# Computational Evolutionary Psychology:

# *in-silico Human Sexuality*

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ABSTRACT: We introduce the *Computational Evolutionary Psychology* approach to the study of human social behavior and underlying psychological mechanisms — a marriage between agent-based modeling and evolutionary psychology. We use as example the adaptive problem of human mate choice, by presenting a set of models with increasing complexity that shows how the approach can be used to gain insights into the "contents" of the human mind. We start with a model for pure monogamous systems incorporating non-negligible courtship time, where the courtship period is used by individuals to strategically swap to better partners when they become available. The model is then extended by introducing costs for being in a relationship, namely, a reduction in the possibility of interacting with individuals of the opposite sex (the potential future partners). Given this constraint, individuals must also strategically decide under which conditions to start a relationship. Finally, we present an (under development) model for serial monogamous system. These models make predictions about human sexual/romantic relationship patterns that are supported by empirical data from the social sciences.

# Talk Outline

- Computational Evolutionary Psychology
- Case study: Human mate choice
- Previous models on mate choice
- Conceptual framework for modeling human mate choice
- City Dating: A model built around courtship
- Model extension: Introducing aspiration levels
- A Serial Monogamy model
- Discussion and future work

# Computational Evolutionary Psychology = EP + AL

- Evolutionary Psychology:

  *"The Adapted Mind : Evolutionary Psychology and the Generation of Culture", Jerome H. Barkow, Leda Cosmides, John Tooby (eds.)", Oxford University Press, 1992.*

  - Contents of **Human mind =**
    $\sum$ domain-specific adaptive problem solvers $+\ \epsilon$
  - Psychological mechanisms tuned (mainly) to: Environment of Evolutionary Adaptation (EEA/ERA)
  - Methodology: Reverse engineering by evolutionary functional analysis and task-decomposition

- How can agent-based modeling help?

  - Environment: Easy to abstract "possible" EEAs
  - Agents: Assume *bounded rational* agents (with plausible psychological mechanism and partial information), but still using the *inclusive-fitness* maximization heuristic (as in animal *behaviour ecology*)
  - Population: Easy to relate individual-level decision rules with population-level patterns (e.g. to explain cultural variation and historical developments)
  - Espistemically: Provide (formal) unified theories of human social behaviour

- Main issues:

  - What to assume from data; what to derive analytically; what to evolve (and with what genetic / inheritance system)
  - What information is available to agents; which one is useful and robust; which decision rules are actually used and how often

# Case study: Human mate choice

- Individual-level psychological mechanisms and decision making
  - Variables/factors involved in mate choice decisions
  - Strategies used
  - Robustness/adaptavity of strategies

- Population-level (demographic) patterns:
  - Correlation of attributes in couples:
    (e.g. “genetic quality, age, etc.)
  - Age at mating time (marriage!?)
  - Global and inter-individual mating success
  - Relationship stability:
    Divorce rates and timing of divorce
  - Relationship stability as function of:
    number of offspring, difference in attributes
  - etc.

# Previous (Formal) Models of Mating: Mate Choice and Battle of the Sexes

- **Mate Choice:** Get the best possible mate
- S. Kalick and T. Hamilton, *"The Matching Hypothesis Re-examined", Journal of Personality and Social Psychology, 4:(51), 1986*
- P. M. Todd and G. Miller, *"From Pride and Prejudice to Persuasion: Satisficing in Mate Search", Simple Heuristics that Make Us Smart, 1999*
- Rufus Johnstone, *"The tactics of mutual mate choice and competitive search", Behavioral Ecology and Sociobiology, 1:(40), 1997*
- **Battle of the Sexes:** Exploit partners (or step-parents!?)
- R. Dawkins, *"The selfish gene", 1976:*
  *model — females: coy/fast; males: philanderous; faithful*
- P. Schuster and K. Sigmund, *"Coyness, philandering and stable strategies", Animal Behaviour, 29, 1981*
- Sido D. Mylius, *"What Pair Formation Can Do to the Battle of the Sexes: Towards More Realistic Game Dynamics", J. Theor. Biology, 197, 1999*
- Carl-Adam Wachtmeister and Magnus Enquist, *"The evolution of female coyness – trading time for information". Ethology, 105, 1999*

# Conceptual framework for modeling human mate choice (1)

- Nature of preferences:
  - Type preferences — *mate value* concept
  - Homotypic (e.g. moral values and attitudes)
  - Risk aversive homotypic (e.g. height)
  - Age: (A special case)
  - Uni/multi-dimensional
  - (non)Functional
  - (+ random noise)

- Courtship process:
  - Evaluation of qualities
  - Evaluation of commitment:
    - ∗ "Quality" time as an honest signal
    - ∗ Get information about intentions of male
    - ∗ Resources (gifts) as an honest signal
  - Wait for "better" alternatives to become available

# Conceptual framework for modeling human mate choice (2)

- Time pressure to mate
  - Limited (reproductive) lifetime
  - Uncertain and risky environment
  - Life-span variation in qualities
- Interaction possibilities:
  - Reduced when engaged in a relationship: mate guarding, "quality" time
  - Costs in switching partners: retaliation
- Estimating one's own qualities:
  - Outcome of past interactions with members of same and opposite sex
  - Health (!?)

# City Dating: A model built around courtship

- Fixed population size ($2 * P$) and sex ratio (50%)

- (Quasi) normal distribution of qualities: mean $\mu$ and variance $\sigma^2$ ($0 < Q_{min} \leq q \leq Q_{max}$).

- Dynamic and growing social network: meeting rate $Y$ (discrete time steps)

- List of alternatives: one as "special status" — the *date*

- Courtship time $K$ before mating; current time $c_t$

- Limited lifetime $L(> K)$

- Strategic decision: continue dating same individual or switch partner

# City Dating: Strategic Behaviour

- Fitness function: $f = q_d^{Q_S} * (L - t)$
- Risk insensitive strategy:

$$\mathbf{S}(q_a, q_d, c_t, t, t_a, t_d) = \begin{cases} q_d = 0 & \longrightarrow & 1 \\ t + K > L & \longrightarrow & 0 \\ t_a + K > L & \longrightarrow & 0 \\ q_a^{Q_S} * [L - (t + K)] > & & \\ q_d^{Q_S} * [L - (t + K - c_t)] & \longrightarrow & 1 \\ \text{otherwise} & \longrightarrow & 0 \end{cases}$$

- Pairing procedure (alternatives sorted by quality):

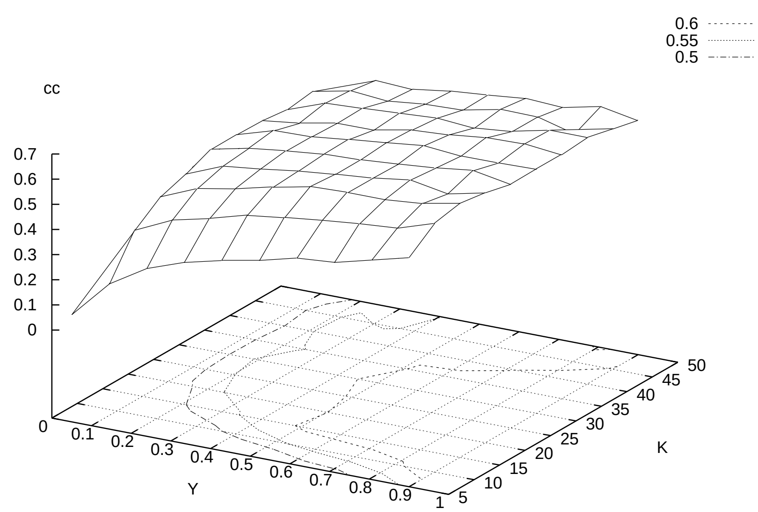
```
for (i: all agents) {
  i desires best alternative
}
boolean nomatch;
int nloops = 0;
do {
  nomatch = false;
  for (i: all agents) {
    for (j: all alternatives of i) {
      if (j is proposing i) {
        break;
      }
    }
    if (i desire isn't j) {
      nomatch = true;
    }
    i desires j
  }
  nloops++;
} while (nomatch && nloops < MAX_LOOP);
```

# Simulation results (1): Correlation of qualities in mated pairs

- Parameter settings: $2 * P = 100$, $L = 200$, $Q_S = 0.75$; $\mu = 10$, $\sigma^2 = 4$, $Q_{min} = 0.001$, $Q_{max} = 20$.

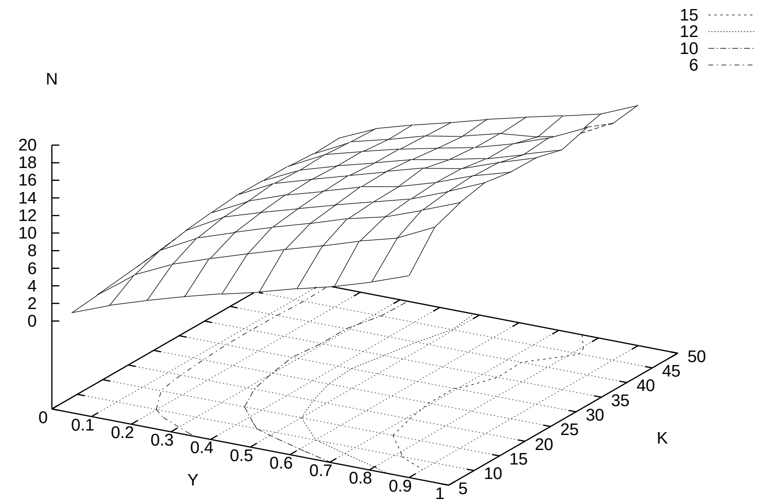
- Simulation steps: $100 * L = 20000$

- Linear correlation coefficients of qualities in mated pairs: {higher $Y * K$ (more alternatives) $\longrightarrow$higher corr.}

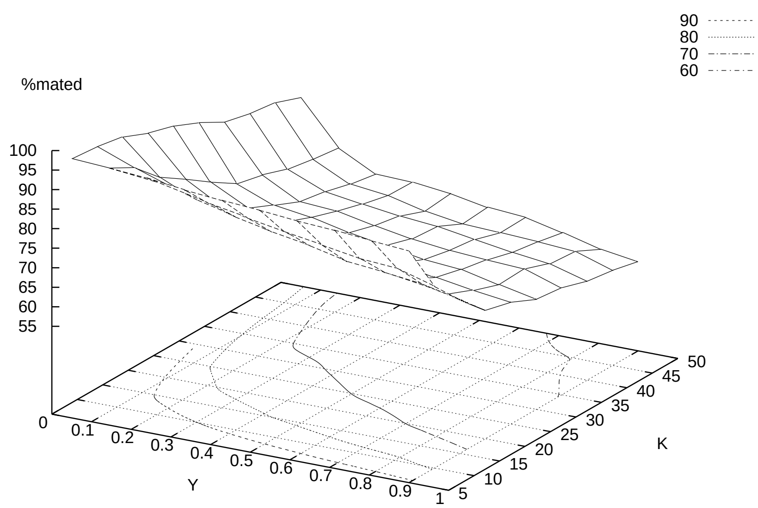


# Simulation results (2): Sampled Alternatives and Mating Success

- Mean number of alternatives seen before settling with the last date: (small)




- Percentage of mated individuals in the population: (most are able to mate)

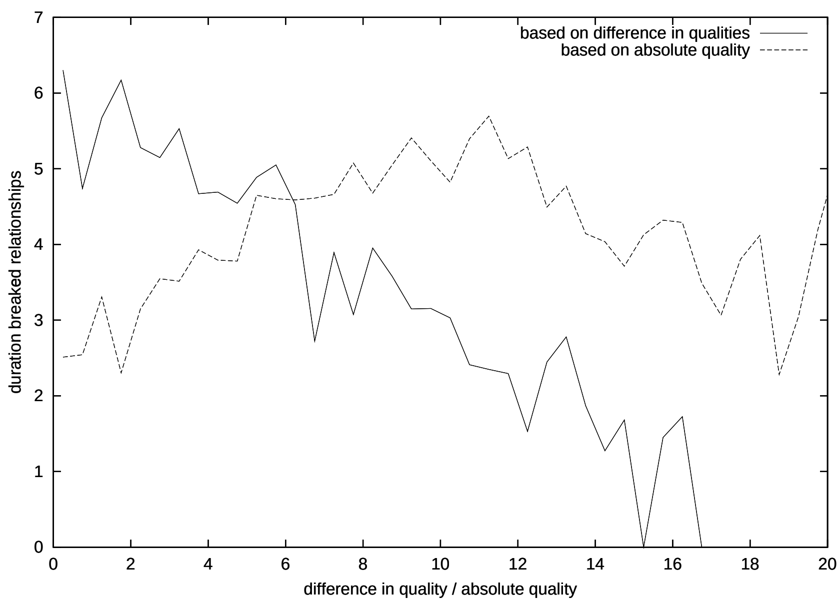


# Simulation results (3): Relationship stability

- Highly dependent on the difference of qualities in the couple (Rusbult's *Investment Model*)

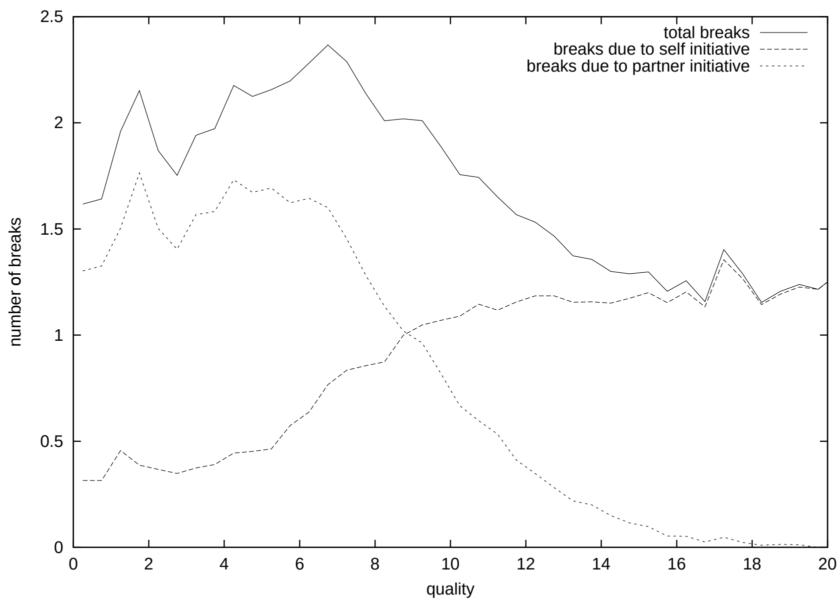
- Less dependent on (absolute) quality of individuals

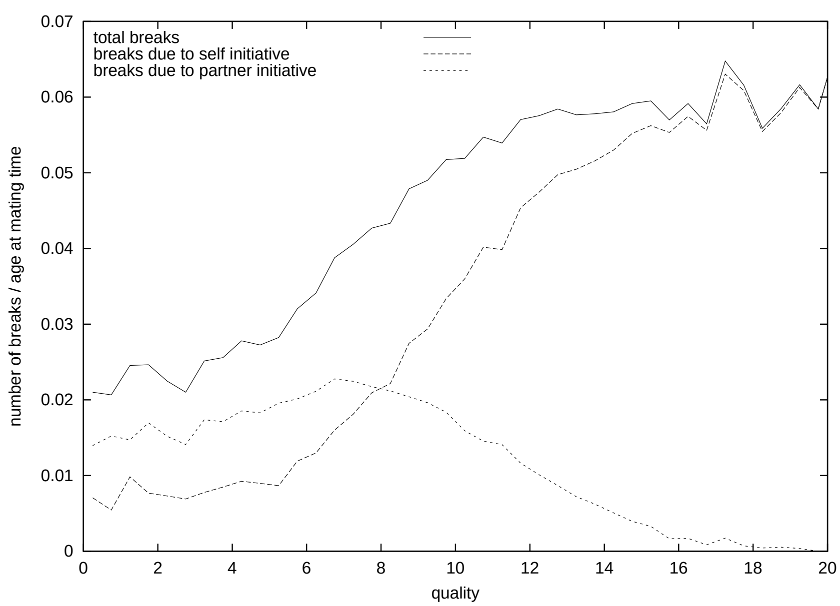
- Duration of relationships ($K = 10; Y = .2$):



# Simulation results (4): Initiative in breaking relationships

- Number of terminated relationships ($K = 10; Y = .2$):



# Model extension: Introducing aspiration levels

- Reduced meeting rate when engaged in a relationship: $Y/Y_R$
- Reduced probability of interacting: $Z$
- For *non-single* individuals: $Y_R^2$ and $Z^2$
- Aspiration level: Based on estimation of own mate value $q_s = w_s * q_p, \quad (q_0)$
- Strategy:

$$\begin{cases} q_d = 0, \ q_a \geq q_s * (1 - W(t_s)) & \longrightarrow & 1 \\ q_d = 0, \ q_a < q_s * (1 - W(t_s)) & \longrightarrow & 0 \end{cases}$$

# Simulation results (5): Comparison of strategies

- Parameter settings: $K = 20$, $Y = .1$, $Y_R = 2$, $Z = .8$, $w_s = .8$, $q_0 = Q_{max}$, and $W(t_s) = t_s/50$ (linear discounting)

- Swapping partners is especially useful for high-quality individuals: 998 $\longrightarrow$1057

| Strategy | $\overline{f}(q \geq \mu)$ | $\overline{f}(q < \mu)$ | $\overline{f}(q \geq \mu + \sigma^2)$ | $\overline{f}(q < \mu - \sigma^2)$ |
|---|---|---|---|---|
| asp.+swap | 963 | 569 | 1057 | 359 |
| asp. | 945 | 667 | 998 | 500 |
| swap | 962 | 738 | 1014 | 617 |

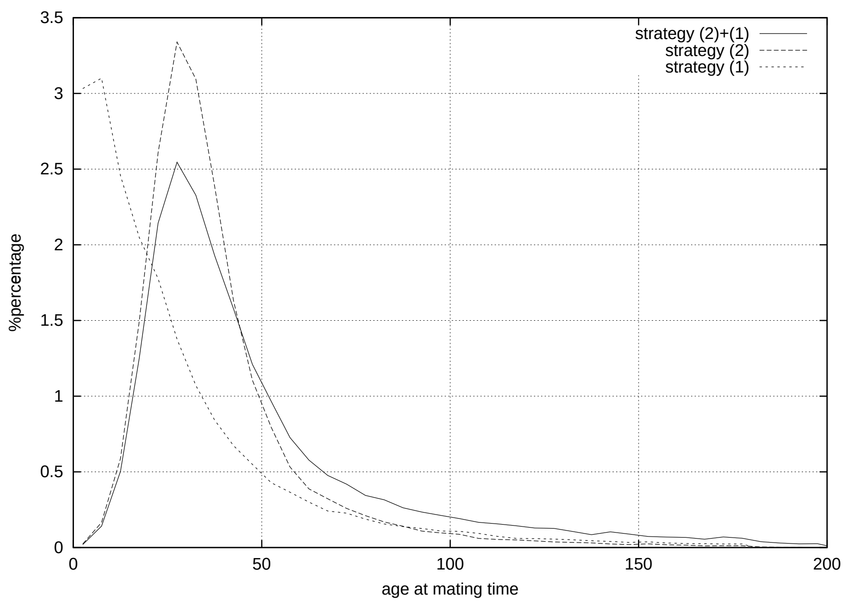
- Reasonable combination of statistics: cc of .56; dates/"friends" (1.25/10); 92% mated individuals

| Strategy | cc | %mated | $\bar{t}$ | $\overline{dates}$ | $\overline{n}$ |
|---|---|---|---|---|---|
| asp.+swap | .56 | 92% | 48 | 1.25 | 10.0 |
| asp. | .40 | 98% | 37 | 1 | 6.2 |
| swap | .23 | 98% | 27 | 1.6 | 5.4 |

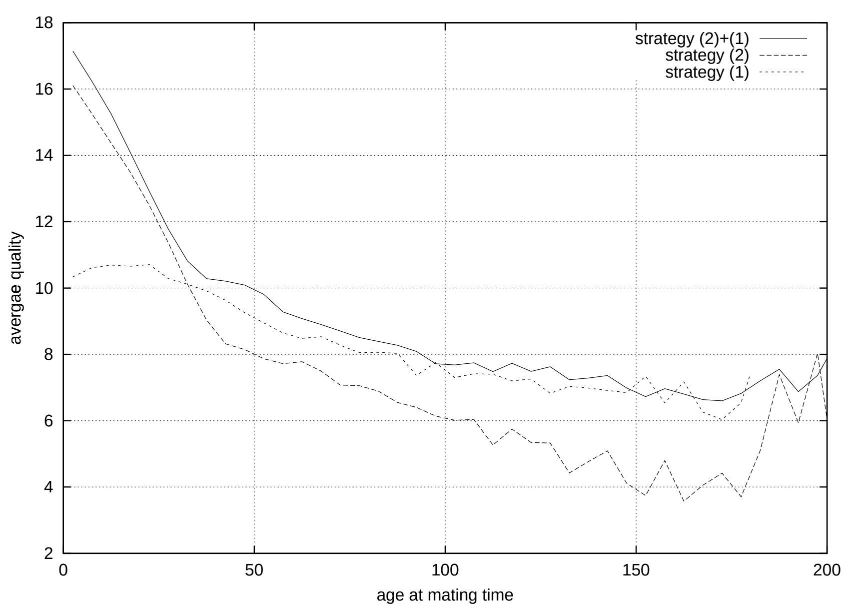
- Holding partners is a good heuristic for a rationally bounded agents — (needs to be further evaluated)

# Simulation results (6): Timing of Mating

- Distribution of age at mating time:




- Mean quality of individuals that mate at a particular age:



# A Serial Monogamy Model (1)

- Fixed population size $P$ with sex ratio $R$
- Bidimesional quality individuals $< q, t >$: genotypic / phenotypic quality and age
- $q \in N(\mu, \sigma^2) \wedge q \in ]0, Q_{max}]$
- Females Reproductive Life-time:
  $L_f \in N(L_f, L_f\sigma^2)$ + menopause ($= D_w + D_w$)
- Male Reproductive Life-time: $L_m \in N(L_f, L_m\sigma^2), L_m > L_f,$
- **Status**: single, dating, mated
- Dynamic and growing social network (max. size $N_S$); discrete time steps
- Status specific meeting rate: $p_s^m$, $p_d^m$, and $p_m^m$
- Status specific interaction ability (max. per time step $N_I$): $p_s^i$, $p_d^i$, and $p_m^i$
- List of alternatives: one as "special status" of *date* or *mate*
- Courtship time $K$ before mating; current time $c_t$

# A Serial Monogamy Model (2)

- After Mating: Offspring continuously produced (with inter-birth time $D_w$)
- Children stay always with mother
- Children development:
  - Weaning phase $D_w$: survival prob. $p^w = (q^c)^{S_w}$
  - Childhood phase $D_c(> D_w)$: with survival prob. $p^c = (q^c)^{S_w}$
- Genetic Quality: $q^g \in [0,1] = \frac{H(q_f + q_m)}{2Q_{max}}$
- Resource Quality:

$$q_r[t] \in [0,1[= \begin{cases} \frac{(2-R_m)q_f + R_m q_m}{2Q_{max}} & \longleftarrow \text{biparental care} \\ \frac{(2-R_m)q_f + R_{m'} q_{m'}}{2Q_{max}} & \longleftarrow \text{stepfather assisted} \\ \frac{(2-R_m)q_f}{2Q_{max}} & \longleftarrow \text{single mother} \end{cases}$$

- Children Quality: $q^c[t] = q_g^{G_s} \times (q_r^{\#ch^{R_s}})^{1-G_s}, R_s \in [0,1[$

# A Serial Monogamy Model: Strategic Behaviour

- Strategic decisions: start relationship; switch partner
- Fitness function:

$$\mathbf{F}^*(f,m,t) = p^c \times \frac{min(L_f - t_f - W, L_m - t_m)}{\frac{D_w}{2} \times (\frac{1}{p^w} - 1) + D_w}$$

$$\begin{cases} W = 0 & \longleftarrow \text{ no child weaning} \\ W = p^w * (D_w - t_w) + (1 - p^w) * \frac{D_w - t_w}{2} & \longleftarrow \text{ child weaning} \end{cases}$$

- **Single (males, and females with no dependent childs):**

$$\mathbf{S^s}(i,j) = \begin{cases} F(i^*, j, t_c + K) \geq F(i^*, i^*, t_c + K) & \longrightarrow 1 \\ \text{otherwise} & \longrightarrow 0 \end{cases}$$

- **Dating:**

$$\mathbf{S^d}(i,j,j_a) = \begin{cases} F(i^*, j_a, t_c + K) > F(i^*, j, t_c + K - c_t) & \longrightarrow 1 \\ \text{otherwise} & \longrightarrow 0 \end{cases}$$

- **Mated (female):**

$$\mathbf{S^m_f}(i,j,j_a) = \begin{cases} F(i, j_a, t + K) + C_{ij}^{f+m'} > F(i,j,t) + C_{ij}^{f+m} & \longrightarrow 1 \\ \text{otherwise} & \longrightarrow 0 \end{cases}$$

- **Mated (male):**

$$\mathbf{S^m_m}(i,j,j_a) = \begin{cases} F(i^*, j_a, t + K) + (1 - PH) * C_{ij}^{f} + & \\ PH * C_{ij}^{f+m'} > F(i^*, j, t) + C_{ij}^{f+m} & \longrightarrow 1 \\ \text{otherwise} & \longrightarrow 0 \end{cases}$$

- **Single (females with children):**

$$\mathbf{S^s}(i,j) = \begin{cases} F(i^*, j, t_c + K) + C_i^{f+m'} \geq F(i^*, i^*, t_c + K) + C_i^{f} & \longrightarrow 1 \\ \text{otherwise} & \longrightarrow 0 \end{cases}$$

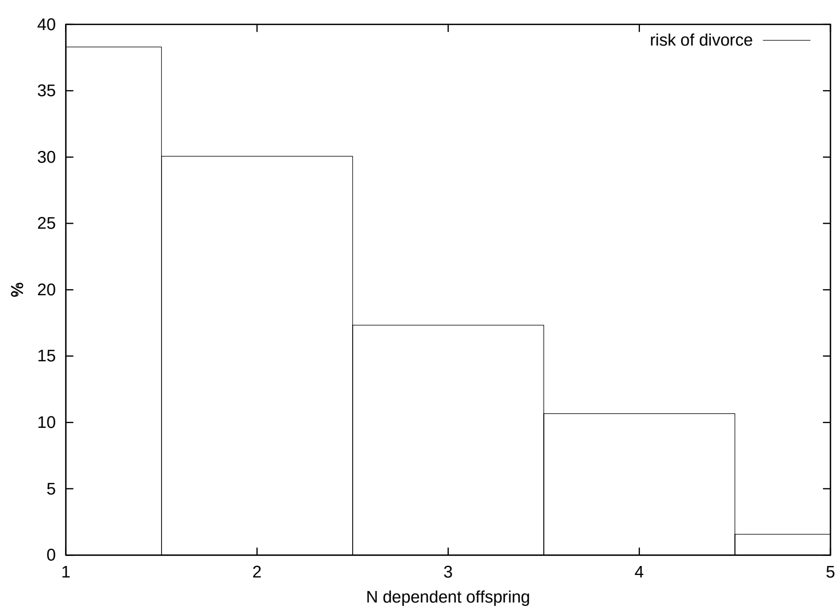
$$C(\{x\}) = \sum_x^{\#ch(\neg wean.)} (1 - (1 - p_x^c) * \frac{D_c - (t_x - D_w)}{D_c}) + (1 - (1 - p_w^w) * \frac{D_c - t_w}{D_c}) \times p_w^c$$

# Some Model Results (1): Parameterizations for $EEA^*$

- (Labeled) parameter settings: (1 time step = 1/10 year)
- small ($P = 100$), balanced ($R = 1$)
- $\mu = 10, \sigma^2 = 4$, $Q_{max} = 20$
- $L_f = 200, L_m = 350, L_f\sigma^2 = L_m\sigma^2 = 40$)
- $N_S = 20, N_I = 5$
- dynamic ($p_s^m = .1$), halfopen ($p_d^m = p_s^m * .8, p_m^m = p_s^m * .5, p_d^i = p_s^i * .8, p_m^i = p_s^i * .5$),
- coy ($K = 10, K\sigma^2 = 2$), $PH = .5$
- $D_w = 30$ (3 years), $D_c = 100$ (dependent until age 13)
- mild ($S_w = .5, S_c = .25$)
- dad ($R_m = 1$), bad stepfather ($R_{m'} = R_m * .5$)
- $R_s = .5, G_s = .5, Q_0 = 18, W_s = .8$
- Simulation steps: $20 * L_m$

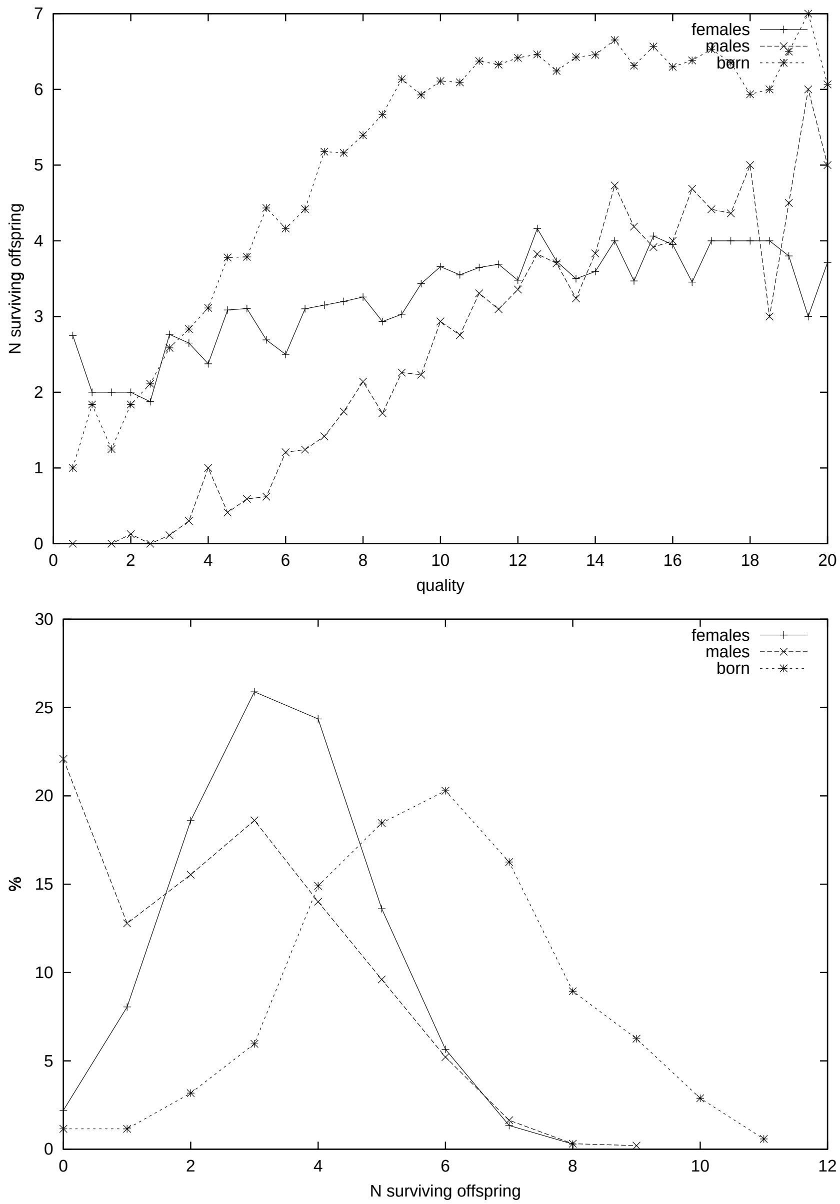
# Some Model Results (2): Divorce Statistics

- Individuals mated at least once: 95%
- Divorce ratio on first mating: 14%
- Divorced ratio on second mating: 8%
- Divorce ratio for all matings: 6%
- Number of dependent children correlates with relationship stability



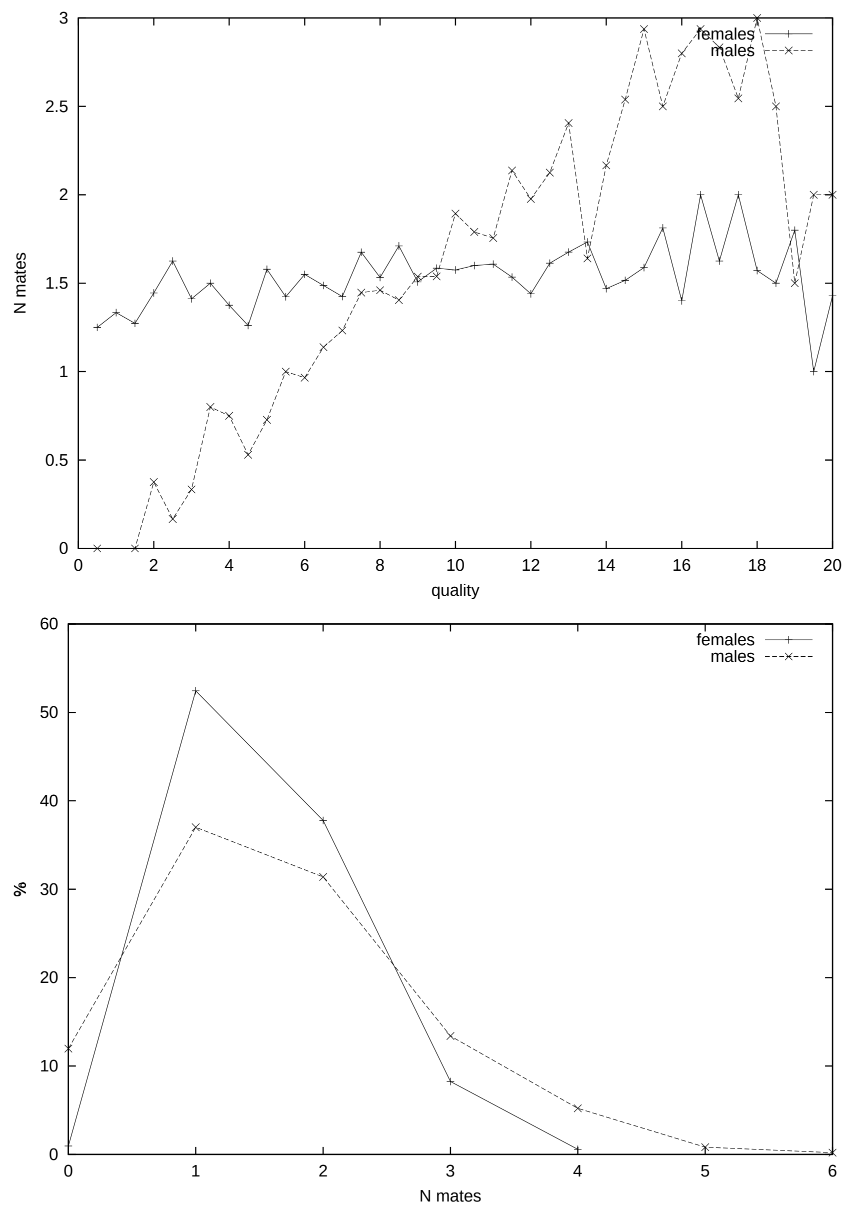
# Some Model Results (3): Differential Reproductive Success

- Male reproductive success distribution more skewed



# Some Model Results (4): Number of Mates

- Female as limiting sex
- Males quality highly correlated with number of partners



# Discussion and Future Work

- CEP promises to be a useful approach to study the deeply and long hidden "contents" of the human mind

- Mate choice: More realistic results than previous models

- Mate choice: Model assumptions more psychologically plausible and more relevant to humans

- Future work:

  – More complex preferences: structure and dynamics

  – Strategically selected courtship times and rates of investment: Relate and integrate with *Battle of the Sexes* models

  – Other mating systems: multiple simultaneous mates (e.g. polygyny)

  – Interaction of long-term and short-term mating