# The Issue and the Context

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**Idea:** Modeling Opinion Dynamics: A Hybrid Approach

**Key Issue:** Traditional Voter Model (1975) is limited to pairwise interactions and immediate responses, which fail to capture real-world complexities such as group influences, nonlinear adoption, and delays.

**Recent Research:**
*Adaptive Voter Model* (2023): Group-based influences using hypergraphs.
*Nonlinear Voter Model* (2023): Persistence of minority opinions through nonlinear adoption.
*Latency Model* (2024): Delays introducing oscillatory opinion swings.

Key Components:

- **Hypergraph Structure:** Influence within a hyperedge $e$:

$$S_X(e) = \sum_{j \in e} \alpha_j \cdot \mathbf{1}(X_j = X)$$

  - $S_X(e)$: Influence score for opinion $X$.
  - $\alpha_j$: Influence weight of node $j$.
- **Nonlinear Influence:** Probability of adopting opinion 1:

$$P(X_i = 1|e) = \frac{S_1(e)^q}{S_0(e)^q + S_1(e)^q}$$

  - $q > 1$: Majority dominates.
  - $q < 1$: Minority persists.
- **Latency:** Opinion update rule:

$$X_i(t+1) = \begin{cases} X_i(t), & \text{if } t - T_i(t) < L_i, \\ \text{argmax}_X P(X_i = X|e), & \text{otherwise} \end{cases}$$

  - $L_i$: Latency period for node $i$.

**Parameters:**

- $V, E$: Nodes and hyperedges.
- $q$: Nonlinearity parameter (majority/minority sensitivity).
- $L_i$: Latency period per node.

**Research Gap:** No single model integrates all three dimensions to address complicated real-world phenomena like polarization and cascading behaviors.

**Our Goal:** Develop the Hybrid Hypergraph-Nonlinear-Latency Voter Model, combining these factors into one unified framework. Applications include understanding polarization, social media trends, and public health campaigns.

# A Preview of One Thing We've Found So Far

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**Preliminary Observations:**

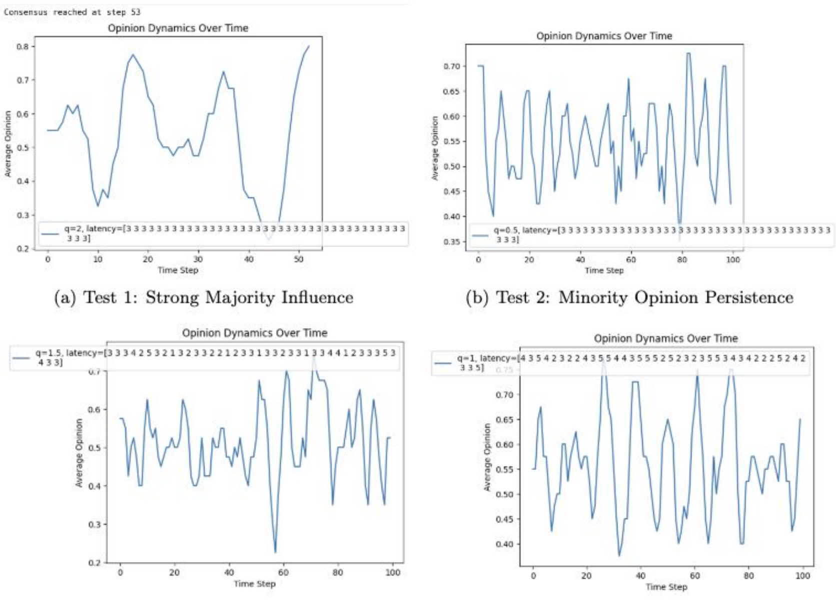
**Test 1:** High nonlinearity parameter (q=2) leads to rapid consensus. Consensus achieved in 53 steps, reflecting viral trends or widespread agreement in simple systems.

**Test 2:** Low q = 0.5 leads to minority opinion persistence. Sustained diversity of opinions, mirroring societal polarization.

**Test 3:** Gaussian-distributed latency introduces oscillatory opinion dynamics. Reflects systems with uniform response times, such as structured decision-making environments.

**Test 4:** Mixed latency settings yield prolonged opinion diversity. Mirrors unpredictable real-world scenarios with delayed responses, such as indecision in polarized debates.

Figure 1: Opinion Dynamics Over Time for Different Test Scenarios.
***X-axis**: Time Steps, **Y-axis**: Average Opinion*




(a) Test 1: Strong Majority Influence

(b) Test 2: Minority Opinion Persistence

(c) Test 3: Low Variable Latency (Gaussian)

(d) Test 4: High Variability Latency (Random)

**Takeaway:** The interplay of q (nonlinearity) and latency governs whether systems converge to consensus, oscillate, or maintain diversity. These insights offer critical understanding into societal polarization, decision-making delays, and the dynamics of consensus-building.