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Mathematical Modeling of the Marital Interaction Dynamics

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Introduction to Rapid Couples Interaction Scoring System (RCISS)

Rapid Couples Interaction Scoring System (RCISS)

Takes place during a videotaped discussion between the couple and detailed aspects of their emotions get coded during a 15-minute session. On each conversational turn, the total number of positive RCISS speaker codes minus the total number of negative speaker codes gets computed for each spouse using a linear regression analysis, which can determine if the couple is regulated or non-regulated.

Benefits of RCISS:

♥ Useful tool for understanding, explaining, and predicting the dynamics between a couple to differentiate between happily and unhappily married couples

♥ Used for assessing and predicting whether a couple would divorce and help with prevention and intervention

Types of Couples

Regulated vs Non-regulated Couple Types

♥ Regulated couples: Both husband and wife speaker slopes were **significantly positive**

Consists of: Validators, volatiles, and avoiders

♥ Non-regulated couples: At least one of the speaker slopes was **not significantly positive**.

Consists of: Hostile and hostile-detached

Regulated couples: displayed more positive than negative RCISS codes.

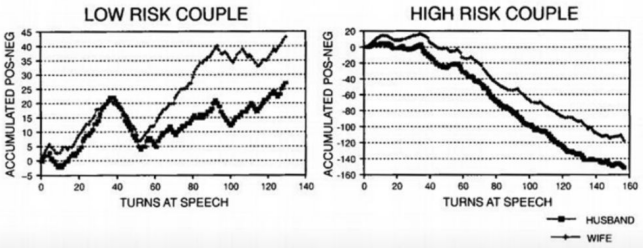


Figure 1. Cumulative Rapid Couples Interaction Scoring System (RCISS) speaker point graphs for a regulated (low risk) and a nonregulated (high risk) couple. Pos-Neg = Positive–Negative. Revised art from "Marital Processes Predictive of Later Dissolution: Behavior, Physiology, and Health," by J. M. Gottman and R. W. Levenson, 1992, *Journal of Personality and Social Psychology, 63,* p. 225. Copyright 1992 by the American Psychological Association.

Stable Couples vs Unstable Couples

Stable Couples

♥ Validators: Are calm and intimate. These couples appear to place a high degree of value on companionate marriage and shared experiences, not on individuality.

♥ Volatiles: Are romantic and passionate. Engage in high levels of persuasion to outset discussion. Love to argue and debate in a respectful manner.

♥ Avoiders: Avoid the pain of confrontation and conflict. This couple hardly attempts to persuade one another.

Unstable couples

♥ Hostile and Hostile-detached: The hostile-detached group was significantly more negative (more defensive and contemptuous) than the hostile group and they were more detached listeners.

♥ Negative slope in the RCISS scoring

Math Modeling for Marital Interaction

Influence Function Model

♥ This model shows the effect of a change in one observation due to an external parameter. It's useful in calculating variance-covariance matrices for certain types of estimators to assess the effect or “influence” during an observation efficiently.

♥ Functions and differential equations with calculus were mainly employed to set up the models

Models and Theories in the Talk:

♥ **Influence function model** (constant vs. non-constant): Considers interpersonal influence parameter to represent influence from spouses and uninfluenced parameter to represent each spouse’s individual dynamics.

♥ **Discrete function model**: Considers scores for any spouse by functions with distinct and separate values and a parameter in respect to a spouse’s turn with coupled difference equations.

♥ **Stability Analysis Theory**: Considers intersection points of nullclines and uses calculus to determine the steady states for equilibrium

Influence Function Model and RCISS

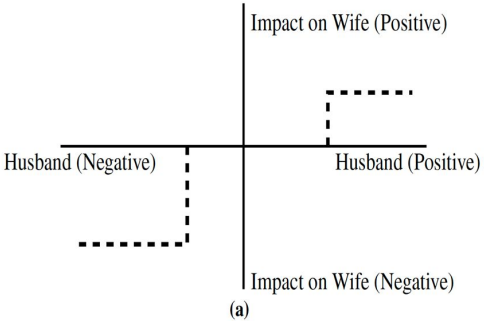
- This model considers Interpersonal Influence from spouse to spouse (**influence**) + each spouse's Individual Dynamics (**uninfluenced**).
- The influence function:

  husband on wife: $I_{HW}(t)$;
  wife on husband: $I_{WH}(t)$

  A sequence of RCISS score: $W_1, H_1, W_2, H_2, W_3, H_3, \ldots\ldots W_t, H_t, W_{t+1}, H_{t+1} \ldots \ldots \ldots$

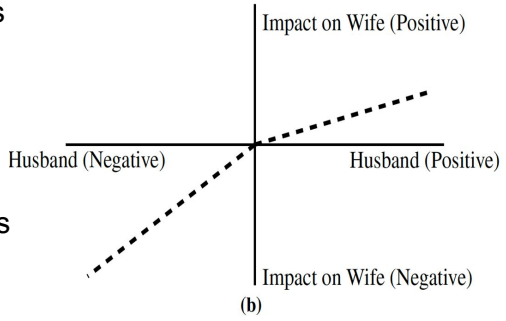
- **Assumption**: there is a threshold before a positive value has an effect in a positive direction and a threshold before a negative value has an effect in a negative direction.
- The parameters of these influence functions can vary as a function of culture, marital satisfaction, the level of stress the spouses were under at the time, their individual temperaments and so forth.

Constant Influence



1. The horizontal axis shows the variable for one spouse. The vertical axis shows the dependent variable for the other spouse's following behavior.
2. Influence function remains constant once there is an effect.

Non-Constant Influence



1. An influence function in which the more positive the previous behavior, the more positive the effect on the spouse.
2. The more negative the behavior, the more negative the effect on the spouse.

Discrete Model

- Score for any spouse in any talk turn is determined only by the two most recent scores from self and the spouse.
- We denote by and W_t and H_t the husband's and wife's scores respectively at turn *t* and assume that each person's score is determined solely by their own and their partner's previous score. The sequence of scores is then given by an alternating pair of coupled difference equations:

$$W_{t+1} = f(W_t, H_t),$$
$$H_{t+1} = g(W_{t+1}, H_t),$$

Remember: wife talks first
(1) f and g need to be determined
(2) f and g each are a summation of influence (from spouse) and uninfluenced (itself) results.

- Uninfluenced state: Primarily a function of the individual rather than being influenced
- We define the uninfluenced state (for husband or wife) to be: $P = \frac{a_i}{1-r_i}$,

  where $0 \leq r_i < 1$, is called the inertia parameter

  The bigger r_i, the influence has more inertia
- Each husband/wife's RCISS score is a summation of the influenced state and the uninfluenced state. We need to find the four parameters r_1, a, r_2, b

$$W_{t+1} = I_{HW}(H_t) + r_1 W_t + a,$$
$$H_{t+1} = I_{WH}(W_{t+1}) + r_2 H_t + b.$$

RCISS Score equation

RCISS Null Cline and Steady States

- A person's null cline is a function of their partner's last score
- The value of their own score is unchanged over time. $W_{t+1}=W_t$ and $H_{t+1}=H_t$
- After substitution, null clines are N_{HW} (Wife vs. Husband) and N_{WH} (Husband vs. wife) :

$$W_{t+1} = I_{HW}(H_t) + r_1 W_t + a,$$
$$H_{t+1} = I_{WH}(W_{t+1}) + r_2 H_t + b.$$

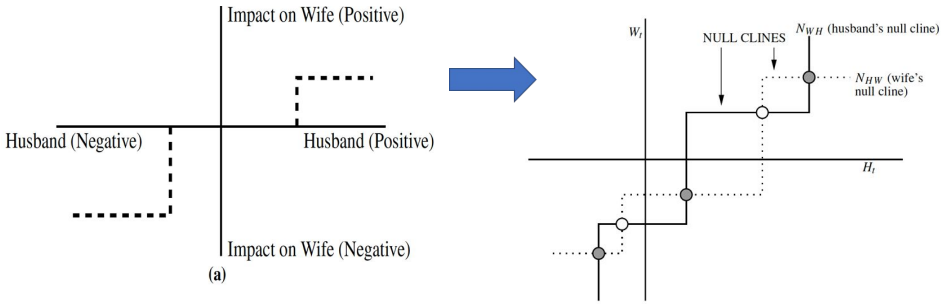
RCISS equation

$$N_{HW}: W(H_t) = \frac{I_{HW}(H_t)+a}{(1-r_1)}, \quad N_{WH}: H(W_t) = \frac{I_{WH}(W_t)+b}{(1-r_2)}.$$

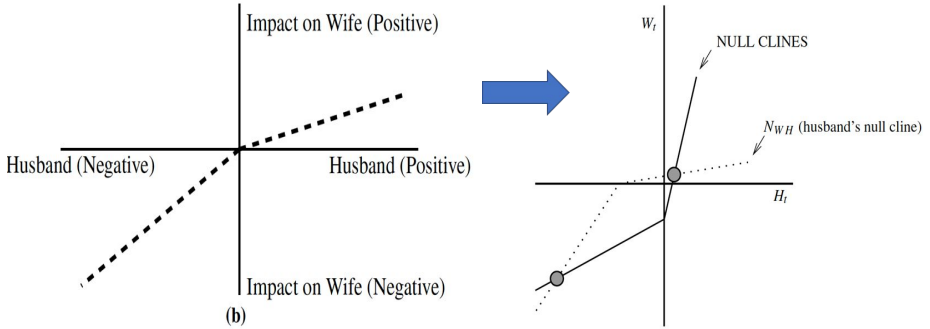
Steady states are then given by the intersections of N_{HW} and N_{WH}

Null cline (Case 1) Constant Influence

$$N_{HW}: W(H_t) = \frac{I_{HW}(H_t)+a}{(1-r_1)}, \quad N_{WH}: H(W_t) = \frac{I_{WH}(W_t)+b}{(1-r_2)}.$$



Null cline (Case 2) Non-Constant Influence



Assume a<0 and b>0. We know $0 \le r_1 < 1$ and $0 \le r_2 < 1$

Analyzing Stable Steady States

- For any steady state (W_s, H_s), consider addition of small **perturbations w_t and h_t** as:

$$W_t = W_S + w_t$$
$$H_t = H_S + h_t,$$

$$W_{t+1} = I_{HW}(H_t) + r_1 W_t + a,$$
$$H_{t+1} = I_{WH}(W_{t+1}) + r_2 H_t + b.$$

RCISS score equation

$$\begin{bmatrix} w_{t+1} \\ h_{t+1} \end{bmatrix} = \begin{bmatrix} r_1 & I'_{HW}(H_S) \\ r_1 I'_{WH}(W_S) & r_2 + I'_{WH}(W_S) I'_{HW}(H_S) \end{bmatrix} \begin{bmatrix} w_t \\ h_t \end{bmatrix} = M \begin{bmatrix} w_t \\ h_t \end{bmatrix},$$

where M, is the stability matrix.

Stability Matrix

$$\left.\begin{matrix} w_t \\ h_t \end{matrix}\right\} \propto \lambda^t$$

- λ is an eigenvalue of the matrix M (stability matrix)
- Only when all eigenvalues satisfying -1<λ<1, can the steady states be stable.

$$I'_{WH}(W_S) I'_{HW}(H_S) < (1 - r_1)(1 - r_2),$$

Linear stability matrix satisfying -1<λ<1

$$\left.\frac{dW}{dH}\right]_{\substack{\text{On wife's} \\ \text{null-cline, } N_{HW}}} = \frac{I'_{HW}(H)}{1 - r_1}, \quad \left.\frac{dH}{dW}\right]_{\substack{\text{On husband's} \\ \text{null-cline, } N_{WH}}} = \frac{I'_{WH}(W)}{1 - r_2}.$$

Derive Linear stability matrix

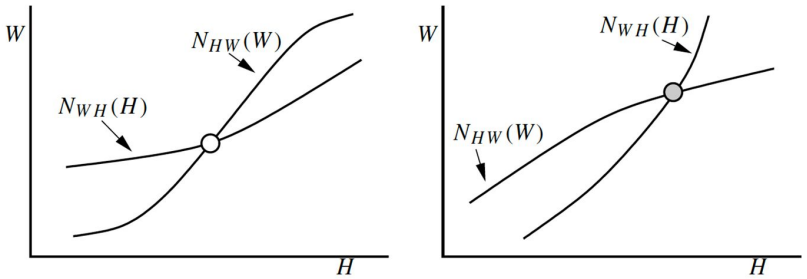
$$\left[\frac{dW}{dH}\right]_{\substack{\text{On wife's} \\ \text{null-cline, } N_{HW}, \\ \text{at } W_S, H_S}} < \left[\frac{dW}{dH}\right]_{\substack{\text{On husband's} \\ \text{null-cline, } N_{WH}, \\ \text{at } W_S, H_S}}.$$

Guaranteed stable steady states

- To assess stability of a steady state, we evaluate the derivatives of the influence functions
- We interpret instability as the amplification of small perturbations
- The last expression guarantees stability

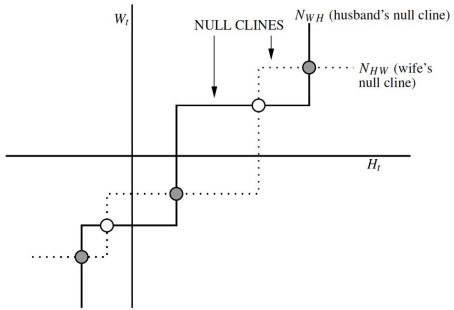
Analyzing Stable Steady States

Null cline: Non-Constant Influence



- Left graph: $N_{HW}(W) > N_{WH}(H)$. Unstable.
- Right graph: $N_{HW}(W) < N_{WH}(H)$. Stable.

Null cline: Constant Influence



•The stable and unstable steady states alternate: one stable, then one unstable, and one stable again.

•The lowest and highest steady states are stable

•There are an odd number of steady states

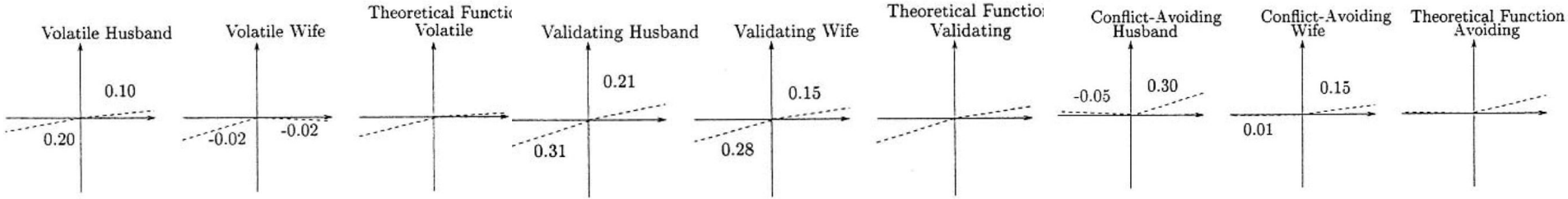
- Positive initial RCISS scores for both wife and husband may approach a negative stable steady state in the third Quadrant and vice versa.
- High inertia (strong-will people) and high influence (volatile people) may easily jump to negative stability and positive stability in different time periods based on how they start the talks.

Low Risk Couples with Matched Emotions

♥ Three types of low-risk marriage: volatile, validating, conflict-avoiding

♥ There are also such three types of husbands including volatile husbands, validating husbands, and conflict-avoiding husbands. The same for the wife.

♥ Only when their types match (emotion match), the marriage can be at low risk by theory, that is, volatile husband with volatile wife, validating husband with validating wife, conflict-avoiding husband with conflict-avoiding wife.



♥ Volatile: Easily influenced by negative score and not influenced by positive score.

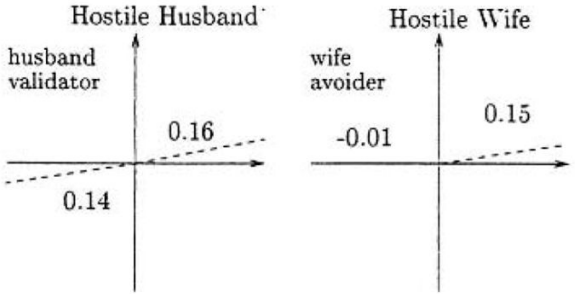
♥ Validating: Positive slope on both positive and negative side. Both easily influenced by spouse.

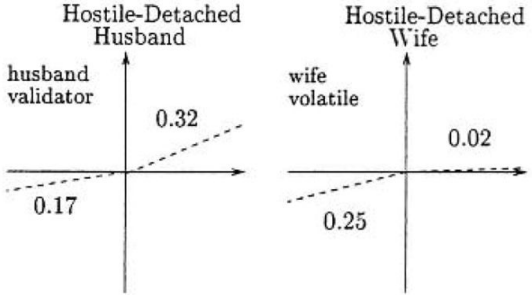
♥ Conflict Avoiding: Near zero slope on negative side and positive slope on right side.

High Risk Couples with Unmatched Emotions

Two types of high-risk marriages

- ✤ Validating husband + conflict avoiding wife
- ✤ Validating husband + volatile wife





✤ Validating husband + conflict avoiding wife: Husband is easily influenced by negative score and both are influenced by positive score.
✤ Validating husband + conflict avoiding wife: Husband and wife are easily influenced by negative score and husband is easily influenced by positive score.
✤ Hostile and Hostile-detached couples fail to create a stable adaptation to marriage that is either Volatile, Validating, or Avoiding.

Russia’s High Divorce Rate Study

♥ In this independent study, 1 country was examined to visualize the effects of a high divorce rate in 2020.

♥ The adjustments of parameters were done to make the models closely match real population data.

♥ The goal was to explain how divorce rates can be improved through the utilization of mathematics to find the stable steady states and figure which parameters are essential to help in the marital interaction.

♥ This study was done to learn more about marital interactions in a population to develop a better understanding of how these methods could be utilized in society.

Divorce Rates of Russia's Populations

♥ The equation suggested shows the crude divorce rate that can give a general overview of marriage in an area, but it does not take people who cannot marry into account.

♥ In a place with large numbers of children or single adults, the crude divorce rate can seem low and vice versa with a low amount of children showing an increased crude divorce rate.

$$\text{Crude Divorce Rate} = \frac{\text{Number of divorces}}{\text{Population}} \times 1000$$

♥ The next equation suggests a measurement of the number of divorces per 1,000 women married to men, so that leaves all unmarried people out of the calculation.

$$\text{Refined Divorce Rate} = \frac{\text{Number of divorces}}{\text{Number of married women}} \times 1000$$

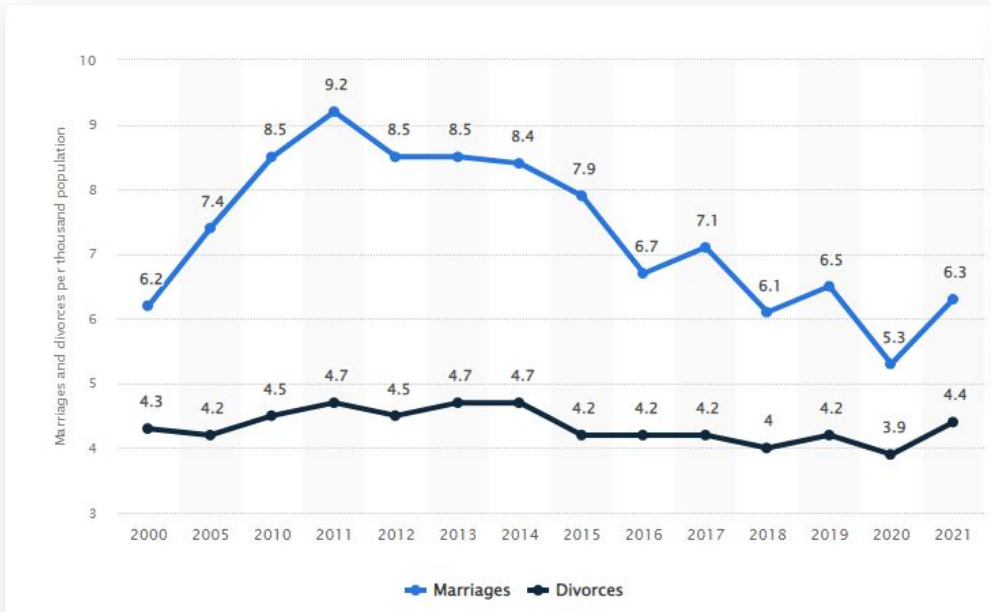
♥ The following ratio compares the number of divorces in a given year to the number of marriages in that same year.

♥ Essentially, the ratio of the crude divorce rate to the crude marriage rate, which was the main equation utilized to figure out the divorce rates in this study.

$$\text{Divorce-to-Marriage Ratio} = \frac{\text{Number of divorces}}{\text{Number of marriages}}$$

Russia’s Divorce Data

♥ Using the divorce-to-marriage ratio, Russia had a 3.9 divorce rate out of 5.3 marriage rate, making it a 73.6% divorce rate



Number of marriages and divorces per 1,000 population in Russia from 2000 to 2021

Analyzing Stable Steady States in Russia

♥ You can't predict complete compatibility in a marriage, however, you can predict the influence functions which can lead to compatibility of the couples, which can lead to stability in the marriage.

♥ The total RCISS scores for both the husband and wife are depicted by the following RCISS expression.

♥ To figure out the probability of divorce, a piecewise constant function depicted was utilized.

♥ "H" is the husband's RCISS score and "W" is the wife's RCISS score in Russia.

$$W_{t+1} = I_{HW}(H_t) + a * W_t + b; \quad H_{t+1} = I_{WH}(W_{t+1}) + c * H_t + d,$$

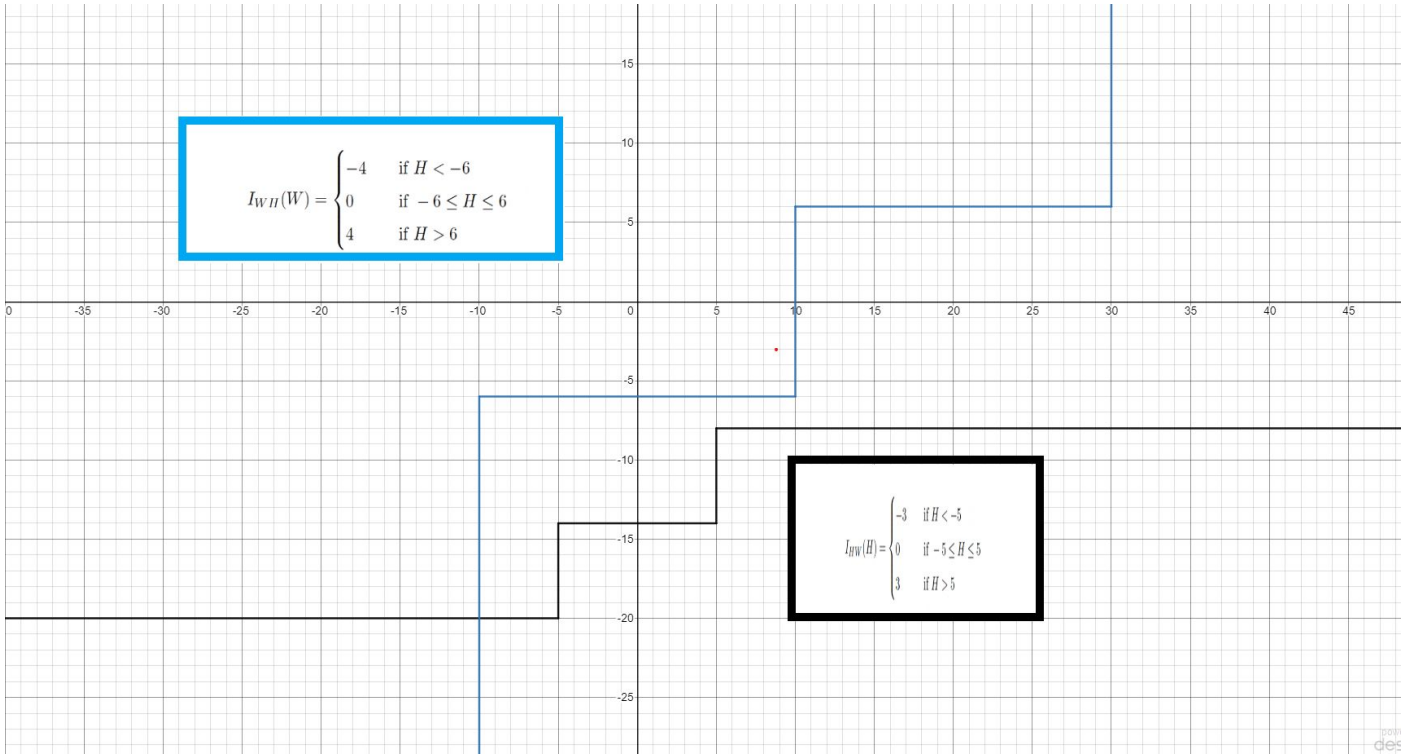
RCISS equation

$$I_{HW}(H) = \begin{cases} -3 & \text{if } H < -5 \\ 0 & \text{if } -5 \le H \le 5 \\ 3 & \text{if } H > 5 \end{cases} \qquad I_{WH}(W) = \begin{cases} -4 & \text{if } H < -6 \\ 0 & \text{if } -6 \le H \le 6 \\ 4 & \text{if } H > 6 \end{cases}$$

Piecewise Functions

Russia's Divorce Data Steady States

Figure 1. The Piecewise Function and RCISS Score Equation of Russia



Summary and Discussion

♣ We established discrete mathematical models for the score curves using RCISS, and used dynamics to study conditions a couple needs to be in to be considered a stable or unstable marriage.

♣ The models provide dynamic analysis for divorce risk in marriages by spouse's behavior tested in theory from small perturbations using a linear regression analysis.

♣ Our model was used to analyze how several personalities (including volatile, validating, and conflict-avoiding) of each one of the couple types could impact the stability of a marriage.

♣ RCISS and the mathematical models are a useful tool for understanding, explaining, and predicting the dynamics between a couple to differentiate between happily and unhappily married couples.

♣ Used for assessing and predicting whether a couple would divorce and help with prevention and intervention to help reduce divorce rates.

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Thank you for your time
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