A Comparative Analysis of Interventions on Social Prejudice Across Different Environments: A Multi-Agent Simulation Using NetLogo

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Abstract

Social prejudice is one of the leading factors in many of the worst conflicts worldwide. Intervening is sometimes possible, however. Choosing the right intervention for specific environments remains a challenge for many politicians and researchers. In this paper we analyze 6 intervention methods - legal policy, diversity training, community events, economic incentives, resource incentives and youth socialization - in 3 environments – totally segregated, partially segregated and mixed, and compared their effectiveness.

Keywords: sociology; experiment; prejudice; interventions; prejudice

Introduction

Throughout history, humans tended to surround themselves like-minded individuals, to improve survival rates among the group. As societies grew, polarization increased with it (Xu, 2023). Today, connecting diverse groups to combat violence caused by polarization remains important. (Smidt, H. M., 2020).

For the purposes outlined in this paper, prejudice and polarization can be considered the same (Bizumic, 2015; Bramson et al., 2017). In recent years, many new local conflicts have arisen because of prejudice. These lie in varied factors, including differences in economic status, political beliefs, and culture (Stewart, Frances 2002).

Prejudice, or implicit bias, has caused systemic inequality, especially in interpersonal relations and systems. It causes people to be treated in unfair ways. Examples are the apartheid in South Africa, or the differences in education and economic status for black people in the US (Valentino, 2013).

Recent events may be even more telling, with the Israël-Palestine conflict being attributed to prejudice (The Carter Center., 2003; Bramson A, 2017), as well as the Russia-Ukraine conflict (Pawłuszko, T., 2023).

This study attempts to address the following questions:

- To what degree can interventions such as community events or economic incentives lessen prejudice and develop cooperation between groups?
- How do personal factors such as age, economic status and group identity interact in geographical and social environments in a way that affects prejudice levels and cooperation strategies in society?

This approach shows how interventions influence social prejudice and cooperation and advance towards reducing social boundaries.

Model description and methods

Agent types and properties

This study builds on Hammond and Axelrod's (2006) Ethnocentrism model, simulating six interventions across three environments using NetLogo.

Segregated Environment (0)

In the first environment, there is a high degree of segregation, with a correspondingly high baseline prejudice value, with minimal interaction between groups (blue square slightly in the pink region in [Image 1]). Agents are confined to their colored areas. Movement between areas is extremely limited.

Mixed Environment (1)

With only shared space in which the agents operate, segregation is removed entirely. Agents move freely throughout the area. No association between groups and regions exists, which results in more inter-group interactions.

Partially Segregated Environment (2)

This environment represents nation-states with various kinds of distance between them, represented by physical distance in our model. The regions per agent type are clustered and separated by neutral area (distance). 70% of agents are in their own zones, but 30% have freedom to move beyond it (see the black stars in [Image 3]).

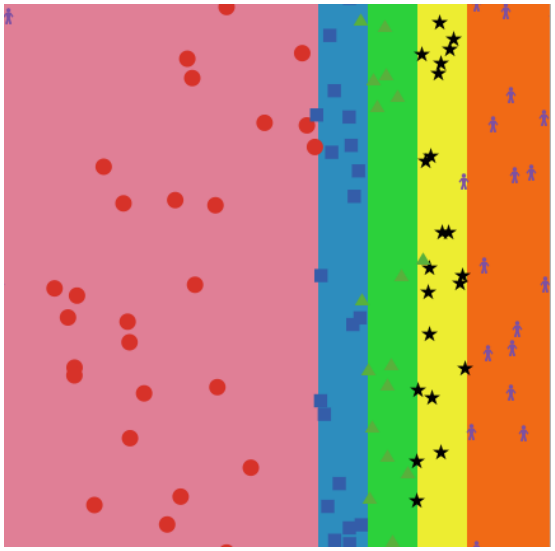


Image 1: Segregated Environment (0)

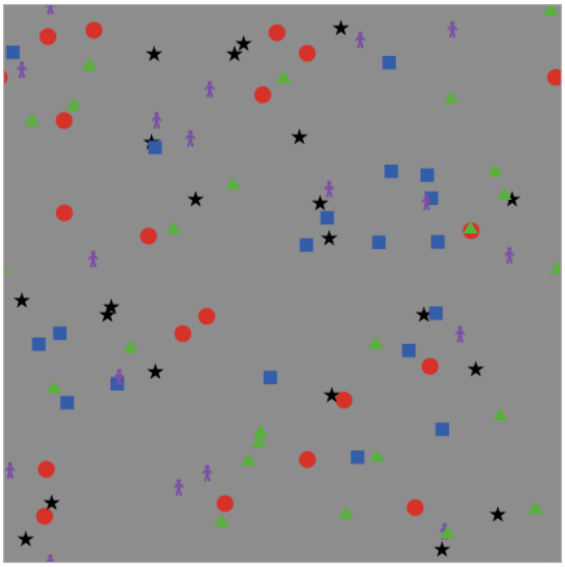


Image 2: Mixed Environment (1)

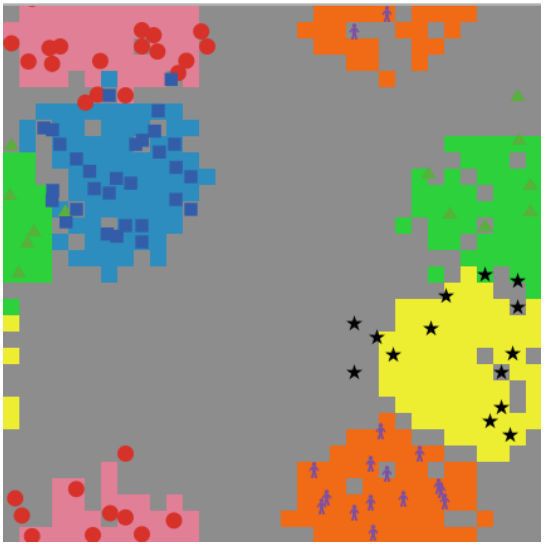


Image 3: Partially Segregated Environment

The environments

In the environment, gray area represents neutral space. In [Table 1] the agents and their areas are noted.

Group	Color & Shape	Area
A	Red Circle	Pink
B	Blue Square	Light Blue
C	Green Triangle	Lime
D	Black Star	Yellow
E	Violet Person	Orange

Table 1: Colors, Shapes and Areas per Group

The interface

The interface ([Image 4]) consists of some components, described in [Table 2]

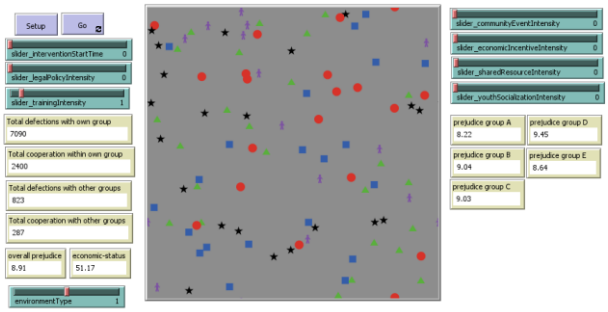


Image 4: The interface

Environment Field	The environment field is visible in the middle and displays the current state of the agents. The Setup and Go buttons prepare and run the model.
Intervention start time slider	This slider is constant and set to 0. It is not used in this paper.
Environment type slider (0, 1, 2)	This slider allows switching between environments.
Counters of defection and cooperation for own and other agent interactions	These four monitors show the number of defections or cooperations between same- or different-colored agents
Prejudice monitors	Overall prejudice displays the average prejudice level among all agents, in

	percentages. The prejudice of group A / B / C / D / E monitors show prejudice per group.
Economic status monitor	This monitor shows the average agent's economic status.
Intervention sliders	These 6 sliders correspond to the intensity at which each intervention is applied. These correspond to the interventions described below. Each slider ranges from 0 to 10, indicating no, up to 100% strength intensity.

Table 2: The interface

Legal policy Intervention

The first intervention we decided to investigate was a law-and-policy-based intervention. Curry & Klumpp (2009) show legal interventions can inherently include social prejudice (racial or economical). The Migration Policy Group (2003) argues that non-discrimination clauses in legislation are a good method of combatting racism, an argument that is further reinforced in Clark's work (2022).

This intervention causes agents with a high prejudice level (over 50), to have their prejudice directly reduced by a hundred percent, divided by the intensity of the intervention. The exact implementation of each kind of legislation and their effect on the behavior of human beings is not researched here.

Diversity Training Intervention

To increase understanding of for other (segregated) groups, training has the potential to help (Devine, 2022; Nnawulezi, Ryan & O'Connor, 2016) Hence, we include prejudice training.

This training directly reduces prejudice of all agents. The intensity of the training is the percentage by which the prejudice is decreased (intensity of one, means an agent with 50% prejudice has 49.5% prejudice after each training).

Community-Event Intervention

Scacco & Warren (2018) experimentally showed that social contact between segregated groups reduces discriminatory behavior.

Community events are run with all agents in a single-colored area. They will participate in the event, and their prejudice is reduced in percentage, by the intensity of the intervention.

The more diverse the agents in the area are, the more effective the event becomes. Specifically, for each environment the prejudice is reduced by an additional modifier * the intensity * the amount of different group agents in a radius of 3 of the current agents. For environment 0 the modifier is 0.3, for environment 1 this is 2.0, and for environment 2 this is 1.0.

Economic Incentives Intervention

Higher socio-economic status (education level, income, and social class) is associated with lower levels of prejudice (Birtantie, 2021). Economic incentives to uplift lower-status individuals within society can improve social relationships and prejudice against other groups; since they become more similar (in a non-compulsory manner) (Clark, 2022).

Both authors note that incentives should focus on culture versus economic fear. However, since culture is much more difficult to model, we focus exclusively on economic incentives. Since the relation between economic status and a reduced prejudice level is established by literature, we model our agents such that when their economic status is below 50, their prejudice is directly reduced when in inverse proportion to their economic status.

Shared Resource Intervention

Berkebile-Weinberg (2022) found – based on 3 independent studies – that scarcity heightens the expression of social prejudice, which is further analyzed by Clark (2022). They note that resource scarcity becomes a "justification" for expressing latent stereotypes.

In our model, we simulate this where all people not in group A (the 'advantaged group' in both environment 1 and 3, where they 'possess' the largest area) will have their prejudice levels decreased directly by percentage of the intensity, because of receiving more

resources. Using the same modifiers as before (environment 0: 0.3, environment 1: 2.0, environment 2: 1.0), the prejudice is reduced additionally in correspondence to the effect in a segregated environment with less access to resources due to space constraints for the minority groups (space here is equivalent to economic opportunities).

Youth Socialization Intervention

Prejudice is mostly taught, and addressing prejudice at an early age is the best method of systemically reducing it, Weiss (2023) showed experimentally with many Israeli students. Making systemic changes early prevents long-term consequences (Clark, 2023).

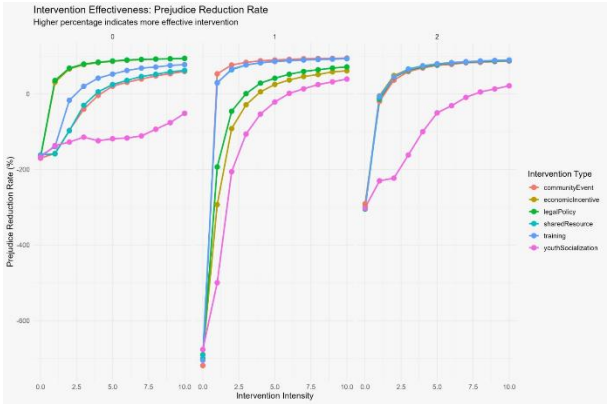
Hence, in our model we target 'young agents' (hatched recently) with direct modifications to their prejudice level. Their prejudice is decreased by the intensity level in percentage. These agents then carry their prejudice for a longer period than the average agent (naturally).

Analysis methods

We utilized NetLogo's BehaviorSpace tool to conduct detailed parameter tests for our study. The simulation explored the impact of the 6 types of interventions each with intervention levels (0-10), combined with 3 environmental settings (0,1,2). Each combination of parameters was repeated in 15 trials, executed over 150 ticks. NetLogo code was modified to generate an organized csv file, which registered metrics such as mean prejudice reduction rates, cooperation rates, and group specific prejudice levels. These files were then exported for analysis in R, whereby data wrangling, aggregation and statistical modeling were applied.

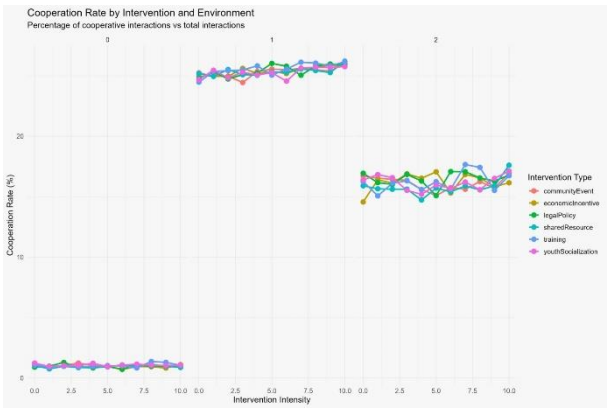
Results

Visual



Graph 1: Intervention Effectiveness: Prejudice Reduction Rate

[Graph 1] illustrates the prejudice reduction rate (%) based on intervention intensities according to intervention type and environment. In environment 0, interventions begin with low prejudice reduction rates, of which some exhibit negative rates (increasing prejudice). There are gradual improvements, with interventions like YouthSocialisation having a consistently poor effect, compounding prejudice at all intensities while others like LegalPolicy, SharedResource and Training show slower growth but achieve moderate prejudice reduction rate at higher intensities.



Graph 2: Cooperation Rate by Intervention and Environment

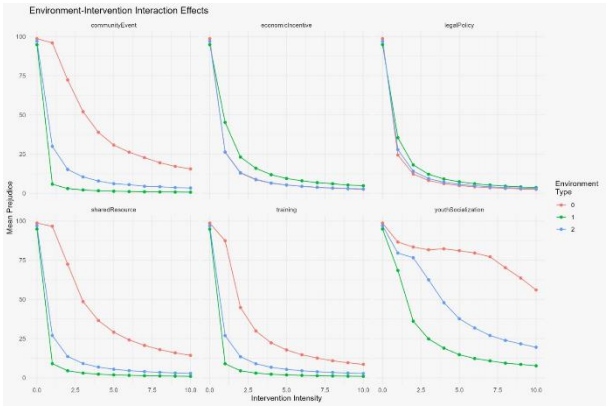
[Graph 2] illustrates the cooperation rate (%) across varying intervention intensities, according to environment and type of intervention.

In environment 0, the cooperation rates remain exceptionally low at all intensities, hardly exceeding 5% even at the highest intensities. This makes it the least conducive for cooperative interactions, regardless of intervention type.

In environment 1, rates of cooperation are higher than in environment 0 and 2. These rates stabilize at about 15-20% after an intervention intensity of 5, thus it is the most cooperative environment across all interventions.

In environment 2, despite being more effective in prejudice reduction (see Graph 1), the cooperation rates in this environment are lower than those in environment 1. This cooperation stabilizes at about 10-15% in higher intensities, which is marginally higher than in environment 0, but lower than in environment 1.

Cooperation rates improve slightly with an increase in intervention intensity, however there is no rapid increase across any intervention or environment type.



Graph 3: Environement-Intervention Interaction Effects

[Graph 3] illustrates the mean prejudice level against intervention intensities, according to intervention and environment type.

In environment 0, interventions are the least effective. The prejudice reduction is slower, with mean prejudice levels staying higher across all intensities. At maximum intensities, YouthSocialisation fails to bring mean prejudice below 50%. Economic Incentive and Shared Resource achieve moderate reductions albeit being less effective than in other environments.

In environment 1, interventions perform better, with rapid reductions in mean prejudice with an increase in intensity. Shared Resource, Economic Incentive and Training show rapid reductions, with prejudice at 0 at maximum intensity. The YouthSocialisation falls short but shows improvement compared to environment 0.

In environment 2, prejudice reduction is highest. All interventions bar YouthSocialisation display near-zero mean prejudice at low intensities. There is a narrower gap between interventions here, as YouthSocialisation performs better than in other environments.

Statistical Analysis

ANOVA and Posthoc Tests

A factorial ANOVA test was conducted to determine the effect of intervention type, intervention intensity and environment type on the dependent variable (mean prejudice). The results determined:

The effect of intervention type, $F(5) = 172597.51$, $p < 0.001$. This shows that it had a statistically significant effect on mean prejudice levels.

Intervention intensity, $F(1) = 678.96$, $p<0.001$ also had a statistically significant effect on mean prejudice levels overall.

The environment type, $F(2) = 80.03$, $p<0.001$ showed statistical significance in its effect on mean prejudice levels overall.

The interaction between intervention type and intervention intensity was also significant, $F(5) = 898.26$, $p<0.001$. Also, between intervention type and environment type there was a statistically significant interaction, $F(10) = 43025.22$, $p<0.001$.

The results from the ANOVA test show that the effects of interventions on the mean prejudice level were affected by both the intervention intensity and the environment they were conducted within.

Posthoc comparisons, specifically Tukey's Honest Significant Difference (HSD) showed the following:

Community Event interventions showed significantly higher effects on prejudice means than any of the other interventions. Economic, $\Delta = 29.01$, $p < 0.001$. Legal Policies, $\Delta = 29.01$, $p < 0.001$). Shared Resources, $\Delta = 1.35$, $p < 0.001$). Training, $\Delta = 12.06$, $p < 0.001$. Youth Socialization, $\Delta = -33.67$, $p < 0.001$. These results also varied per environment as further reinforced by the ANOVA test. Therefore, it highlights the importance of tailoring interventions to the type of environment they are being implemented in.

Discussion and conclusions

The results of our study show the role of interventions in prejudice reduction and development of cooperation. Environment 0 was highly segregated and showed the most resistance to change; interventions showed limited effectiveness. This coincides with prior research that suggests that deep-seated segregation heightens prejudice, limiting positive cross-group interaction (Stewart, 2002). Environment 1's structure supported higher cooperation and significant prejudice reductions, highlighting cross group interaction importance in reducing discriminatory behavior (Scacco and Warren, 2018).

In terms of interventions, SharedResource and EconomicIncentive were effective at reducing prejudice in all environments, matching studies associating resource equity and socio-economic improvement to reduced bias (Birtantie, 2021; Berkebile-Weinberg, 2022). The low output of YouthSocialisation, especially in segregated environments, displays the challenges of addressing prejudice exclusively via early interventions without greater system reforms. This supports evidence suggesting that institutional roadblocks often limit the success of youth-targeted interventions (Weiss, 2023).

While Environment 2 enabled near-zero prejudice levels at higher intervention intensities, cooperation rates were lower than Environment 1, suggesting cooperation demands stronger common goals (Bramson et al., 2017).

Despite the observations, several weaknesses demand attention. First, the model assumes linear relationships between intervention intensity and outcomes, which may distort real-world situations. For example, Economic and Training incentives show threshold effects not captured in the simulations. Secondly, the exclusion of cultural and historical factors limits the model's ability to address deep-seated biases or long-term discriminatory patterns. Third, simplified representation of environments ignores factors like migration or political influences which play an increasing influence in modern societal dynamics (Xu, 2023).

Future research should tackle these limitations by integrating advanced representations of social and cultural principles. Furthermore, exploring combinations of interventions like LegalPolicy with SharedResource, could reveal benefits that enhance their collective impact. Extending the model with dynamic environmental conditions like shifting boundaries would also expand its usage in practice.

This study provides a foundation for understanding the relationship between interventions and environment settings, helping researchers and policymakers. Future work could boost efforts to break social barriers and strengthen cohesion in our ever-divided societies if limitations are addressed.

Bibliography

Berkebile-Weinberg, M. M., Krosch, A. R., & Amodio, D. M. (2022). Economic scarcity increases racial stereotyping in beliefs and face representation. *Journal of Experimental Social Psychology, 102*, 104354. https://doi.org/10.1016/j.jesp.2022.104354

Birtantie, C. (2021). *The effect of socio-economic status on anti-immigrant prejudice: A study in the European context* [Master's thesis, Tilburg University]. Tilburg School of Social and Behavioral Sciences. https://doi.org/10.7910/DVN/X8ZRVO

Bizumic, B. (2015). Ethnocentrism. In *Encyclopedia of Psychology* (pp. 533–539). https://doi.org/10.1163/9789004290433

Bleich, E. (2011). Punishing racial discrimination and hate crimes. In E. Bleich (Ed.), *The freedom to be racist?: How the United States and Europe struggle to preserve freedom and combat racism* (pp. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199739684.003.0006

Bramson, A., Grim, P., Singer, D. J., Berger, W. J., Sack, G., Fisher, S., Flocken, C., & Holman, B. (2017). Understanding polarization: Meanings, measures, and model evaluation. *Philosophy of Science, 84*(1), 115–159. https://doi.org/10.1086/688938

Carter Center, The. (2003). *The Israeli-Palestinian conflict: Historical and prospective intervention analyses.* The Carter Center. https://www.cartercenter.org/documents/1435.pdf

Clark, E. C., Cranston, E., Polin, T., et al. (2022). Structural interventions that affect racial inequities and their impact on population health outcomes: A systematic review. *BMC Public Health, 22*, 2162. https://doi.org/10.1186/s12889-022-14603-w

Curry, P. A., & Klumpp, T. (2009). Crime, punishment, and prejudice. *Journal of Public Economics, 93*(1-2), 73–84. https://doi.org/10.1016/j.jpubeco.2008.06.001

Devine, P. G., & Ash, T. L. (2022). Diversity training goals, limitations, and promise: A review of the multidisciplinary literature. *Annual Review of Psychology, 73*, 403–429. https://doi.org/10.1146/annurev-psych-060221-122215

Muis, Q. (2024). "Who are those people?": Causes and consequences of polarization in the schooled society. *Open Press Tilburg University.* https://doi.org/10.56675/tsb.27333853

Migration Policy Group. (2003). *Combating racial and ethnic discrimination: Taking the European legislative agenda further.* Migration Policy Group. https://www.migpolgroup.com/_old/wp-content/uploads/2016/10/81.CombatingRacialandEthnicDiscrimination-TakingtheEuropeanLegislativeAgendaFurther_03.02.pdf

Nnawulezi, N., Ryan, A., & O'Connor, R. (2016). Reducing prejudice within community-based organizations. *Journal of Community Practice, 24*, 182–204. https://doi.org/10.1080/10705422.2016.1157541

Pawłuszko, T. (2023). The conflict between Russia and Ukraine: The causes of the war, security studies and the formation of an epistemic community in Poland. *Bezpieczeństwo: Teoria i Praktyka, 3(LII)*, e-ISSN 2451-0718.

https://doi.org/10.48269/2451-0718-btip-2023-3-001

Scacco, A., & Warren, S. S. (2018). Can social contact reduce prejudice and discrimination? Evidence from a field experiment in Nigeria. *American Political Science Review*, *112*(4), 1–24. https://doi.org/10.1017/S0003055418000151

Smidt, H. M. (2020). United Nations peacekeeping locally: Enabling conflict resolution, reducing communal violence. *Journal of Conflict Resolution*, *64*(2-3), 344–372. https://doi.org/10.1177/0022002719859631

Stewart, F. (2002). Root causes of violent conflict in developing countries. *BMJ (Clinical Research Ed.)*, *324*(7333), 342–345. https://doi.org/10.1136/bmj.324.7333.342

Valentino, N. A., Brader, T., & Jardina, A. E. (2013). Immigration opposition among U.S. whites: General ethnocentrism or media priming of attitudes about Latinos? *Political Psychology*, *34*(2), 149–166. https://doi.org/10.1111/j.1467-9221.2012.00928.x

Weiss, C. M., Ran, S., & Halperin, E. (2023). Educating for inclusion: Diversity education programs can reduce prejudice toward outgroups in Israel. *Proceedings of the National Academy of Sciences*, *120*(16), e2218621120. https://doi.org/10.1073/pnas.2218621120

Xu, C., Li, J., Sun, D., Li, J., Abdelzaher, T., Graham, J., Macy, M., Lebiere, C., & Szymanski, B. (2023). The paradox of information access: On modeling polarization in the age of information. *IEEE Transactions on Control of Network Systems*, *PP*(1), 1–12. https://doi.org/10.1109/TCNS.2023.3330198

Appendix A1: Anova + R Code

https://drive.google.com/drive/folders/1NP_0u9pmWi_UrLz3miL_6dYeIjDBD_Or?usp=drive_link

Appendix A2: NetLogo Code

Click this link to the Code difference between the Ethnocentrism model and our code. Unfortunately, due to inexperience with Git, we could not track everyone's work (Sjoerd's is in the repository under the same link).

This was Nathan's work.

```
breed [people person]

turtles-own [
  group                      ; Group A to F, representing ethnic groups
  prejudice                  ; Prejudice level towards other groups (0 to 100)
  economic-status            ; Economic status of each agent (0-100 scale)
  location                   ; Neighborhood or area where the agent lives
  age                        ; Age for youth socialization
  ptr                        ; Probability to reproduce
  cooperate-with-same?       ; Cooperation strategy with the same group
  cooperate-with-different?  ; Cooperation strategy with other groups
]

globals [
  meet                               ; Total interactions this turn
  meet-agg                           ; Total interactions through the run
  coopown                            ; Cooperation with same group this turn
  coopown-agg                        ; Total cooperation with same group through the run
  coopother                          ; Cooperation with other groups this turn
  coopother-agg                      ; Total cooperation with other groups through the run
  defother                           ; Defection with other groups this turn
  defother-agg                       ; Total defection with other groups through the run
  defown                             ; Defection within the same group this turn
  defown-agg                         ; Total defection within the same group through the run


  interventionStartTime              ; Time when interventions start
  ; Intensity variables for each intervention
  legalPolicyIntensity               ; Intensity of legal and policy reforms
  trainingIntensity                  ; Intensity of diversity/anti-prejudice training
  communityEventIntensity            ; Intensity of community-based events
  economicIncentiveIntensity         ; Intensity of economic incentives
  sharedResourceIntensity            ; Intensity of shared resource management
  youthSocializationIntensity        ; Intensity of youth socialization


  avg-prejudice-group-A
  avg-prejudice-group-B
  avg-prejudice-group-C
  avg-prejudice-group-D
  avg-prejudice-group-E


  current-environment                ; Tracks current environment type
]
```

```
; ------------------------------
; Setup the simulation
to setup
  clear-all
  setup-environment
  setup-variables
  setup-people
  reset-ticks
end


to setup-environment
  if environmentType = 0 [ ; Fully Segregated with vertical stripes
    let region-size floor (max-pxcor / 5)


    ask patches [
      if pxcor < region-size [ set pcolor pink ]
      if pxcor >= region-size and pxcor < region-size * 2 [ set pcolor sky ]
      if pxcor >= region-size * 2 and pxcor < region-size * 3 [ set pcolor lime ]
      if pxcor >= region-size * 3 and pxcor < region-size * 4 [ set pcolor yellow ]
      if pxcor >= region-size * 4 [ set pcolor orange ]
    ]


    ; Place agents strictly in their regions
    ask people [
      if group = "A" [ move-to one-of patches with [pcolor = pink] ]
      if group = "B" [ move-to one-of patches with [pcolor = sky] ]
      if group = "C" [ move-to one-of patches with [pcolor = lime] ]
      if group = "D" [ move-to one-of patches with [pcolor = yellow] ]
      if group = "E" [ move-to one-of patches with [pcolor = orange] ]
    ]
  ]


  if environmentType = 1 [ ; Fully Mixed
    ask patches [ set pcolor gray ]
    ask people [ move-to one-of patches ]
  ]


  if environmentType = 2 [ ; Partial Segregation with natural clusters
    ; Start with all patches gray
    ask patches [ set pcolor gray ]


    ; Create cluster centers for each group
    let cluster-centers sort n-of 5 patches
    let colors (list pink sky lime yellow orange)
    let group-num 0


    ; For each cluster center
    foreach cluster-centers [ center ->
      ; Color a circular region around the center
      let this-color item group-num colors
      ask center [
        ask patches in-radius 6 [ ; Adjust radius as needed
          if random 100 < 90 [ ; 90% chance to be part of cluster
            set pcolor this-color
          ]
        ]
      ]
      set group-num group-num + 1
    ]


    ; Create interaction zones between clusters
    ask patches [
      if count neighbors with [pcolor != [pcolor] of myself] > 2 [
        if random 100 < 30 [ ; 30% chance to become interaction zone
          set pcolor gray
        ]
      ]
    ]


    ; Place agents with mixed strategy
    ask people [
      let target-color ifelse-value (group = "A") [pink]
        [ifelse-value (group = "B") [sky]
        [ifelse-value (group = "C") [lime]
        [ifelse-value (group = "D") [yellow]
        [orange]]]]


      ifelse random-float 100 < 70
        [ move-to one-of patches with [pcolor = target-color] ]
        [ move-to one-of patches with [pcolor = gray] ]
    ]
  ]
end
```

```
; ------------------------------
; Setup variables and agents
to setup-variables
  set meet 0
  set meet-agg 0
  set coopown 0
  set coopown-agg 0
  set coopother 0
  set coopother-agg 0
  set defother 0
  set defother-agg 0
end


to setup-people
  create-people 100 [
    setxy random-xcor random-ycor
    set group one-of ["A" "B" "C" "D" "E"]


    ; Different initial prejudice based on
environment
    set prejudice random-float (
      ifelse-value (environmentType = 0)
        [ 75 ]  ; Higher initial prejudice in
segregated
        [ ifelse-value (environmentType = 1)
            [ 25 ]  ; Lower initial prejudice in
mixed
            [ 50 ]  ; Medium initial prejudice in
partial
        ])


    ; Different economic status distributions
    set economic-status random-float (
      ifelse-value (environmentType = 0)
        [ 100 * (random-float 0.5 + 0.5) ]  ;
Higher inequality in segregated
        [ ifelse-value (environmentType = 1)
            [ 100 ]  ; More equal in mixed
            [ 100 * (random-float 0.7 + 0.3) ]  ;
Moderate inequality in partial
        ])


    set age random 100
    set ptr 0.5


    ; Different initial cooperation strategies
    set cooperate-with-same? (
      ifelse-value (environmentType = 0)
        [ true ]  ; Always cooperate with same
group in segregated
        [ random 2 = 0 ]  ; Random in other
environments
    )


    set cooperate-with-different? (
      ifelse-value (environmentType = 1)
        [ random 2 = 0 ]  ; More likely in mixed
        [ random 5 = 0 ]  ; Less likely in others
    )
  ]
  update-shape
end
```

```
; ------------------------------
; Update shapes dynamically
to update-shape
  ask people [
    if group = "A" [ set shape "circle" set color
red ]       ; Group A → Pink region
    if group = "B" [ set shape "square" set color
blue ]      ; Group B → Sky region
    if group = "C" [ set shape "triangle" set color
green ]   ; Group C → Lime region
    if group = "D" [ set shape "star" set color
black ]       ; Group D → Yellow region
    if group = "E" [ set shape "person" set color
violet ]    ; Group E → Orange region
  ]
end
```

```
; ------------------------------
to go
  ;; Sync sliders to global variables
  set interventionStartTime
slider_interventionStartTime
  set legalPolicyIntensity
slider_legalPolicyIntensity
  set trainingIntensity slider_trainingIntensity
  set communityEventIntensity
slider_communityEventIntensity
  set economicIncentiveIntensity
slider_economicIncentiveIntensity
  set sharedResourceIntensity
slider_sharedResourceIntensity
  set youthSocializationIntensity
slider_youthSocializationIntensity


  ;; Determine if forced interventions are active
  let forced-intervention-active? (
    youthSocializationIntensity > 0 or
    sharedResourceIntensity > 0 or
    communityEventIntensity > 0
  )


  ;; Movement logic for environment 0
  if environmentType = 0 [
    if forced-intervention-active? [
      ;; Apply movement logic based on the active
intervention
      ask people [
        move-based-on-intervention
      ]
    ]
    if not forced-intervention-active? [
      ;; Confine all agents to their assigned
regions
      ask people [
        move-within-region
      ]
    ]
  ]


  ;; Movement for other environments
  if environmentType = 1 [
    ask people [ move-around ]
  ]
  if environmentType = 2 [
    ask people [
      let stay-segregated random-float 100 < 70
      if stay-segregated [ move-within-region ]
      if not stay-segregated [ move-around ]
    ]
  ]


  clear-stats
  ask people [
    interact
    update-prejudice
  ]


  implement-interventions
```

```
  update-stats
  tick
end
```

```
; ------------------------------

to move-based-on-intervention
  ;; Community Events: All agents move visibly
across boundaries
  if communityEventIntensity > 0 [
    let step-size (communityEventIntensity / 10) +
2 ;; Higher intensity = larger steps
    let move-chance communityEventIntensity / 100
;; Higher intensity = more frequent movement
    if random-float 1 < move-chance [
      rt random 360
      fd step-size
      stop
    ]
  ]


  ;; Shared Resources: All agents move visibly
across boundaries
  if sharedResourceIntensity > 0 [
    let step-size (sharedResourceIntensity / 10) +
2 ;; Higher intensity = larger steps
    let move-chance sharedResourceIntensity / 100
;; Higher intensity = more frequent movement
    if random-float 1 < move-chance [
      rt random 360
      fd step-size
      stop
    ]
  ]


  ;; Youth Socialization: Only agents under 18 move
  if youthSocializationIntensity > 0 and age < 18 [
    let step-size (youthSocializationIntensity /
10) + 2
    let move-chance youthSocializationIntensity /
100
    if random-float 1 < move-chance [
      rt random 360
      fd step-size
      stop
    ]
  ]


  ;; Agents not affected by active interventions
stay within their region
  move-within-region
end
```

```
;; Modified move-within-region procedure to
differentiate behavior
to move-within-region
  let current-region-color
    ifelse-value (group = "A") [pink]
    [ifelse-value (group = "B") [sky]
    [ifelse-value (group = "C") [lime]
    [ifelse-value (group = "D") [yellow]
    [orange]]]]


  ;; Different behavior based on environment type
  if environmentType = 0 [
    ;; Strictly enforce region boundaries
    if pcolor != current-region-color [
      move-to one-of patches with [pcolor =
current-region-color]
    ]
    ;; Very limited movement within region
    rt random 30
    fd 0.5
  ]


  if environmentType = 2 [
    ;; Allow some boundary crossing
    ifelse pcolor = current-region-color [
      ;; When in home region, chance to stay or
leave
      ifelse random-float 100 < 30 [  ;; 30% chance
to try leaving
        let neighbor-regions patch-set patches with
[
          distance myself < 3 and               ;;
Look at nearby patches
          pcolor != [pcolor] of myself and      ;;
Different color than current
          pcolor != black                       ;;
Not a boundary
        ]
        if any? neighbor-regions [
          move-to one-of neighbor-regions
        ]
      ][
        ;; Stay in region but more movement freedom
        rt random 90
        fd 1
      ]
    ][
      ;; When outside home region, higher chance to
return
      if random-float 100 < 60 [  ;; 60% chance to
return home
        move-to one-of patches with [pcolor =
[current-region-color] of myself]
      ]
    ]
  ]
end
```

```
;; Modified movement procedure
to move-around
  if environmentType = 1 [
    ; More random movement in mixed environment
    rt random 360
    fd 2  ; Increased movement distance
  ]
  if environmentType = 0 [
    ; Very limited movement in segregated
environment
    rt random 45  ; Limited turning
    fd 0.5  ; Limited movement distance
  ]
  if environmentType = 2 [
    ; Moderate movement in partially segregated
    rt random 180
    fd 1
  ]
end
```

```
to interact
  let neighbor one-of turtles in-radius 1
  if neighbor != nobody [
    let interaction-group [group] of neighbor
    let interaction-outcome 0 ;; Default outcome is
defection

    ;; Calculate base interaction probability based
on environment type
    let base-interaction-probability 0

    ;; Env 0: Highly segregated - very low
probability of inter-group interaction
    if environmentType = 0 [
      ifelse group = interaction-group [
        set base-interaction-probability 0.9  ;;
High in-group interaction
      ][
        set base-interaction-probability 0.1  ;;
Very low out-group interaction
      ]
    ]

    ;; Env 1: Fully mixed - equal probability for
all interactions
    if environmentType = 1 [
      set base-interaction-probability 0.5
    ]

    ;; Env 2: Partially segregated - moderate
probability differences
    if environmentType = 2 [
      ifelse group = interaction-group [
        set base-interaction-probability 0.7  ;;
Moderate in-group preference
      ][
        ifelse [pcolor] of patch-here = gray [
          ;; In interaction zones, higher inter-
group interaction
          set base-interaction-probability 0.6
        ][
          ;; Outside interaction zones, moderate
inter-group interaction
          set base-interaction-probability 0.3
        ]
      ]
    ]

    ;; Check if interaction occurs based on
probability
    if random-float 1 < base-interaction-
probability [
      ;; Calculate intervention effects
      let intervention-multiplier 1
      if ticks >= interventionStartTime [
        set intervention-multiplier (1 +
          (legalPolicyIntensity / 100 * 0.3) +
          (trainingIntensity / 100 * 0.4) +
          (communityEventIntensity / 100 * 0.3) +
          (economicIncentiveIntensity / 100 *
ifelse-value (economic-status < 50) [0.4] [0.1]) +
```

```
          (sharedResourceIntensity / 100 * 0.3) +
          (youthSocializationIntensity / 100 *
ifelse-value (age < 18) [0.5] [0.1])
        )
      ]

      ;; Environment-specific cooperation effects
      let cooperation-effect
        ifelse-value (environmentType = 0) [
          ifelse-value (group = interaction-group)
[2] [5]  ;; Bigger impact in segregated
        ][
          ifelse-value (environmentType = 1) [
            3  ;; Moderate impact in mixed
          ][
            ifelse-value ([pcolor] of patch-here =
gray) [4] [3]  ;; Enhanced effect in interaction
zones
          ]
        ]

      ;; Determine if cooperation occurs
      ifelse random-float 1 < (base-interaction-
probability * intervention-multiplier) [
        set interaction-outcome 1

        ;; Apply prejudice reduction based on
environment and location
        let prejudice-reduction cooperation-effect
*
          ifelse-value (environmentType = 2 and
[pcolor] of patch-here = gray)
          [1.5]  ;; Enhanced effect in interaction
zones
          [1]

        set prejudice max list 0 (prejudice -
prejudice-reduction)
      ][
        ;; Failed interaction increases prejudice
        let defection-effect
          ifelse-value (environmentType = 0) [2]
          [ifelse-value (environmentType = 1) [1]
[1.5]]

        set prejudice min list 100 (prejudice +
defection-effect)
      ]
    ]

    ;; Update interaction counters
    if interaction-outcome = 1 [
      ifelse group = interaction-group [
        set coopown coopown + 1
      ][
        set coopother coopother + 1
      ]
    ]
    if interaction-outcome = 0 [
      ifelse group = interaction-group [
        set defown defown + 1
      ][
        set defother defother + 1
      ]
    ]
  ]
]end
```

```
to update-prejudice
  ask people [
    ;; Natural prejudice growth varies by
environment
    if random-float 100 < 20 [
      let growth-rate (
        ifelse-value (environmentType = 0) [
          0.8  ;; Higher growth in segregated
        ][
          ifelse-value (environmentType = 1) [
            0.3  ;; Lower in mixed
          ][
            0.5  ;; Medium in partial
          ]
        ]
      )
      set prejudice prejudice + growth-rate
    ]


    if ticks >= interventionStartTime [
      let total-effect 0


      ;; Legal Policy
      if legalPolicyIntensity > 0 [
        let env-multiplier (
          ifelse-value (environmentType = 0) [
            2.0  ;; Most effective in segregated
          ][
            ifelse-value (environmentType = 1) [
              0.5  ;; Less needed in mixed
            ][
              1.0  ;; Medium in partial
            ]
          ]
        )
        set total-effect total-effect +
(legalPolicyIntensity / 100 * 0.3 * env-multiplier)
      ]


      ;; Training
      if trainingIntensity > 0 [
        let env-multiplier (
          ifelse-value (environmentType = 0) [
            0.5  ;; Less effective in segregated
          ][
            ifelse-value (environmentType = 1) [
              2.0  ;; Most effective in mixed
            ][
              1.0  ;; Medium in partial
            ]
          ]
        )
        set total-effect total-effect +
(trainingIntensity / 100 * 0.3 * env-multiplier)
      ]


      ;; Community Events
      if communityEventIntensity > 0 [
        let env-multiplier (
          ifelse-value (environmentType = 0) [
            0.3  ;; Least effective in segregated
          ][
            ifelse-value (environmentType = 1) [
              2.0  ;; Most effective in mixed
            ][
              1.0  ;; Medium in partial
            ]
          ]
        )
        let nearby-diversity length remove-
duplicates [group] of turtles in-radius 3
        set total-effect total-effect +
(communityEventIntensity / 100 * env-multiplier *
(nearby-diversity / 5))
      ]


      ;; Economic Incentives
      if economicIncentiveIntensity > 0 [
        let env-multiplier (
          ifelse-value (environmentType = 0) [
            2.0  ;; Most effective in segregated
          ][
            ifelse-value (environmentType = 1) [
              0.5  ;; Less needed in mixed
            ][
              1.0  ;; Medium in partial
            ]
          ]
        )
        let economic-factor ifelse-value (economic-
status < 50) [1.5] [0.5]
        set total-effect total-effect +
(economicIncentiveIntensity / 100 * 0.3 * env-
multiplier * economic-factor)
      ]


      ;; Shared Resources
      if sharedResourceIntensity > 0 [
        let env-multiplier (
          ifelse-value (environmentType = 0) [
            0.3  ;; Least effective in segregated
          ][
            ifelse-value (environmentType = 1) [
              2.0  ;; Most effective in mixed
            ][
              1.0  ;; Medium in partial
            ]
          ]
        )
        set total-effect total-effect +
(sharedResourceIntensity / 100 * 0.3 * env-
multiplier)
      ]


      ;; Youth Socialization
      if youthSocializationIntensity > 0 [
        let env-multiplier (
          ifelse-value (environmentType = 0) [
            0.7  ;; Less effective in segregated
          ][
            ifelse-value (environmentType = 1) [
              2.0  ;; Most effective in mixed
            ][
```

```
            1.2  ;; Medium-high in partial
          ]
        ]
      )
      let youth-factor ifelse-value (age < 18)
[2.0] [0.1]
      set total-effect total-effect +
(youthSocializationIntensity / 100 * 0.3 * env-
multiplier * youth-factor)
    ]

    ;; Apply total effect
    set prejudice prejudice * (1 - total-effect)
    set prejudice max list 0 (min list 100
prejudice)
  ]
]
end
```

```
; ------------------------------
; Implement all interventions
to implement-interventions
  if ticks >= interventionStartTime [
    ;; Legal and policy reforms apply to all people
with high prejudice
    ask people with [prejudice > 50] [
      set prejudice max list 0 (prejudice * (1 -
(legalPolicyIntensity / 100)))
    ]

    ;; Training can apply to a specific group or
globally
    ask people [
      set prejudice max list 0 (prejudice * (1 -
(trainingIntensity / 100)))
    ]

    ;; Community events occur in specific areas
(lime or yellow patches)
    ask patches with [pcolor = lime or pcolor =
yellow] [
      ask people-here [
        let neighbor one-of other people-here
        if neighbor != nobody and group != [group]
of neighbor [
          set prejudice max list 0 (prejudice * (1
- (communityEventIntensity / 100)))
        ]
      ]
    ]

    ;; Economic incentives target people with low
economic status
    ask people with [economic-status < 50] [
      set prejudice max list 0 (prejudice * (1 -
(economicIncentiveIntensity / 100)))
    ]

    ;; Shared resource management applies to all
groups except A (adjust if needed)
    ask people [
      if group != "A" [
        set prejudice max list 0 (prejudice * (1 -
(sharedResourceIntensity / 100)))
      ]
    ]

    ;; Youth socialization targets people under 18
    ask people with [age < 18] [
      set prejudice max list 0 (prejudice * (1 -
(youthSocializationIntensity / 100)))
    ]
  ]
end
```

```
; ------------------------------
; Reset counters each tick
to clear-stats
  set meet 0
  set coopown 0
  set coopother 0
  set defother 0
  set defown 0
end



; ------------------------------
; Update statistics
; Update statistics
to update-stats
  set meet-agg meet-agg + meet
  set coopown-agg coopown-agg + coopown
  set coopother-agg coopother-agg + coopother
  set defother-agg defother-agg + defother
  set defown-agg defown-agg + defown


  if any? people with [group = "A"] [
    set avg-prejudice-group-A mean [prejudice] of
people with [group = "A"]
  ]
  if not any? people with [group = "A"] [ set avg-
prejudice-group-A 0 ]


  if any? people with [group = "B"] [
    set avg-prejudice-group-B mean [prejudice] of
people with [group = "B"]
  ]
  if not any? people with [group = "B"] [ set avg-
prejudice-group-B 0 ]


  if any? people with [group = "C"] [
    set avg-prejudice-group-C mean [prejudice] of
people with [group = "C"]
  ]
  if not any? people with [group = "C"] [ set avg-
prejudice-group-C 0 ]


  if any? people with [group = "D"] [
    set avg-prejudice-group-D mean [prejudice] of
people with [group = "D"]
  ]
  if not any? people with [group = "D"] [ set avg-
prejudice-group-D 0 ]


  if any? people with [group = "E"] [
    set avg-prejudice-group-E mean [prejudice] of
people with [group = "E"]
  ]
  if not any? people with [group = "E"] [ set avg-
prejudice-group-E 0 ]
end
```

Appendix B: Contributions

Abraham	Came through when drafting the paper. Made a good model for the part he was assigned. Mostly reactive work but delivered.
Arnas	Did some work on a preliminary model. Attended part of the meetings and showed little proactivity (within and outside of meetings). No contributions to writing the paper. Communication was lacking.
Gabriel	Gabriel performed an especially useful literature review and created a preliminary version of the model. He attended all the meetings.
Nathan	All contributions to the model. Performed the tests within R and generated the graphs in the paper. He also wrote a skeleton for the paper and found some references. He participated actively in all meetings.
Sjoerd	He wrote a large part of the paper, made data analysis tools in python, and performed an extensive literature review. Finding useful major papers and most minor (supportive) papers.