Appendix A. Calibration Data

Table 1: Demographic Comparison Across Surveys

	Study Survey Jun. 2019 (%)	General Social Survey (GSS), 2018 (%)	U.S. Census Bureau (Estimates, 2019) (%)
Age:			
18–22	7.1	5.5	6.5
23–35	25.2	23.1	18.0
36–55	39.7	33.2	25.2
Older than 55	28.0	38.2	28.9
Gender:			
Male	46.8	44.8	49.2
Female	53.2	55.2	50.8
Race / Ethnicity:			
White	75.2	71.2	76.3
Hispanic or Latino	6.5	5.4	18.5
Black or African American	10.1	16.4	13.4
Asian	5.6	3.1	5.9
Education:			
High school or less	35.2	61.3	38.9
Some college	25.0	8.3	27.8
Bachelor's degree or more	39.8	30.3	33.3
Household Income:			
Less than $15,000	11.6	21.2	9.1
$15,000 to $24,999	9.8	12.7	8.0
$25,000 to $49,999	21.1	30.8	20.0
$50,000 to $99,999	33.3	24.0	28.8
$100,000 to $149,999	15.9	3.3	15.5
$150,000 to $199,999	4.8	7.9	8.3
$200,000 or more	3.5	0.0	10.3

Note: 'Race' was measured by respondents' first mention. 'Some college' includes those who reported 'Junior College' as their highest degree in the GSS, and Household Income was measured in inflation-adjusted constant dollars (see GSS Methodological Reports). The right column shows official estimates of the resident population by single year for the United States (2019). For education attainment, Census figures refer to population age 18 and older, and 'some college' also includes those with an associate's degree. Household-level income data in the third column is based on information from the Current Population Survey Annual Social and Economic Supplements (CPS ASEC). Source: U.S. Census Bureau, Population Division.

Age:

Table 2: The summary statistics of sampled dataset and full dataset

Variable	Full dataset (Mean/SD)	Sampled dataset (Mean/SD)	KS Statistic	p-value
Party	3.012 (1.172)	2.966 (1.147)	0.019	0.999
Ideology	3.121 (1.170)	3.052 (1.178)	0.027	0.928
News Frequency	2.288 (0.814)	2.286 (0.769)	0.029	0.892
Discussion Frequency	2.081 (0.913)	2.045 (0.863)	0.025	0.967
Polarization	5.198 (3.326)	5.238 (3.319)	0.017	1.000

Table 3: Survey measurement for the five key variables.

Variable	Description
Frequency of News Consumption (1 to 10 Likert Scale)	1. How often **did you use** the following social media sites for getting news in the past month? (Facebook, Twitter, Snapchat, LinkedIn, WhatsApp, Instagram, Tumblr, Reddit, YouTube, Houseparty) 2. How often did you use the following media sources for getting news in the past month? (Printed, Television, Radio, Computer web browser (laptop or desktop), Tablet app (iPad, 7 inches or larger), Smartphone app (handheld mobile device smaller than 7 inches), Podcasts (online or smartphone), Netflix)
Frequency of Interpersonal Discussion (1 to 10 Likert Scale)	1. How often did you talk about politics or public affairs offline (face-to-face or over the phone) with the following categories in the past month? (Spouse/partner, family, relatives, Friends, Neighbors, co-workers you know well, Acquaintances, Strangers, Neighbors, co-workers you don't know well) 2. How often did you talk about politics or public affairs online with the following categories in the past month? (Spouse/partner, family, relatives, Friends, Neighbors, co-workers you know well, Acquaintances, Strangers, Neighbors, co-workers you don't know well)
Party Identification	Generally speaking, do you usually think of yourself as a Republican, a Democrat, an Independent, or something else? Please rate yourself on a scale where 1 = Strong Democrat, 6 = Independent, and 11 = Strong Republican.
Ideology	1. On political issues, where would you place yourself on a scale of 1–11, where 1 = Strong liberal and 11 = Strong conservative? 2. On economic issues, where would you place yourself on a scale of 1–11, where 1 = Strong liberal and 11 = Strong conservative?
Affective Polarization	1. We would like to know your feelings toward some political figures on a scale from 0 to 10. – Barack Obama 2. We would like to know your feelings toward some political figures on a scale from 0 to 10. – Donald Trump 3. We would like to know your feelings toward some political figures on a scale from 0 to 10. – Joe Biden 4. We would like to know your feelings toward some political figures on a scale from 0 to 10. – Mike Pence Affective polarization in the present study was operationalized as the absolute difference between respondents' average feeling thermometer ratings toward Democratic and Republican candidates. Specifically, respondents rated their feelings toward Barack Obama and Joe Biden (Democratic candidates), and Donald Trump and Mike Pence (Republican candidates), each on a 0–10 scale. For each respondent, we computed the mean rating for the Democratic and Republican candidates separately, took the absolute difference between these two means. Higher scores indicate greater affective distance between in-party and out-party candidates, reflecting stronger affective polarization.

To address concerns about the temporal validity of our 2019 dataset in a shifting political and media landscape, we benchmarked affective polarization levels against two national samples from 2024: the American National Election Study (ANES) and America's Political Pulse (APP), as shown in Figure 1. In both comparisons, we constructed a standardized 0–10 polarization index based on the absolute difference between respondents' average feeling thermometer ratings of Democratic and Republican presidential and vice-presidential candidates. For the 2019 data, this included ratings of Obama/Biden and Trump/Pence; for ANES 2024, Harris/Walz and Trump/Vance; and for APP 2024, direct ratings of the Democratic and Republican parties. Higher values reflect greater affective polarization between partisan candidates.

Statistical tests confirmed modest but statistically significant differences. For ANES, the Kolmogorov–Smirnov test ($D = 0.092$, $p < .001$) and Wilcoxon rank-sum test ($W = 2,227,143$, $p < .001$) indicated distributional shifts, but the effect size was negligible (Cohen's $d = 0.17$, 95% CI: [0.10, 0.23]). Similarly, comparisons with APP 2024 showed significant differences as well ($D = 0.10$, $p < .001$; $W = 28,895,767$, $p < .001$), with a negligible effect size in the opposite direction (Cohen's $d = -0.16$, 95% CI: [–0.22, –0.10]). Despite evolving political dynamics, these results suggest that affective polarization in our 2019 sample remains broadly comparable to recent national benchmarks.

Figure 1: The distribution of the affective polarization of Authors' dataset, ANES 2024 and APP 2024
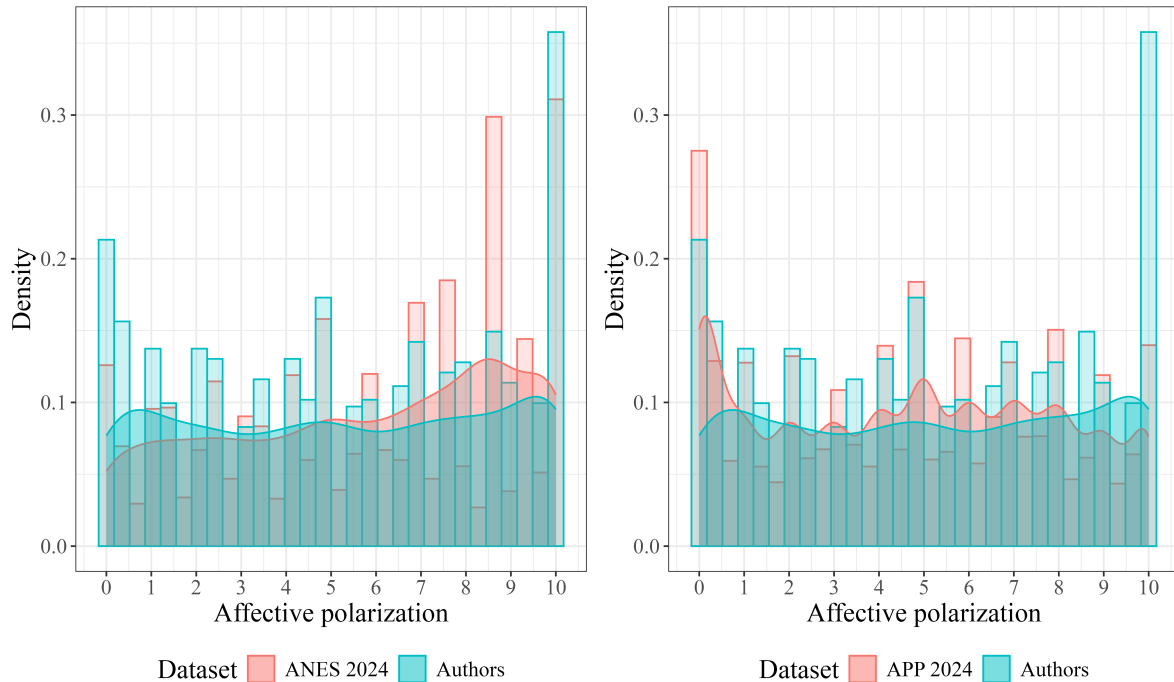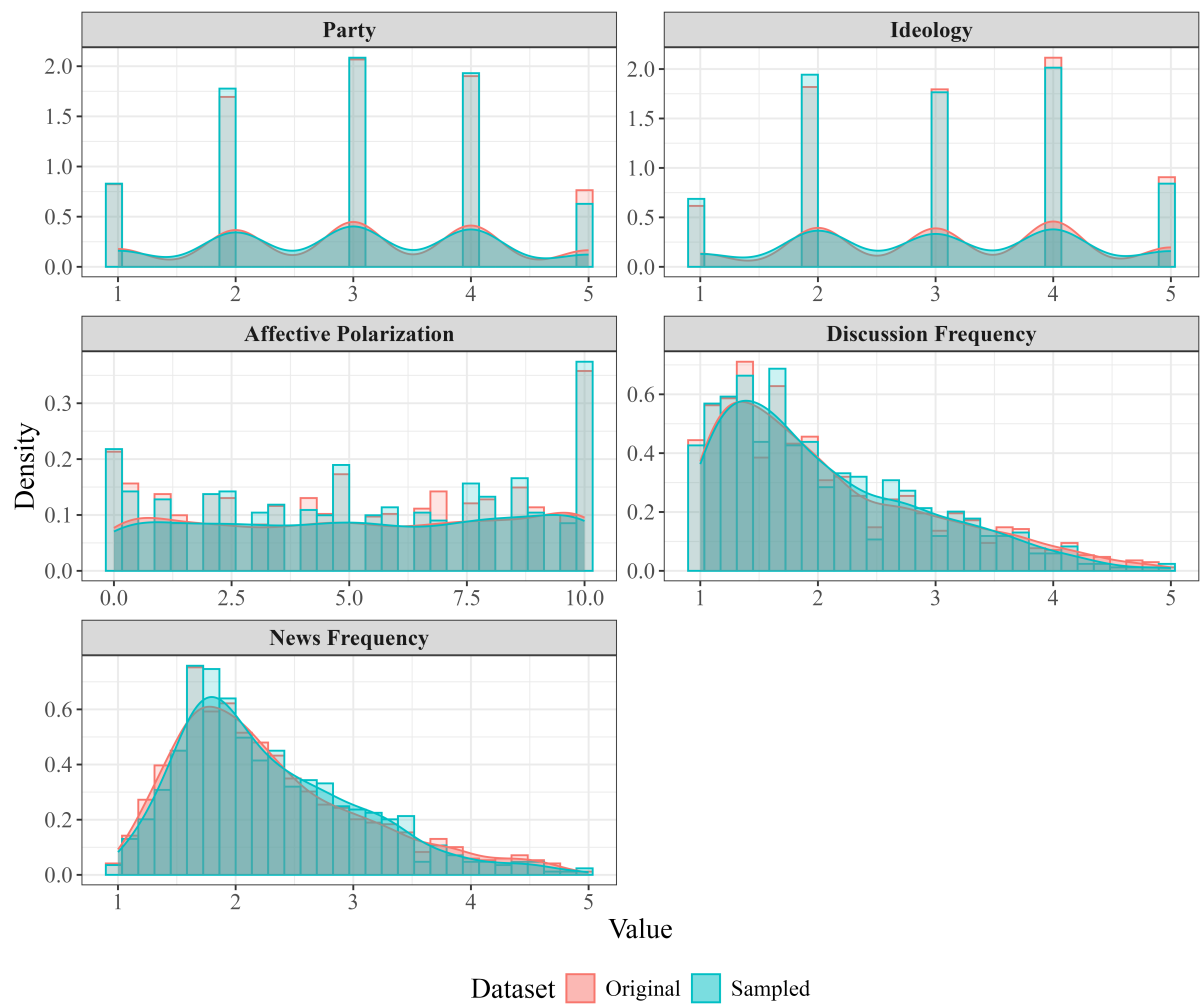
Figure 2: The distribution of the five key variables of sampled dataset and full dataset

Appendix B. Technical and Implementation Details of Models

A Global key model parameters

Parameters	Names (in code)	Range	Default	Description
Population settings				
Population density	`population-density`	0–100%	40%	Share of patches that host *human* agents
Media density	`media-density`	0–100%	40%	Share of patches that host *media* outlets
Independent share	`independent%`	0–100%	20%	Probability that a new agent is Independent
Experimental variables				
Social influence	`global-social-influence`	0–1	0.50	Baseline weight of interpersonal influence
Media influence	`global-media-influence`	0–1	0.50	Baseline weight of media influence
Homogenous discussion	`global-homogenous-discussion`	0–1	0.50	Baseline preference for like-minded partners
Selective exposure	`global-selective-exposure`	0–1	0.50	Baseline preference for choose congruent outlets
Interaction modifiers				
Discussion modifier	`discussion-modifier`	0–5	2.0	Controls how AP steepens the window in partner selection.
Consumption modifier	`consumption-modifier`	0–5	2.0	Controls how AP narrows the window in media selection.
Beta media bias	`beta-media-bias`	0–6	2.0	Steepness of exponential weighting for outlets
Mobility settings				
Baseline stress	`baseline-stress`	0–1	0.50	Constant subtracted from comfort index
Social-comfort weight	`social-comfort-weight`	0–1	0.50	Social vs. media weight in relocation score
Search radius	`search-radius`	1–5	5	Patch radius scanned when relocating
Flip threshold	`flip-threshold`	1–5	2	"Unhappy" ticks required before moving
Polarization dynamics				
Disagreement threshold	`disagreement-threshold`	0–4	0.50	Onset of hostile zone
Disagreement penalty	`disagreement-penalty`	0–2	0.40	AP increment in hostile zone (non-backfire)
Like-minded threshold	`like-minded-threshold`	0–2	0.30	Upper bound of reinforcement zone
Like-minded AP boost	`like-minded-ap-boost`	0–1	0.10	AP increment in reinforcement zone
Cross-cutting threshold	`cross-cutting-threshold`	0–2	0.30	Lower bound of moderation zone
Cross-cutting AP reduction	`cross-cutting-ap-reduction`	0–1	0.10	AP decrement in moderation zone
AP decay rate	`ap-decay-rate`	0–1	0.08	Per-tick cool-down of affective polarization
Backfire effects				
Backfire probability	`p-backfire-when-incongruent`	0–1	0.30	Chance a hostile encounter triggers backfire
Backfire amplifier	`backfire-amp`	1–5	1.5	Multiplier for AP increment after backfire

B Agent initialization and parameter specifications

B.1 Human agent attributes

Each human agent i is initialized with the following attributes:[1]

- **Political affiliation and ideology:**
  - Party affiliation: $party_i \in \{\text{dem, rep, ind}\}$ with probabilities determined by the independent% parameter
  - Baseline ideology: $ideology_i \sim \mathcal{N}(\mu_{party}, 0.5)$ where:
    * $\mu_{dem} = 1.5$ (liberal)
    * $\mu_{rep} = 4.5$ (conservative)
    * $\mu_{ind} = 3.0$ (moderate)
  - Affective polarization: $AP_i \sim \text{Uniform}(0, 10)$

- **Interaction parameters:**
  - Social influence:
    $$soc\_influ_i \sim \mathcal{N}\big(\text{global-social-influence}, 0.5\big), \quad soc\_influ_i \in [0, 1]$$
  - Selective exposure tendency:
    $$sel\_exp_i \sim \mathcal{N}\big(\text{global-selective-exposure}, 0.\big), \quad sel\_exp_i \in [0, 1]$$

---

[1]Political affiliation, ideology, social interaction frequency and media consumption frequency are calibrated by real-world data

– Homophily preference:

$$hom\_disc_i \sim \mathcal{N}\big(\text{global-homogenous-discussion}, 0.1\big), \quad hom\_disc_i \in [0, 1]$$

- **Behavioral frequencies:**
    – Social interaction frequency (neighbors considered per tick):

$$dis\_freq_i \sim \text{Uniform}(1, 5)$$

    – Media consumption frequency (sources consumed per tick):

$$news\_freq_i \sim \text{Uniform}(1, 5)$$

B.2 Media agent attributes

Media outlets j are distributed as follows:

- **Ideological distribution:**
    – Liberal media (40%): $media\_ideology_j \sim \text{Uniform}(1.0, 2.0)$
    – Moderate media (20%): $media\_ideology_j \sim \text{Uniform}(2.5, 3.5)$
    – Conservative media (40%): $media\_ideology_j \sim \text{Uniform}(4.0, 5.0)$
- **Interaction parameter:**
    – Media influence:

$$media\_influ_j \sim \mathcal{N}(\text{global-media-influence}, 0.1) \in [0, 1]$$

C   Selection algorithms

C.1 Media sources selection

Agent i selects media sources using exponential weighting with the following algorithm:

- Step 1: Calculate selection parameters

$$\mu = ideology_i$$

$$AP_{scaled} = \frac{affective\_polarization_i}{10}$$

$$\beta = \beta_{media\_bias} \times sel\_exp_i \times (1 + AP_{scaled})$$

- Step 2: Define ideological tolerance window

$$base\_max = 4 \times (1 - sel\_exp_i)$$

$$max\_diff = \max(0, base\_max - AP_{scaled} \times consumption\_modifier)$$

- Step 3: Create Candidate Pool

$$\text{Pool} = \{j : |media\_ideology_j - \mu| \leq max\_diff\}$$

If Pool $= \emptyset$, then Pool $=$ all media agents.

- Step 4: Calculate Selection Probabilities
  For each $j \in$ Pool:

$$w_j = \exp(-\beta \times |media\_ideology_j - \mu|)$$

Normalize probabilities:

$$p_j = \frac{w_j}{\sum_{k \in \text{Pool}} w_k}$$

- Step 5: Select $\min(news\_freq_i, |\text{Pool}|)$ sources via weighted sampling without replacement.

C.2 Social partner selection

Social partner selection uses identical exponential weighting logic applied to spatial neighbors:

- Step 1: Identify candidate pool
  - Sort other humans by distance from agent i
  - Pool = closest dis_freq_i agents (or all if fewer exist)
- Step 2: Calculate weights (same exponential weighting as media selection with):

$$\beta = hom\_disc_i \times discussion\_modifier \times (1 + AP_{scaled})$$

- Step 3: Select $\min(dis\_freq_i, |\text{Pool}|)$ partners using weighted sampling.

D Influence mechanisms

D.1 Ideological influence function

For agent i influenced by source s (social or media):

- **Parameter definitions:**
  - $ideology_{before}$ = current ideology of agent i
  - $source\_ideology$ = ideology of source s
  - $diff = source\_ideology - ideology_{before}$
  - $disagreement = |diff|$
  - $normalized\_disagreement = \frac{disagreement}{4.0}$
  - $AP_{scaled} = \frac{affective\_polarization_i}{10.0}$
- **Backfire detection:**

$$agent\_extreme = (ideology_{before} \leq 2) \vee (ideology_{before} \geq 4)$$

$$source\_extreme = (source\_ideology \leq 2) \vee (source\_ideology \geq 4)$$

$$opposite\_sides = \text{sign}(ideology_{before} - 3) \neq \text{sign}(source\_ideology - 3)$$

The probability of a backfire event being triggered, $P_{\text{trigger\_backfire}}$, is:

$$P_{\text{trigger\_backfire}} = \begin{cases} p_{\text{backfire\_when\_incongruent}} & \text{if } agent\_extreme \wedge source\_extreme \wedge opposite\_sides \\ 0 & \text{otherwise} \end{cases}$$

A backfire event ("backfire occurs") is determined by a Bernoulli trial with probability $P_{\text{trigger\_backfire}}$.

$$direction\_multiplier = \begin{cases} -1 & \text{if backfire occurs} \\ +1 & \text{otherwise} \end{cases}$$

- **Receptivity Calculation:**

$$\text{receptivity} = \begin{cases} \max\left(0, 1 - AP_{\text{scaled}} \times normalized\_disagreement\right) & \text{if normalized\_disagreement} > 0.05, \\ \qquad \times dampening\_factor & \\ 1.0 & \text{otherwise.} \end{cases}$$

Where $dampening\_factor = 0.5$ for media influence and $dampening\_factor = 1.0$ for social influence.

- **Ideology Update:**
  - For media influence:

$$\Delta ideology = global\_media\_influence \times media\_influ_s \times receptivity \times diff \times direction\_multiplier$$

– For social influence:

$$\Delta ideology = soc\_influ_i \times receptivity \times diff \times direction\_multiplier$$

– Final update:

$$ideology_{new} = \max(1, \min(5, ideology_{before} + \Delta ideology))$$

D.2 Affective polarization update

- **Like-minded reinforcement**

  Else if $disagreement \leq like\_minded\_threshold$:

  $$AP_{amplifier} = 1 + \frac{current\_AP}{10}$$

  $$like\_minded\_effect = like\_minded\_ap\_boost \times \left(1 - \frac{disagreement}{4}\right) \times AP_{amplifier}$$

  $$\Delta AP = +like\_minded\_effect$$

- **Cross-cutting moderation**

  Else if $cross\_cutting\_threshold < disagreement \leq disagreement\_threshold$:

  $$optimal\_distance = 0.5$$

  $$effectiveness = 1 - \left|\frac{disagreement}{4} - optimal\_distance\right|$$

  $$cross\_cutting\_effect = cross\_cutting\_ap\_reduction \times effectiveness \times AP_{amplifier}$$

  $$\Delta AP = -cross\_cutting\_effect$$

- **Hostile exposure**

  If $disagreement > disagreement\_threshold$:

  $$\Delta AP = +disagreement\_penalty$$

  – **Backfire effect**

  If backfire is triggered and $disagreement > 0.05$:

  $$\Delta AP = +disagreement\_penalty \times backfire\_amp$$

- **Final bounds:**

  $$AP_{new} = \max(0, \min(10, AP_{old} + \Delta AP))$$

E   Satisfaction and mobility algorithm

E.1   Comfort index

For agent i at time t:

- **Social comfort:**

  Let P_t = set of interaction partners in tick t.

  $$social\_similarity_k = 1 - \frac{|ideology_i - ideology_k|}{4} \quad \forall k \in P_t$$

  $$social\_comfort = \begin{cases} \frac{\sum_{k \in P_t} social\_similarity_k}{|P_t|} & \text{if } |P_t| > 0 \\ 0 & \text{otherwise} \end{cases}$$

- **Media comfort:**

  Let M_t = set of consumed media in tick t.

  $$media\_similarity_j = 1 - \frac{|ideology_i - media\_ideology_j|}{4} \quad \forall j \in M_t$$

  $$media\_comfort = \begin{cases} \frac{\sum_{j \in M_t} media\_similarity_j}{|M_t|} & \text{if } |M_t| > 0 \\ 0 & \text{otherwise} \end{cases}$$

- **Overall comfort:**

  $$comfort\_index = \frac{social\_comfort + media\_comfort}{2} - baseline\_stress$$

E.2 Tolerance index

$$tolerance_i = \frac{1}{1 + \exp(AP_i - 5)}$$

$$tolerance_i = \max(0.001, tolerance_i)$$

E.3 State transition

- **Unhappiness Probability:**

  $$P(\text{unhappy}) = \begin{cases} \frac{tolerance_i - comfort\_index}{tolerance_i} & \text{if } comfort\_index < tolerance_i \\ 0 & \text{otherwise} \end{cases}$$

- **Update with hysteresis:**

  – Draw $unhappy\_signal \sim \text{Bernoulli}(P(\text{unhappy}))$

  – If currently happy:

  * If $unhappy\_signal$: $mood\_streak \leftarrow mood\_streak + 1$

  * If $mood\_streak \geq flip\_threshold$: transition to unhappy, reset streak

  * Else: reset $mood\_streak = 0$

  – If currently unhappy: symmetric logic for transition to happy

E.4 Spatial relocation

- **Relocation criteria:**

  – Agent must be unhappy ($happy = \text{FALSE}$)

  – Minimum 2 ticks since last move (cooldown period)

- **Destination Selection:**

  – Search within radius R of current location. Evaluate each empty patch p using utility function:

  $$U(p) = social\_comfort\_weight \times social\_similarity(p) + (1 - social\_comfort\_weight) \times media\_similarity(p)$$

  Where:

  * $social\_similarity(p)$ = mean similarity to human neighbors of p

  * $media\_similarity(p)$ = mean similarity to media neighbors of p

  – Move to patch with maximum $U(p)$.

F   (Social/Media) Diversity index

For each human agent i we quantify the ideological differences of (1) the set S_i of social partners encountered in the current tick and (2) the set M_i of media outlets consumed, using the *Shannon evenness* index

$$\text{Div}_i^{(X)} \;=\; \frac{-\sum_{c=1}^{5} p_{ic}^{(X)} \ln p_{ic}^{(X)}}{\ln 5}, \qquad X \in \{S, M\},$$

where $p_{ic}^{(X)}$ is the proportion of other agents (or media outlets) whose ideology, rounded to the nearest integer on the 1–5 scale, falls in category c. The limit convention $p \ln p := 0$ is applied when $p_{ic}^{(X)} = 0$. Normalising by $\ln 5$ bounds the index in $[0, 1]$, with 0 indicating perfectly like-minded exposure and 1 indicating an even distribution across all five ideological bins. [2]

G   Output data structure

The model generates time-series data with the following variables measured at each tick:

- **Population-Level Measures:**
    - $mean\_ideology$: Population mean ideology
    - $sd\_ideology$: Population standard deviation of ideology
    - $mean\_agent\_diversity$: Average social diversity index
    - $mean\_media\_diversity$: Average media diversity index
    - $happy\_percent$: Percentage of satisfied agents
- **Subgroup Measures (by party):**
    - $mean\_agent\_diversity_{\{\text{dem,rep,ind}\}}$: Social diversity by party
    - $mean\_media\_diversity_{\{\text{dem,rep,ind}\}}$: Media diversity by party

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[2]Continuous ideology scores are first mapped to categories via $\text{bin}(x) = \max\{1, \min\{5, \text{round}(x)\}\}$.