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"New Insights into Neighborhood Racial Segregation: Some lessons from a careful exercise in sociological modeling"

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ABSTRACT

We have extended the Schelling model of neighborhood racial segregation.to include agents who can authentically 'see' their neighbors up to a distance *R*, called 'vision'. In our model, rational agents have variable racial preferences for their own race and racial apprehension about agents of a different race.

Two versions of such a sociological model have been studied in depth. In the discrete version, agents can authentically 'see' their neighbors up to a distance *R*, called 'vision' and assign equal weight to all agents within the sphere of vision and zero weight to agents beyond R. In the continuum version, where we introduce a utility factor that decays exponentially with distance from the agent and whose strength, decay length and sign can be varied systematically. By exploring the consequences of systematically varying *R*, we have developed an understanding of how vision interacts with racial preferences and minority concentrations and leads to novel, complex racial segregation behavior. We have discovered three distinct regimes: a *fear* regime, where societies invariably segregate; an *enlightened* regime, where integrated societies are stable; and an *intermediate* regime where the behavior is complex. We will present detailed results for the symmetric case (which maximizes conflict), where equal numbers of agents of two races occupy the same cityscape. We briefly indicate the policy implications of these simulations. Future directions for research will be suggested.

I. Introduction:

This summer marks the 50th anniversary of Brown v. Board, the landmark supreme court case which, by declaring racial segregation of U.S. public schools as unconstitutional, encouraged further laws and social movements aimed at racial integration, in all senses of the phrase, of these United States. Even as we celebrate the strides towards racial equity and integration that have been made in the intervening half century, we must also acknowledge that contemporary major metropolitan areas continue to be marred by a particularly glaring blemish, i.e. pervasive and persistent residential neighborhood segregation (Massey and Denton, 1987); (Massey and Denton, 1993). One must acknowledge the slight decrease in the intensity of racial neighborhood segregation in a few small cities, as has been documented by (Farley and Frey, 1991) and (Thernstrom and Thernstrom, 1997), but this doesn't alter the fact that all major American metropolitan centers continue to be nearly completely segregated, a condition that breeds an array of severe social problems.

Despite the wealth of literature analyzing the factors possibly influencing neighborhood segregation, the scholarly community remains quite divided about the root causes of as well as policy prescriptions about this socio-demographic condition. In December 2003, the present authors published a theoretical analysis (Laurie and Jaggi, 2003) that attempted to reconcile some of these divergent viewpoints by computing the evolution of a generalized Schelling type model with sufficient richness to encompass the different kinds of segregation-dynamics that might be instantiated in real societies. The key new ingredient introduced in that study was the notion of 'vision' of the rational agents that make up the society. While we were pleased that our study did help resolve some of the key disputes about what rational-agent models have to say regarding racial neighborhood segregation, we were slightly concerned about the robustness of our conclusions with respect to the manner of implementing the so-called 'vision' of the social agents in our model. The present short contribution addresses that concern by investigating alternate and more realistic means of taking 'vision' into account, and concludes that the theoretical claims of our earlier paper are indeed robust.

II. Scope of This Study:

A review (Clark, 1991) of the literature on the different forces affecting racial neighborhood segregation states, " In the debate about the relative role of these forces, the consensus is that the patterns of separation have a multifaceted explanation: Among the explanatory factors, neighborhood composition preferences have been singled out as a critical variable both by economists, who view preferences from the perspective of consumer behavior theory, and by geographers and sociologists, who use preferences and expectations as elements of models of residential choice within cities and neighborhoods."

In two pioneering papers, Schelling (1969; 1971) had studied a model system of two distinguishable types of agents with discriminatory individual preferences for certain neighborhood compositions. In recent years, this work has been extended and commented upon by many scholars, (Vandell and Harrison, 1978); (Epstein and Axtell, 1996); (Krugman, 1996); (Sander et al., 2000); (Wasserman and Yohe, 2001); (Rauch, 2002). All these studies conclude by affirming the inevitability of racial neighborhood segregation even when the agents are supposedly race-neutral. We (Laurie and Jaggi, 2003) were skeptical of such claims and suspected that either these models were incomplete in some fundamental way or they had been explored only in an artificially narrow region of the phase-space. The thrust of this paper is to compare the predictions of two variants of Schelling's model, and examine them closely and systematically with respect to one additional parameter we believe to be quite significant, viz. the *range of vision* of the agent.

We do not claim to be the first to have studied the effect of vision in this context. After finishing our computations and during the writing phase, we became aware of two recent studies, one unpublished (Sander et al., 2000) and the other published (Wasserman and Yohe, 2001), which are related to our work. One study (Wasserman and Yohe, 2001) introduces a utility function that decreases exponentially with the distance from the agent making the decision, as a way to include the effects of racial composition away from the agent. They (Wasserman and Yohe, 2001) conducted computer simulations in a portion of the parameter space and concluded with a "strong support" for Schelling's claim of segregation. They reported, "The second case expanded residents' vision … The segregation in the equilibrium neighborhood was, in fact, even more obvious than before. … This result suggests that segregation is positively correlated to the vision parameter—an observation that is also consistent with Schelling's hypothesis."

In the other study (Sander et al., 2000), the neighborhood of approximately 2500 homes is divided into 25 fixed tracts each containing 100 cells. The utility function of the agent depends upon, apart from the Moore neighborhood (see fig 1), upon the racial composition in the tract in which the agent is currently located and the tract which contains the trial site where the agent is considering to move. They can vary the relative weights of the Moore neighborhood and of the tract. They find that as the weight of the extended tract is increased from 0 to 1, the dissimilarity index increases from about 0.4 to 0.8. This conclusion is similar to that of Wasserman and Yohe (2001), viz. increasing the vision makes segregation worse.

By systematically and simultaneously varying the range of 'vision' and racial-preferences in two related models, we discover that the effect of increased vision is, in fact, much more complex and interesting than implied by these recent studies (Wasserman and Yohe, 2001) and (Sander et al., 2000). For details of our 'discrete model', we refer the reader to our earlier paper (Laurie and Jaggi, 2003), but for the sake of continuity, the next section offers a one paragraph summary of the main results of the discrete model

III. Main results for our discrete model:

In the standard Schelling model of a two-race 'artificial society' (Epstein and Axtell, 1996), agents are characterized by a parameter p, which is a measure of their preference for agents of their own kind. Agents evaluate the racial composition of their *immediate* neighborhoods and compare the composition with their own value of racial preference, p, to determine whether they will attempt to relocate elsewhere. Our variant differs from this in that the agents in fact *"see"* their neighborhood[1] up to a certain 'distance' *R* from their own home while evaluating their decisions to relocate.

We find that, depending upon the values of *p* and *R*, the system evolves in one of two possible modes. In one region of the parameter space, the system displays the familiar (Schelling, 1969; 1971; 1971a; 1978); (Epstein and Axtell, 1996); (Sander et al., 2000); (Wasserman and Yohe, 2001) mode where initially integrated communities are unstable and quickly resegregate. We call this the *unstable* regime. But we have discovered that there is a large region of the parameter space (p,R), particularly for moderate values of *R* ($2 \leq R \leq 7$), where integrated communities remain stable for arbitrarily long times. We call this the *stable* regime.

It is important to note that what we have called the stable regime does not correspond to some unrealistic, Gandhian levels of racial preferences/tolerances of the agents. Once the range of vision *R* is expanded from myopic levels (say R=1) to rather modest levels (say R= 3 to 5), non-segregated stable communities are found to be fully consistent with non-zero and quite substantive values of *p*. If this insight were to diffuse into the collective consciousness of policy makers and of the general populace, it could help generate an optimistic outlook for the future of neighborhood integration.

[1] In its standard demographic usage, the term 'neighborhood' evokes a region with fixed boundaries of a specified size. We use the term 'cityscape' for this and reserve the term 'neighborhood' to denote the agent-specific and variable subset of homes within a certain distance of the instantaneous location of the agent.

IV. Our Continuous Model:

We have designed a *continuous* model where the range of vision (denoted R_2 for notational clarity) can be varied continuously. In this model, racial preferences are modeled by a utility function which is maximized during simulation. Each pair of agents contributes a certain utility which depends upon the racial identities of the agents and upon their geographic distance, r_{ij}, from each other.

Our continuous model is a generalization of the model found in a study by Wasserman and Yohe (2001), which introduces a utility function that decreases exponentially with distance as a way to include the effects of the racial composition of neighbors further away from the agent's immediate neighborhood. Wasserman and Yohe's utility function incorporates an agent's desire to be near its own kind and the agent's desire to be far from the other kind, according to the formula:

$$U_j = \sum_{i=0}^{n} 2^{-(d(i)-1)} - \sum_{k=0}^{n} 2^{-(d(k)-1)}$$

where $d(i) \geq 1$ is the distance of a neighbor of individual j's own race, $d(k) \geq 1$ is the distance of a neighbor of a different race, and n is the number of neighbors within a range of vision. Notice that in Wasserman and Yohe's model, equal weight is attached to an agent's desire to be near its own kind and its desire to avoid the other kind. An agent will try to move if its utility falls below a certain value, and Wasserman and Yohe present results for simulations in which the threshold is zero. This is qualitatively similar to the moving criteria for our discrete model (for the case p=0.5, i.e. an agent will move if the (weighted or unweighted) fraction of like neighbors equivalently falls below 50%), except that in our discrete model the effects on utility do not decay with distance from the agent.

Our continuous model is an extension of our discrete model, but it also generalizes Wasserman and Yohe's model. The utility function which controls our continuous model is,

$$U_j = \frac{1}{R_2^{\,2}} \left(\sum_{i=1}^{l} e^{-\frac{r_i}{R_2}} - \mu \sum_{k=1}^{u} e^{-\frac{r_k}{R_2}} \right)$$

where r_i and r_k represent the distances[2] of the i^{th} and k^{th} agents, respectively, from the agent performing evaluation, l and u represent the number of like and unlike neighbors, respectively, μ is a parameter which indicates agent attitude, and R_2 represents a range of

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[2] In this continuous model, the distance between agents is literally the closest distance from one site to the other, taking into consideration our periodic boundary conditions. In other words, $r = \sqrt{x^2 + y^2}$, where x is the fewest number of columns between agents counting either east or west and y is the fewest number of rows between agents counting either north or south.

vision appropriate for our continuous model. While our utility function retains certain features of Wasserman and Yohe's model, such as exponentially-decaying utility and disutility contributions from like and unlike neighbors, we have added the two important parameters, μ and R_2, which bear qualitative similarity to p and R in our dicrete model. Positive values of μ correspond to an agent wanting to be far from agents of the other race, but negative values of μ indicate that an agent wants to be near agents of the other race (possibly even more so than agents of its own race if $\mu < -1$). Note that Wasserman and Yohe's model is a special case of our continuous model – in the language of our continuous simulations, Wasserman and Yohe only use $\mu = 1$. The range of vision, R_2, controls how rapidly the magnitude of the utility contributions decay with distance from the evaluator. The factor of R_2^{-2} preceding the summations is merely a scaling factor to allow equal comparison of simulations with different R_2 values when a nonzero moving threshold is used.

Notice that in our discrete model, all occupied sites within an evaluating agent's range of vision contribute the same amount of utility (or disutility). Thus, for the discrete case $R = 7$, an agent's desires are equally impacted by those one home away and by those seven homes away. While this "square" utility function (see Fig. 1) may seem unrealistic, it was employed in our original work for the sake of simplicity. The exponentially-decaying utility function (see Fig. 1) seems intuitively more realistic.

Discrete Model, $R = 5$ Continuous Model, $R_2 = 1.5$

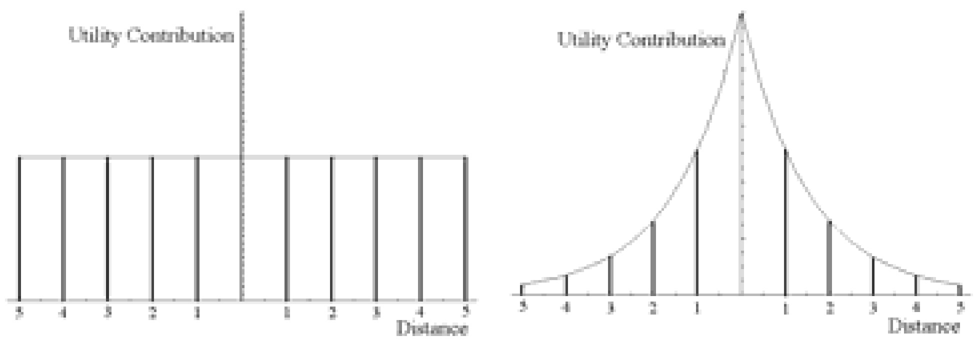

Fig. 1
Utility Contribution vs. Distance
The utility contributions of neighboring agents in our *continuous* model "decay" with distance from the evaluating agents; those in our *discrete* model do not.
Note: Agents can be non-integer distances away from the evaluator. For example, agents can be a distance of $\sqrt{2}$ or $\sqrt{5}$ from one another. The vertical lines seen in the figure, located at only integer distances, are meant to be only a guide to the eye.

V. Comparison of Discrete and Continuous models: Effect of increasing 'vision'

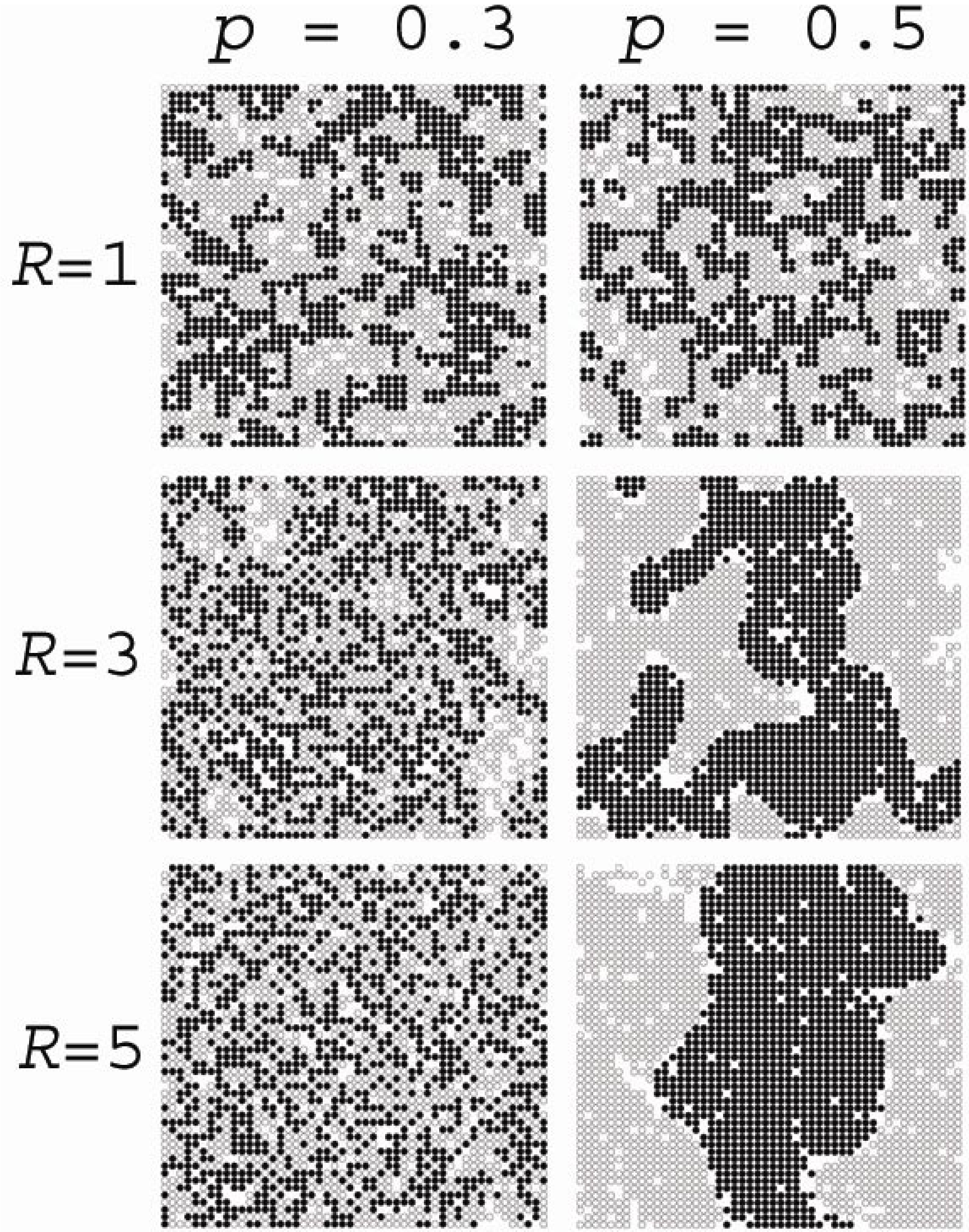

Fig. 2 Equilibrium societies for different values of *R* and *p*
The left column corresponds to the *stable* regime (p=0.3) and the right column corresponds to the *unstable* regime (p=0.5).

Fig. 2 above shows a very small selection of representative results for equilibrium societies that emerge in the discrete model. For *R*=1, the equilibrium societies for both cases (*p*=0.3 and 0.5) appear to have what we have called "small domain" or "dendritic" segregation. In fact, they are barely distinguishable from each other. This is very similar to earlier results of other studies (e.g. Epstein and Axtell, 1996) and explains why people have believed that segregation happens for all values of p, and therefore is, in some sense, inevitable. Our results show the actual situation to be richer in detail. For example, for the *p*=0.5 case, as demonstrated by the panels on the right half of Fig. 4, it is clear that increasing the range of ‘vision’ from R=1 to R=5 makes the problem of segregation much worse; the degree of segregation is much larger now and the nature of segregation is now of the two-ghetto variety.

But for the *p*=0.3 case, displayed by the panels on the left half of Fig. 2, it is obvious that as *R* is increased, the tendency of the society towards segregation is reduced dramatically, and monotonously. Indeed, the equilibrium society for *p*=0.3, *R*=5 case is almost completely integrated: for this case, the computed value of *S* --please see Laurie and Jaggi 2003 for the definition of S, the ensemble-averaged degree of segregation—turns out to be 0.03± 0.03, corresponding to fully integrated and stable neighborhoods.! Even for *R*=3, a very modest increase in one's vision, the value of *S* for the equilibrium society is already down to 0.16± 0.04! This result, in and of itself, is important.

Recall that we have chosen to concentrate on the worst-case scenario of *c*=0.5 (equal numbers of two races trying to live in the same cityscape). And, even in this worst case scenario, stable, integrated communities are formed with a rather modest increase in vision (*R*=3 to 5) and for significant non-zero values of *p* (0.3 in this case). We conclude that in order to have stable, integrated societies, it is not necessary for the agents to have utopian attitudes (actively seeking more diverse neighborhoods): this is not allowed in the present model. Nor is it necessary for the agents to have a Gandhian, color-blind world-view, where one does not care at all about the typology of one’s neighbors: this would correspond to *p*=0. All one needs is a rather modest decrease in one’s obsession with insisting that one must never be a minority in one’s own neighborhood at any length scale (which is what *p*=0.5 means)! A decrease from *p*=0.5 to *p*=0.3 when combined with the powerful amplifying effect of even a modest increase in vision; from a myopic *R*=1 to a modest *R*=3 or 4, leads to stable, integrated societies!

Fig. 3 below summarizes comparable results for our continuous model. (Please recall that because of the R^{-2} pre-factor in the definition of the utility function, R_2 of the continuous model is not identical in magnitude to the corresponding *R* in the discrete model, though they are monotonic functions of each other.) It is extremely reassuring that all aspects of the behavior described above for the discrete model are reproduced precisely for our continuous model as displayed in the Fig.3 below. This time, small values of μ correspond to small preference (panels on the left half of Fig.3) and larger values of μ correspond to larger preference (panels on the right half of Fig.3) The similarity of patterns for small values of R_2, between μ=0.4 and μ=0.7, is identical to the discrete case. That the effect of increasing 'vision' is dramatically different in the 'stable' and the 'unstable' domains is reconfirmed in the continuous model also. This robustness of conclusions with respect to quite different implementations of 'vision' increases our confidence of our claims.

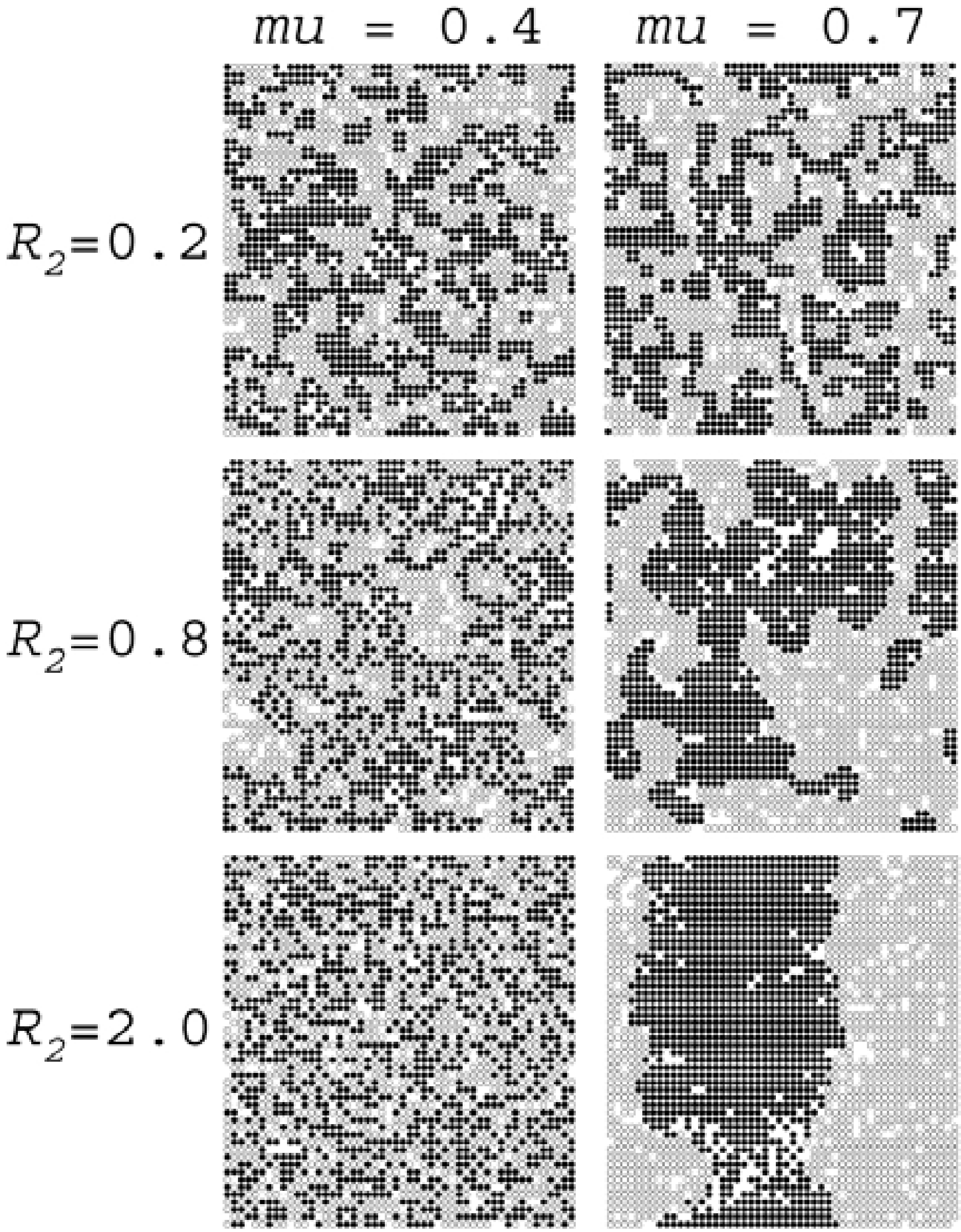

Fig. 3 Equilibrium societies for different values of R_2 and μ:

[The left column in the figure corresponds to the *stable* regime (μ=0.4) and the right column corresponds to the *unstable* regime (μ=0.7)]

The fact that stable, integrated neighborhoods form for such modest and eminently reasonable values of the parameters can have significant impact on the perspectives of policy makers. It provides some reason for the hope that reduction in racial neighborhood segregation—even complete integration—is a politically and socially viable goal. This result is also reassuring from another point of view. Recall that there is robust empirical demographic evidence (Farley and Frey 1991); (Farley et al. 1993) that there has been some significant decrease in the intensity of racial segregation in small and medium cities in the United States. Conservative commentators (Thernstrom and Thernstrom, 1997) have labored to make this point, but usually in the context of challenging what they believe to be exaggerated claims of liberal scholars or activists regarding the extent of racial neighborhood segregation. Our work suggests that we should not abandon Schelling type models: when extended to include agent-vision, they have the potential of giving us useful insights *and* of being consistent with empirical findings. Our work strongly supports the belief (Carr, 1999) that "Initiatives aimed at changing perceptions that fuel the desire to segregate will have a broader impact on reducing or eliminating segregation". Our simulations also lend some theoretical support to two specific policy initiatives (Yinger, 1995): to improve the availability and the flow of housing market information (increase *R*) and to encourage home-seekers to consider alternate neighborhoods where their own race is not concentrated (increase *R*, effectively encourage a decrease in *p*).

VI. Comparison of Discrete and Continuous models: The entire phase diagram

We have discovered that the phase diagram of both discrete and continuous models is much richer than previously believed: there are two distinct regimes of behavior in this model.

In one regime, typified by p=0.5 for the discrete model and μ=0.7 for the continuous model, initially integrated cityscapes segregate, the value of *S* increases with time, and it approaches a large value at equilibrium. This equilibrium segregation, $S(R)$, increases if *R* is increased: we call this the *unstable* regime.

In the other regime, exemplified by p=0.3 for the discrete model and μ=0.3 for the continuous model, initially integrated cityscapes segregate very little and *S* approaches a small value at equilibrium. This equilibrium segregation, $S(R)$, decreases if *R* is increased: we call this the *stable* regime. Fig. 4 and 5 graphically summarize our results for $S(R)$, $1 \leq R \leq 7$: the bifurcation and the two distinct types of regimes are quite self-evident in this phase-diagram. To the best of our knowledge, this is a new technical result, whose importance lies in suggesting a new way of talking about the relation between agent-intent, agent-vision and the degree and nature of segregation in this and related models. The outstanding agreement between the two models lends additional credibility to these claims.

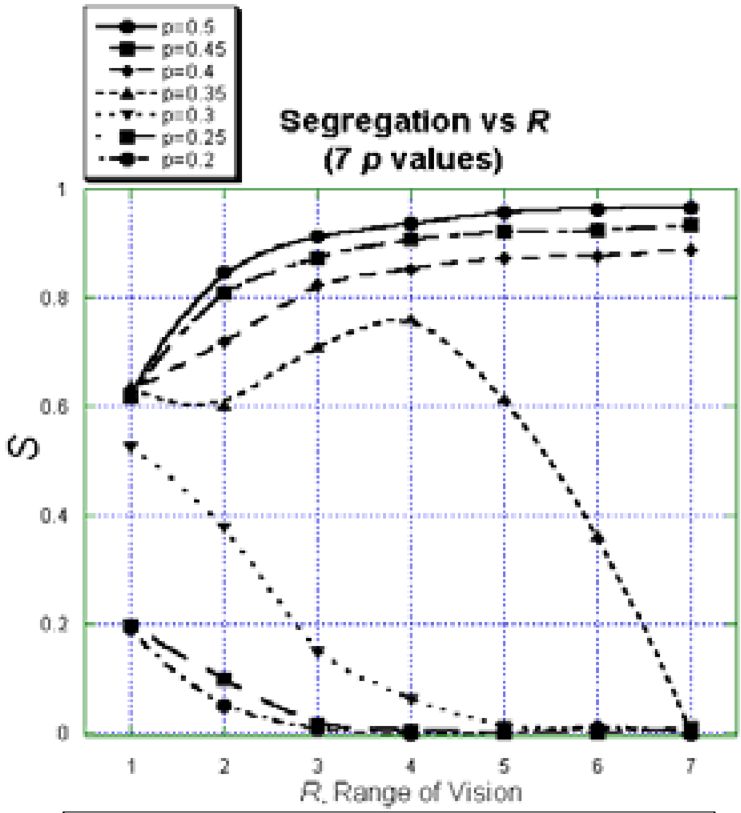

Fig.4 Segregation vs. *R* for several different preferences in the discrete model

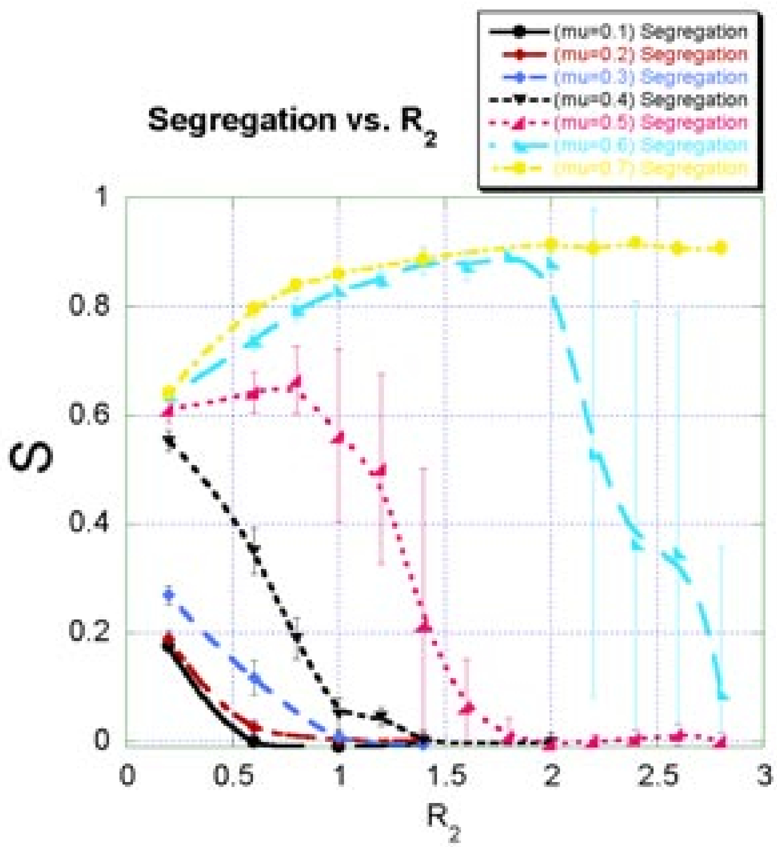

Fig. 5Segregation vs. R_2 for Several Different Preferences μ
The continuous model exhibits the same qualitative behavior as the

VII. Conclusions

We have introduced and studied two extended Schelling models, a discrete version and another continuous version, of racial neighborhood segregation, in which the agents authentically 'see' their neighbors up to a distance R; we call it the 'vision'. We have systematically and quantitatively explored the consequences of varying R and have developed a qualitative sense of how vision interacts with racial preferences and minority concentrations to lead to a non-simple segregation behavior.

We have discovered that the parameter space of these model has three regimes of behavior: the *unstable* regime, where the societies invariably segregate and segregation increases as vision, R, increases; the *stable* regime, where integrated societies are stable and segregation decreases as vision, R, increases; and a narrow *intermediate* regime where a complex behavior is observed.

The discovery of the presence of the same three behavioral regimes and all associated trends in both our models confirms that our original results were robust and not merely algorithmic artifacts related to the specific treatment of vision used in our discrete model.

The central policy implication of our study is an optimistic note: contrary to popular belief, rather modest decreases in xenophobia and/or preferences for one's own kind, *when coupled with increased vision*, can lead to stable and integrated neighborhoods. Public policy or procedures can *effectively* increase vision, e.g. realtors and clients could be provided with demographic data for $c(R)$ around various locations and/or tax incentives could be offered to avoid regions where fluctuations in $c(R)$ are above the global average. The education community and other social agents who work to lower preference for one's own kind and to increase tolerance for the 'other', can take strong encouragement from this study.

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