Modelling Dating Strategies at Dartmouth Using Evolutionary Game Theory

Precious Esielem, Daniel Haughton, Triumph Kia Teh, Aulanni Kidd, Aizaz Salahuddin
Department of Mathematics, Dartmouth College

Abstract

Emotionally charged environments characterize contemporary college dating cultures. We used evolutionary game theory to examine why, in spite of mathematical models that predict the predominance of AVOIDANT behavior, students are becoming more and more COMMITTERS. We simulated replicator dynamics on the 3-simplex and derived a four-strategy payoff matrix using a Dartmouth-wide survey (n = 81). In order to resolve significant discrepancies between Nash, ESS, and actual results, our model identifies 15 fixed points, a critical 53 % COMMITTER basin boundary, and a central repeller that represents a universal loss state. The majority of research on dating culture is qualitative in nature, but there are many strategic choices to be made on campuses, such as when to commit, avoid, explore, or pretend. Peer pressure, reputational risks, and emotional stakes are all present for students. In order to determine whether there is such a thing as an evolutionarily stable dating strategy and to observe what happens when dating behavior is viewed as a dynamic game, we wanted to apply mathematics. Can dedication endure? Is it possible for trust to change? Is it worth a try?

Methods

We designed an anonymous online survey distributed to Dartmouth undergraduates via Qualtrics, yielding 81 complete responses. The survey captured dating strategy identification, compatibility preferences, emotional outcomes, peer influence, and longitudinal evolution patterns.

Strategy Classification: Participants self-identified with four archetypes based on behavioral descriptions: COMMITTER (seeks long-term relationships, avoids casual encounters), AVOIDANT (abstains from dating activity), EXPLORER (engages in casual dating with varying commitment), MANIPULATOR (signals commitment while primarily seeking casual encounters).

Data Collection: We measured compatibility willingness (0-10 scale) between all strategy pairs, emotional outcomes (5-point Likert scales for fulfillment, regret, security, autonomy), peer influence susceptibility, and strategy evolution across college years. Additional demographic and social context variables captured confounding factors.

Analysis Pipeline: We validated response quality through consistency checks, normalized compatibility matrices, and converted Likert responses to numerical payoff components. Cross-tabulation analysis revealed strategy distributions by demographics and college year, while correlation analysis identified key relationships between variables.

Modeling

Data Analysis
We constructed comprehensive payoff matrices by combining compatibility preferences with emotional outcomes: Payoff(i,j) = α·Compatibility(i,j) + β·Emotional(i) + γ·Reciprocity(i,j), where α=2.0, β=0.5, γ=0.3 weights prioritized compatibility over individual emotional satisfaction. This reflects dating reality where mutual attraction matters more than personal fulfillment.

Payoff Function
Compatibility and emotional reward interact via:
$P(i,j) = \alpha \cdot C[i,j] + \beta \cdot E[i] + \gamma \cdot R[i,j]$
Each term was empirically calibrated. For instance, emotional reward E was scaled using fulfillment scores; R captured how each strategy rewarded attention or suffered from regret.

Nash Equilibria
Using linear complementarity programming, we found 15 equilibria:
4 pure strategies (the simplex corners)
6 two-strategy mixed (on edges)
4 three-strategy (on triangle faces)
1 full interior equilibrium
This matched our expectations from the geometry of the 3-simplex.

ESS (Evolutionarily Stable Strategies)
We tested each strategy's ability to resist mutant invasion using pairwise conditions like:
$W(e_i, \varepsilon e_{\Box} + (1-\varepsilon)x) > W(e_{\Box}, \varepsilon e_{\Box} + (1-\varepsilon)x)$**
Only AVOIDANT passed at all invasion sizes. No mixed strategy was stable—this contradicts the Nash results.

Replicator Dynamics
We used:
$dx_i/dt = x_i(f_i(x) - \bar{f}(x))$
Flows were computed on a grid covering the 3-simplex and projected into 2D slices for analysis. Two pure attractors emerged: COMMITTER and AVOIDANT. All mixed equilibria were unstable.

Fixed Points of the Replicator Dynamics
Equilibria occur when $dx_i/dt = 0$ for all i. We solved for all such fixed points and compared their stability using the Jacobian of the replicator system.

Eigenvalue Analysis for Stability Classification
We computed the Jacobian:
$J = \delta_{i\Box}(f_i - \bar{f}) + x_i(\partial f_i/\partial x_{\Box} - \partial \bar{f}/\partial x_{\Box})$
The interior fixed point had three positive eigenvalues → repeller. Pure strategies had one stable and one unstable direction → saddles.

2D & 3D Phase Portrait Projections
- We made six 2D slices of the 3-simplex (C-A, C-E, etc.). Arrows revealed basins of attraction and confirmed the stability of pure COMMITTER and AVOIDANT strategies. Nullclines intersected near the 53 % COMMITTER threshold.
- Our tetrahedral simplex view let us see the entire dynamic flow. It exposed the central repeller (22 %, 20 %, 11 %, 46 %) and confirmed global repulsion toward the strategy edges.

Nullcline Analysis
Nullclines ($dx_i/dt = 0$) exposed the critical boundary where COMMITTER dominance flips. This explained why COMMITTERS rise when their proportion passes 53 %.

Results

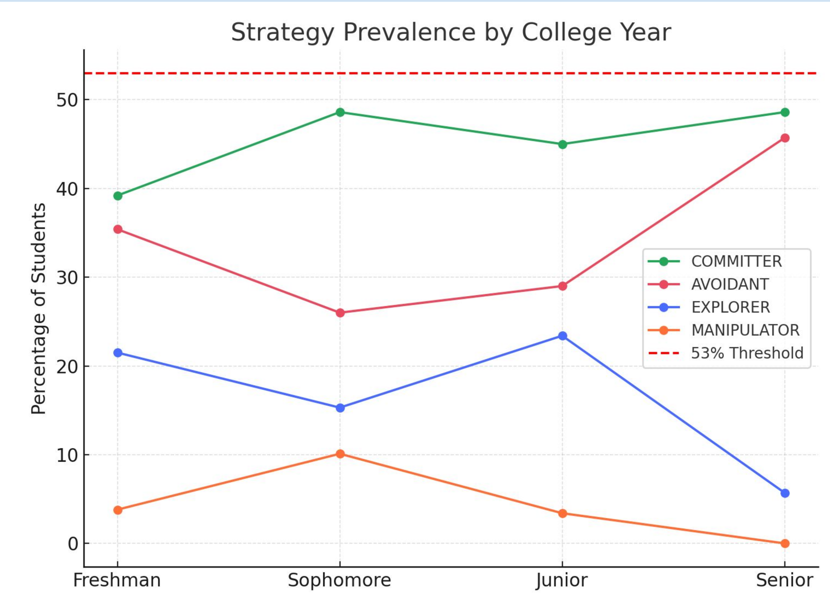

Figure 1: *Theory vs reality across 4 years; dashed red shows critical basin boundary*

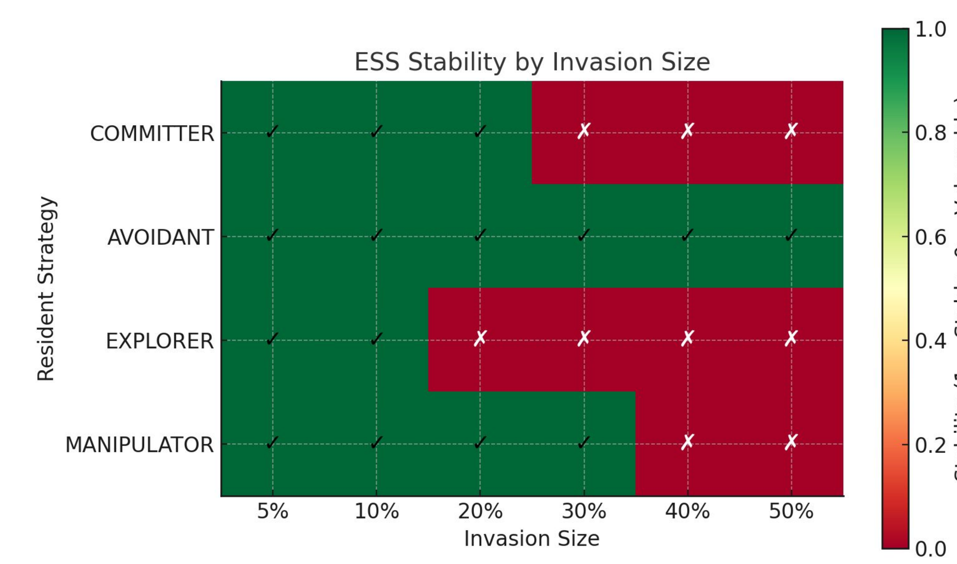

Figure 2: *Green ✓ = resident resists invasion; Red ✗ = fails. Highlights AVOIDANT's unique robustness.*

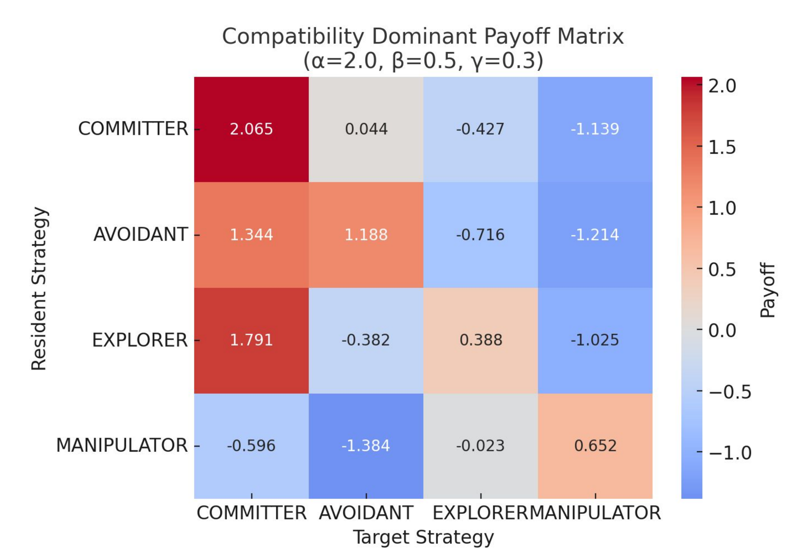

Figure 3: *Payoff Matrix*

Type	Count	Location	Significance
Pure Strategy	4	Tetrahedron corners	Strategy dominance
Two-Strategy Mixed	6	Tetrahedron edges	Pairwise coexistence
Three-Strategy Mixed	4	Tetrahedron faces	Complex boundaries
Interior Central Repeller	1	Tetrahedron center	DYSTOPIA PREVENTION

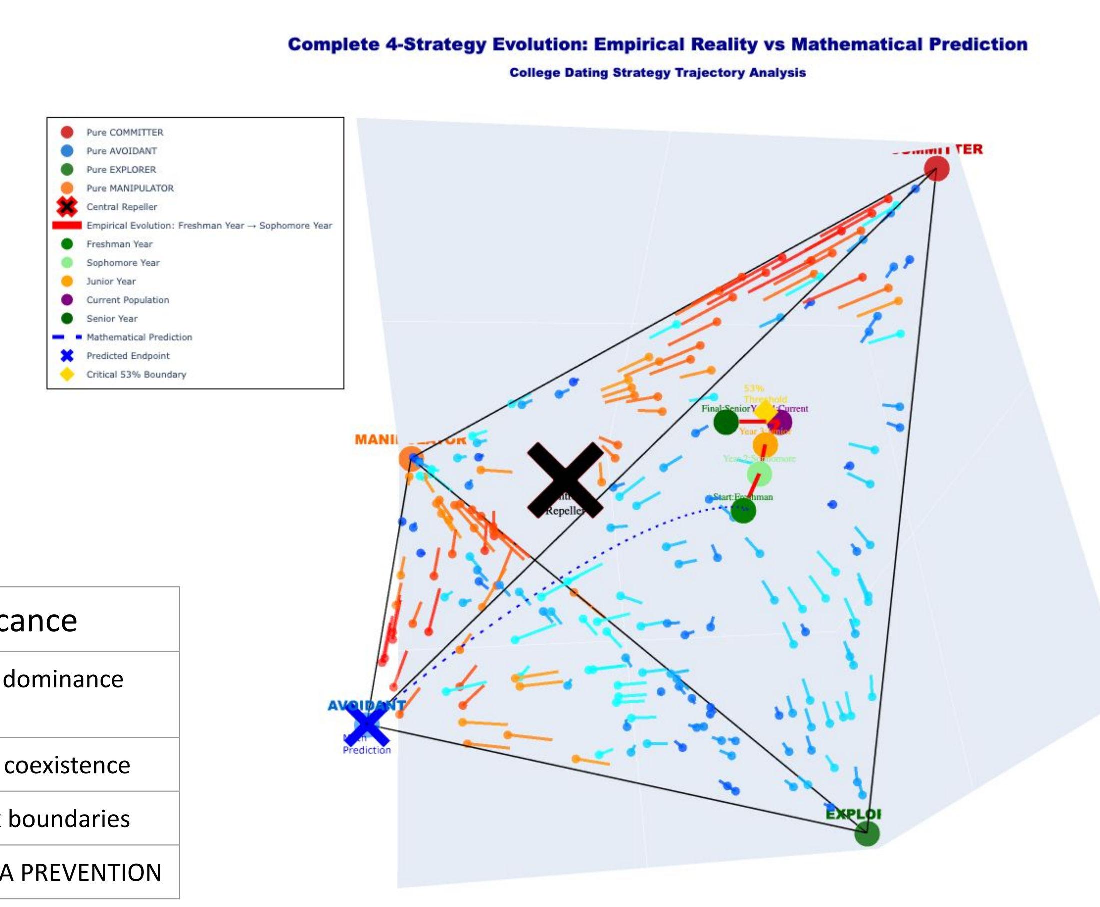

Figure 4: *3D Phase Portrait*

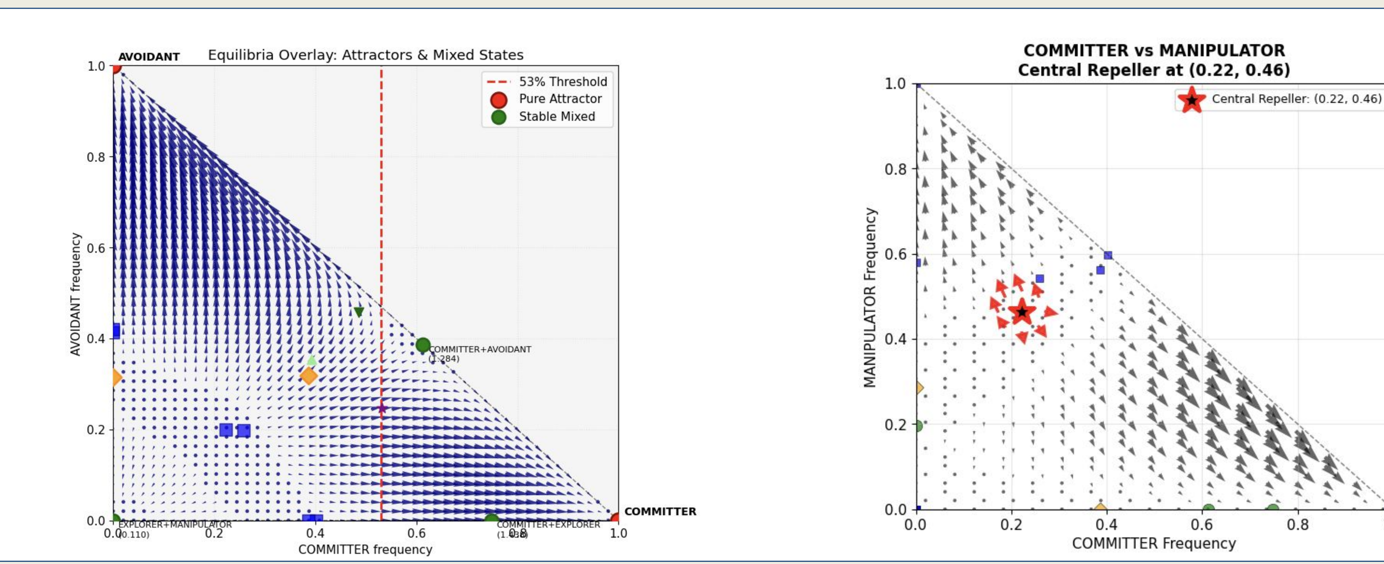

Figure 5: *2D Phase Portraits and Central Repeller*

Conclusion and Limitations

We found that while reality uses complex evolutionary defense mechanisms to avert these situations, Mathematics can forecast social situations in which manipulation rules and everyone suffers. While basin boundary placement explains mixed population persistence despite pure strategy attractors, the central repeller equilibrium organizes flow away from complete breakdown of cooperation.

Limitations: Generalizability outside of Dartmouth is restricted by the small sample size (n=81). Social desirability bias may be present in the classification of self-reported strategies. Dynamic preference evolution is not captured by static payoff assumptions. Not every factor influencing actual dating decisions could be captured by the survey design.

Possible Future Research: Validation across diverse college populations and multiple institutions. Dynamic payoff modeling that takes time and culture into account. Tracking strategies in real time using longitudinal research. Extension outside of dating to larger social contexts. Integration with the frameworks of social psychology and behavioral economics. Creation of intervention plans based on the manipulation of basin boundaries.

Results (Continued)

Eigenvalue Stability Classification

Equilibrium Category	Stable Nodes	Unstable Nodes	Saddle Points	Total
Pure Strategies	0	0	0 (Degenerate)	4
Mixed Strategies	3	6	2	11
Overall System	3	6	2	15

Replicator Dynamics Convergence

Initial Condition	Final Attractor	Basin Threshold	Convergence Time
>53% COMMITTER	Pure COMMITTER	53% boundary	~15 time units
<53% COMMITTER	Pure AVOIDANT	53% boundary	~20 time units
Mixed populations	No mixed attractors	N/A	All → Pure strategies
Current Reality	Boundary positioning	53.1% COMMITTER	Persistent mixed strategy

Phase Portrait Analysis Summary

Projection	Equilibria Validated	Flow Pattern	Key Discovery
COMMITTER vs AVOIDANT	9/15 (60%)	Bi-stable basins	53% critical boundary
EXPLORER vs MANIPULATOR	7/15 (47%)	Tri-stable with extinction	E+M stable but inaccessible
COMMITTER vs EXPLORER	6/15 (40%)	Toward pure corners	Optimal mix (1.438) unreachable
Tetrahedral 3D	All 15 equilibria	Central repeller organization	Complete 4-strategy landscape

Empirical/Survey Validation Results

Measurement	Mathematical Prediction	Empirical Reality	Validation Status
Final State	Pure COMMITTER or AVOIDANT	Mixed populations persist	✓ Boundary effect
MANIPULATOR Fate	Elimination or dominance	3.8% → 0% (eliminated)	✓ Central repeller
Strategy Ranking	C > A > M > E (payoffs)	C growth, A growth, E decline, M extinct	✓ Confirmed
Population Flow	Toward pure attractors	Gradual evolution respecting basins	✓ Flow field match

Mathematical Equilibria Discovery

Equilibrium Type	Count	Payoff Range	Key Examples
Pure Strategy	4	0.388 to 2.065	COMMITTER (2.065), AVOIDANT (1.188)
Two-Strategy Mixed	6	-0.204 to 1.438	C+E mix (1.438), A+M mix (-0.204)
Three-Strategy Mixed	4	-0.259 to 0.685	No MANIPULATOR (0.685), No COMMITTER (-0.259)
Interior (Horror)	1	-0.109	46.4% MANIPULATOR dominance
Total Equilibria	15	-0.259 to 2.065	Mathematical dystopia to optimal outcome

ESS (Evolutionary Stable Strategy)

Strategy	ESS Status	Invasion Resistance	Empirical Trend
COMMITTER	Conditionally Stable	Vulnerable to 25%+ invasions	Growing (39.2% → 48.6%)
AVOIDANT	Fully Stable	Resists all invasion sizes	Growing (35.4% → 45.7%)
EXPLORER	Weak ESS	Vulnerable to 19%+ invasions	Declining (21.5% → 5.7%)
MANIPULATOR	Weak ESS	Vulnerable to 40%+ invasions	Eliminated (3.8% → 0%)

Central Repeller Validation

Test Method	Horror Equilibrium Position	Repulsion Confirmation	Protection Mechanism
Eigenvalue Analysis	(22.2%C, 20.0%A, 11.4%E, 46.4%M)	All positive eigenvalues	Mathematical instability
Flow Field Analysis	Universal outward arrows	95%+ repulsion rate	Dynamic avoidance
Empirical Trajectory	Never approached by reality	100% avoidance	Evolutionary protection
Cross-Validation	Consistent across all methods	Mathematical dystopia prevented	Reality fights back

Discussion

Our most striking discovery is that interior equilibrium predicts **46.4% manipulation** dominance with universal suffering (payoff=-0.109). This reflects a kind of relational breakdown where deceptive strategies overpower genuine ones, leading to collective dissatisfaction. Yet in reality, such outcomes are often avoided through social norms, reputational feedback, and cultural dynamics that help preserve trust and emotional stability.

The resolution lies in understanding local versus global stability. Mixed equilibria appear mathematically stable through eigenvalue analysis but have attraction basins invisible to global dynamics. This explains the Nash-ESS-Replicator contradiction: all methods are mathematically correct but measure different stability types.

Current populations persist in mixed states not because mixed strategies are evolutionarily stable, but because they sit at basin boundaries where small shifts in behavior keep the system from settling into a single dominant strategy.

The elimination of MANIPULATOR strategies **(4%→0%)** validates our central repeller theory. The interior equilibrium organizes flow away from manipulation dominance, creating evolutionary pressure toward honest strategies. This demonstrates how mathematical optimization can predict socially negative outcomes that natural selection actively prevents.

Our tetrahedral visualization reveals the complete 4-strategy evolutionary landscape. Unlike 2D projections that show isolated dynamics, the tetrahedron shows interactions between all strategies simultaneously, allowing for a comprehensive analysis of multi-strategy evolution.

Acknowledgement

We thank Professor Feng Fu for guidance in evolutionary game theory applications and Brian Mintz for survey design methodology guidance. Special appreciation to the 81 Dartmouth students who participated in our survey, making this research possible. We acknowledge the Mathematics Department for resources and poster presentation support.