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An Exploration Of The Relation between Neighborhood Resource, Crime, And The Development Of Paranoia.

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Abstract:

Schizophrenia is characterized, often, by the positive symptom paranoia, which can be caused by stressors like income, crime, diet, and trauma. But, is it possible that "schizophrenic" behavior is not indicative of impending psychosis but rather a coping mechanism to environmental stressors? This paper explores how paranoia could function as a coping mechanism to stressors, poverty and crime, through a computer-simulation of the Iterated Prisoner's Dilemma. Results showed that paranoia was directly related to crime, regardless of poverty level, but in no-crime neighborhoods, individuals in poverty showed less paranoia than did those in high-income areas. Therefore, individuals in poorer areas with higher crime display paranoia in response to a dangerous environment, not as a potential indication of schizophrenia.

Keywords: schizophrenia, paranoia, crime, poverty, environmental factors, social psychology

An Exploration Of The Relation between Neighborhood Resource, Crime, And The Development Of Paranoia.

SNL, with its long history of using humor to attack serious social issues, has a particularly poignant recurring skit, involving a fake game called "Black Jeopardy." The skit focuses on the issues in Black America-- particularly issues regarding governmental intervention, and distrust of large governmental bodies. The skit uses outrageous humor to show how from slavery through Jim Crow, to the current brutalization of young Blacks by the police, Black Americans are rightly wary of large government power. This unhealed, racial trauma has consequences, as summed up by author Resmaa Menakem when he wrote, "Trauma in a person, decontextualized over time, looks like personality. Trauma in a family, decontextualized over time, looks like family traits. Trauma in a people, decontextualized, looks like culture." This "decontextualized trauma" spills into every facet of life, even medicine. Jonathan Metzl (2010), the author of *Protest Psychosis: How Schizophrenia Became a Black Disease*, states that Black men are around 4x more likely to be diagnosed with psychosis illnesses like schizophrenia than their White counterparts, and he posits that the diagnosis of diseases like schizophrenia in the Black population have a much larger sociological component (not just a psychological and environmental component). In his book, he proves that this is due to the inherently ambiguous nature of mental illness diagnosis coupled with the lack of awareness of issues facing specifically the Black population through the years and the politicization of Black issues through history.

Schizophrenia was historically diagnosed most frequently in White women, and was largely considered non-threatening as a disease. But during the Black Power movement, Black males, already culturally understood as dangerous, became more likely to be diagnosed with schizophrenia. The reconceptualization of schizophrenia as a "Black disease" was rooted in articles stating that schizophrenic symptomology was influenced by social pressures like the

Civil Rights Movement or Black Muslim ideology (Metzl, 2010). In addition, Metzl also attributes this change in diagnosis to modifications in the DSM-II. In an effort to align the DSM to international definitions of mental illnesses, diseases were no longer listed as “reactions,” as they were in DSM-I (Metzl, 2010), shifting the focus of underlying causes of disease from potentially environmental to indicating an intrinsic disorder. In addition, the DSM also adopted masculine pronouns as opposed to gender-neutral pronouns used in DSM-I (Metzl, 2010). According to Metzl, “Masculinized hostility was so central to the revised diagnosis that it formed its own subtype of paranoid schizophrenia”(Metzl, 2010). Previous diagnoses like sociopathic personality or antisocial personality were changed to paranoid schizophrenia to keep up with the changing literature. Science and politics converged to overdiagnose a whole generation of Black men as schizophrenic. This problem continues to persist; Black men are still overdiagnosed with schizophrenia, partly due to the emphasis clinicians place on paranoia (Johnson, 2015). This clinical preference, coupled with the implicit distrust that Black communities have for agents in power, does little to reduce the overdiagnosis of schizophrenia in Black men, nor does it address issues of distrust in the Black community. Recently, paranoid behavior has been linked to contextual factors like poverty and crime (Wickam, 2014), but is it possible that this link may fall prey to the same pitfall that has led to this overdiagnosis? This paper explores the possibility that paranoid behavior in response to crime and poverty may not be an indicator of schizophrenia, but rather simply an adaptation to a high risk environment.

What Are Schizophrenia and Paranoia?

It is important to first consider what schizophrenia and paranoia are, and how they are measured. Schizophrenia is defined as a disorder in which people perceive reality abnormally (NIMH, 2020). The symptoms of schizophrenia are divided into positive (meaning symptoms that appear in individuals with schizophrenia) and negative symptoms (attributes that are diminished, or disappear in individuals with schizophrenia). Positive symptoms are delusions, hallucinations and disorganized speech. The negative symptoms are flattened affect (lack of emotion), reduced speech, and lack of initiative. Paranoid behavior (sometimes also called suspiciousness), falls under delusional perception-- a positive symptom, which typically manifests as delusions of persecution, or the feeling that someone or an organization is "out to get you"(Miller, 2003). When diagnosing schizophrenia, patients should present with at least two symptoms (either two positive symptoms, two negative symptoms, or a combination thereof).

Current Problems with Measuring Paranoia:

Current diagnostic tools (Positive And Negative Syndrome Scale (PANSS) and the Structured Interview for Prodromal Syndromes (SIPS)) are not robust. Each uses metrics based on a single question, and a scale with limited social range that doesn't take into account the patient's cultural context and social identities (Ellett, 2013). The PANSS defines paranoid behavior as "ideas of persecution, as reflected in guardedness, a distrustful attitude, suspicious hypervigilance, or frank delusions that others mean harm" (Lavin et al, 2019), and uses a quantitative number with a strict cutoff to classify a behavior. The SIPS measures prodromal schizophrenia (which is the presence of schizophrenic symptoms in a patient that has not reached psychosis), but acknowledges that paranoid behavior runs on a continuum with normal social functioning (Miller et al, 2003). In addition, around 62% of clinicians use incorrect calculations in administering the PANSS (Obermier, 2011), and only 40% of patients labeled clinically high risk (CHR) on the SIPS convert to full psychosis in a 2.5 year follow up study (Pearson, 2012). Even though the PANSS and SIPS are the most trusted surveys to determine psychosis, perhaps there is room for improvement--a way to consider the individual patient's manifestation of the symptom relative to their environment, especially since paranoia is one of the best indicators of schizophrenia spectrum disorder (Johnson et al, 2009).

Other Ways Of Measuring Paranoia:

Johnson et al seeks to measure paranoia through interpersonal relationships. Paranoia is best seen in scenarios that require a decision to be made without knowing how the other person will react--individuals who are paranoid will display impractical risk aversion. Johnson et al (2009) looked at the difference between risk aversion and paranoia through an experiment involving repeated iterations of the Minnesota Trust Game; a game used by behavioral economists and social scientists to understand interpersonal trust--the ability to trust a stranger. The Minnesota Trust Game requires subjects to decide either to invest in a partner with the hope that the partner will return a larger sum or select an assured payoff, where money is guaranteed to be returned. If the subject decides to invest in the partner, there is a chance that the partner might not return the money, or return a smaller amount than the loan.

This interaction is crucial for determining the difference between an individual suffering from paranoia, and an individual who is simply distrustful. Johnson creates a scenario where the partner payoff is high in reward and more likely. In these situations, the distrustful individual will opt for the payoff determined by the partner because it is more economical. However, in the event that the participant is suffering from paranoia that is a symptom of schizophrenia, the participant will always opt for the assured payoff, not because of an economic decision, but because they believe that “others harbor malicious intentions towards him or her” (Johnson et al 2015, 31). This differentiation between rational mistrust and actual paranoia forms the basis for differentiating the effects of poverty on paranoid behavior, and is incorporated into the model in this paper by creating a bound when analyzing the paranoid behavior agents: if they defect too much, it would be evident of paranoia, but if less than the bound, it would simply be rational mistrust.

The Question & A Brief Overview of the Project:

The link between neighborhood crime and individual risk of paranoia was posed by Wilson et al (2015). Individuals were assessed using the SIPS, and their neighborhood was analyzed against a crime index. It was found that more than any other positive or negative symptom on the SIPS test, paranoia and neighborhood crime were most closely related, across age, gender, and race. "Neighborhood composition and relative social disadvantage increase the incidence of psychosis, even after controlling for individual factors" (Wilson et al, 2015). The paper does state, however, that links between poverty, crime, and environment can create stress, which may play into genetic predispositions towards psychosis, although this concept is not explored in their paper. However, as stated earlier, the SIPS, while a heavily used tool, isn't necessarily a reliable source for diagnosis. Therefore, would it be possible to explore this link between neighborhood crime and individual risk of paranoia through an interpersonal relationship similar to Johnson et al (2009)?

The paper seeks to explore this connection between neighborhood crime and paranoia using an agent based model. Using an agent-based model to understand mental health is not a novel concept. Creating a computerized, agent-based model only requires assigning agents (the interacting individuals in the simulation) with basic instructions on how to interact in the environment. The researcher can then observe how sociological phenomena can emerge dynamically from interactions between the agents and the environment. Kalton et al (2016) made use of that principle by programming local interactions such as the choice of taking medication to manage a mental illness, or the interaction between a healthcare worker and patient with a mental illness, and accumulating events to observe for larger phenomena, like healthcare costs or incarceration rates (Kalton et al 2016). Kalton's model consisted of seventy-five input variables to model care coordination, rates of incarceration, hospitalization, and patient compliance, and was able to show how these disparate phenomena can influence each other to affect rates of recidivism, and patient compliance. The concept of programming agents with instructions and subsequently observing the overall system was used in this model to understand the association between neighborhood poverty and the risk of paranoia.

This paper explores how paranoia commonly thought to be indicative of schizophrenia may actually be rational mistrust exacerbated by the environment through an agent based model that uses the Prisoner's Dilemma. A computer model using the Prisoner's Dilemma will be implemented with three separate behavior strategies, one that is always positive, one that mimics greed-based negative interactions, and one that mimics paranoia, through distrust-based negative interactions. Two basic experiments were conducted: the first set of experiments, called the baseline set, determined the correlation between neighborhood resources and paranoid behavior without the inclusion of crime. The second set of experiments, called the environmental set, determined a direct causal relationship between paranoid behavior and resource levels with the inclusion of crime and determined the existence of a relationship between crime and poverty.

Methods:

Terminology: The Iterated Prisoner's Dilemma & Agent Based Modeling:

The model makes use of the Iterated Prisoner's Dilemma interaction. The Prisoner's Dilemma is a game theory phenomenon created by American mathematician Albert W. Tucker. The game presents a hypothetical scenario of a police officer questioning two partners in separate holding cells, who are suspects in a crime. The officer gives each partner the chance to either confess to the crime, or blame the other partner. If both partners confess to the crime, they spend 4 years incarcerated. If one partner blames while the other partner confesses, the confessor spends 8 years in prison while the other walks free. If neither partner confesses, they spend 6 months. The important caveat is the partners cannot know what the other partner's choice is; the game simulates how individuals behave in an interaction when they are unaware of how the other individual in the interaction will react. If both partners choose to cooperate with each other (not confess), this would show a high level of trust between the two partners. On the other hand, if either partner defects (chooses to confess), this would show a relatively low level of trust between the two. This information is summarized in Table 1 (see Appendix A). These two behaviors (confessing or not confessing) form the basis of the model. This game can be played over and over again, amongst several different agents, creating the Iterated Prisoner's Dilemma (IPD) game.

From a neutral, single-interation, perspective, it seems clear that both partners should confess, because they both get the lowest amount of time in prison. But when analyzed from the viewpoint of the agent, the two main choices are confessing, which would lead to no time in jail, or defecting, which would lead to 8 years in prison. In this case, it is most economically sound to blame the other partner. However, as this game gets played multiple times, this payoff ends up not being ideal. The most natural behavior that maximizes payoff is a mix between cooperation at times and defecting at others (Axelrod's Tournament, 2019). The ability to both cooperate and defect was instrumental in determining whether an individual was normal, or exhibiting signs of paranoia indicative of schizophrenia.

What are Agents in Agent-Based Modeling?

For this research project, IPD was implemented using the agent-based-modeling software, Netlogo. This created a virtual environment for playing IPD that could model varying levels of neighborhood resource and crime, which helped establish a distinction between a normative response and response potentially indicative of a mental illness. This is important because the model, without resource and crime changes, is unable to account for internal aspects of mental illness, like the reasoning behind a specific action (since the IPD model is an interpersonal model). So mental illnesses modeled by IPD can only be observed by the external symptoms. Ultimately, since both paranoid individuals and individuals who have a rational level of mistrust (which will be referred to as “rational mistrust”) defect in a single, given interaction, the major difference between a rational mistrust player and a paranoid individual is the capacity for change. A paranoid individual will always defect (meaning they do not confess) regardless of the environmental context and over a multitude of interactions. However, a rational-mistrust-individual will stop defecting, or start cooperating (meaning they will confess), when placed in an environment where there is no longer a need to be distrustful. This was measured using a defection rate: a self-modifying scale that reflected the total number of times a particular individual defected over all interactions. The level of defection reflected the mental state of the individual. An emotionally neutral human playing IPD would defect around 40% of the time (Eimontate et al, 2013). An angry individual playing IPD would defect around 60% of the time (Eimontate et al, 2013). Anything above this level would be considered paranoid--easily attributable to schizophrenia. However, as has been stated, paranoia and rational mistrust exists on a spectrum, the only difference being that a paranoid individual would continue to defect even when in an environment when it’s not necessary. This would be seen in a very high defection rate, like a defection rate over 90%. When translated into a computerized agent based model, these “individuals” become “agents” as per correct terminology. Agents that reached a defection rate above 90% were considered paranoid. Between a defection rate above 60%, but below 90%, individuals exhibited rational mistrust, and a defection rate between 40-60% was considered normal. Every paranoia agent (the virtual individual whose emotional response is being measured through the model) had a defection rate that starts out at 40% (Eimontate et al, 2013), as this was the defection rate for an emotionally neutral human playing the Prisoner’s Dilemma. Based on the environment, and who the agent encounters (cooperators, defectors, or other paranoia agents), the defection rate can increase or decrease by a single percentage point. There were three types of agents playing: cooperator agents who never defected and who acted, simplistically, as another member of society; defector agents who always defected and served as a measure of crime, otherwise known as greed-based defection; and paranoia agents who were normal and had the capacity to defect or cooperate based on how their defection rate changed throughout the game. When a paranoia agent’s defection rate increases to 100%, they look similar to defector agents, however defector agents’ behavior are greed motivated while paranoia agents’ behavior is motivated by distrust.

There are several advantages to using agents in a computer model rather than recruiting participants to play an iteration (or several) of the Prisoner’s Dilemma. First of all, having agents who, apart from their behavior, are otherwise identical, neutralizes participant differences that would contribute to sampling biases. In addition, other internal variables that can contribute to the presentation of mental illnesses like genetics and internal state of mind are not considered. This uniformity amongst the agents controls the environment, creating an experiment with better internal validity. In addition, it is difficult to prove a causative relationship between neighborhood resource, crime, and paranoia in the real world because it’s extraordinarily difficult and highly unethical to experimentally test these hypotheses on a human population. However, in an agent-based model, by imbibing the agents with instructions on their behavior, it is quite simple to experiment with resource density and crime and observe how these changes impact the concentrations of defectors and paranoid agents numerically change in the population. In addition, computerized, agent-based models don't rely on one interview to label an individual as having paranoid tendencies. Establishing a paranoia diagnosis over multiple interactions rather than reducing it to one interview between a clinician in power and a patient reduces error. Finally, the use of a computer model with agents, rather than an in person experiment with participants allows for multiple interactions to be observed at the same time, and then aggregated and analyzed quickly.

Outlining the Interaction:

Programming the Prisoner's Dilemma model consists of three main parts: outlining the interaction, tying the interactions to "resource patches" (a square piece of ground in the two-dimensional environment), and finally augmenting the interaction with a genetic algorithm.

The first part of creating the interaction was building the framework for the interactions between the agents. Each interaction is conducted according to the rules of the Prisoner's Dilemma model. The gains and the losses are measured through the decision matrix presented in Table 2 (see Appendix A). The agents move around the virtual environment until they face another agent. At this point, the interaction is carried out, and then the agents continue to move randomly through the space. In Table 2, which contains the distribution breakdown, a turtle is synonymous with an agent.

The next step was to tie the interactions between the agents to the resource patches. In the two dimensional world of NetLogo, the environmental variable of neighborhood resources was controlled by the number and concentration of resource patches. The visualized Netlogo model consists of agents on a grid made of squares, or patches. Resource patches had a different color from the surrounding patches in the environment, and the presence of a resource patch indicated the presence of resources, which are needed for the agent to live, on that square. This was important because in order to determine the effect of resource scarcity on behavior, the only place to test the interactions was when two agents were deciding how to share a resource on the resource patch. The Iterated Prisoner's Dilemma was modified to only have interactions which involve the sharing of tangible resources in lieu of prison time. The aim of the agents is to accumulate as many resource units as possible and subsequently reproduce (which will be discussed in the genetics algorithm). In the event that an agent lands on a resource patch and there are no nearby agents as partners, the agent can extract one resource unit. In the event that there is another agent who lands on the same patch, they interact using the Prisoner's Dilemma to divide or allocate the single resource. Any interactions that don't take place on resource patches don't involve the sharing/distribution of resources and therefore are not counted. There are two substeps: the first is to create the resource patches, and the second is to modify the interaction to only work on the resource patches--which includes modifying the payoff. The model would stop running when there were no resources left.

The first sub-step was to populate the environment with resource patches. The number of resource patches was decided with a sliding scale that could be modified before running the model. The distribution of patches with resources was accomplished by creating a distribution variable (that could be modified between trials) and assigning each patch a number. If the patch number was smaller than the distribution variable, it was colored green, and assigned 100 resource units. That patch was now a resource patch. Else it remained black. Agents began with a stock of 50 resources and need to acquire additional resources to survive and propagate. As agents move through the environment, they move onto green or black patches patches that either do or don’t contain resources (respectively). The total number of resource patches available models neighborhood poverty (a poorer neighborhood will have fewer patches scattered through the environment and a more affluent neighborhood will have a larger density of resource patches in the environment). In the event that an agent lands on a patch that contains resources, and no other agent is also on that patch, they are free to take 1 resource unit from the patch. When agents have no resources, they die. When agents have 50 resources, they can propagate. When a resource patch has no more resource units, it becomes black.

In the event that there are two agents on the same resource patch, then there has to be a way to divide the 1 resource unit between the two of them that also reflects the potential outcomes of IPD. In the event that both agents cooperate (which in a regular play of the Prisoners Dilemma, the individuals refuse to confess), they each get ½ of the resource unit. In the event that one agent defects (confesses)and the other one cooperates (does not confess), the agent that defects gets 1 resource unit while the other agent gets nothing. In the event that both agents defect (confess), neither of them get the resource. Because of the extractive process of the game, it is expected that neighborhood poverty will increase as the game progresses (the number of resources on each patch and the number of resource patches will decrease). After each interaction, the defection probability of the paranoia agents is reevaluated. In the event that the paranoia agent’s partner defected (confessed), the defection rate of the paranoia agent was increased by 1, and that particular agent was now more likely to defect in a future interaction. In the event that the paranoia agent’s partner cooperated (didn’t confess), the defection rate was decreased by 1, and that agent was more likely to cooperate on the next interaction. *The defection* *rate was bounded between 0 and 100, with 0 indicating pure trust in another person, like a cooperator agent, and 100 indicating paranoia symptomatic of schizophrenia, which looks like a defector but again, does not happen out of malice but rather distrust based on prior history*. The experiment stops when there are no more resources available. This happens when all of the patches are depleted of resources.

The last step of the model was to create a genetic algorithm. The genetic algorithm only allows agents above a certain score to propagate, and this is used to determine which behavior is adaptively beneficial. For now, the threshold number of resources required for propagation is 50, after which, the agent's score will drop to 25, and the new agent will start with a score of 12.5 as well as the same behavior as the parent. Initially the scores of the new agent were set to 40 and the old agents were left with 10, but these did not yield observable test runs. It was found that these scores of 25 for the old agent and 12.5 for the new agent allows for observable test runs. It was assumed that as the number of resource patches increased, the total number of agents would increase.

The Experiments:

Three experiments were conducted to analyze the relationship between neighborhood resources, crime, and risk of developing non-clinical paranoia.

The first experiments, called the baseline set, tried to determine the correlation between neighborhood resources and paranoid behavior without the inclusion of crime. Therefore, the experiment only consisted of the paranoia agents (whose behavior the model is trying to measure) and the cooperator agents. The number of paranoia agents and cooperators was kept at 20. The entire experiment consisted of 10 trials. Each trial changed the resource density, incrementing by 5%. The average rate of defection of all paranoia agents and the number of paranoid agents at the end of each trial (when there were no resources left) was monitored through the course of the experiment.

The second set of experiments, called the environmental set, served two purposes. First the environmental set aimed to establish a relationship between poverty and paranoid behavior in the presence of crime. Secondly the environmental set tried to determine the existence of a relationship between defective behavior and poverty--essentially which behavior was rewarded at lower resource densities. The number of defectors, paranoia agents, and cooperators was set to 20 at the beginning of every trial. The only factor that changed was the resource level, which incremented by 5% every trial (like the baseline experiment). The average defection rate of paranoia agents, the number of paranoia agents, and the number of defector and cooperator agents was measured through the course of the trial.

A third set of experiments, called the combined experiment, was also conducted to determine whether a gradation of crime across resource densities could potentially affect paranoid behavior. This third set of experiments had a similar setup to the baseline set: it consisted of 20 cooperators, and 20 paranoia agents, but increased its resource density by 25% increments with each trial. At each resource density, 20 trials were run, each time increasing the number of starting defectors by 1. This was done to determine which environmental factor had more of an impact--resource density or crime. Again, like in the baseline experiment, the changes in defection rate and number of paranoia based defectors was measured.

The aim of all three experiments was to determine whether operating in an environment without sufficient resources can give rise to nonclinical paranoid behavior. Due to the random nature of agent based modeling, each trial can yield different results even if the parameters are kept constant. Therefore, it was imperative that models using each combination of parameters was run at least 10 times. For all experiments, unless otherwise indicated, the number of agents of each behavior was set at the beginning to 20. Using 20 agents at the beginning for all trials provided a good baseline. Too few agents, and they died quickly, but not before hastily propagating, leading to an unmanageable concentration of agents in the environment, also making that particular trial unobservable. Too many agents, and the evolutionary advantage of different behaviors was not observable, because they didn't reach the score threshold to propagate.

It was expected that as the resource density decreases, the number of paranoid agents would increase, as would the defection rate for the paranoia agents. This effect would be compounded by the presence of a significant number of defector agents (representing crime). In addition, it was expected that the number of paranoia agents will also increase if there are defectors present regardless of the resource level, illustrating that high crime will affect a neighborhood regardless of income level.

Results:

The aim of the baseline experiment was to determine a relationship between average neighborhood income and defector (confessing) behavior in "paranoia" agents. As the poverty of the environment increases, it was expected that the defection rate of paranoia agents would also increase. What was seen across the trials, was as the resource density increased, the defection rate went down from around 40% (when the resource density was around 0%, which is also the starting defection point for all paranoia agents) to 0 (when the resource density was 100%). This finding was significant ($p < 0.05$) and had an $r = -0.37$. This means that paranoia agents' behavior resembles cooperative agent's behavior in areas of high resource density. In addition, paranoid behavior triggered by the environment is not strongly associated with high-resource neighborhoods. A negative relationship between the starting resource density and the end number of paranoid agents was also observed; the number of paranoia agents went from 1400 (at 20% resource density) to 200 (at 100% resource density). This was a strong correlation ($r = -0.609$) that was significant ($p < 0.05$), and it could mean that individuals in high resource neighborhoods are less likely to display paranoid behavior potentially symptomatic of schizophrenia, because that behavior is not rewarded at higher resource densities. These findings are summarized in Figure 1 and Figure 2 (see Appendix B).

However, it’s clear that the environment of the baseline trial is not indicative of the real world, as it does not account at all for crime. The environmental trials looked at the relationship between neighborhood resources and development of paranoia in the presence of crime and are shown mostly in Figure 3 (see Appendix C). Figure 3 seems to not show a strong, but still significant, correlation between resource density and rate of defection of paranoid agents ($r = 0.11$, $p < 0.05$), with the numbers hovering between 47% and 53% defection. In comparing these to Figure 2 (the baseline experiment with no crime, that saw a negative relationship between resource density and rate of defection), it’s clear that even at levels of high resource density, crime plays a factor in a paranoid individuals’ behavior--it just isn’t enough to make an agent present with paranoid symptoms indicative of schizophrenia. In low resource neighborhoods, defection was simply a reaction to the environment, as defection did not become their standard behavior. In fact, contrary to the expectations, paranoia agents in low income resource neighborhoods with the presence of crime did not develop a paranoid defection rate (as in a defection rate above 60%). However, the defection rates at low resource densities in the environmental experiment are still higher than the defection rates at low densities in the baseline experiment, but this is likely due to a scarcity mentality, which is exacerbated when there is both poverty and high crime in an environment. Figure 4 (in Appendix C), which is meant to show most rewarded behavior, also clearly exemplifies that increasing resource density is accompanied by a lower population; among paranoia agents the peak population is 1200 paranoid individuals at a resource density of 20%. At 100% resource density, the paranoid population is 200. This trend was also observed in the baseline experiments, indicating that this finding is independent of the presence of crime.

The environmental experiments also examined which behaviors were rewarded at lower neighborhood resources by measuring the number of defectors and cooperators in addition to the number of paranoia agents. As the resource density of the environment increased, it was found that the number of cooperator agents decreased (see Figure 4, Appendix C). The peak was at 20% resource density, where the number of paranoia agents was around 700 individuals. A similar pattern was seen for the relationship between resource density and defectors (crime), though the peak population of defectors was significantly higher: 2000 agents at a resource density of 10%. The relationship between paranoia and resource density was already explored in the results of the previous hypothesis of the environmental experiments. Overall, it was clear that at low resource density, defection behavior (crime) was heavily rewarded, and following behavior was paranoia-based defectors. Cooperators were least rewarded at low resource-densities.

The final experiment, the combined experiment, modified resource density as well as the number of defectors. The results from this experiment should be compared to Figures 1 and 2, which looked at resource density vs. paranoid behavior with no defectors (no crime), or to Figures 3 and 4, which looked at the resource density vs. paranoid behavior with 20 starting defectors. Overall, each of the graphs in the final experiment showed the same thing: the increasing number of defectors leads to higher defection rates for the paranoid agents, but it leads to a lower rate of population growth for paranoia agents.

When comparing the end population of paranoid agents at 25%, 50%, 75%, and 100% resource population, it is seen that with increasing resources, the overall number of paranoia agents at the end of the trial decreases (a finding that was also observed in the baseline and environmental experiments). At 25% resource density, the end defection rate is around 55% (at 20 defector agents), and at 0 defector agents, the defection rate is 0%. The number of paranoia agents at 25% oscillates as the number of defectors are increased in the population. The peak is seen at 3 defector agents in the population, where the number of paranoia agents is 1600.

At 50% resource density, clearer patterns are observed with the changing number of defectors. The peak number of agents was seen when there were 0 defectors at the start: 700, while the lowest number of paranoia agents was seen when there were 20 defectors at the start: 450. When looking at the defection rate, the opposite trend was seen, the peak was seen with 19 starting defectors, with a paranoia rate of 55%, while the lowest defection rate of 0% was seen with 0 starting defectors.

The same essential pattern was seen at 75% resource density, with the max defection rate of 50% occurring at 19 starting defector agents, and the max ending paranoia population of 320 paranoia agents occurring at 4 starting defectors, while the minimum ending paranoia population of 220 agents occurring at 14 starting defectors.

At 100% resource density, the largest end population of paranoid agents was 190, and was seen at a starting defector population of 3, while the lowest 150, seen at a starting defector population of 19. The defection rate of paranoia agents increased from 0% at 0 starting defector population to 50% defection rate with a starting defector population of 20. These results are summarized in Table 3 (see Appendix D).

The models' results show that average neighborhood resource levels and crime are each key components of the development of paranoid behavior. The paranoid behavior displayed by the agents, however, is not high enough to indicate potential psychosis-- that is, the rate of defection for the paranoid agents remained at or below 60%. These results showed that there was a direct relationship between crime and paranoid behavior. In addition, there was an inverse relationship between neighborhood resources and paranoid behavior, and at low resource densities, this relationship was strengthened further with the addition of crime. Finally, there was an inverse relationship between neighborhood resources and crime. This was seen in a comparison of Figure 1 (which measures end defection rate in relation to resource level changes without the presence of defectors) and Figure 3 (the same thing with the presence of defectors). Without the presence of crime, as in Figure 1, the model showed that a decreased level of resources is linked to an increased level of paranoia. However, the defection rate quickly plummeted when the resource level was increased slightly. On the other hand, in Figure 3, the defection rate of paranoia in the presence of greed-based defectors (crime) stayed elevated, even when the resource density increased. Therefore, both poverty and crime appear to be factors that can lead to levels of paranoid behavior above that needed to indicate schizophrenia.

Discussion:

The original intent of the paper was to explore the relationship between resource density, crime, and paranoid behavior, and this was accomplished using agent based modeling. It is worth reiterating that in this model, while there are individuals who display paranoia that could be indicative of schizophrenia, an essential component of schizophrenia requires the ability to understand the internal state of the agent, and this cannot be measured with an agent-based model. While on the surface, the results supported the hypothesis, the model illuminated the relationship between crime, poverty, and paranoid behavior, in a way that was unexpected. It was observed that while poverty is related with paranoid behavior, it is triggered by crime, and this effect can keep paranoid behavior elevated across neighborhood resource levels.

As elaborated upon in the Introduction, there are several symptoms associated with the presence of schizophrenia, but this model focused on paranoia. According to Yiend (2018), paranoid symptoms are correlated with negative interpretation bias, which is the tendency to view ambiguous situations as threatening, or negative. Negative interpretation bias is one of the key factors psychologists and psychiatrists look for to determine future psychosis, and it was the symptom used to misdiagnose an entire generation of Black men during the Civil Rights Era. The fact that this symptom remains in the current DSM implies despite its contentious history means that it should be evaluated in more depth.

This paper contributes to our understanding of the multitude of environmental factors that can play a role in the development of schizophrenia. Head injury, child abuse, and other adverse child rearing experiences have been known to contribute to future psychosis (Dean, 2005), as have dopamine sensitization and drug abuse. Additionally, it is clear that environmental factors like housing, poor job prospects, and high crime can influence the presence of schizophrenic symptoms. The current research adds low resources and crime to the list. However, schizophrenia is a complicated disease, and not everyone who is exposed to these factors will develop it. The model exists to highlight the fact that a more nuanced discussion is needed. Some individuals exposed to an environment with poor housing, high crime and low resource density will exhibit adaptive traits to survive in that environment, while others might be more adversely affected and develop a mental health disease. Each of these individuals are suffering from their circumstances and a better understanding of their needs is required to properly treat them.

Future Directions:

Despite the already interesting findings, it is worthwhile to understand this as well in context of other social situations where non-clinical paranoia is seen. One of these examples is, as commonly termed, White paranoia. There are ample examples of White paranoia, where typically White, upper class individuals view a heterogeneous group as dangerous in the intent of protecting their wealth/resources/status, as was seen with the McCloskey case. This behavior is not classified as a mental illness but sociologically looks similar to other mental illnesses, like paranoid schizophrenia, therefore making it similar to nonclinical paranoia. In these situations, there is a sustained high paranoia, even in areas where crime is not present and resource density is high. It would appear then that the paranoid behavior displayed is not a function of the environment. This is because the concept of White paranoia is different from other understandings of paranoia. White paranoia is, generally, a learned behavior. White paranoia consists of the individual trying to anticipate the actions of others--it is fear of retribution by the Black population for the previous decades of mistreatment by Whites (Berke, 173).

In future explorations of White paranoia, a similar model could be changed to create a separate set of agents who look like defectors, but act like cooperators, or tit-for-tat individuals, along with a differentiated area where the “White” agents live. There are several steps to this type of model. This would be done by maintaining a dictionary containing the different types of agents, and the behaviors that the paranoid agent believes that opponent/partner would do. This dictionary would be the equivalent of a stereotype. Apart from the “White” agents, all of the agents would have the tit-for-tat behavior (the behavior that most closely resembles human interaction), but the “White” agent would expect a certain behavior based on the color of the opposing agent (for example, a blue agent would look like a defector but in reality be imbibed with the tit-for-tat behavior). Each paranoia agent can maintain a hash table that contains the interaction details, specifically, the color of the partner, the behavior the paranoid agent guessed, and then the partner’s actual behavior. For each paranoia agent, a score can be maintained that contains the number of times the behavior of the paranoia agent’s partner wasn’t equivalent to the stereotyped behavior. This model can also be elevated further by accounting for the principle of private property, and creating an interaction whenever an agent lands on the specified resources of the paranoia agent. Agents would analyze and guess their partner’s behavior based on the color of the agents, and this behavior would not be subject to easy change based on experience. This can be done by altering the interaction model such that the paranoid agents preempt the actions of their partner, and then having the paranoid agents model their behavior based on what they believe that agent would do. For example, if a particular paranoia agent encountered a blue agent, and to the paranoid agent, the behavior of blue agents was to defect, then the paranoid agent would also defect to try to win that interaction, regardless of what the blue agent actually does.

Another potential idea to take the model forward, apart from studying different types of paranoid behavior, would be to develop a better understanding of what environmental factors can lead to positive and negative symptoms of paranoia. Previous studies do not cover the relationship between paranoia and poverty in much depth, as seen with the papers discussed in the Introduction and Methods section. The closest is the paper by Wilson et al (2016), which looked at crime and paranoia. It was found that there was a relationship between neighborhood crime and paranoid behavior, even across other demographic changes like age, gender, and race.

In addition, the paper explicitly states that crime rates did not correlate with other positive psychosis symptoms (Wilson, 58), which specified the environmental factors to paranoia, not potential schizophrenia. A little bit of research has been done to that effect, but certainly not through an agent-based modeling, making it difficult to determine certainty. A paper from 2011 states that there is a relationship between household income and mental disorders. The paper came to the conclusion that the presence of Axis II mental disorders (which includes schizophrenia and other psychosis disorders) was correlated with an income below 20,000 a year. In addition, the authors note that “ A few mental disorders were associated with every level of decrease in income (ie, bipolar disorder, social phobia, nicotine dependence, paranoid PD, schizoid PD, schizotypal PD, and borderline PD)” (Sareen, 2011). The model and the Sareen paper could be taken further by examining the presence of a causative relationship between wage decrease and paranoid behavior. This could be done by expanding the “score” to be closer to a modifiable “wage” that affects the interactions between agents.

Another way to take the current model further is to explore the relationship between poverty and schizophrenia not using an agent based model, but rather using real world data. This would work by first recruiting individuals who were suffering from prodromal schizophrenia symptoms, specifically paranoia. These individuals would probably be around 3-4 on the SIPS scale. Then, their score could be compared to their neighborhood where they lived, and the relative poverty and the crime of that area.

Conclusion:

Overall, this paper has shown that there is a relationship between poverty and the presence of non clinical paranoia, through exacerbated crime. While the psychological details of paranoia are hard to model due to the limitations of a computer based model, it is clear that poverty is an environmental factor that leads to the development of nonclinical paranoia. The model could be elaborated in the future to look at disease progression and the environmental factors that lead to psychotic disorders, either from a neurological, or sociological perspective. This aim of this paper is not to discredit the notion that environmental factors can contribute to the presence of psychotic disorders, but rather present a nuanced depiction of the interaction between disease and environmental factors, where healthcare providers consider the context of their patient, thereby reducing the disparities in healthcare between different races and classes.

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Appendix A

Prisoners Dilemma Payoff Model when played 1 time as opposed to the payoff within the context of the agent based model.

Table 1

Payoff in the Prisoner's Dilemma with 2 individuals

	Partner Defects	Partner Cooperates
Agent defects	6 months each incarcerated	Agent gets 0 years Partner gets 8 years
Agent Cooperates	Agent gets 8 years. Partner gets 0 years.	Both agents spend 4 years

Note: Table 1 shows the payoff if the Prisoners Dilemma game was played once. These are the general rules.

Table 2, on the other hand, has modified Table 1 to occur over further interactions. Now the currency is not jail time--it is resource value units (what the agent needs to survive). The interaction was modified to only occur on resource patches--areas of the environment where agents are able to procure a resource unit.

Table 2,

The Distribution of a Resource Unit in the Event Two Agents Land on The Same Resource Patch

	Partner Cooperates	Partner Defects
Turtle Cooperates	(½, ½)	(0,1)
Turtle Defects	(1, 0)	(0,0)

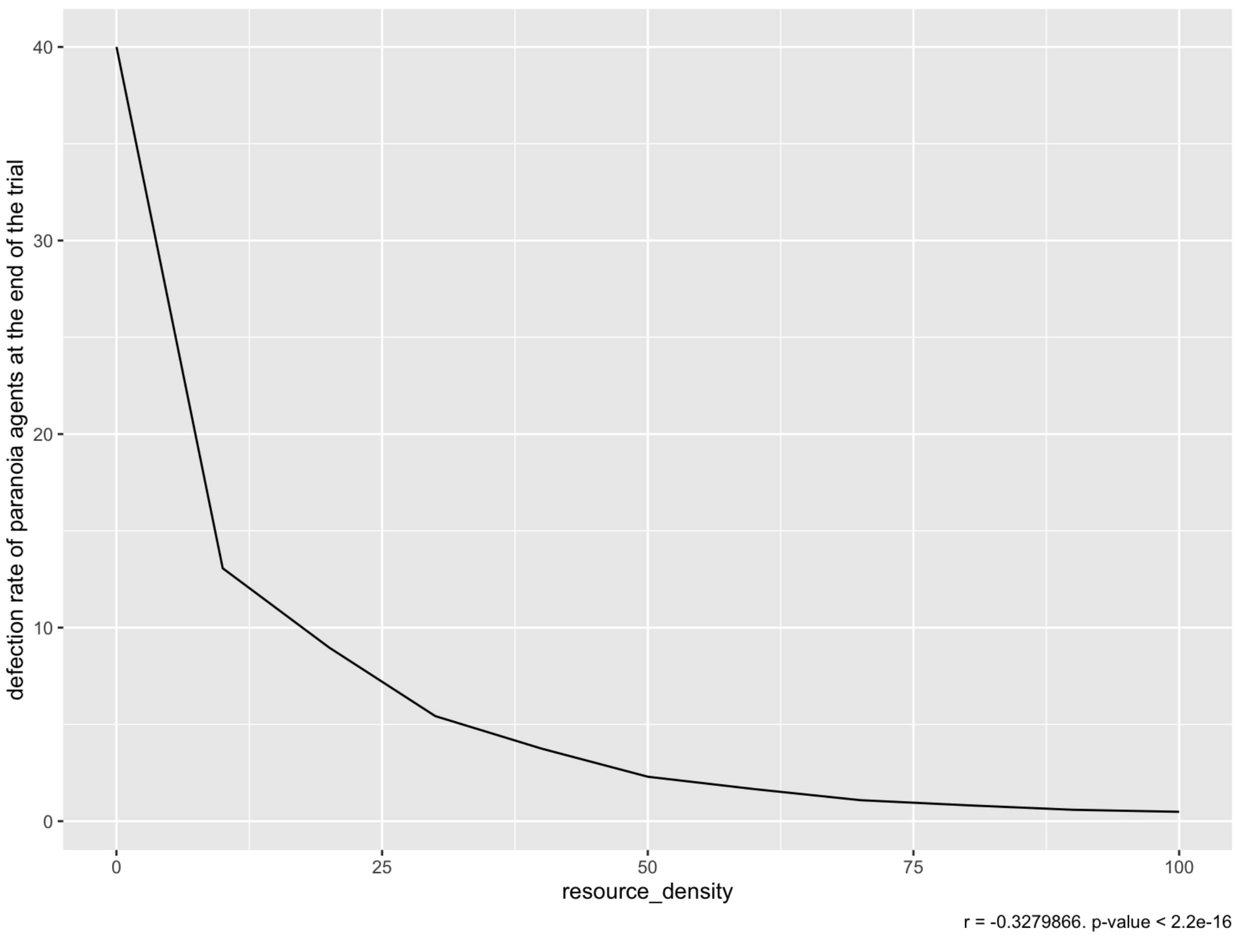
Note: (Outcome written as (Turtle, Partner)). Turtle is synonymous with Agent.

Appendix B

The Graphs that correspond to the Baseline Experiment Results

Figure 1

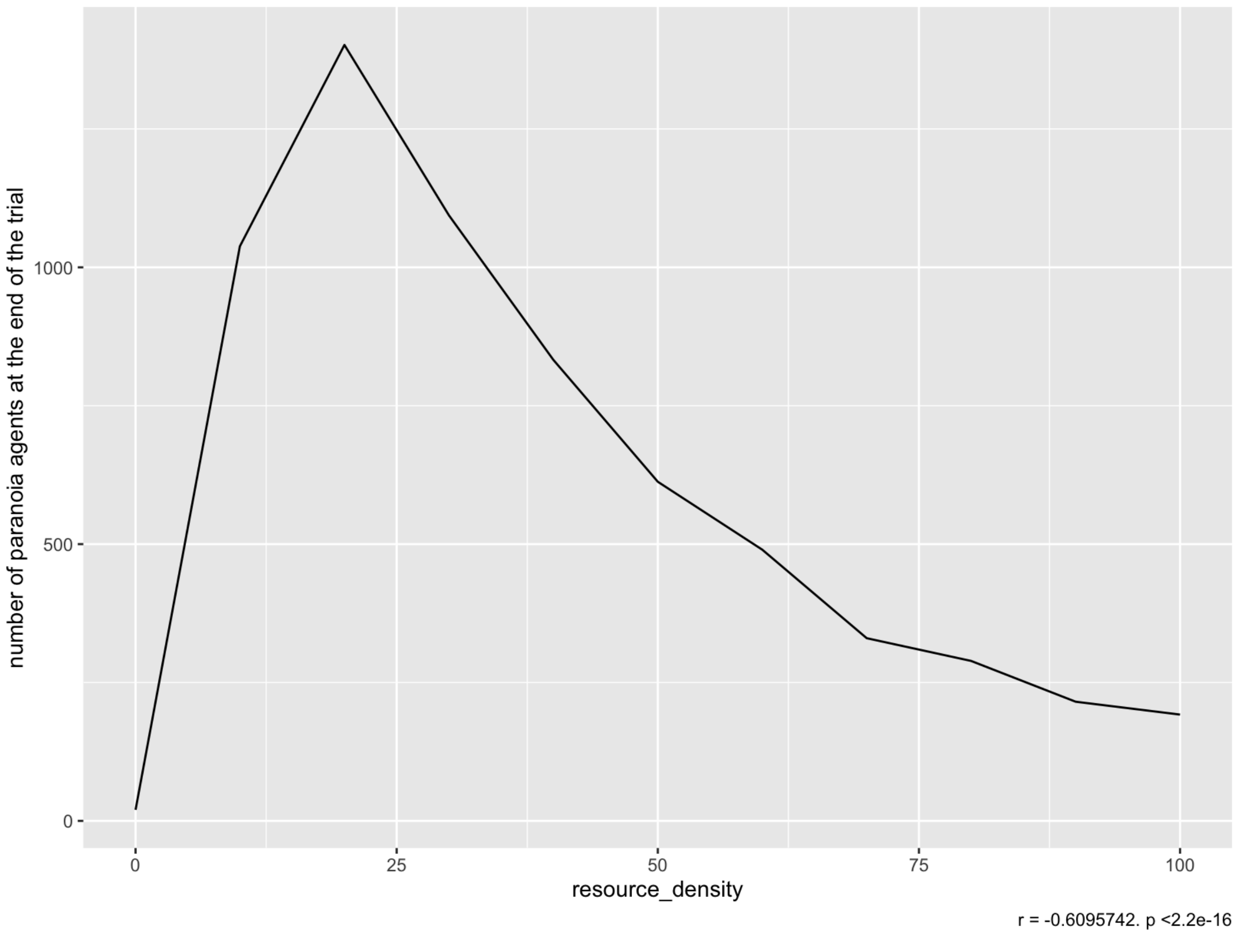
Graph Of The Average Defection Rate Of Paranoia Agents At The End Of The Trial At Each Resource Density



Note: The baseline experiments looked at the correlation between paranoid behavior and resource density without the effect of crime. Resource densities increased in 5% increments. Ten trials were conducted at each resource density; the value presented at each resource density is averaged across the 10 trials and across paranoia agents at that trial.

Figure 2

Graph of Average Number of Paranoia Agents at the End of the Trial Against varying Resource Densities in the Baseline Experiment



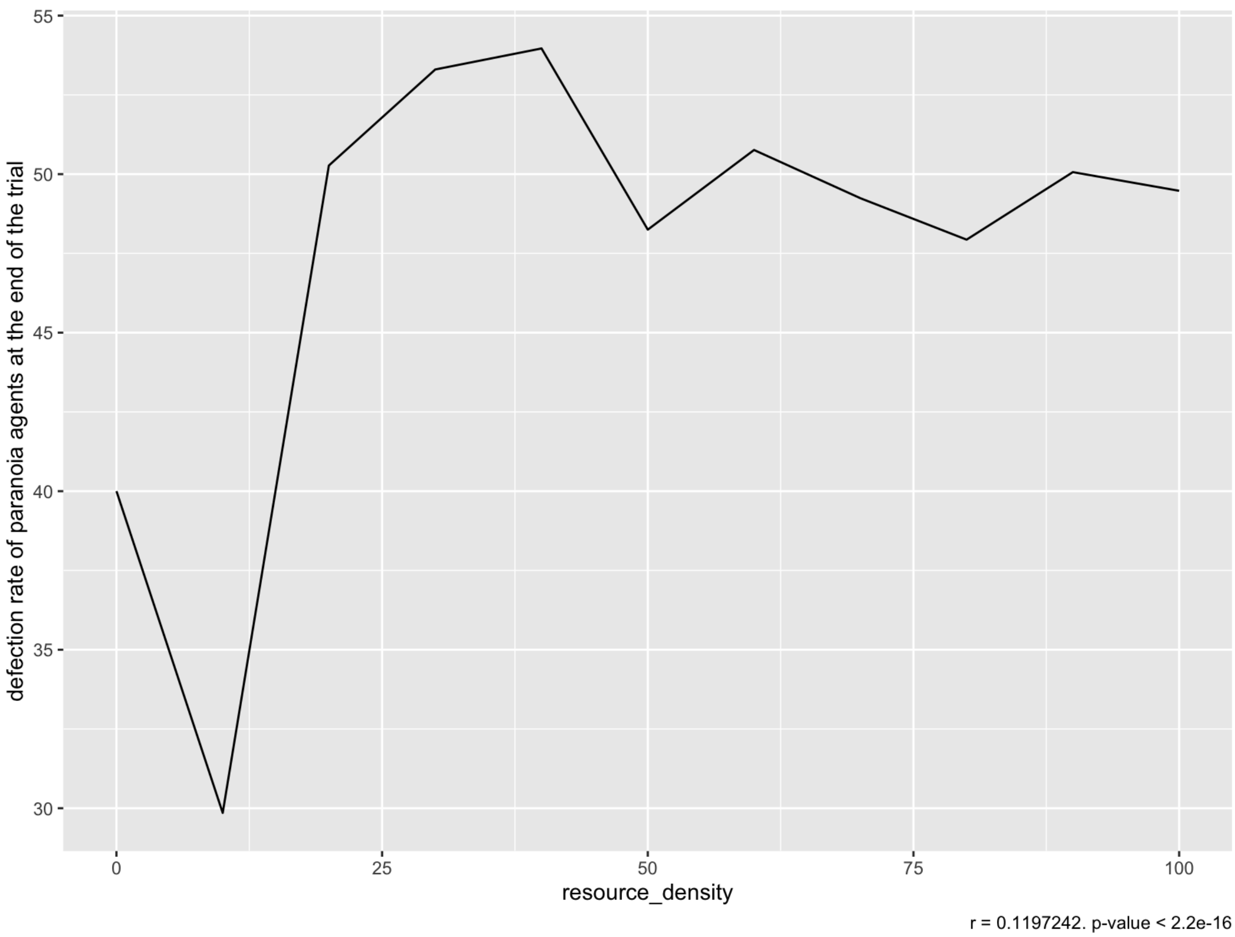
Note: The baseline experiments looked at the correlation between paranoid behavior and resource density without the effect of crime. Resource densities increased in 5% increments. Ten trials were conducted at each resource density; the value presented at each resource density is averaged across the 10 trials and across paranoia agents at that trial.

Appendix C

The Graphs that Correspond to the Environmental Experiment

Figure 3

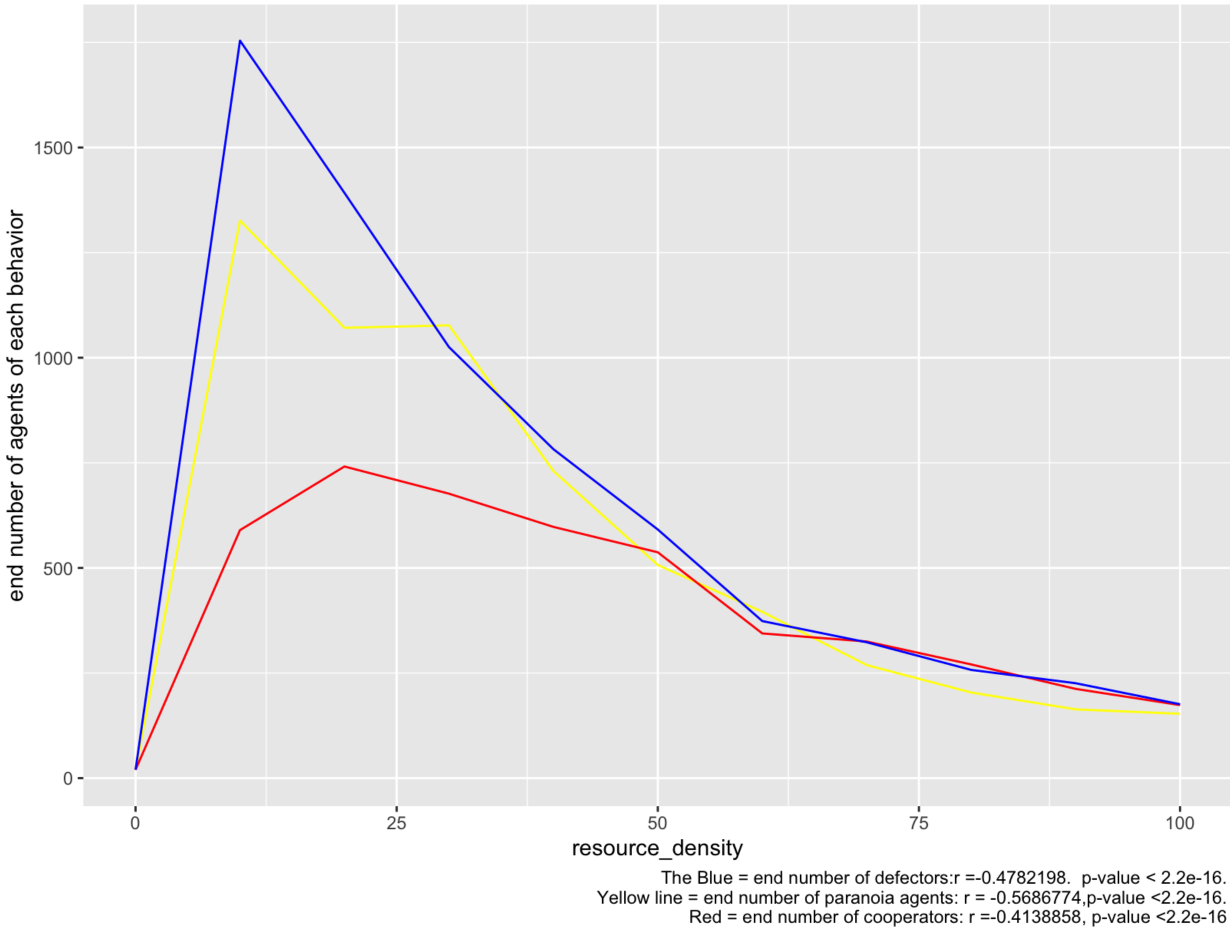
Average Defection Rate of Paranoia Agents at the End of the Trial Across Resource Densities in the Environmental Experiment.



Note: The environmental experiments include the addition of crime. Ten trials were conducted at each resource density; the value presented at each resource density is averaged across the 10 trials and across paranoia agents at that trial.

Figure 4

Count of Defectors, Cooperators and Paranoia Agents at the End of the Trial in the Environmental Experiment, Across Resource Densities



Note: The environmental experiments include the addition of crime. Ten trials were conducted at each resource density; the value presented at each resource density is averaged across the 10 trials and across paranoia agents at that trial.

Appendix D

A Table that presents the Results of the Combined Experiment.

Table 3

The Results of the Combined Experiment, at 0%, 25%, 50%, 75% and 100% resource density.

	Lowest average defection rate, size of defector population	Highest average defection rate, size of defector population	Smallest average population size, size of defector population	Largest average population size, size of defector population
0% resource density	40%, 0	40%, 0	20, 0	20, 0
25% resource density	0%, 0	55%, 19	1000, 19	1600, 3
50% resource density	0%, 0	55%, 19	450, 20	700, 0
75% resource density	0%, 0	50%, 19	220,15	320, 4
100% resource density	0%, 0	50%, 20	150, 19	200, 3

Note: This table shows the results for the combined experiment which modified both defectors and resources