A New Heuristic in Mutual Sequential Mate Search

Saglam, Ismail

Ankara, Turkey

28 May 2017

A New Heuristic in Mutual Sequential Mate Search

Ismail Saglam

Abstract. In this paper, we propose a new heuristic to be used as a mate search strategy in the Todd and Miller's (1999) human mate choice model. This heuristic, which we call *Take the Weighted Average with the Next Desiring Date*, is a plausible search rule in terms of informational assumptions, while in terms of mating likelihood it is almost as good as the most successful, yet also unrealistic, heuristic of Todd and Miller (1999), namely the Mate Value-5 rule, which assumes that agents in the mating population completely know their own mate values before interacting with any date. The success of our heuristic stems from its extreme power to lead an average agent in the mating population to always underestimate his/her own mate value during the adolescence (learning) phase of the mating process. However, this humble heuristic does not perform well in terms of marital stability. We find that the mean within-pair difference is always higher under our heuristic (possibly due to high estimation errors made in the learning phase) than under any heuristic of Todd and Miller (1999). It seems that becoming ready to pair up with agents whose mate values are well below one's own mate value pays off well in the mating phase but also incurs an increased risk of marital dissolution.

Key words: Mate Choice, Mate Search, Simple Heuristics, Agent-Based Simulation

1 Introduction

A seminal work by Todd and Miller (1999) studies the human mate choice with the help of a boundedly rational model where agents follow a simple heuristic (feedback rule) as their mate search strategies. This model involves two phases, the first of which is called the adolescence phase. Agents who have homogeneous preferences over the agents of the opposite sex randomly interact with a number of dates sequentially in this phase and inform each of their dates regarding whether he/she was found desirable. Using these feedbacks, agents adjust their aspiration levels after every interaction according to some rule used by the whole population. In the second phase, called the mating phase, agents randomly interact with potential mates and decide whom to make a proposal. At each stage of this phase, every pair of agents are removed from the mating pool as a married couple if they have simultaneously proposed to each other. The mating phase ends after a stage at which either the mating pool contains no agents or no pair of agents inside the mating pool can form a married couple.

The adjustment rules used in the adolescence phase are five simple heuristics, called Take the Next Best, Mate Value-5, Adjust Up/Down, Adjust Relative, and Adjust Relative/2. According to Take the Next Best, each agent has an initial aspiration level of zero and after each instance of dating sets his/her aspiration to the mate value of his/her date provided that this date is desirable, i.e., the mate value of this date exceeds his/her previous aspiration level. Under Mate Value-5, each agent always sets his/her aspiration level to a constant value that is lower than his/her own mate value by the value of 5. The other three adjustment rules set the initial aspiration level of each agent to the average mate value. Of these rules, Adjust Up/Down requires that each agent adjusts at each instance of dating his/her aspiration upwards (downwards) by a constant parameter if he/she is found by his/her date desirable (non-desirable). The Adjust Relative Rule is a modification of Adjust Up/Down with mutual desirability taking place of desirability. Under this rule, an agent raises (reduces) his/her aspiration level by a constant parameter, if he/she and his/her date find each other desirable (non-desirable). In other possible cases, agents make no adjustments. Finally, the rule of Adjust Relative/2 is similar to Adjust Relative with the difference that for each agent the adjustment parameter at any instance of dating is equal to the difference between his/her previous aspiration level and the mate value of his/her present date.

Computer simulations of Todd and Miller (1999) for the mate search model described above show that the mating likelihood, as measured by the number of mated pairs in the population, becomes always highest under the rule of Mate Value-5, extremely differing from the other rules. In addition, with respect to a notion of mating stability that is measured by the mean within-pair difference in mate value, mated pairs formed always become more stable under Mate Value-5 than under Adjust Up/Down, Adjust Relative, and Adjust Relative/2. In fact, Mate Value-5 also performs better than Take the Next Best when the adolescence length is short to medium. Overall, Mate Value-5 becomes the best search rule both in paring up a great proportion of the population and in pairing up agents with almost identical mate values. But, unfortunately, this rule has a very serious problem. It is based on the unrealistic assumption that each agent enters the adolescence phase of mate search by already knowing his/her own mate value, while one should be aware of the fact that:

> "Knowing one's own mate value is not necessarily an easy thing. We cannot be born with it, because it is both context sensitive (it depends on the others around us) and changes over time as we develop. We cannot simply observe ourselves to determine it, because we do not see ourselves in the same way that the others who judge us as potential mates see us. We do not even know the proper criteria on which to judge ourselves from the perspective of the opposite sex. Without this initial knowledge, then, we must somehow estimate our own mate value, if we are to use it to form our aspiration level." (Todd and Miller, 1999, pp. 303-304)

In line with the above view, all search rules of Todd and Miller (1999), apart from the self-centered and unrealistic rule of Mate Value-5, have the goal of correctly estimating one's own mate value to use it as a proxy for one's own aspiration level. Of these rules, Adjust Relative/2 becomes superior to the other realistic rules of Todd and Miller (1999) with respect to a success measure that appropriately balances the likelihood and stability of matings. However, if the individual performances of Adjust Relative/2 and Mate Value-5 are compared, one can see, irrespective of the adolescence length, around two-fold difference between the mating likelihoods generated by these two search rules always in favor of Mate Value-5. Clearly, Adjust Relative/2, which is plausible as a rule, is not a successful alternative to the unrealistic rule of Mate Value-5. This brings us to the following question: Can we find a heuristic that is plausible and that is almost as successful as Mate Value-5 in terms of likelihood of mating? The answer we provide in this paper is 'yes'. We introduce a realistic heuristic, which we call Take the Weighted Average with the Next Desiring Date, yielding almost as high likelihood of mating as Mate Value-5, especially when the adolescence length is long.

Our work, which closely follows Todd and Miller (1999), can be located within a strand of literature which models human mate search with the help of some dating phase where agents can approximate their own mate values by using feedbacks from potential mates they date (see, for example, Dombrovsky and Perrin, 1994; Mazalov et al., 1996; Todd, 1997; and Collins et al., 2006). Two related works recently appeared in this literature are Shiba (2013) and Saglam (2014). Shiba (2013) extends the symmetric two-sided sequential mate search model of Todd and Miller (1999) to an asymmetric case (of firm or job with worker mating), and evaluates how the mating outcome changes when the two sides of the mating population use different adjustment rules (with one of the sides, the firms, using Mate Value-5 and the other side, the workers, using Adjust Relative/2). Findings of this study involve that the likelihood and stability of mating are similar under the symmetric and asymmetric cases, while the average value of successful agents (workers) are higher under the asymmetric case, pointing to the failure of agents with relatively low values in finding mates (jobs). Saglam (2014) studies a similar robustness problem regarding whether any search rule of Todd and Miller (1999) can be used as a Nash (1950) equilibrium strategy by the whole population so that no agent would have an incentive to unilaterally deviate from that search rule to any other rule so as to increase the likelihood of his/her mating. Simulations of Saglam (2014) show that in terms of this game-theoretical stability concept, Adjust Relative on average performs better than the other four search rules of Todd and Miller (1999).

The rest of our paper is organized as follows: In Section 2 we present the model which we borrow from Todd and Miller (1999). We present five simple heuristics (search rules) introduced by Todd and Miller (1999) for this model in Section 3, where we also explore why some of these heuristics are more successful than the others. In Section 4 we introduce our new heuristic and in Section 5 we evaluate its performance by computer simulations. Finally, we conclude in Section 6.

2 Model

We borrow our model from the mutual sequential mate search model of Todd and Miller (1999). This model considers a set of agents, $N = \{1, 2, \ldots, 2n\}$, involving n males and n females each of whom search for some mate from opposite sex. Each agent has a mate value which is always unknown to himself/herself while completely observable to any agent interacted in any phase of mate search. The mate value of agent i, denoted by $v(i)$, is randomly drawn from the uniformly distributed values over some interval $[0, V]$ that is common for all agents.

Mate search involves two phases: the adolescence phase and the mating phase. Agent i enters the adolescence phase with an initial aspiration level, denoted by $a(i, 0)$, and then randomly and sequentially meets a fixed number of dates of opposite sex. This fixed number is common for all agents and denoted by the integer $S \geq 1$, implying that the adolescence phase consists of S stages of dating. At each stage $s = 1, \ldots, S$, agent i observes the mate value of his/her date $d(i, s)$ and after comparing this value with his/her aspiration level of the previous stage $a(i, s-1)$, agent i decides whether his/her date in stage s is desirable (as a potential mate). Next, agent i and his/her date $d(i,s)$ in stage s exchange information as to whether they find each other desirable. Finally, taking this information into account, agent i determines his/her aspiration level, $a(i,s)$, for stage s using some adjustment (feedback) rule commonly used by the whole population. (We will describe the adjustment rules introduced by Todd and Miller (1999) for the studied model in the next section.) After the adolescence phase is over, agents enter the mating phase, where males and females are randomly paired. Here, agent i observes the mate value of his/her partner and compares it with his/her finalized aspiration level $a(i,S)$ to decide whether to make a proposal. If the agents in a random pair propose to each other, then they are mated and removed from the mating pool. Otherwise, both agents become available for the next stage. The mating phase ends when the mating pool becomes empty or each of its member has already been paired with all potential mates inside the mating pool.

3 Aspiration-Adjustment Heuristics of Todd and Miller (1991)

Below, we describe five aspiration-adjustment heuristics (or simply mate search strategies) introduced by Todd and Miller (1991).

Take the Next Best Rule: Agent i sets the aspiration in stage s to the mate value of his/her current date if agent i finds this date desirable, and makes no adjustment otherwise.

$$a(i,s) = \begin{cases} v(d(i,s)) & \text{if } v(d(i,s)) \geq a(i,s-1), \\ a(i,s-1) & \text{otherwise.} \end{cases}$$

Mate Value-5 Rule: This rule sets the aspiration at the beginning of the adolescence phase to the constant $v(i) - 5$, and does not change it. Thus, in any stage s,

$$a(i,s) = v(i) - 5.$$

This rule assumes that each agent knows his/her mate value.

Adjust Up/Down Rule: In stage t, agent i adjusts up the stage $s-1$ aspiration by the constant $\bar{\beta} = (V/2)/(1+S)$ if he/she is found desirable by the date $d(i,s)$. Otherwise, agent i adjusts down his/her aspiration of the previous stage by $\bar{\beta}$.

$$a(i,s) = \begin{cases} a(i,s-1) + \bar{\beta} & \text{if } v(i) \geq a(d(i,s), s-1), \\ a(i,s-1) - \bar{\beta} & \text{otherwise,} \end{cases}$$

Adjust Relative Rule: Here, there is the possibility of non-adjustment, as well. Agent i adjusts up the stage $s-1$ aspiration by the constant $\bar{\beta} = (V/2)/(1+S)$ if agent i and the date $d(i,s)$ find each other desirable. If neither of these two agents finds his/her date desirable, then agent i adjusts down the stage $s-1$ aspiration by $\bar{\beta}$. In other cases, agent i makes no adjustment.

$$a(i,s) = \begin{cases} a(i,s-1) + \bar{\beta} & \text{if } v(i) \geq a(d(i,s), s-1) \text{ and } v(d(i,s)) \geq a(i,s-1), \\ a(i,s-1) - \bar{\beta} & \text{if } v(i) < a(d(i,s), s-1) \text{ and } v(d(i,s)) < a(i,s-1), \\ a(i,s-1) & \text{otherwise.} \end{cases}$$

Adjust Relative/2 Rule: This is a modification of the Adjust Relative Rule in that the size of adjustment in stage s is equal to the half of the difference between the stage $s-1$ aspiration level of individual i and the mate value of his/her date in stage s; i.e., $\beta(i,s) = |v(d(i,s)) - a(i,s-1)|/2$.

$$a(i,s) = \begin{cases} a(i,s-1) + \beta(i,s) & \text{if } v(i) \geq a(d(i,s), s-1) \text{ and } v(d(i,s)) \geq a(i,s-1), \\ a(i,s-1) - \beta(i,s) & \text{if } v(i) < a(d(i,s), s-1) \text{ and } v(d(i,s)) < a(i,s-1), \\ a(i,s-1) & \text{otherwise.} \end{cases}$$

The initial aspiration level of agent i is assumed to be $a(i,0) = 0$ under Take the Next Best, $a(i,0) = v(i) - 5$ under Mate Value-5, and $a(i,0) = V/2$ under the other three rules.

To evaluate the performances of the mate search strategies described above, Todd and Miller (1999) conducted a set of Monte Carlo simulations. One of the success measures they used was the likelihood of mating, as represented by the number of mated pairs formed in 100 potential pairs. Their simulations according to this measure, which we have reproduced and illustrated in Figure 1, show that Mate Value-5 dominates the other four rules, yielding an incomparably high likelihood of mating for all values of adolescence length.

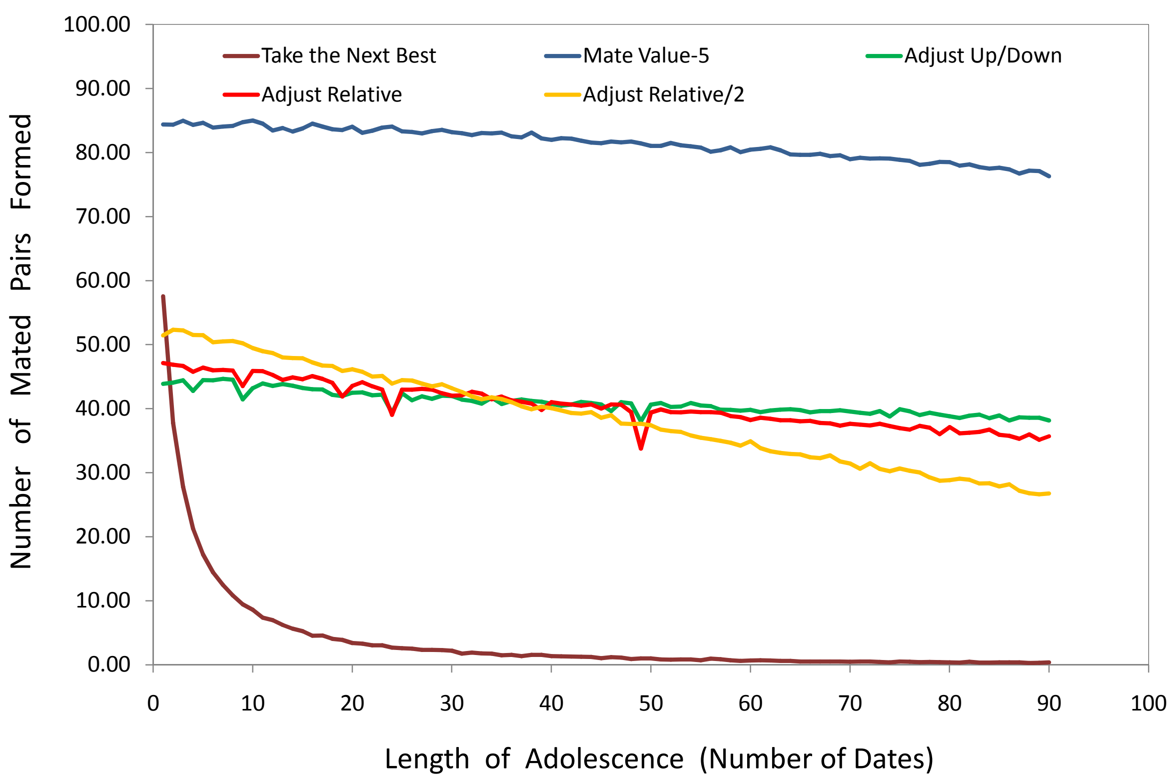

Figure 1.

Under the other four search rules, the likelihood of mating is found to be around 50% for very low levels of adolescence length, while it quickly drops to almost zero under the rule of Take the Next Best as the adolescence length starts to increase. In result, Take the Next Best is dominated by every other rule on average. Of the remaining rules, Adjust Relative/2 performs mildly better than both Adjust Relative and Adjust Up/Down for short to medium adolescence lengths, whereas the converse becomes true when the adolescence length is large.

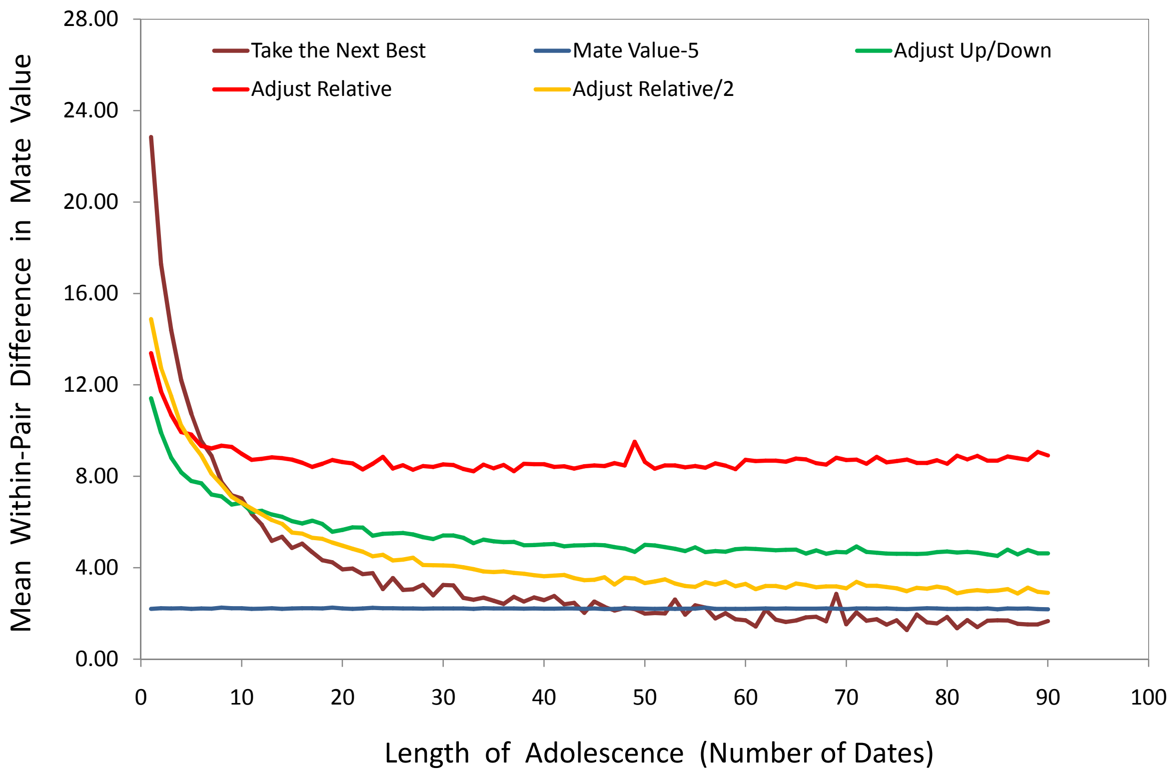

Figure 2.

A second measure of success, introduced by Todd and Miller (1991), for assessing mate search strategies is concerned with the stability of mating, as defined by the mean within-pair difference in mate value. Rules that have lower scores with respect to this measure are considered to perform better as they would lead to more stable matings. The performances of the Todd and Miller's (1991) mate search strategies with respect to this second measure, according to our simulations, are illustrated in

Figure 2 above. Once again, Mate Value-5 is found to be the best rule for short to medium adolescence lengths, yielding an extremely low mean within-pair difference in mate value. As a matter of fact, this rule yields more stable matings than the other rules with the exception of Take the Next Best. Although Take the Next Best is the worst rule with respect to the stability measure for very low adolescence lengths, it becomes as good as Mate Value-5 and always dominates the other three rules when the adolescence length is not very small. Over the same range of adolescence lengths, it is also found that Adjust Relative/2 is always superior to Adjust Up/Down, which on the other hand is always superior to Adjust Relative.

Taking Figure 1 and Figure 2 together, it is apparent that Mate Value-5 is the best search rule both in paring up a great proportion of the population and in pairing up agents with almost identical mate values. But, unfortunately, this rule is based on the unrealistic assumption that each agent enters the adolescence phase of mate search by already knowing his/her own mate value. As a matter of fact, this unrealistic rule is a member of a class of humble search rules called Mate Value-α where agents constantly underestimate their own mate values by the value $\alpha \geq 0$. A limiting member of this class, Mate Value-0, is the search rule under which no estimation errors are ever made. In the mutual sequential search model of Todd and Miller (1991) (where the mate values of all males and females are drawn from the same distribution and no agent, male or female, would desire to be paired up with another agent who has a lower mate value than his/her aspiration level), a search rule, like Mate Value-0, under which all agents always know/learn their own mate values must yield a likelihood of mating as high as 100 percent and a mean within-pair difference in mate value as low as zero. Given the moderate findings in Figures 1 and 2, we can infer that under no realistic search rule of Todd and Miller (1991) agents can estimate their mate values with a high precision. We can further claim that under some of Todd and Miller's (1999) search rules, especially under Take the Next Best, the estimation errors of agents must be extremely high if we are to posit a positive link between the likelihood of mating and the precision of information agents in the mating population obtain about their own mate values during the adolescence phase. Below, we will explore the existence of such a link.

Formally, we define the precision of information obtained by agents in the mating population during the adolescence phase as the inverse of the root mean square error (RMSE) they make in estimating their own mate values at the end of S stages of dating, i.e., $RMSE = [\sum_{i=1}^{2n}[v(i) - a(i,S)]^2]^{1/2}$. In Figure 3, we plot RMSE generated by each search rule of Todd and Miller (1991). Interestingly, there is a striking similarity between Figure 2 and Figure 3. If the rule of Take the Next Best is excluded, it is even possible to make -using these two figures- the generalization that a search rule is more stable than another search rule if it yields a lower RMSE. The exception with Take the Next Best is due to the fact that under this rule the aspiration of each agent quickly converges to the highest mate value in the population. Hence, under this rule most agents extremely overestimate themselves in the adolescence phase. This implies that in the mating phase only a tiny fraction of the population becomes able to find mates, while this fraction involves only some elite members of the mating population who make almost no estimation errors. This is because they have extremely high mate values and interacting a desirable date is therefore very unlikely for them. Consequently, the mean within pair-difference in mate value becomes very low under the Take the Next Best rule.

Another observation from Figure 3 is that RMSE becomes very low under Mate Value-5, attaining a constant value of 5 by the definition of the rule. One can argue that this finding is consistent with a claim stating that the lower the RMSE of agents in estimating their own mate values, the more successful a search rule in terms of the mating likelihood. But, one should not rush to conclude, as this claim can be easily rejected once one also considers the rule of Adjust Relative/2. Even though the RMSE values calculated for Adjust Relative/2 and Mate Value/5 are almost the same for medium to long adolescence lengths, there is a huge and puzzling difference between the mating likelihoods of these two rules over the same range of adolescence lengths, as one can recall from Figure 1.

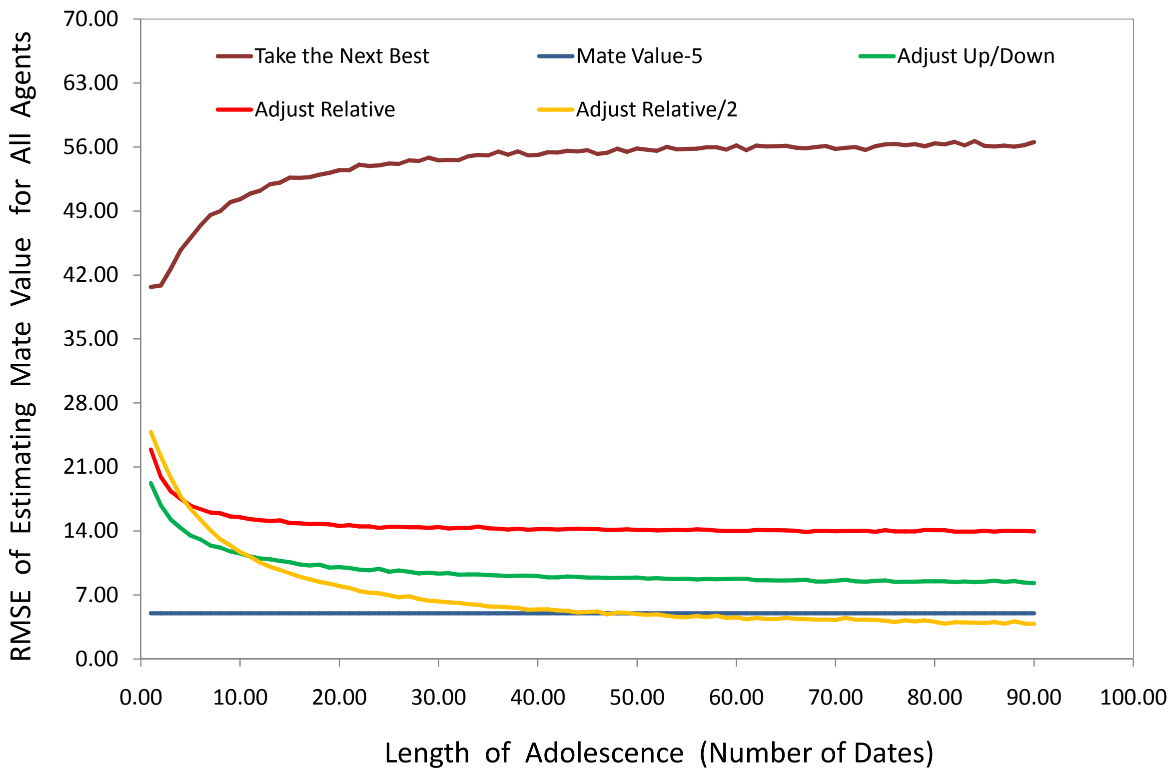

Figure 3.

To shed light on this puzzle, we report in Figure 4 our calculations for the mean aspiration level of all agents at the end of the adolescence phase. Apparently, the mean aspiration levels under the search rules of Adjust Up/Down, Adjust Relative, and Adjust Relative/2 are always around the value of 50, which is also the mean level of mate values of all agents. This should not be surprising though, since under each of these three rules, where the initial aspiration level is 50, not only the upward and downward adjustments are always of the same magnitude but also the conditions as to when to make these adjustments are symmetric.

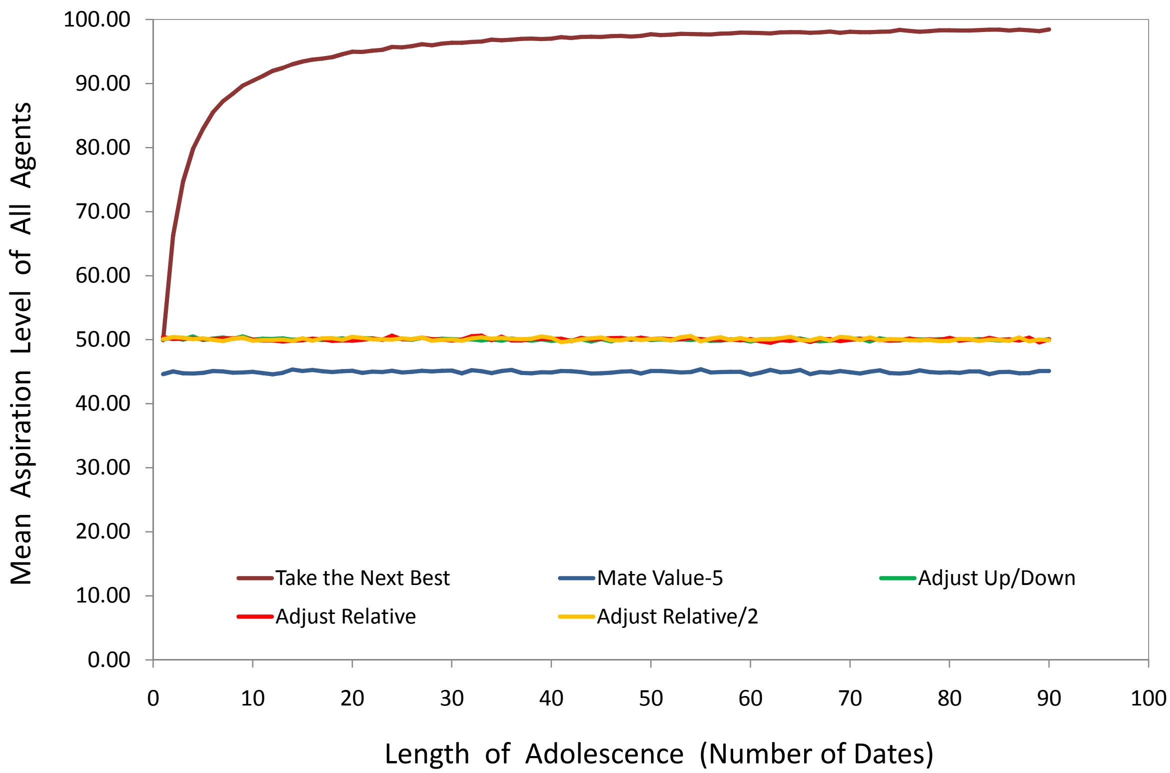

Figure 4.

Comparing the performances of Mate Value-5 and Adjust Relative/2 in Figures 3 and 4 reveals that the precision of information acquired in the adolescence phase of mating process, or the magnitude of estimation errors made by agents, is not a sufficient indicator of the success of a mate search rule. Evidently, the direction in which agents make estimation errors also matters. As a matter of fact, agents always underestimate their own mate values under the search rule of Mate Value-5, while the likelihoods of underestimating and overestimating can be inferred, from Figure 4, to be the same under Adjust Relative/2. So, it seems that the success of Mate Value-5 stems from the humbleness of agents in setting their aspirations under this rule always sufficiently below their own mate values.

Overall, we can say that of the five search rules proposed by Todd and Miller (1991) the most successful one, Mate Value-5, is not realistic while the other rules do not lead to a level of learning -in the adolescence phase- that can ensure a high likelihood of mating. This brings us to the following question: Can we find a simple search rule which is not self-centered (and unrealistic) like Mate Value-5 and under which mating is almost as likely as under Mate Value-5? We will explore this question in the rest of our paper.

4 A New Aspiration-Adjustment Heuristic

Given our observations in the previous section as to the reasons underlying the relative success of Mate Value-5, we will consider a search rule that can be predicted to yield humble aspirations. The initial aspiration level of each agent under this rule is set to zero, and if an agent finds out that her date is desiring him/her in any stage s of the adolescence phase, then he/she will set the stage-s aspiration level to the weighted average of his/her aspiration in stage $s-1$ and the mate value of his/her date in stage s. Here, the relative weight of the stage $s-1$ aspiration becomes equal to the number of incidents that the condition for updating was satisfied until the end of stage $s-1$. Because of this, our weighted average rule actually sets the aspiration level of any agent at any particular stage of dating precisely to the arithmetic average of the mate values of his/her all past dates satisfying the condition for updating. More formally, this search rule is described as follows:

Take the Weighted Average with the Next Desiring Date (TWAN_Desiring) Rule: If agent i finds that his/her date in stage s is desiring him/her, then agent i sets the stage-s aspiration to the weighted average of his/her stage $s-1$ aspiration and the mate value of his/her current date, using the respective weights of $m/(m+1)$ and $1/(m+1)$ with m denoting the number of the previous stages (before stage s) in which agent i was found desirable by his/her date. Otherwise, agent i makes no adjustment.

$$a(i,s) = \begin{cases} \dfrac{m}{m+1}\,a(i,s-1) + \dfrac{1}{m+1}\,v(d(i,s)) & \text{if } v(i) \geq a(d(i,s),s-1), \\ a(i,s-1) & \text{otherwise.} \end{cases}$$

The above rule has two modifications over the Take the Next Best rule of Todd and Miller (1999). One modification replaces the action of 'taking the next satisfactory date' with 'taking the weighted average with the next satisfactory date', while the other modification changes the condition as to when a date is found to be satisfactory. Whereas under Take the Next Best an agent finds a date satisfactory if he/she desires this date, under TWAN_Desiring an agent finds a date satisfactory if this date is desiring him/her.

Also note that under the rule of TWAN_Desiring any agent with a positive mate value will certainly be found desirable by his/her first date since the aspirations of all agents are initially zero. Then, after the first stage of dating the aspiration level of each agent will be positive with probability one. In fact, just because of this, starting with the second dating stage, each agent will face the likelihood of being found non-desirable by some of his/her dates. Since this likelihood is higher for agents with lower mate values, these agents will have lower levels of aspirations on average, due to the definition of the search rule. On the other hand, the lower is the mate value of the date of an agent, the higher will be the likelihood that this agent will be found desirable. As a consequence, interacting with a date will reduce the aspiration of each agent on average. One can then predict for the whole population that starting from some dating stage, the mean level of aspirations will always be below the mean level of mate values and they will decrease as the number of interacted dates becomes higher. We will be able to directly check this prediction in the next section.

5 Simulations

We will measure the performance of our new search rule using computer simulations. Like in Todd and Miller (1999), the value of N is set to 200 in our simulations to consider a population involving 100 males and 100 females, and we assign all mate values randomly from the uniformly distributed values in $[0, V]$ where V is set to 100. Also, we change the length of adolescence (the number of dates), S, from 1 to 90, and conduct 100 Monte Carlo simulations for each adolescence length. [All simulations are conducted with the help of GAUSS Software Version 3.2.34 (Aptech Systems, 1998). The source code of the simulation program and the resulting data are available from the author upon request.]

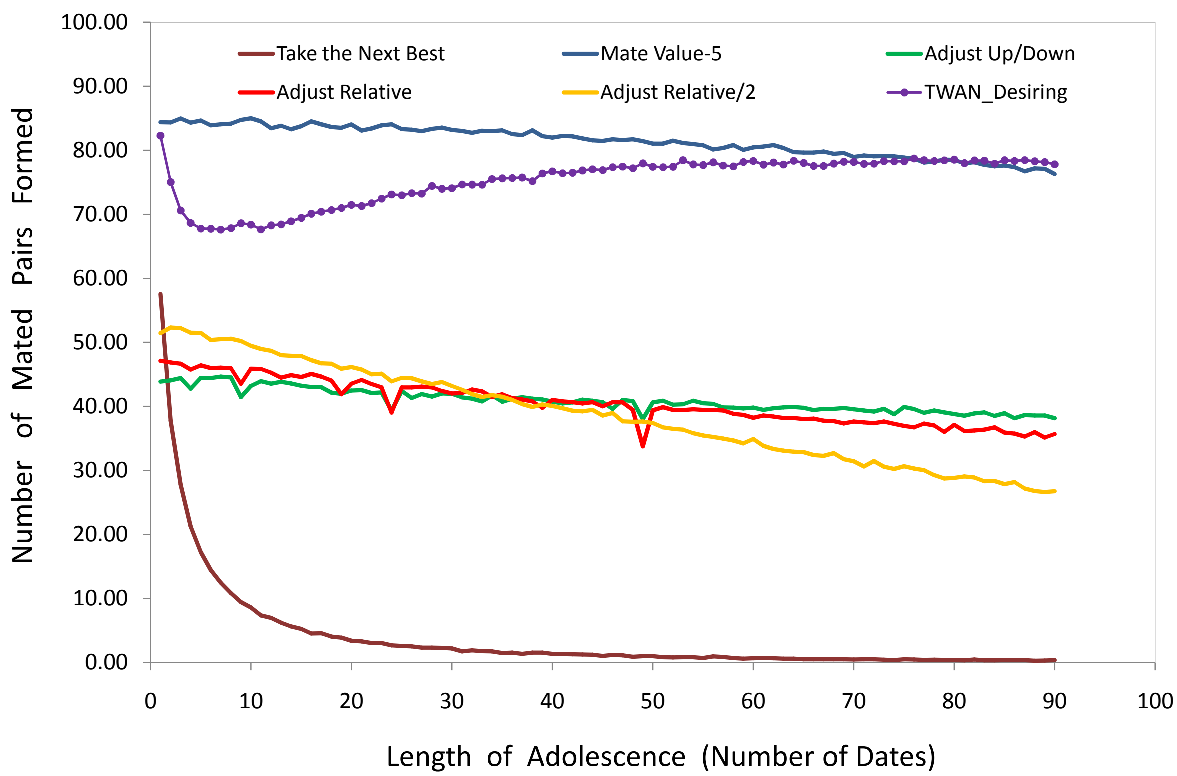

Figure 5.

In Figure 5, we plot the mating likelihoods calculated under our new search rule and the five search rules of Todd and Miller (1991). Apparently, TWAN_Desiring is outstandingly superior to any other search rule except for Mate Value-5 in terms of mating likelihood. In addition, when the adolescence length is not extremely low, an increase in the adolescence length improves the performance of TWAN_Desiring, and eventually, at very high levels of adolescence length, TWAN_Desiring becomes as good as Mate Value-5 or even slightly better.

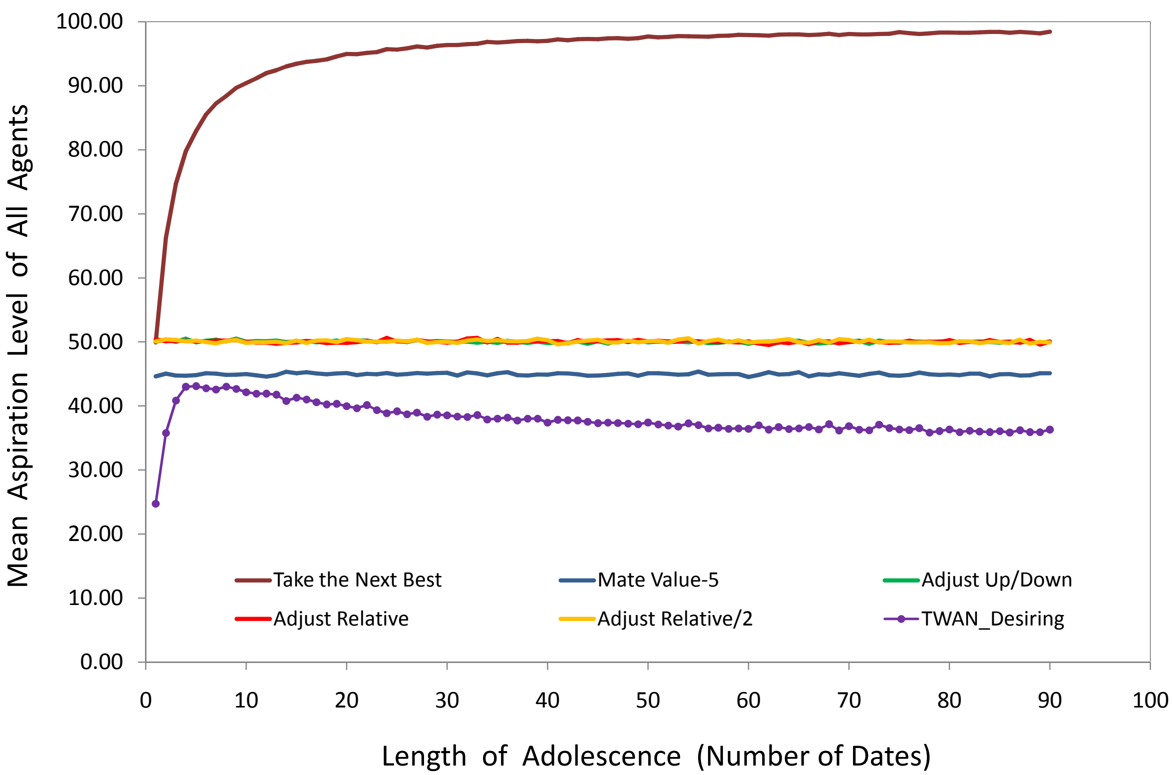

Figure 6.

To explore the secret behind the success of TWAN_Desiring in terms of mating likelihood, we report in Figure 6 our calculations for the mean aspiration levels of all agents at the end of the adolescence phase under all search rules studied in this paper. Apparently, the mean aspiration level of all agents always attains its lowest value under TWAN_Desiring, quickly rising from the initial value of 0 to 43 after the first five dates and smoothly reducing back to 36 when the number of dates increases up to 90. Overall, Figures 5 and 6 make it clear that the success of a search rule in terms of the mating likelihood is closely related to whether this rule is humble or not, i.e. whether agents in the mating population set their aspirations on average below their own mate values.

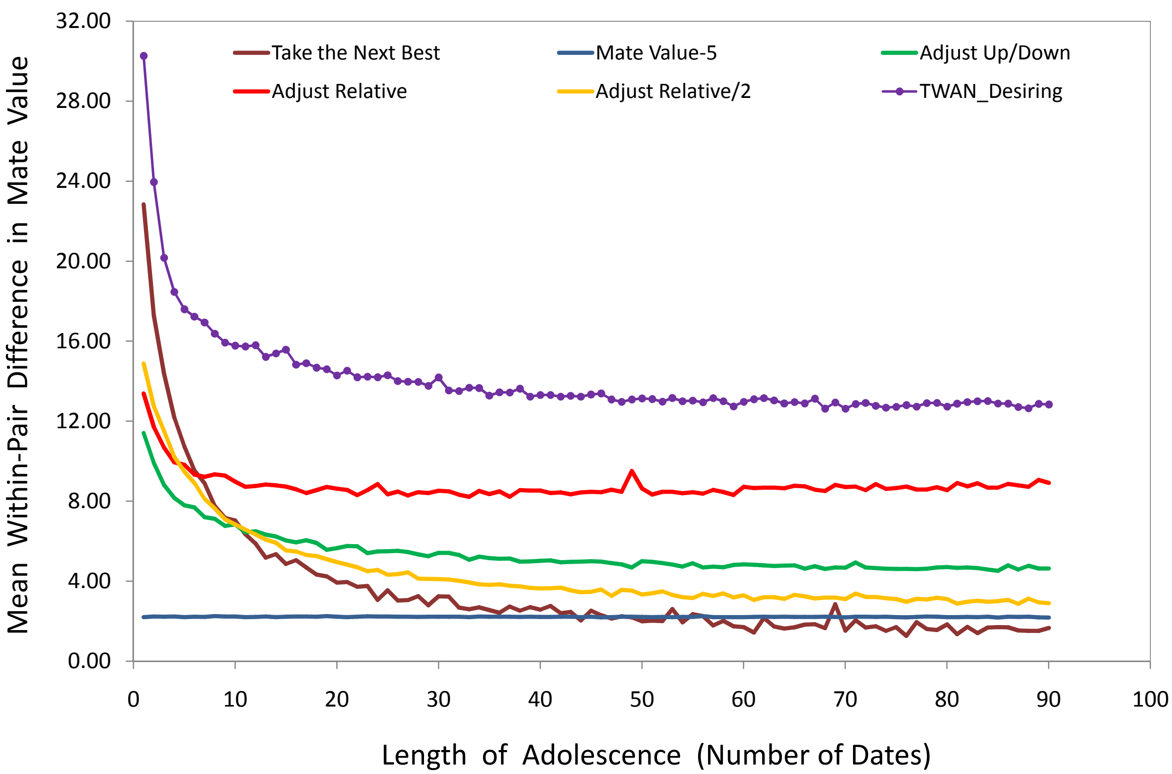

Figure 7.

In Figure 7, we illustrate the performance of our new search rule with respect to the stability measure described in Section 3. Interestingly, TWAN_Desiring now becomes always inferior to all search rules of Todd and Miller (1999) irrespective of the adolescence length. Taking both Figure 5 and Figure 7 into consideration, we can say that both mating and divorcing are more likely under the rule TWAN_Desiring than under any other realistic search rule of Todd and Miller (1999). It seems that being humble in mate search and becoming ready to pair up with agents whose mate values are well below one's own mate value pays off well in the mating phase but also incurs an increased risk of marital dissolution.

Finally, we calculate RMSE for our new search rule and present it below in comparison to RMSE values we have previously calculated for the search rules of Todd and Miller (1999).

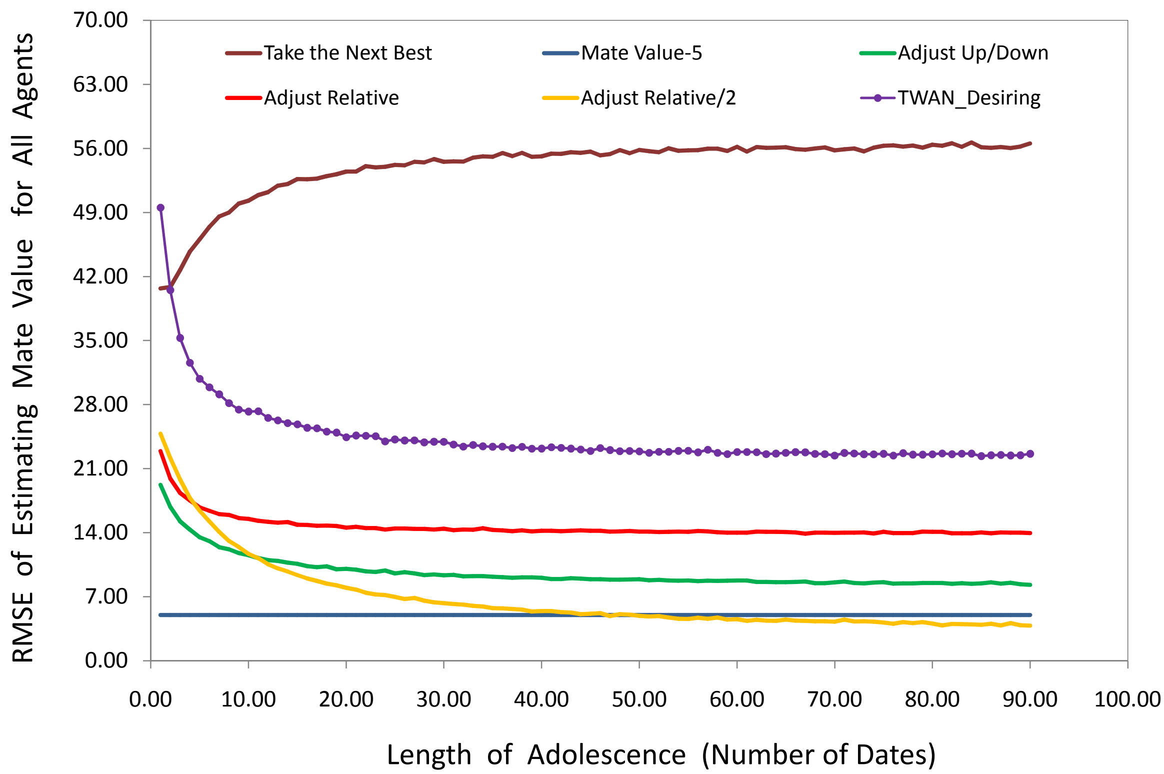

Figure 8.

Figure 8 shows that RMSE is higher under TWAN_Desiring than under any search rule of Todd and Miller (1991), except for Take the Next Best. Given the extremely poor performance of TWAN_Desiring in terms of the stability of mating (as illustrated in Figure 7), Figure 8 supports our previous finding in Section 3 regarding the seemingly negative relationship between the estimation errors made in the adolescence phase and the stability of mating.

6 Conclusions

In this paper, we have attempted to uncover why some of the simple heuristics or search strategies in the Todd and Miller's (1999) human mate choice model are more successful than the others, and given our answer to this question we have proposed a new heuristic that is in terms of mating likelihood as good as the most successful, yet also unrealistic, heuristic of Todd and Miller (1999), namely Mate Value-5. Regarding our first object, we have calculated, for each heuristic of Todd and Miller (1999), the root mean square error (RMSE) made by all agents in the mating population in estimating their own mate values in the adolescence phase of the mating process. We have found that the estimation errors attain their lowest values under Mate Value-5, while they are in general lower under Adjust Relative/2 than under the other realistic rules, namely Take the Next Best, Adjust Up/Down, and Adjust Relative. In addition, the estimation errors under Adjust Relative/2 are as low as they are under the unrealistic rule of Mate Value-5 when the adolescence length is medium to long. This is quite puzzling given the huge difference between the mating likelihoods generated by these two heuristics always in favor of Mate Value-5. However, this puzzle vanishes away once we calculate the mean aspiration levels of all agents. Whereas under Mate Value-5 the mean aspiration level is -by definition- lower than the mean mate value of the population by the value of 5, it is approximately equal to the mean mate value under Adjust Relative/2. This finding indicates that the success of a heuristic may not be only related to the precision or correctness of agents in estimating their own mate values in the adolescence phase but also to their humbleness in making their estimations.

To realize our second object -the finding of a plausible heuristic that is comparable to Mate Value-5 and superior to Adjust Relative/2 in terms of mating likelihood- we have proposed a search rule, called Take the Weighted Average with the Next Desiring Date (TWAN_Desiring). Our simulations using this search rule have revealed that in terms of the generated mating likelihood TWAN_Desiring is outstandingly superior to all realistic search rules of Todd and Miller (1991), including Adjust Relative/2. As a matter of fact, TWAN_Desiring is also almost as good as the unrealistic rule of Mate Value-5 when the adolescence length is sufficiently long.

To understand the secret behind the success of TWAN_Desiring in terms of mating likelihood, we have calculated the corresponding root mean square error made by all agents in estimating their own mate values. We have found that RMSE for TWAN_Desiring is higher than RMSE for any search rule of Todd and Miller (1991), except for Take the Next Best. This shows that the success of TWAN_Desiring in terms of mating likelihood cannot be attributed to the precision of information agents obtain about their own mate values. As we have suspected that this success is caused by the direction of estimation errors of agents like in the case of Mate Value-5, we have also calculated the mean aspiration levels of all agents at the end of the adolescence phase for all search rules studied in this paper. Interestingly, we have found that the mean aspiration level of all agents always attains its lowest value under TWAN_Desiring, implying that this heuristic is even more humble than the most humble (but unrealistic) heuristic of Todd and Miller, namely Mate Value-5.

Our findings have revealed that our new mate search rule has an undesirable implication as well. With respect to a notion of stability, measured by the mean within-pair difference in mate value, TWAN_Desiring performs always worse than any heuristic of Todd and Miller (1999). When agents become extremely willing to pair up with agents whose mate values are below their own mate values, they increase not only their chances of mating but also the likelihood they will divorce in the future.

Taking stock of our results, both mating and divorcing are found to be more likely under our humble search rule, called TWAN_Desiring, than under any realistic heuristic of Todd and Miller (1999). The future research may profitably search for plausible search rules under which not only the likelihood of mating but also the stability of mating would become sufficiently high.

References

APTECH SYSTEMS. (1998) GAUSS version 3.2.34. Maple Valley, WA: Aptech Systems, Inc.

COLLINS, E. J., McNamara, J. M. & Ramsey, D. M. (2006) Learning rules for optimal selection in a varying environment: Mate choice revisited. *Behavioral Ecology*, 17, 799-809.

DOMBROVSKY, Y. & Perrin, N. (1994) On adaptive search and optimal stopping in sequential mate choice. *American Naturalist*, 144, 355-361.

MAZALOV, V., Perrin, N. & Dombrovsky, Y. (1996) Adaptive search and information updating in sequential mate choice. *American Naturalist*, 148, 123-137.

NASH, J. (1950) Equilibrium points in n-person games. *Proceedings of the National Academy of Sciences*, 36, 48-49.

SAGLAM, I., (2014) Simple heuristics as equilibrium strategies in mutual sequential mate search. *Journal of Artificial Societies and Social Simulation*, 17 (1), 12.

SHIBA, N., (2013) Analysis of asymmetric two-sided matching: Agent-based simulation with theorem-proof approach. *Journal of Artificial Societies and Social Simulation*, 16 (3), 11.

TODD, P. M. (1997) Searching for the next best mate. In R. Conte, R. Hegselmann & P. Terna (Eds.), *Simulating Social Phenomena* (pp. 419-436). Berlin: Springer-Verlag.

TODD, P. M. & Miller, G. F. (1999) From pride and prejudice to persuasion: Satisficing in mate search. In G. Gigerenzer, P. M. Todd & the ABC Research Group

(Eds.), *Simple Heuristics That Make Us Smart*(pp. 287-308). New York: Oxford University Press.