A Mathematical Model of Human Relationships

Attraction emotional exchange and dynamic stability

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Abstract

This paper proposes a mathematical framework for describing attraction, emotional exchange, and the evolution of intimate relationships. Individual characteristics are represented as a vector, while attraction is expressed as an observer-specific weighted evaluation. Behavioral experiences modify perceived attraction and accumulate through a memory-weighted attachment process. Relationship dynamics are then described through investment, trust, reciprocity, goal alignment, and emotional volatility. A four-mode interaction matrix distinguishes voluntary movement toward a partner, withdrawal, forcing, and punishment. A complementary directional model represents the desire for closeness or distance. The central proposition is that sustained voluntary reciprocity and effective repair support relational continuity, whereas persistent pressure, punishment, and disengagement can undermine it. The equations are conceptual assumptions rather than calibrated predictions. The framework does not assign objective worth to people, establish neurological mechanisms, or present empirical validation.

Keywords: human relationships; emotional exchange; attachment; reciprocity; behavioral dynamics; mathematical modeling

1 Introduction

Attraction alone does not explain why relationships endure. A partner may appear compatible on paper while interactions produce distrust, pressure, or emotional distance. Conversely, repeated care and shared experience can make a relationship meaningful beyond an initial assessment of personal traits. A useful model must therefore distinguish initial attraction from the history of interaction and from the conditions that sustain cooperation.

Here, human energy refers to the subjective capacity and motivation to invest attention, care, effort, and emotional engagement. It is a psychological metaphor, not a physical quantity measured in joules.

Emotional exchange describes how interactions influence that capacity and the willingness to continue investing.

The framework organizes these processes into a tractable set of variables. It is intended to support conceptual discussion and future operationalization, rather than to score individuals, diagnose partners, or predict the outcome of a particular relationship.

2 Personal characteristics and perceived attraction

2.1 The characteristic vector

Represent the characteristics of person j by a vector p_j. The characteristic vector includes appearance, finances, age, health, education, work orientation, social skills, family orientation, social status, and charm or sexual attraction. These dimensions are descriptive choices; they do not constitute a universal scale of human worth.

$$p_j = (x_{j1}, x_{j2}, \ldots, x_{j10}) \quad (1)$$

A numerical implementation would require each dimension to be defined and placed on a comparable scale. Raw age, income, and subjective assessments cannot be combined meaningfully without a transformation. Some preferences may also be nonlinear: a person may prefer an age range rather than a monotonically increasing age score.

2.2 Attraction as an observer specific evaluation

Let w_i denote the preference weights of observer i. An initial evaluation of person j can be represented as a weighted sum:

$$V_{ij}^{0} = w_i^T p_j = \Sigma_k \, w_{ik} x_{jk} \quad (2)$$

The same characteristics can yield different evaluations for different observers. V_{ij} is consequently directed: the attraction that i experiences toward j need not equal the attraction that j experiences toward i. Weights can change with circumstances, experience, and relationship goals.

2.3 Behavior changes the evaluation

Kindness, support, reliability, disrespect, betrayal, and shared experiences modify the meaning of a partner's characteristics. A behavioral adjustment $b_{ij}(t)$ extends the initial evaluation:

$$V_{ij}(t) = w_i(t)^T p_j(t) + b_{ij}(t) \quad (3)$$

This formulation preserves the distinction between a personal profile and its relational interpretation. It also allows behavior to outweigh an initially favorable or unfavorable assessment. The linear form is a simplifying assumption; interaction effects and thresholds may be needed in a tested model.

2.4 Emotional distance and influence

This framework proposes a field analogy in which influence depends on perceived attraction and emotional distance. A regularized illustrative expression avoids division by zero:

$$H_{ij}(t) = V_{ij}(t) / [d_{ij}(t)^2 + \varepsilon], \quad \varepsilon > 0 \quad (4)$$

Here, d_{ij} is a defined measure of emotional distance and H_{ij} is an influence index. The inverse-square form is an analogy, not an established psychological law. Distance can have different effects across relationships, so this expression would require comparison with alternative functional forms.

3 Attachment as a memory dependent process

An instantaneous evaluation does not capture the accumulated significance of a relationship. Attachment can persist despite current disappointment because previous experiences remain meaningful. A memory-weighted formulation represents the continuing contribution of those experiences.

3.1 Accumulation and decay

Let $A_{ij}(t)$ be a signed relational attachment index, $A_{ij}(0)$ its initial value, $E_{ij}(t)$ the net impact of interaction, and λ_{ij} a nonnegative decay parameter. Then:

$$A_{ij}(t) = A_{ij}(0)e^{(-\lambda_{ij}t)} + \int_0^t E_{ij}(\tau)e^{[-\lambda_{ij}(t-\tau)]}\, d\tau \quad (5)$$

The corresponding differential form is:

$$dA_{ij}/dt = E_{ij}(t) - \lambda_{ij}A_{ij}(t) \quad (6)$$

Recent events have greater weight under an exponential memory kernel. Earlier experiences retain influence but gradually contribute less. Repeated negative experiences can continue affecting the relationship because new negative input arrives before previous input has faded.

3.2 Positive and negative experiences

Separate bonding input u_{ij}^{+} from harmful input u_{ij}^{-}, with a nonnegative sensitivity parameter η_{ij}:

$$E_{ij}(t) = u_{ij}^{+}(t) - \eta_{ij}u_{ij}^{-}(t) \quad (7)$$

The parameter η_{ij} allows positive and negative experiences to have unequal effects. No universal numerical ratio is assumed. The meaning of an event also depends on interpretation: the same conversation may feel like reassurance to one partner and pressure to the other.

A signed index summarizes net relational experience but cannot fully represent simultaneous affection, fear, resentment, and longing. A richer model would track positive attachment and relational injury separately. Strong attachment must not be interpreted as evidence of safety or relationship quality.

3.3 Withdrawal and the absence of reinforcement

If new relational input is zero, the model reduces to exponential decay:

$$A_{ij}(t) = A_{ij}(0)e^{\wedge}(-\lambda_{ij}t) \quad (8)$$

This is a consequence of the model's assumptions, not a claim that every separation weakens every bond. A temporary pause may enable regulation and later repair. Persistent disengagement, however, removes the reinforcing interaction assumed by this formulation.

4 Investment trust and relationship stability

A relationship can be represented as a repeated interaction in which both partners choose how much to invest. Investment includes time, attention, practical care, emotional availability, and repair. The relevant question is how each person responds to the other over time, rather than which person has greater intrinsic value.

4.1 The relational state

$$z(t) = [I_a(t), I_\beta(t), T_a(t), T_\beta(t), V_{a\beta}(t), V_{\beta a}(t)] \quad (9)$$

I_a and I_β describe investment, and T_a and T_β describe each partner's trust. Investment should be assessed relative to capacity and agreed roles. Equal expenditures of money or time are not required for reciprocal care.

4.2 A conceptual stability index

$$Q(t) = \alpha C(t) + \beta R(t) + \gamma \bar{T}(t) - \delta \Omega(t) \quad (10)$$

C is goal and lifestyle alignment, R is reciprocity, $\bar{T}$ is mean trust, and Ω is volatility. Coefficients α, β, γ, and δ are nonnegative. Q summarizes selected relational conditions; it is neither a probability of staying together nor a validated measure of health.

Goal alignment should use vectors of relationship goals, g_a and g_β, rather than all personal characteristics. For nonzero goal vectors, cosine similarity is one possible representation:

$$C = (g_a^T g_\beta) / (\|g_a\| \|g_\beta\|) \quad (11)$$

For normalized investment I_a, $I_\beta \in [0, 1]$, investment balance can be written as $R = 1 - |I_a - I_\beta|$. Balance alone is insufficient: both partners investing nothing would also produce R = 1. The level of mutual engagement must therefore be examined alongside balance.

4.3 Update rules and feedback

$$I_a(t+1) = f_a[T_a(t), V_{a\beta}(t), response_\beta(t), capacity_a(t)] \quad (12)$$

$$T_a(t+1) = clip[T_a(t) + a_a u_a^+(t) - b_a u_a^-(t), 0, 1] \quad (13)$$

An analogous update applies to partner B. The coefficients a_a and b_a represent sensitivity to positive and negative experiences. The clip function keeps normalized trust within its defined range. These expressions specify dependencies; prediction would require measured inputs and estimated parameters.

A reinforcing sequence is investment followed by a responsive interaction, increased trust, and renewed investment. A destabilizing sequence may arise when withdrawal prompts greater pressure, which prompts further withdrawal. These are candidate feedback patterns, not inevitable outcomes or fixed personality types.

5 Four behavioral modes and their interactions

The model distinguishes four observable modes. They describe behavior during an interaction rather than permanent identities. A request for clarity, commitment, affection, or practical help is not automatically forcing; context, consent, and the ability to decline matter.

Code	Mode	Operational description
S	Steps toward	Voluntary care, openness, cooperation, affection, or repair.
W	Withdrawal	Reduced engagement or increased distance; may be protective, temporary, or persistent.
F	Forcing	Pressure intended to obtain an outcome despite the other person's unwillingness.
P	Punishment	Retaliation, humiliation, threats, or deliberate emotional injury.

5.1 The interaction matrix

Rows describe partner A and columns describe partner B. The labels summarize possible interaction patterns, rather than diagnoses or guaranteed outcomes.

A / B	S	W	F	P
S	Mutual engagement	Invitation meets distance	Care meets pressure	Care meets injury
W	Distance meets invitation	Mutual disengagement	Distance meets pressure	Distance meets retaliation
F	Pressure meets care	Pursuit and resistance	Mutual control	Pressure and retaliation
P	Injury meets care	Injury and retreat	Retaliation and pressure	Mutual injury

S–S represents mutual voluntary engagement. S–W and W–S can reflect uneven readiness for closeness, temporary exhaustion, or a persistent pursuit–withdrawal pattern. W–W can represent a mutually agreed pause or prolonged disengagement; these possibilities need separate coding.

F–W and W–F describe pressure–resistance loops. F–F represents competing attempts to control outcomes. Interactions involving P introduce deliberate injury and may suppress future openness. They require attention to the direction and severity of harm rather than an assumption that responsibility is shared equally.

5.2 A changing state rather than a fixed label

A pair can move among the 16 cells as stress, expectations, and perceived safety change. A state-transition model would require observed transition probabilities conditioned on context. The matrix identifies possible states; it does not yet supply those probabilities.

The central hypothesis is that recurring voluntary engagement and successful repair support continuity. Persistent forcing, punishment, or disengagement may undermine it. Frequency alone is insufficient: intensity, duration, context, and the consequences of each episode also matter.

6 Autonomy expectations and repair

6.1 Commitment timing and implicit expectations

Partners may agree that commitment matters while disagreeing about its timing. One partner may seek a decision within two years to plan a life, while the other remains uncertain. The expectation itself is not pathological. Tension can arise when a private timeline becomes an assumed obligation that has never been mutually agreed.

The same interaction can have different meanings. A question about the future may communicate a need for security to the speaker while being experienced as pressure by the listener. Neither interpretation establishes that the request is coercive or that delay is reasonable. The model must retain both perspectives and the possibility of incompatible goals.

6.2 A possible pressure and resistance loop

Let $\pi_a(t)$ denote pressure exerted by A and $r_\beta(t)$ resistance by B. A simple hypothesized relationship is:

$$r_\beta(t+1) = r_\beta^0 + \kappa\pi_a(t), \quad \kappa \geq 0 \qquad (14)$$

If perceived resistance then increases A's pressure, the coupled response can produce an escalating loop. This is one possible response to perceived loss of autonomy, not a universal law. Some direct conversations resolve uncertainty; continued ambiguity can itself damage trust.

A damped oscillation, y(t) = y₀e^(−kt)cos(ωt), can illustrate alternating closeness and distance with a shrinking amplitude. For k > 0, it is a damped trajectory, not mathematical instability. Whether oscillations grow, decay, or persist depends on the actual update rules and parameters.

6.3 Requests boundaries and voluntary commitment

An explicit conversation makes expectations reviewable: “I want a relationship moving toward commitment within approximately two years. How do you see that?” A partner can agree, negotiate, or decline. A person can also decide that an incompatible relationship no longer meets their needs. A boundary about one’s own participation differs from an attempt to control another person’s consent.

6.4 Regulated distance and reconnection

The proposed stabilizing principle is to respond to constructive engagement with constructive engagement, while interrupting destructive escalation. A pause can support this process when its purpose and expected return are communicated. Chronic silence, punitive disappearance, and withholding affection to obtain compliance belong to a different pattern.

Repair involves acknowledging impact, clarifying needs, and changing behavior. Returning immediately to closeness is not always appropriate; willingness, safety, and the legitimacy of each person’s boundaries remain necessary. De-escalation should not imply an obligation to remain in a harmful relationship.

7 Directional orientation and shared experience

7.1 The emotional charge analogy

This framework uses a minus sign for movement toward a partner and a plus sign for movement away. These signs indicate direction, not goodness or badness. A normalized orientation variable q_{ij} can represent this convention:

$$q_{ij}(t) \in [-1, 1] \quad (15)$$

Negative values indicate a desire for closeness, positive values a desire for distance, and values near zero a neutral or mixed orientation. This is a descriptive sign convention. It does not follow the physical law of electrostatic charges, and no literal interpersonal field is assumed.

Orientation pair	Conceptual interpretation
Both negative	Both seek closeness; voluntary engagement may be easier.
One negative and one positive	Preferences for distance differ; pursuit and retreat may develop.
Both positive	Both seek distance; distinguish a shared pause from persistent disengagement.

A person's internal orientation and outward behavior are separate variables. Someone seeking closeness may withdraw out of fear, while someone seeking distance may still provide considerate practical support. The charge model therefore complements the behavioral matrix rather than replacing it.

7.2 Common ground

Shared memories, routines, emotional language, practical cooperation, and repeated repair can form common ground. This framework proposes that mutual positive investment expands this shared relational history. An illustrative attachment equation expresses that idea:

$$dA/dt = k\, s_a(t)s_\beta(t) - \lambda A(t) \quad (16)$$

Here, s_a and s_β are nonnegative voluntary engagement measures and k is a responsiveness coefficient. If engagement is constant and $\lambda > 0$, the model approaches the equilibrium $A^* = ks_as_\beta/\lambda$. It does not imply unlimited exponential growth. The product term assumes that jointly engaged interaction contributes differently from unilateral effort.

7.3 Continuity and relational quality

Shared responsibilities, finances, parenting, and living arrangements can maintain the structure of a relationship despite reduced emotional engagement. Conversely, partners may retain affection while choosing separation. Structural continuity, attachment, safety, and satisfaction should therefore be measured separately.

These distinctions prevent a mathematical score from collapsing different outcomes into a single label. A relationship can persist without being satisfying, and a decision to leave can be consistent with autonomy and wellbeing. The relevant outcome must be specified before assessing stability.

8 Experience and attachment formation

A further extension proposes two contributors to attachment formation: openness to new relational learning and resonance with emotionally significant prior experience. Familiarity, shared background, intellectual connection, and remembered relationship patterns may influence how a new interaction is interpreted.

$$G_{ij}(t) = N_i(t)R_{ij}(t) + \mu_i M_{ij}(t) \quad (17)$$

G_{ij} is a proposed attachment input, N_i represents responsiveness to new learning, R_{ij} the rewarding significance of current interaction, M_{ij} resonance with prior experience, and μ_i the weight assigned to that resonance. G can be included as part of positive input in Equation 7 rather than treated as an independently established biological mechanism.

One proposed extension associates new learning with youth and memory resonance with maturity. This is retained as a hypothesis about individual variation, not a demonstrated age rule. Age alone does not determine attachment speed, trust, recovery, or the capacity to form a new bond. Claims about dopamine, oxytocin, neural pathways, or neuroplasticity require independent evidence and cannot be inferred from these equations.

9 Limitations and a validation agenda

The framework is conceptual. It includes no original dataset, estimated coefficients, experimental tests, or validated prediction thresholds. The mathematical notation makes assumptions explicit but does not establish their truth. Additive attraction scores, exponential memory, and linear pressure responses are candidate forms that may be replaced if observations support other relationships.

Operationalization would require clear measures of investment, trust, perceived pressure, withdrawal, repair, and emotional impact. Repeated reports from both partners would help distinguish experience from interpretation. Behavioral coding should separate agreed pauses from punitive silence, direct requests from coercion, and unequal capacity from unwillingness to reciprocate.

A longitudinal study could examine whether changes in reciprocal engagement and repair predict subsequent trust or satisfaction. Candidate models should be compared with simpler baselines,

evaluated on held-out observations, and examined for individual differences. Persistence, satisfaction, attachment, and safety would need distinct outcome measures. Consent and privacy are particularly important when collecting intimate relationship data.

10 Conclusion

Human relationships can be described as evolving systems of perception, memory, investment, and response. Initial attraction is observer-specific; accumulated experience changes its meaning. The proposed framework places voluntary reciprocity, autonomy, and repair at the center of relational continuity while recognizing the destabilizing potential of persistent pressure, punishment, and disengagement. Its contribution is a structured conceptual language and a set of explicit hypotheses for future testing, rather than a universal equation for love.