. And despite the large number of majority topic advocates around, the majority topic advocates who are high in NFCC do not seek to engage in conversation, and even if they do, most are not immediate neighbors to the minority topic advocates.

Popularity. Table 5 shows that when majority topic advocates are low in NFCC, the increase in popularity is only marginal. However when majority topic advocates are high in NFCC, the increase in popularity is large. Even when the initiating popularity of topics are equal, the topic with advocates high in NFCC showed an increase in popularity, rather than a decrease in popularity for the topic initiated with low NFCC agents. Fig. 2 rearranged the values in Table 5 to show this *high NFCC advantage*. This advantage helps increase popularity for a topic when is majority or equal at initiation, and prevents popularity loss when a topic is a minority at initiation. Observing the simulations revealed that this advantage is due to low NFCC agents considering alternative views and allowing themselves to switch, while high NFCC agents are relatively fixed in their advocacy. Hence, this advantage is attributable to the behaviors of the low NFCC agents than that of high NFCC agents.

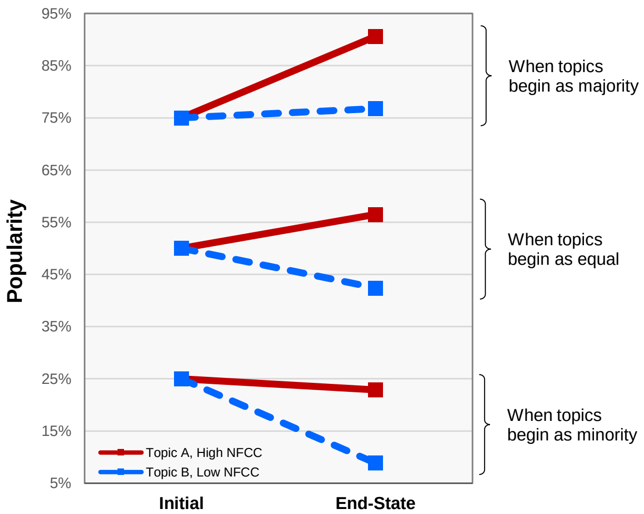

Fig. 2. Popularity when topics initiated at majority, equal, and at minority.

Clusters. Table 6 shows that across all three conditions, the majority topic at initiation is produce more end-state clusters than the minority topic. The increase in clusters for majority topic with high NFCC is much more than that when the majority topic is initiated with low NFCC. Both these results are expected given that the high NFCC advantage leads to greater end-state popularity and hence more cluster for the high NFCC dominated topic will emerge.

VII. DISCUSSION

Edmonds's [15] taxonomy on the uses of ABM defined theoretical exposition as a process of "establishing then characterising … hypotheses about the general behaviour of a set of mechanisms" [para 5.6]. We proposed a novel mechanism of opinion resolution and illustrated its use with a high fidelity formalization of the theory of NFCC. Through two experiments, we found some results from experiment one that converge with other diffusion models [e.g., 11], and results from experiment two to be counterintuitive at first glance but logical when agent dynamics are investigated.

As a nascent model, a wider exploration of the parameters, verification, and validation is needed [14]. For instance the small, but significant, differences in Table 4B could be an artifact of network size that limited the evolution of the "society". Hence, follow-up research will explore the robustness of this and other auxiliary assumptions, and future research could consider docking the model by swapping the dual attitude mechanism with a bipolar univariate attitude formalization to ascertain the robustness of patterns found.

Yet the dual attitude *model* of NFCC could be the first opinion diffusion ABM that uses a unipolar bivariate construction of opinions, while balancing theoretical fidelity with the need for tractability. The experiments were aimed to provide a theoretical exposition of NFCC, and in so doing we observed dynamics similar to what we see in the real world. The evolution of popularity goes through bouts of stases and spurts, especially when initial differences in topic are small. These punctuated equilibriums are observed together with the regularity of a Devil's staircase [38], where we observe self-similar patterns at different time scales in the same simulation run. Hence, if periods of cultural stability is analogical to punctuated equilibriums, the underlying fractal dimensions justifies humans to look into their society's past to foresee the timing of future cultural shifts.

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