

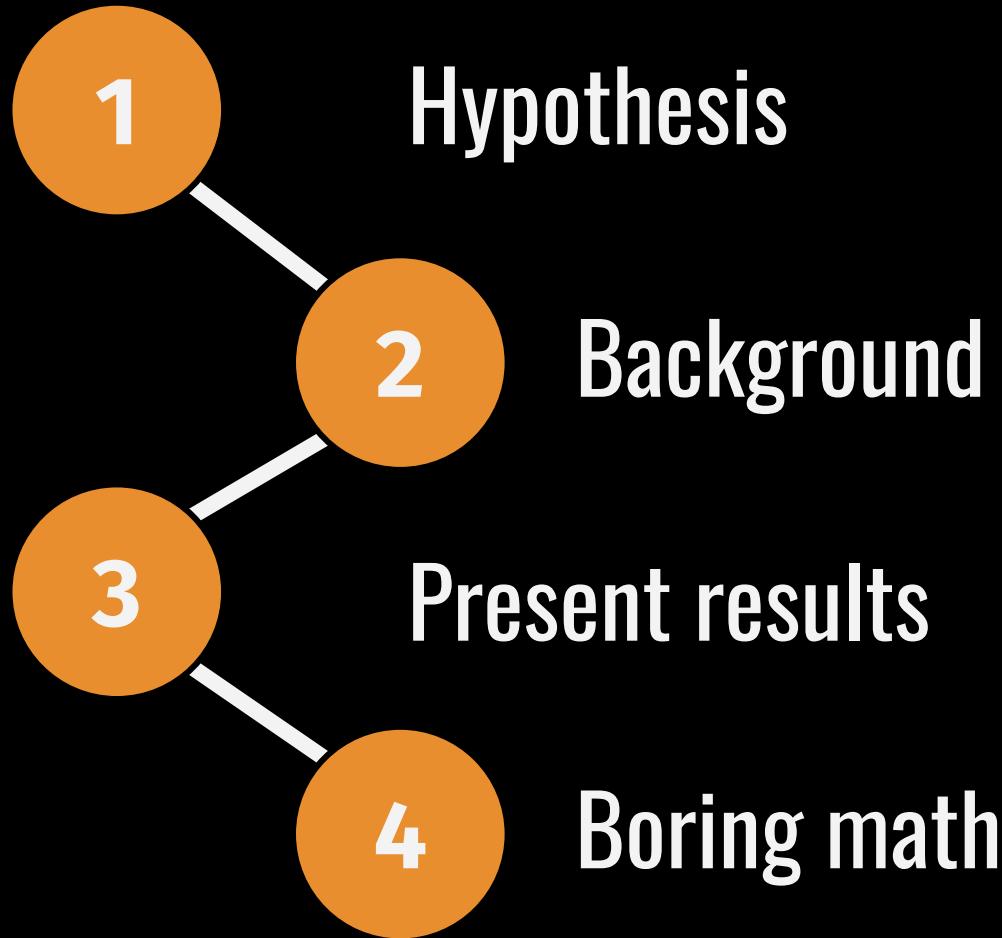


UiT The Arctic University of Norway

# Social network analysis of *Staphylococcus aureus* carriage in a general youth population

Rafael Nozal Cañadas  
HDL Seminar 2021.08.27







Hypothesis



Background concepts



Present results



Boring math

Does alcohol and drugs makes you more popular ?

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Yes; being a total degenerate gives you friends

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Which is the real power of friendship ?

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Which is the real power of friendship ?

Pestilence and diseases

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Pestilence and diseases

What form a strong social cohesion?

Does alcohol and drugs makes you more popular ?

Yes; being a total degenerate gives you friends

Which is the real power of friendship ?

Pestilence and diseases

What form a strong social cohesion?

Total aversion and hate for the opposite sex



Eww!, boys are stupid!



Ugh!, girls are dumb!

Does the social network facilitate the spread of *S.aureus*?

If so, which social factors increases the risk of being a *S. aureus* carrier?

How large is the risk from social influence compared to the biological risk?

Does the social network facilitate the spread of *S.aureus*?

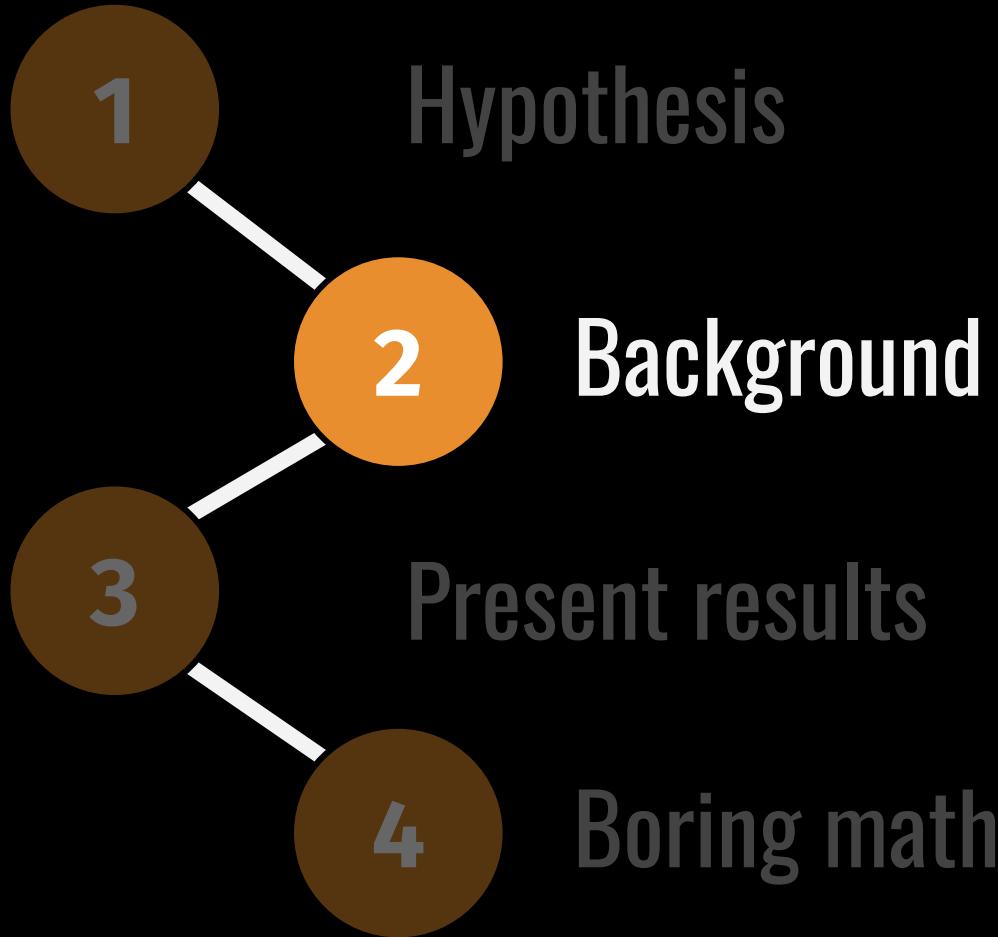
Yes, mostly at school.

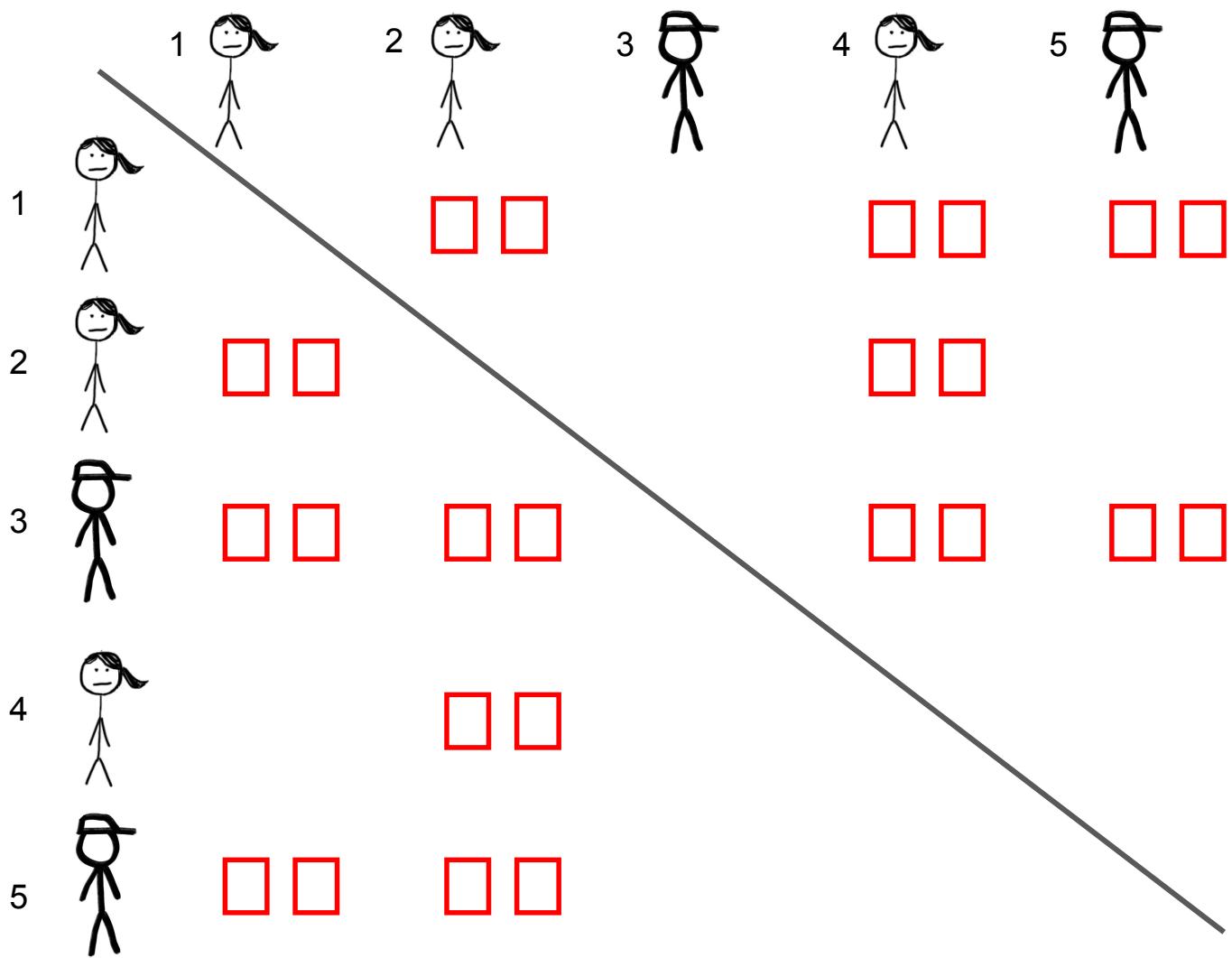
If so, which social factors increases the risk of being a *S. aureus* carrier?

Men by biology. Women by social contact.

How large is the risk from social influence compared to the biological risk?

About 5% risk increase for each additional infected friend.





Are you together...



Physically



School



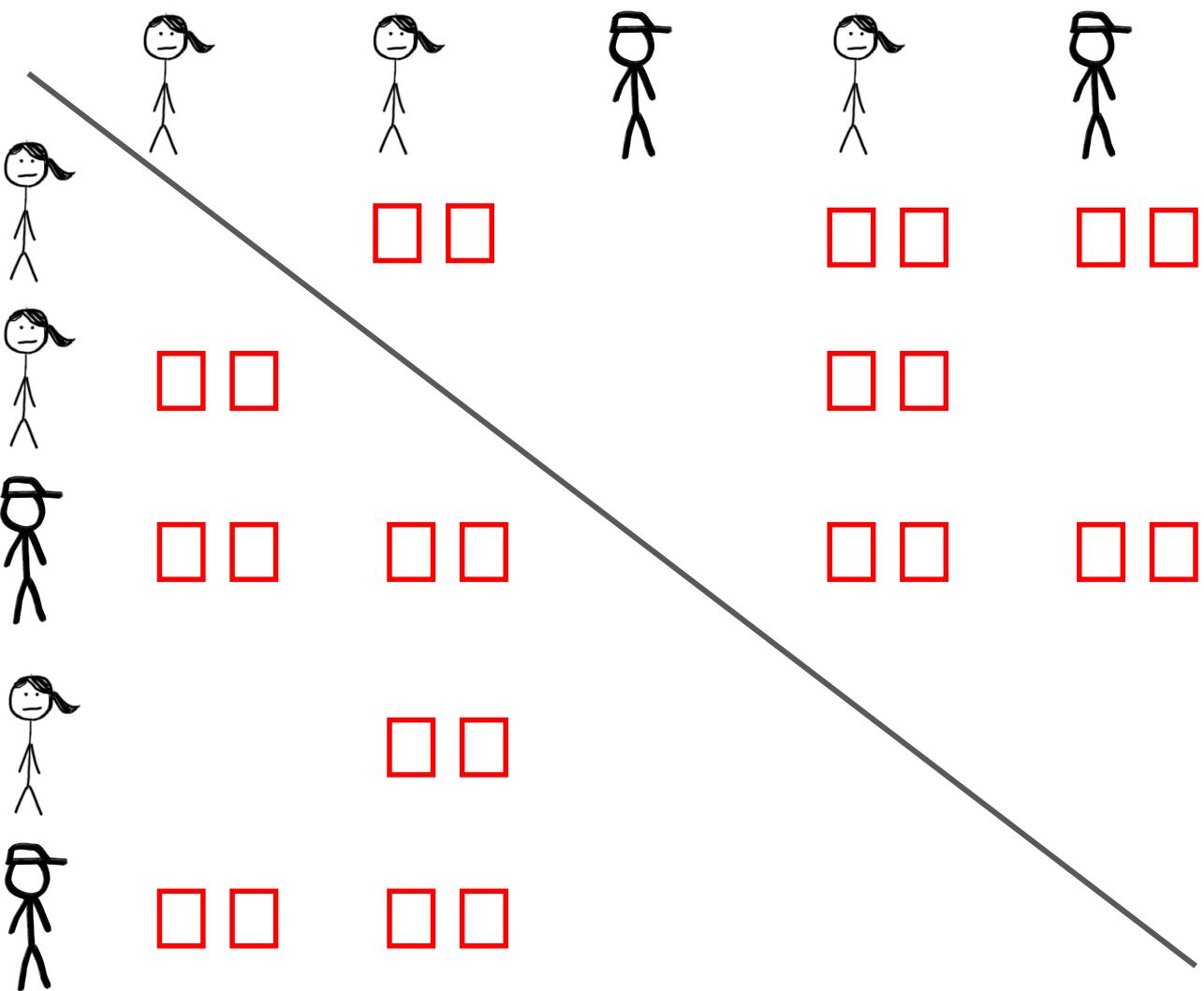
Sports



Home



Other



Are you together...

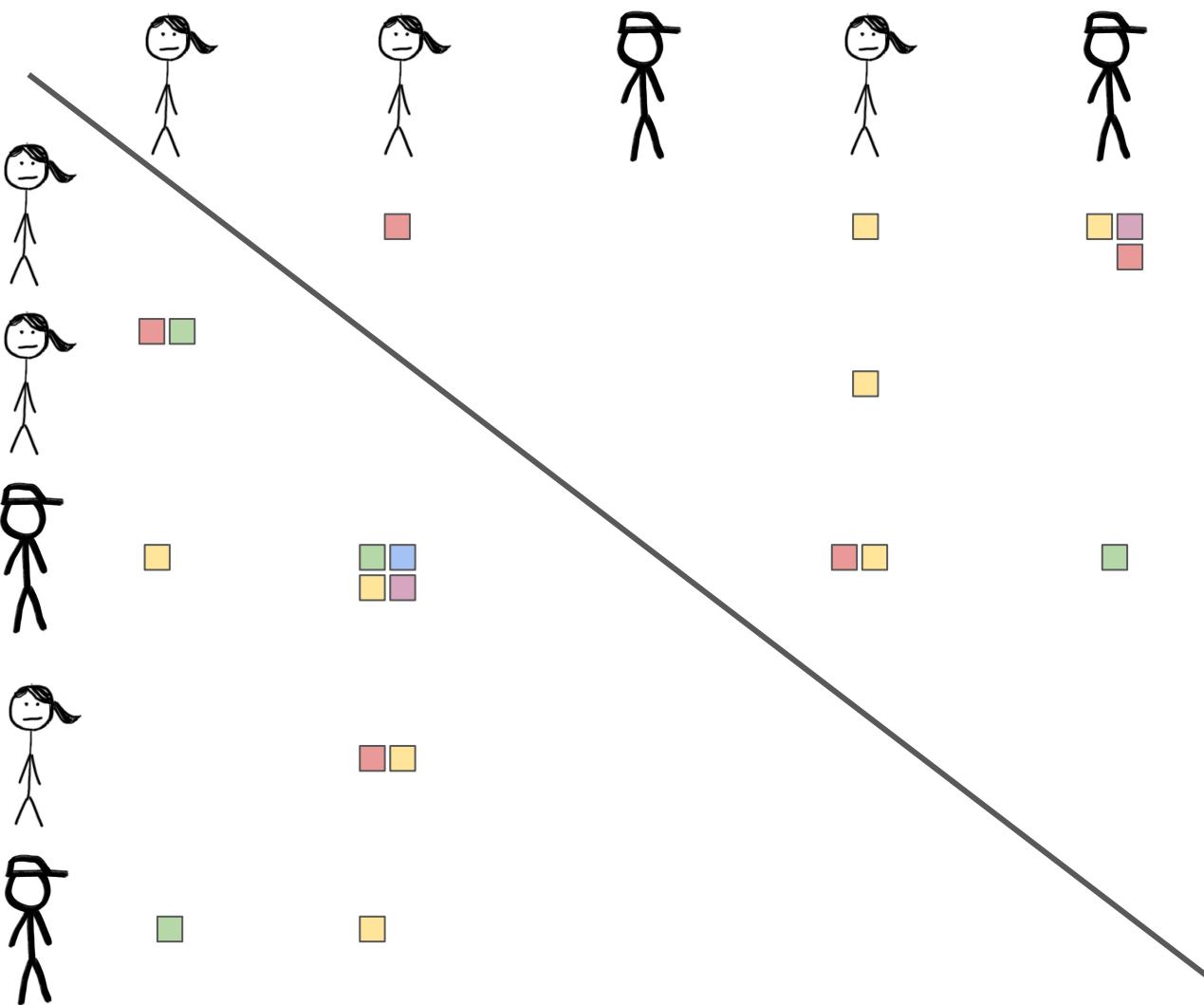
 Physically

 School

 Sports

 Home

 Other



Are you together...

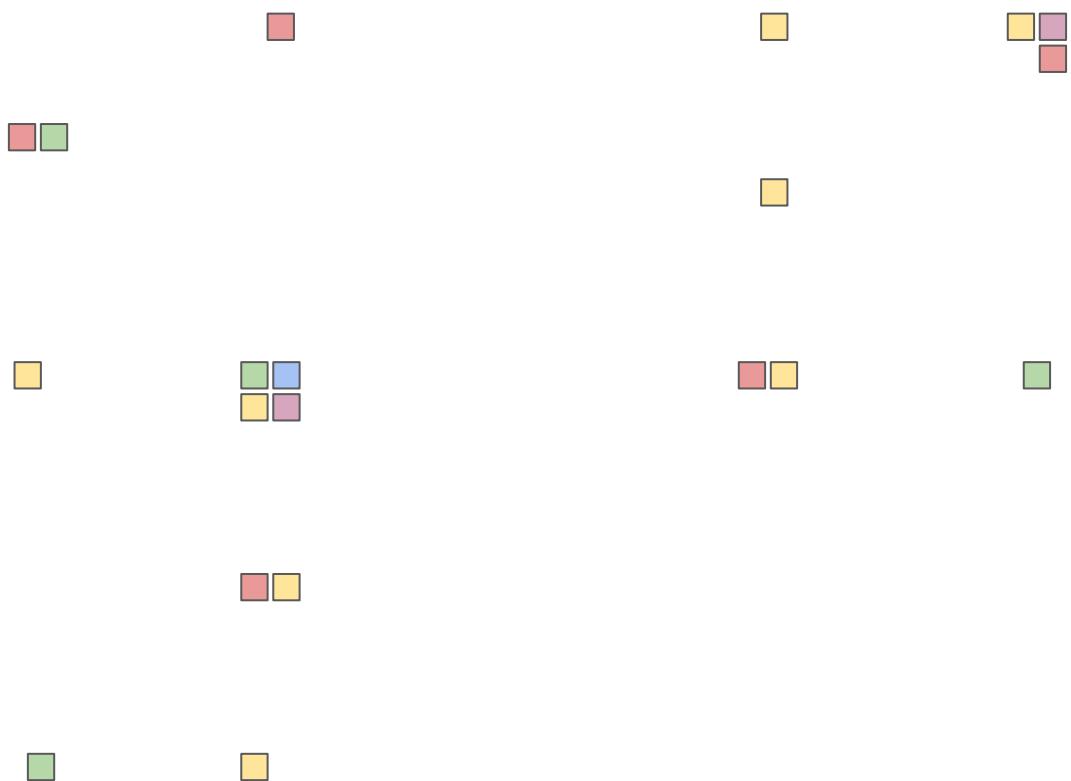
 Physically

 School

 Sports

 Home

 Other



Are you together...

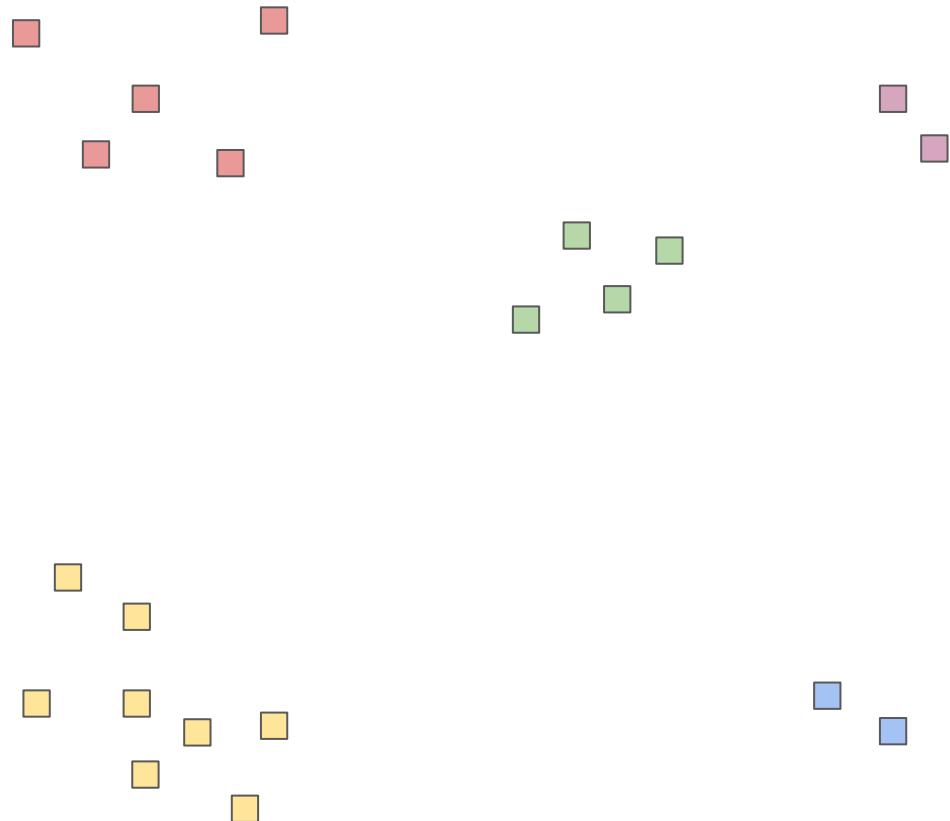
 Physically

 School

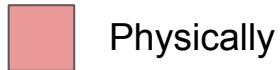
 Sports

 Home

 Other



Are you together...



Physically



School



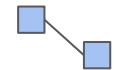
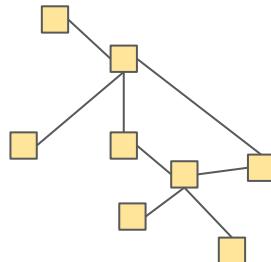
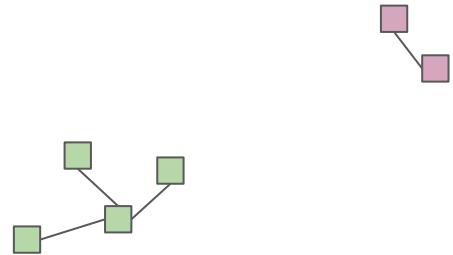
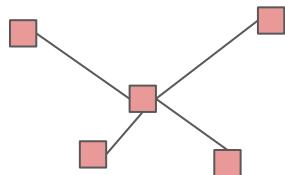
Sports



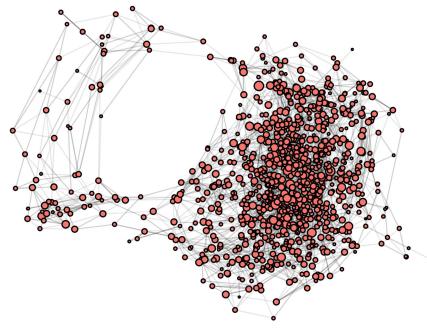
Home



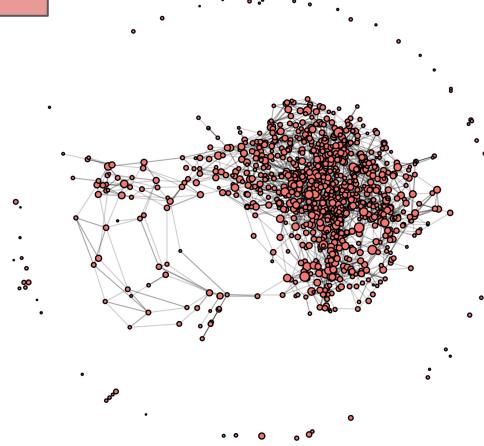
Other



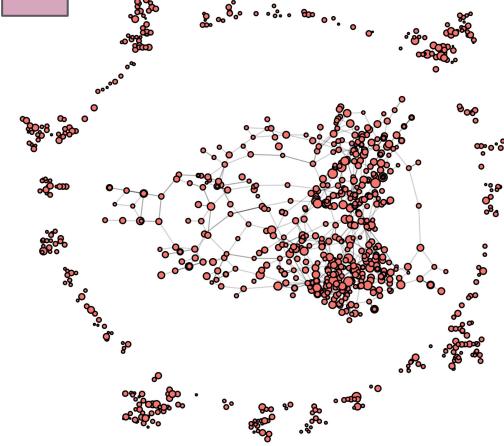
 Overall



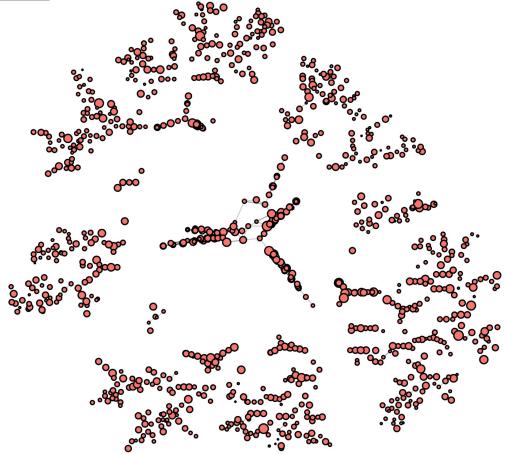
 Physically



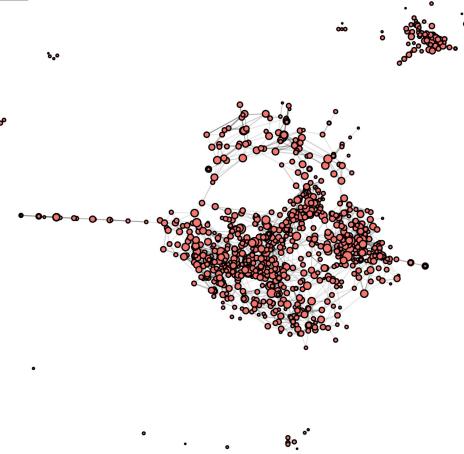
 Other



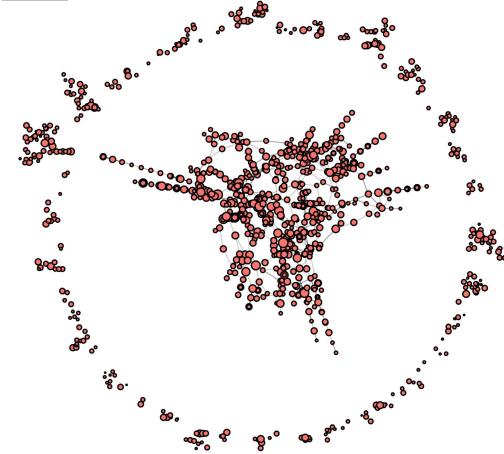
 Sports



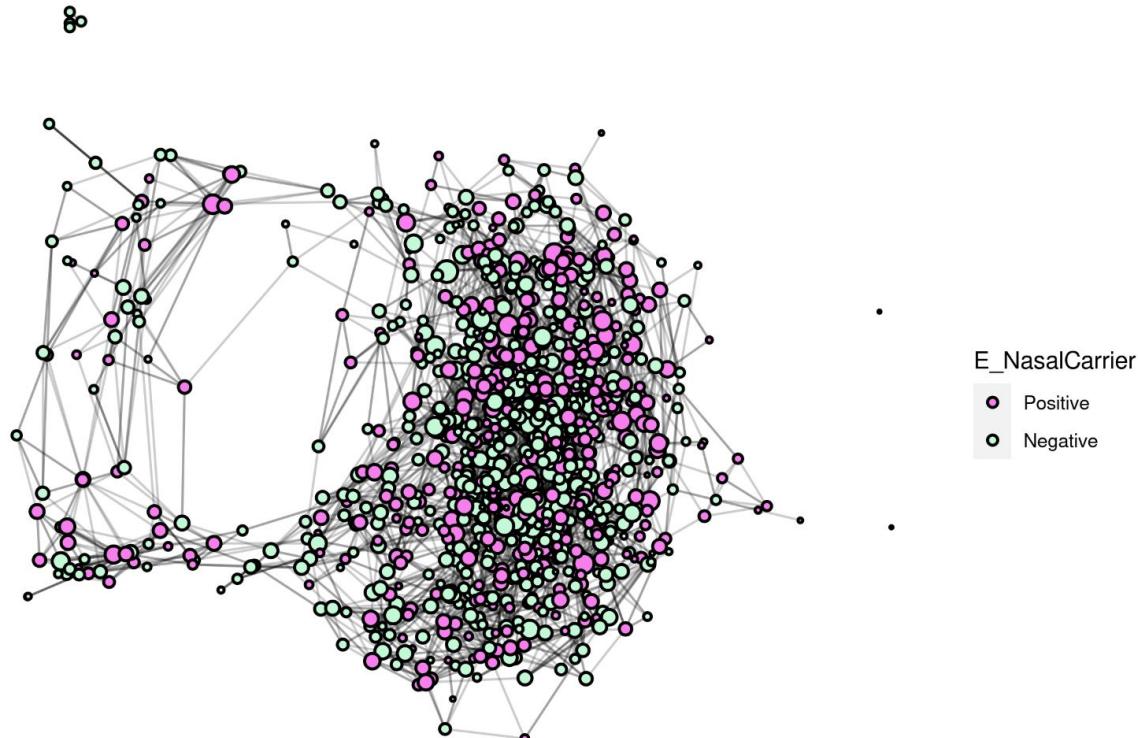
 School



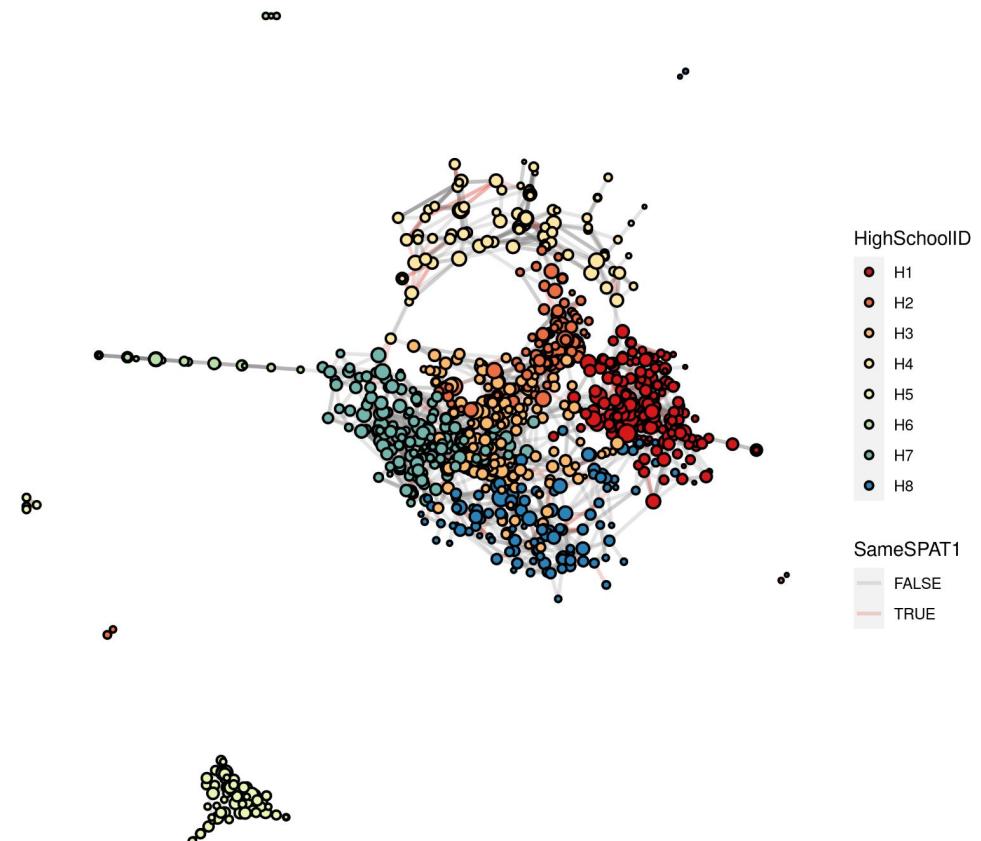
 Home



Overall Network for carrier status  
Size based on number of undirected relationships

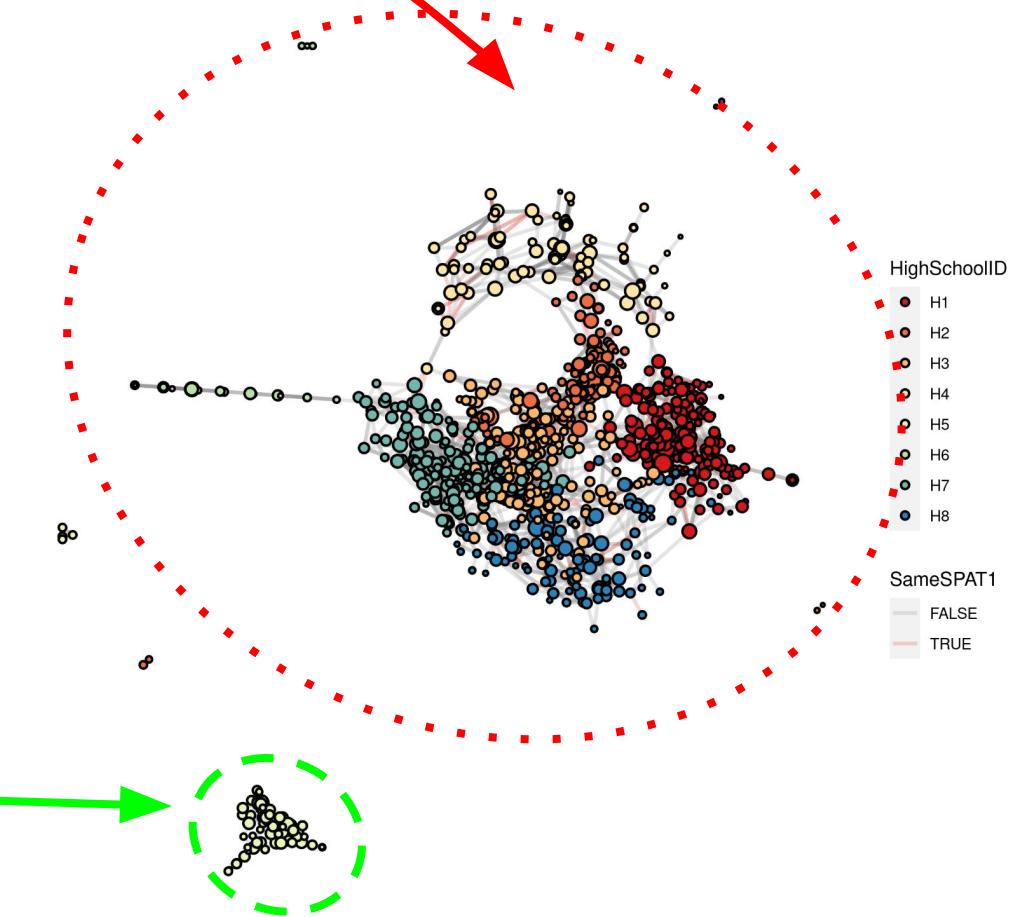


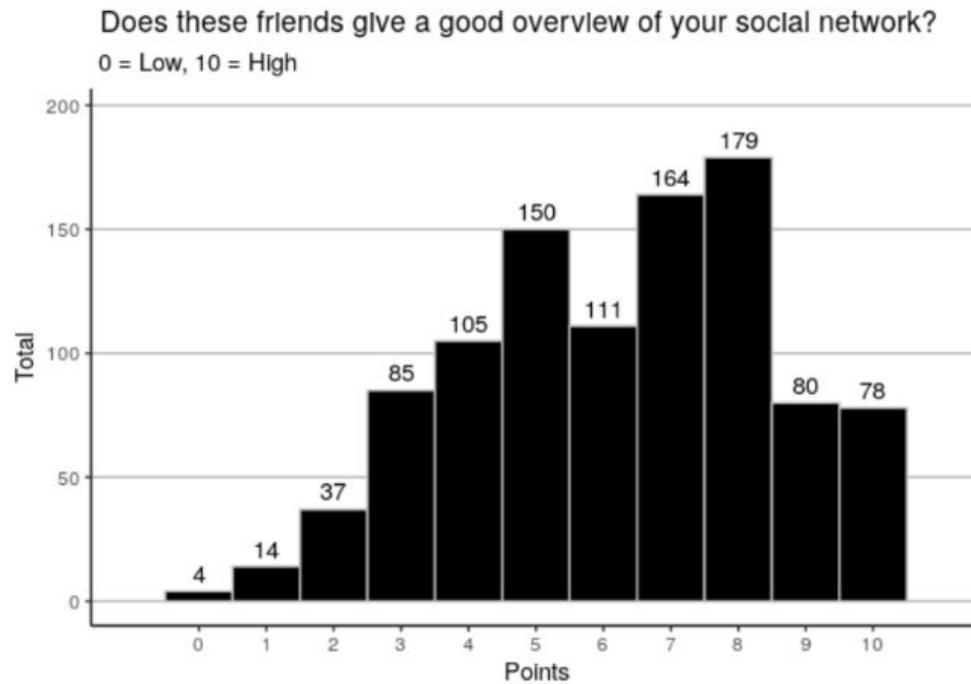
School relationships highlighting highchool in nodes and same SPAT1 in edges.  
Isolated nodes are hidden (21)



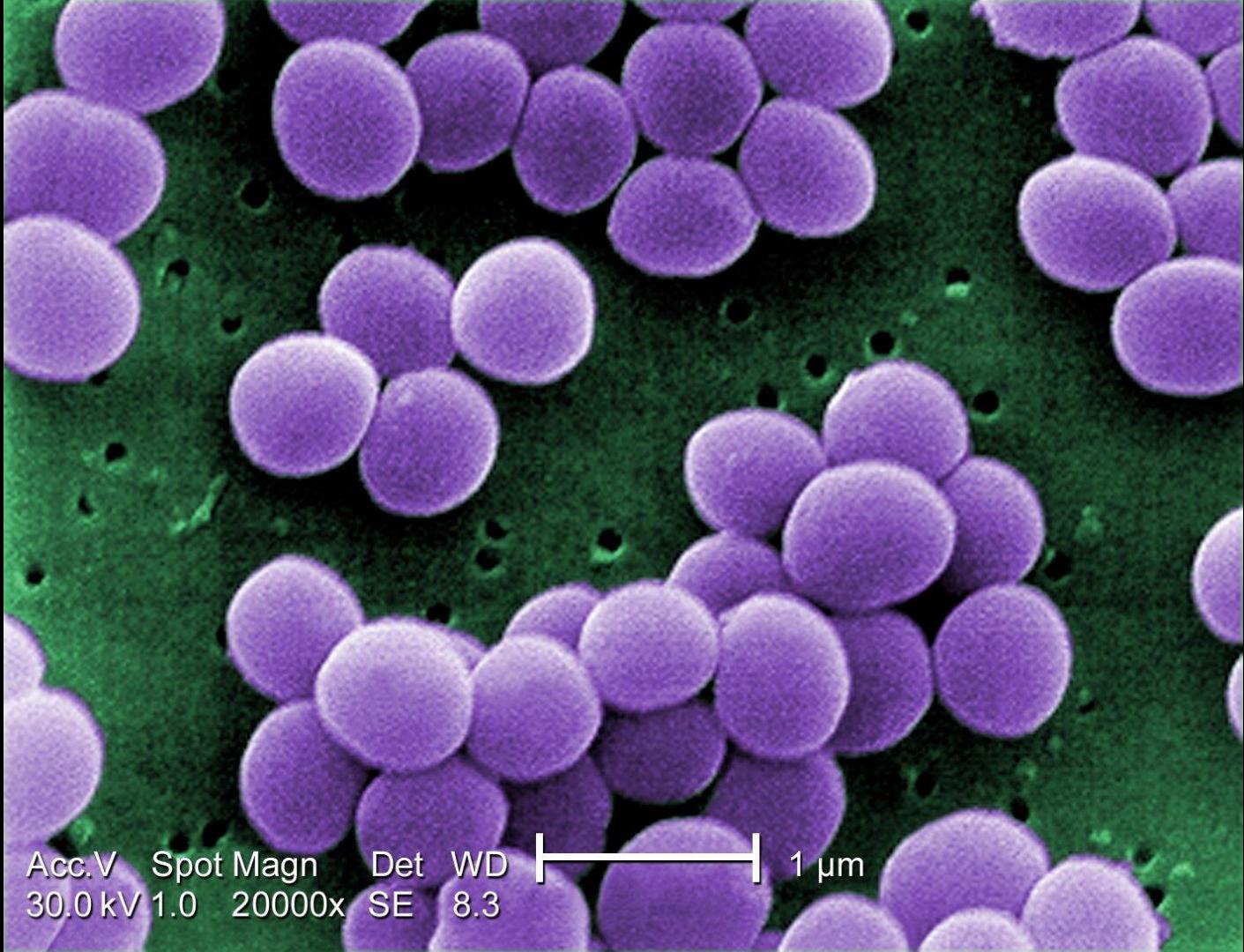


School relationships highlighting highchool in nodes and same SPAT1 in edges.  
Isolated nodes are hidden (21)





**Supplementary Figure 5. Histogram of representativeness of the social network for each of the participants.** With 0 being not representative at all, and 10 being a perfect overview. We also measure for specific networks, having a mean score from top to bottom of School (6.61), Other (6.52), Physical (6.42) Overall (6.29) Sports (6.24) and Home (6.13).



Acc.V Spot Magn Det WD  
30.0 kV 1.0 20000x SE 8.3

Induce a wide range of diseases, including, but not limited to:

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- Pneumonia

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- Pneumonia
- Meningitis

Induce a wide range of diseases, including, but not limited to:

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- Flesh eating disease.

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About 30% of the population has it.

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Immunoevasion; it difficult for your immune system to find it, catch it, or even mount a proper immune response against other pathogens.

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Many strains that are  $\beta$ -lactam antibiotic resistance. No vaccine.

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Many strains that are β-lactam antibiotic resistance. No vaccine.

Responsible for many thousand of intrahospitalary infections related deaths.

Induce a wide range of symptoms

- Pneumonia
- Meningitis
- Flesh eating disease

About 30% of the time

Immuno evasion  
and fails to mount a proper immune response

Many strains that cause disease

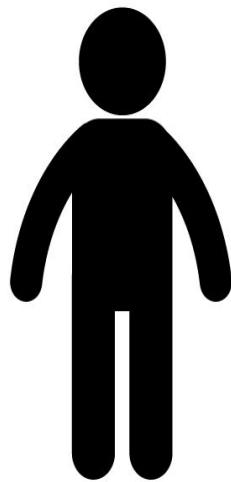
Responsible for many deaths



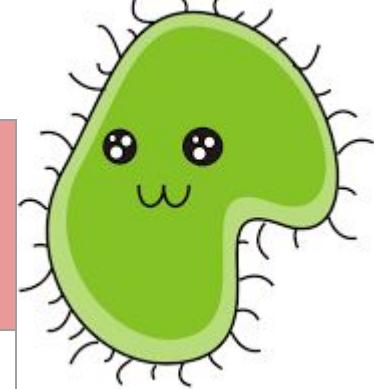
it, or even

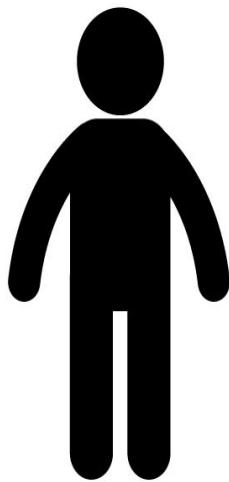
caused deaths.

Why is this not a big problem?

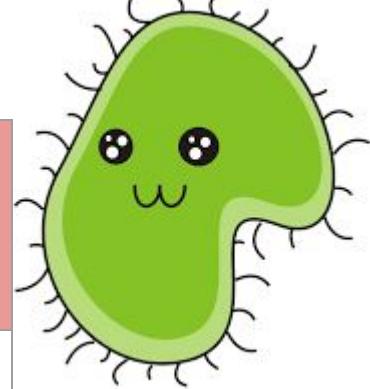


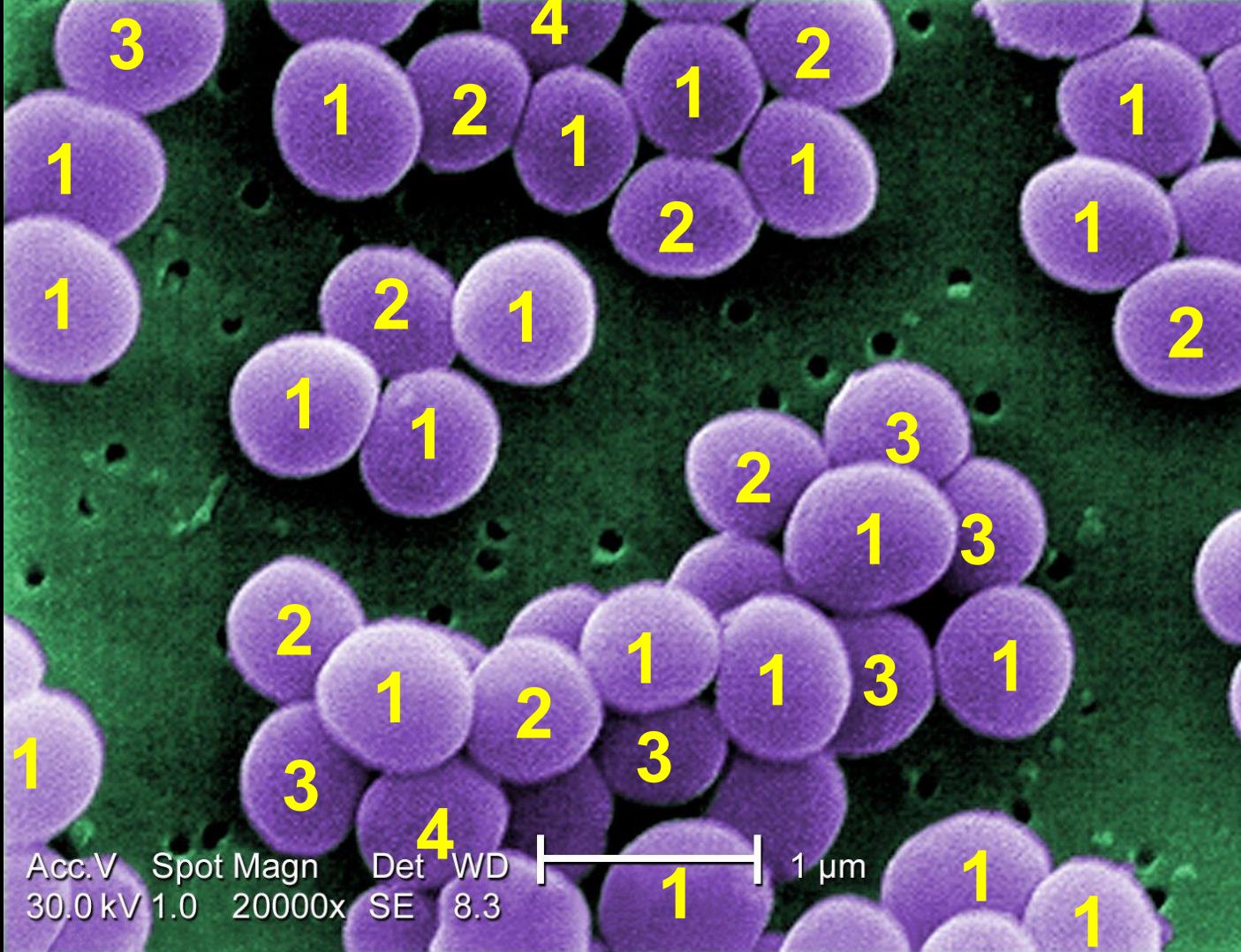
A \ B	+	=	-
+	Mutualism	Comensalism	Parasitism
=	Comensalism	Neutralism	Amensalism
-	Parasitism	Amensalism	Competition



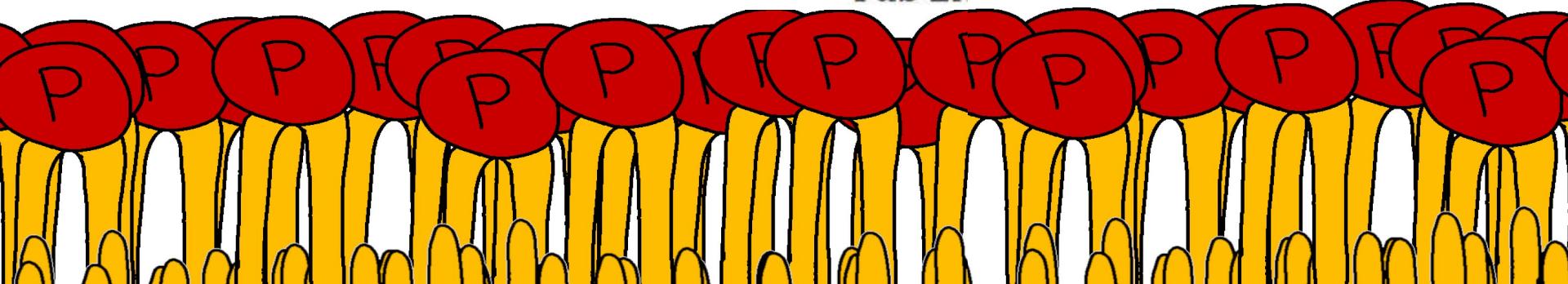
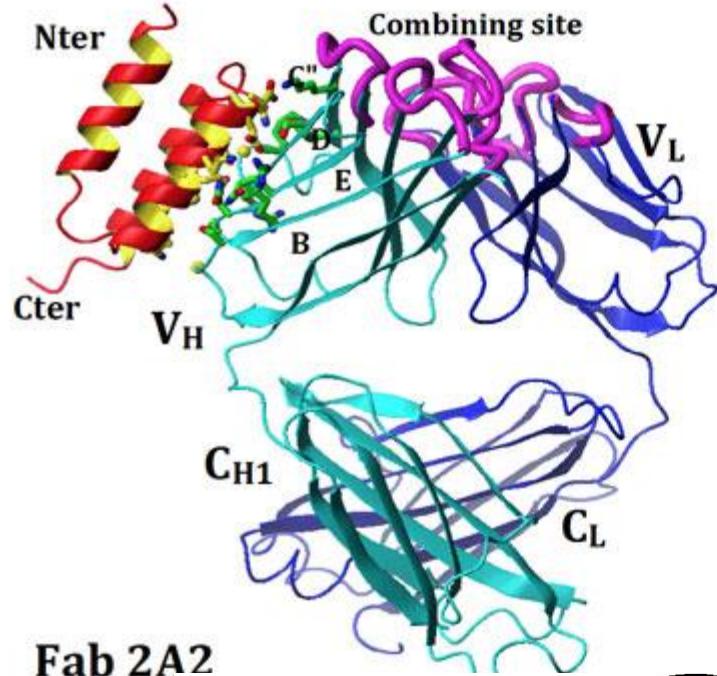


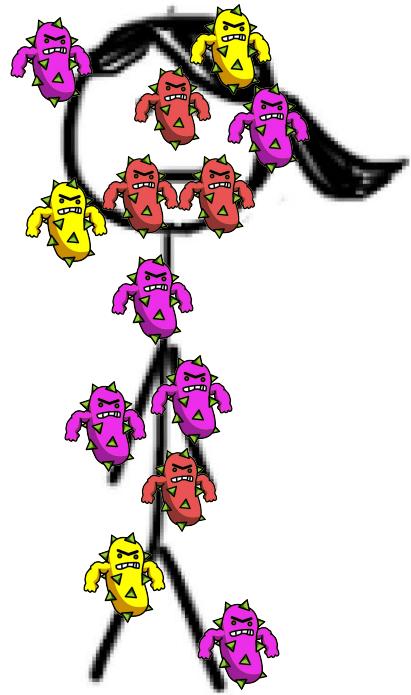
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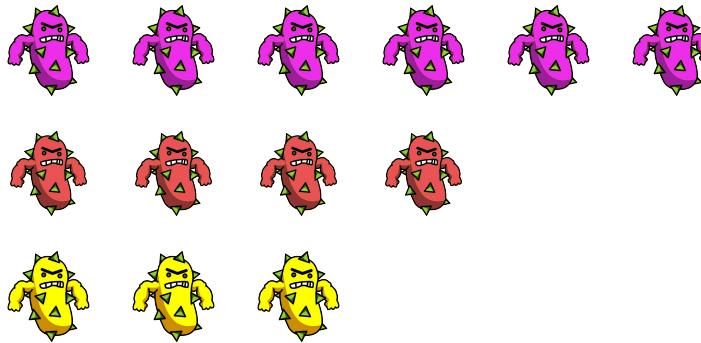
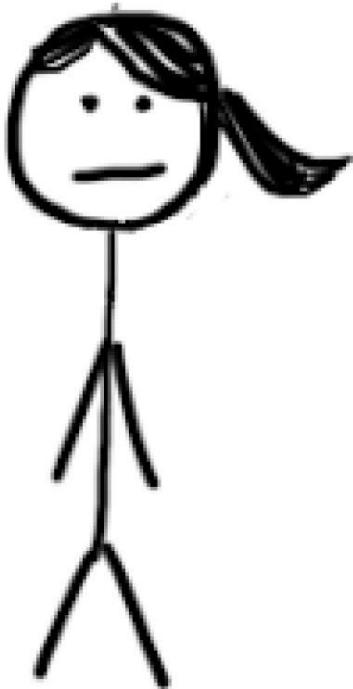




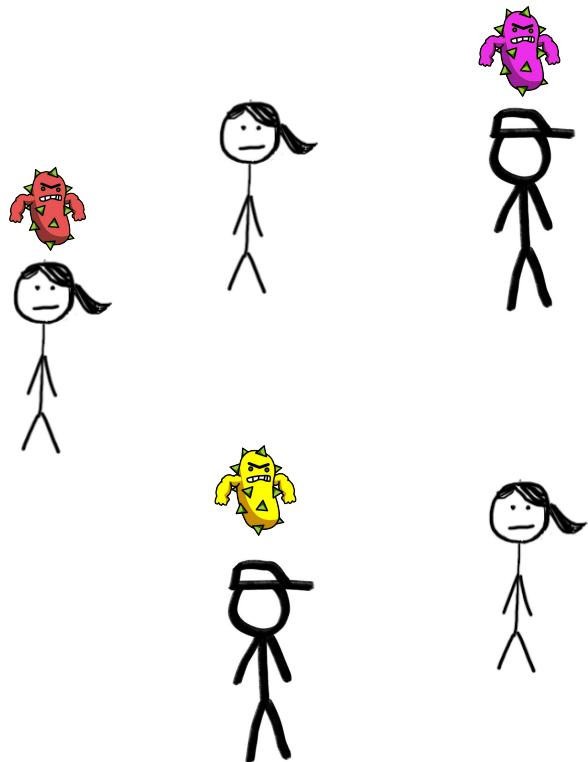
# Staphylococcal Protein A (SPA)



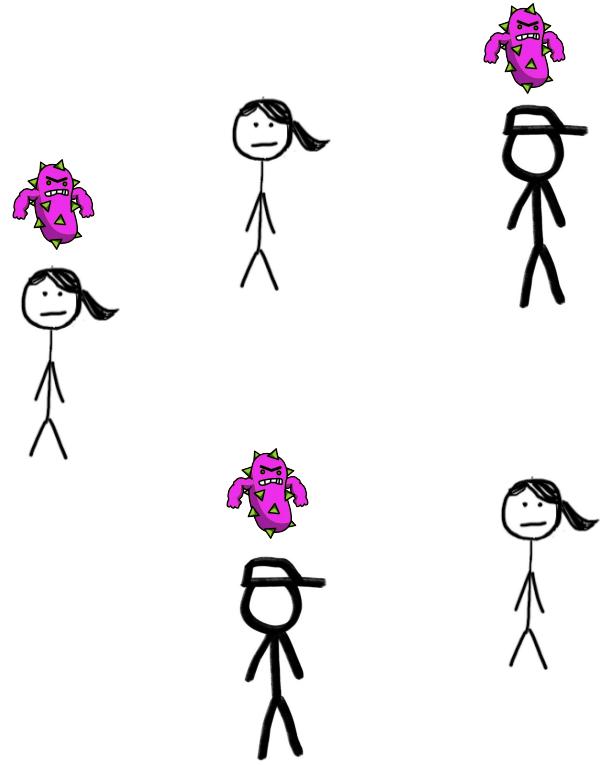




# Different SPA type

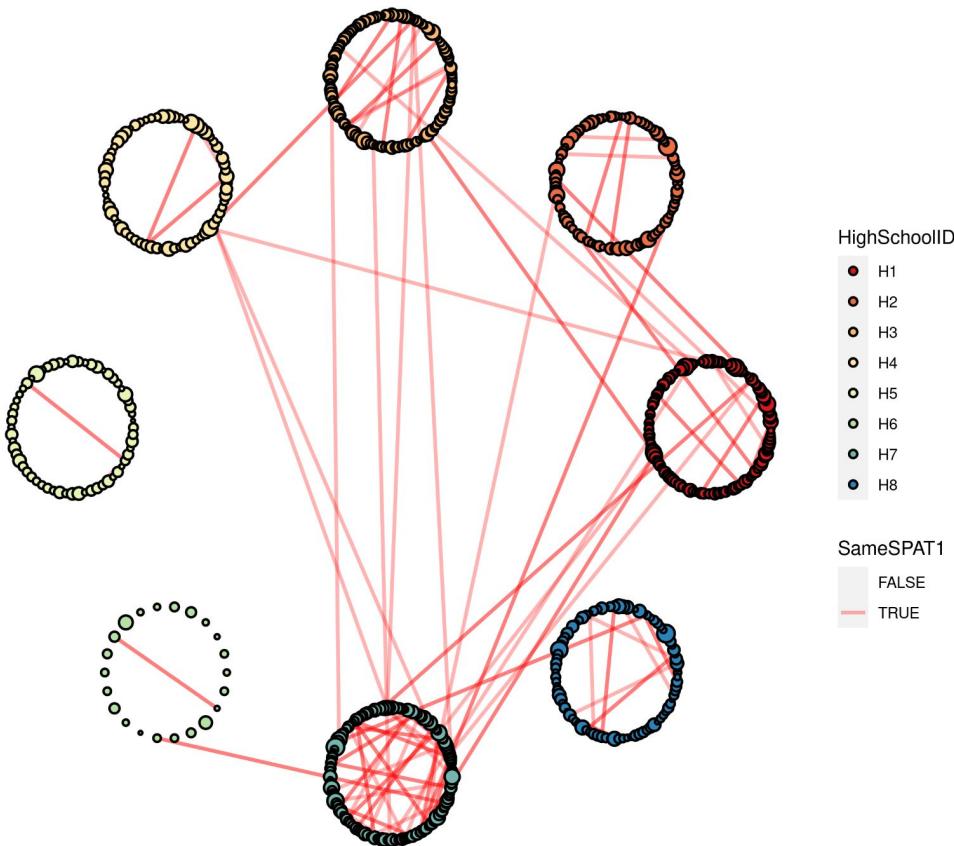


# Same SPA type



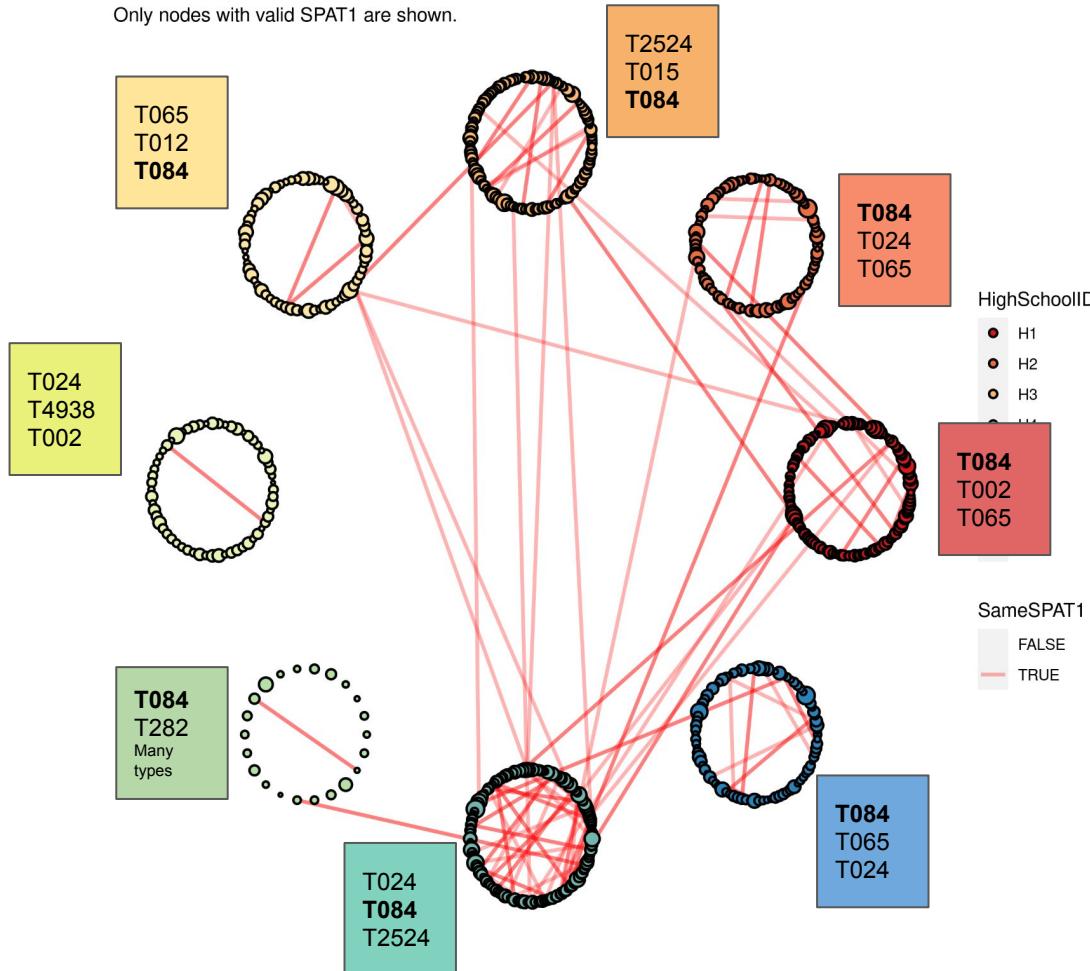
Relationships of students with same SPAT1.

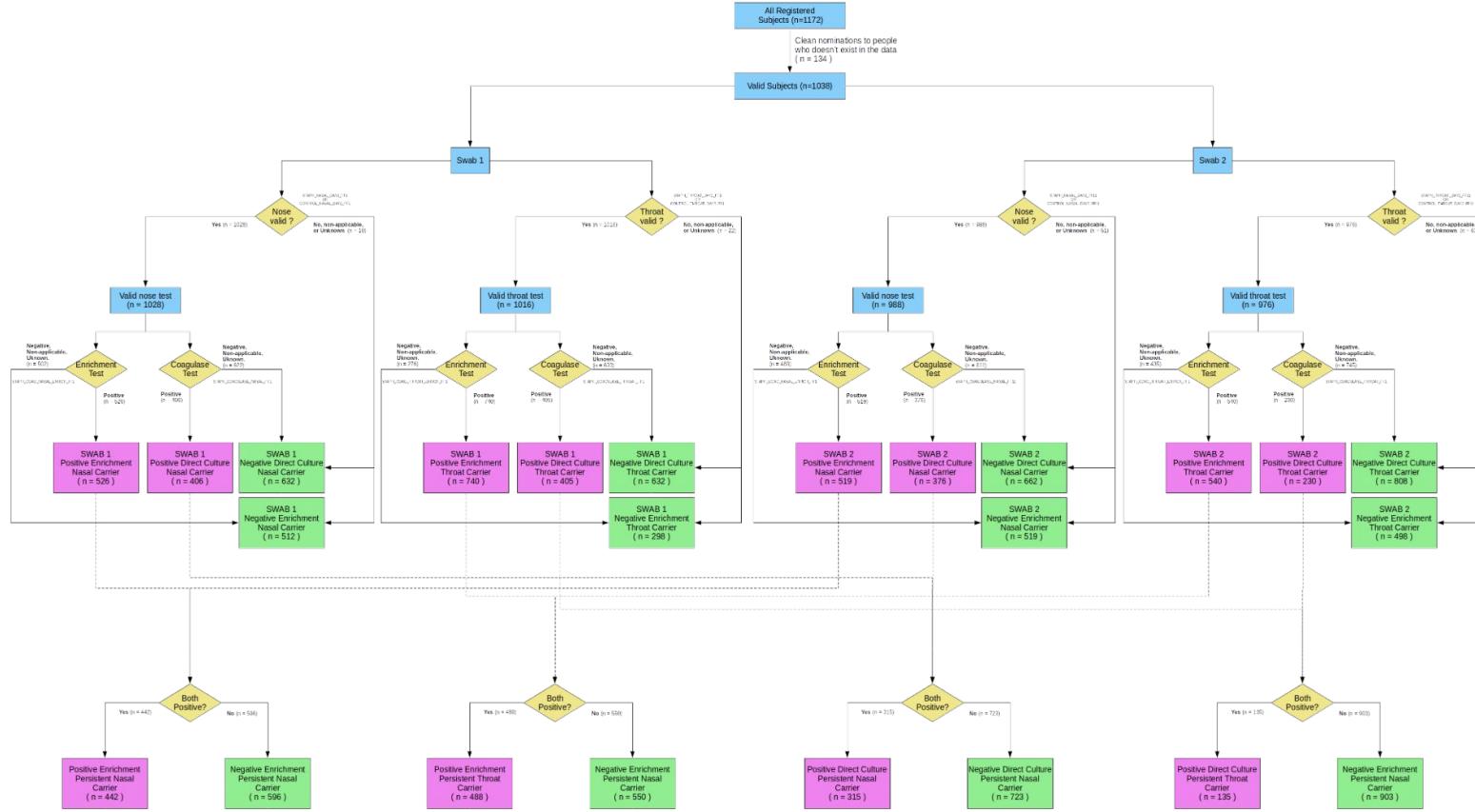
Only nodes with valid SPAT1 are shown.

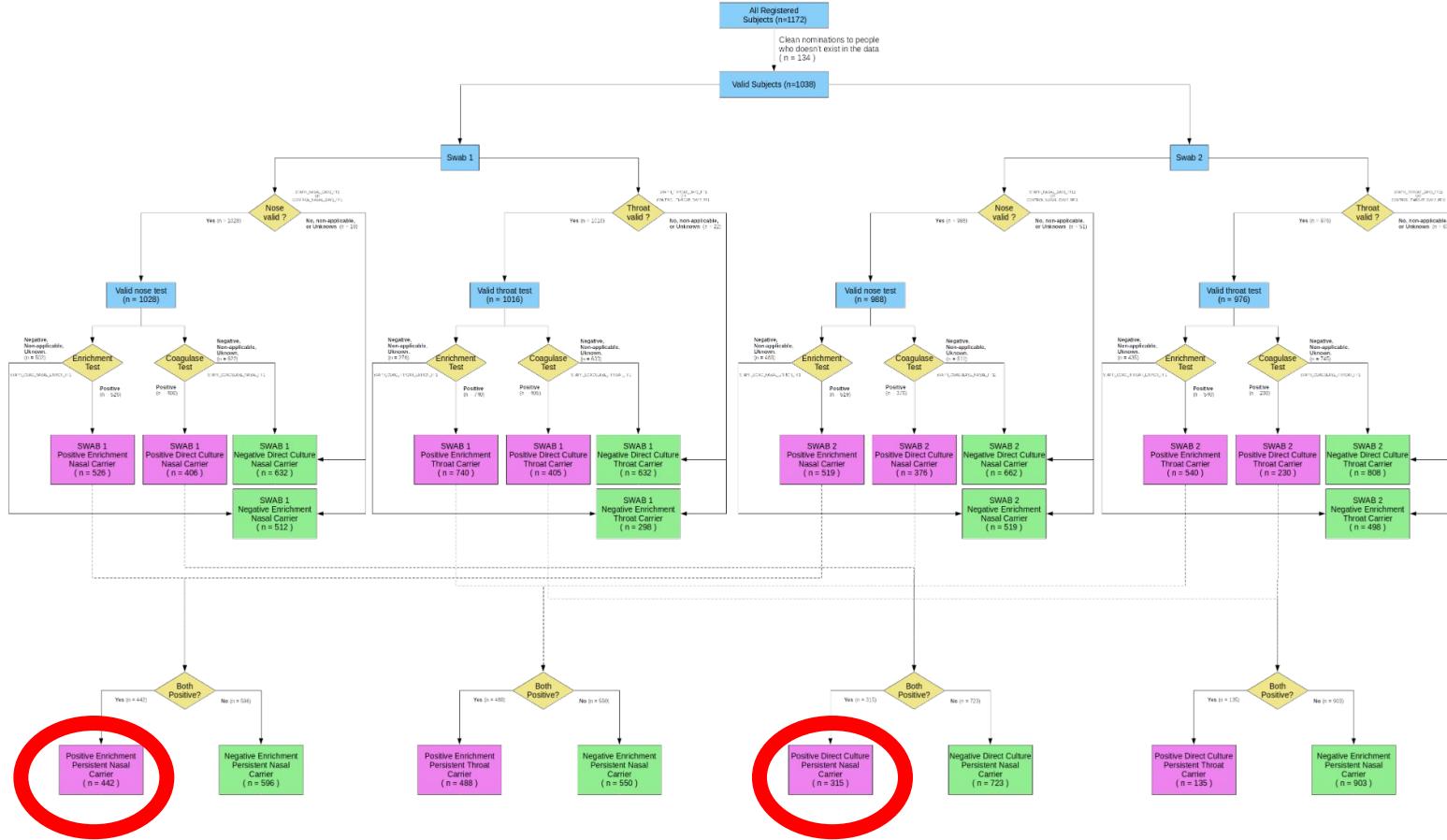


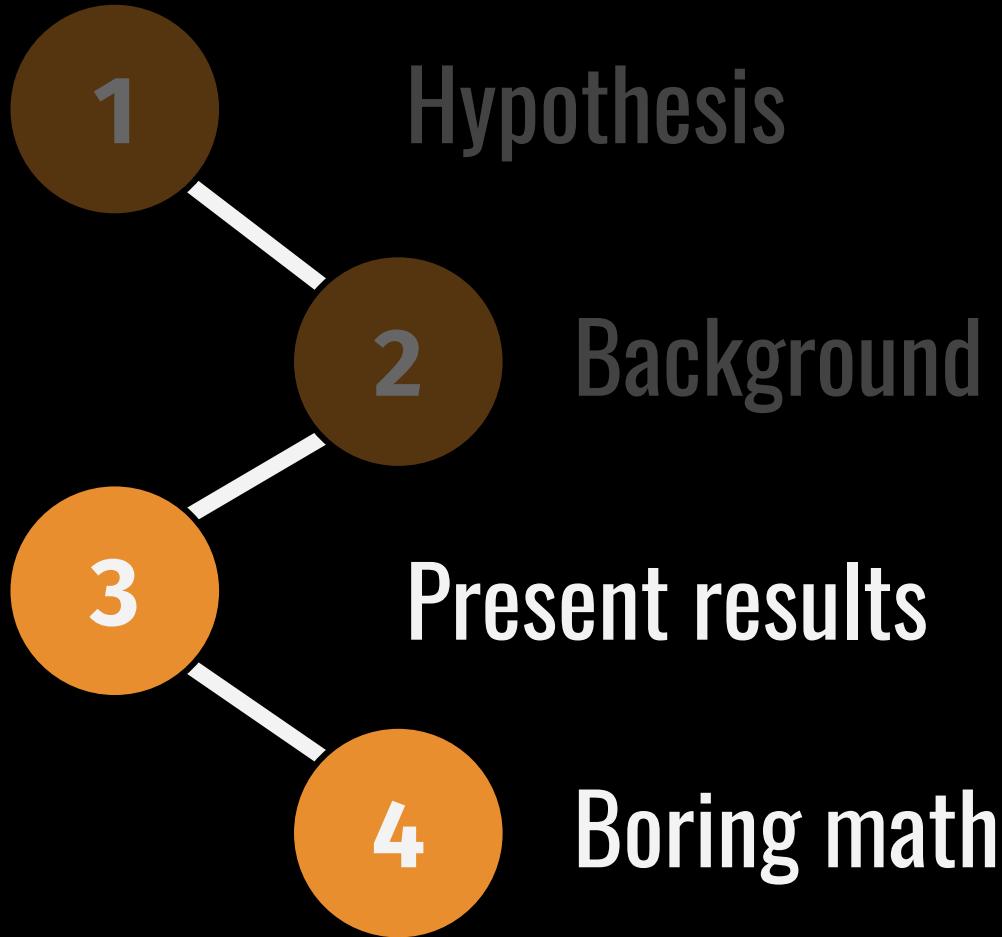
Relationships of students with same SPAT1.

Only nodes with valid SPAT1 are shown.



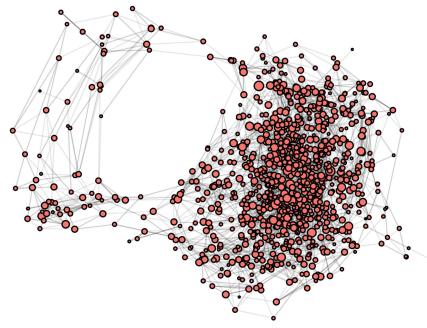




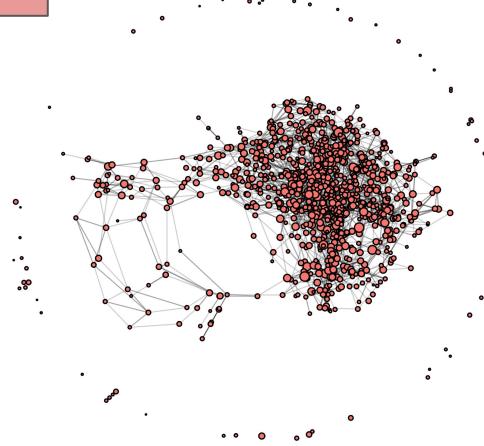


	Direct culture persistent carrier			Enrichment persistent carrier		
	Positive	Negative	Prevalence ( <i>av</i> = 30.3%)	Positive	Negative	Prevalence ( <i>av</i> = 42.6%)
<b>Sex</b>	<b>*** &lt; 0.001</b>			<b>*** &lt; 0.001</b>		
Male	193	337	36.4 %	255	275	48.1 %
Female	122	386	24.0 %	187	321	36.8 %
<b>BMI-category<sup>a</sup></b>	<b>0.99</b>			<b>0.08</b>		
< 18.5 kg/m <sup>2</sup>	35	75	31.8 %	55	55	50.0 %
18.5-<25 kg/m <sup>2</sup>	201	509	28.3 %	289	421	40.7 %
25-<30 kg/m <sup>2</sup>	54	93	32.8 %	68	79	40.3 %
> 30 kg/m <sup>2</sup>	22	45	36.7 %	27	40	46.3 %
<b>Smoking</b>	<b>0.21</b>			<b>0.22</b>		
Daily	14	34	29.2 %	24	24	50.0 %
Sometimes	59	129	31.4 %	76	112	40.4 %
Never	236	546	30.2 %	333	449	42.6 %
<b>Snuff use</b>	<b>0.93</b>			<b>0.49</b>		
Daily	73	172	29.8 %	107	138	43.7 %
Sometimes	43	88	32.8 %	63	68	48.1 %
Never	192	450	29.9 %	263	379	41.0 %
<b>School-type</b>	<b>0.79</b>			<b>0.30</b>		
General	118	272	30.3 %	163	227	41.8 %
Sports	31	73	29.8 %	55	49	52.9 %
Vocational	166	378	30.5 %	224	320	41.2 %
<b>Physical activity<sup>b</sup></b>	<b>0.32</b>			<b>0.80</b>		
None	80	149	34.9 %	107	122	46.7 %
Light	99	239	29.3 %	129	209	38.2 %
Medium	67	192	25.9 %	105	154	40.5 %
Hard	63	131	32.5 %	93	101	47.9 %
<b>Alcohol habits</b>	<b>0.15</b>			<b>0.07</b>		
Never	88	192	31.4 %	115	165	41.1 %
<= 1 Month	134	286	31.9 %	183	237	43.6 %
> 2 Month	86	232	27.0 %	134	184	42.1 %
<b>Hormonal Contraceptives<sup>c</sup></b>	<b>(<i>av</i> = 24%)</b>			<b>(<i>av</i> = 36.8%)</b>		
	<b>0.70</b>			<b>0.62</b>		
None	79	249	24.1 %	122	206	37.2 %
Progestin only	3	17	15.0 %	5	15	25.0 %
Combination contraceptives, low estradiol	12	41	22.6 %	19	34	30.2 %
Combination contraceptives, high estradiol	26	70	27.1 %	39	57	40.6 %

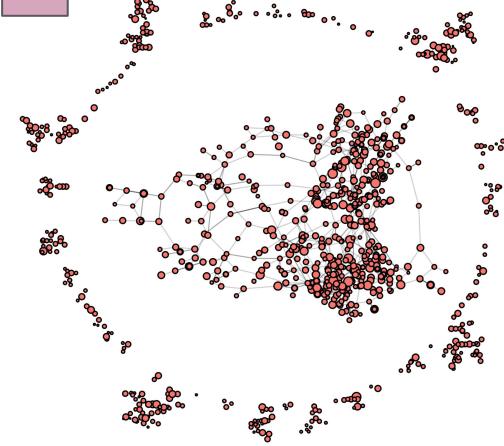
 Overall



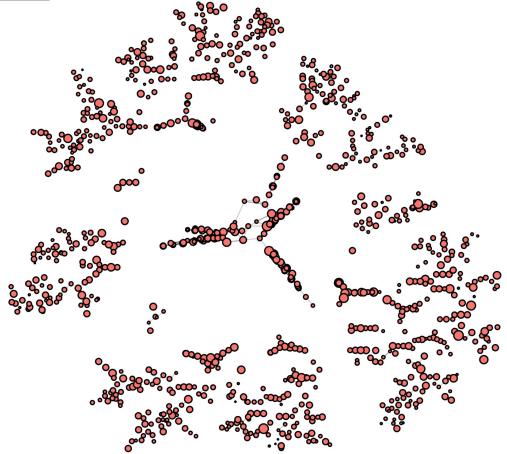
 Physically



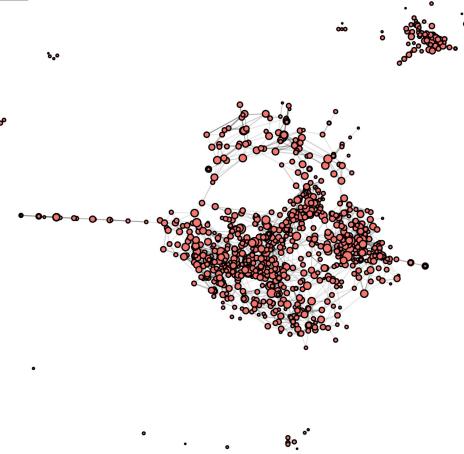
 Other



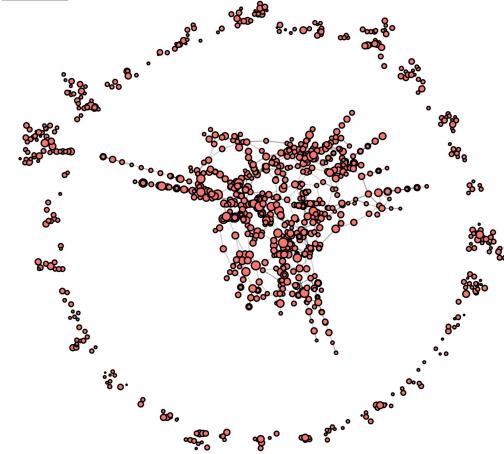
 Sports



 School

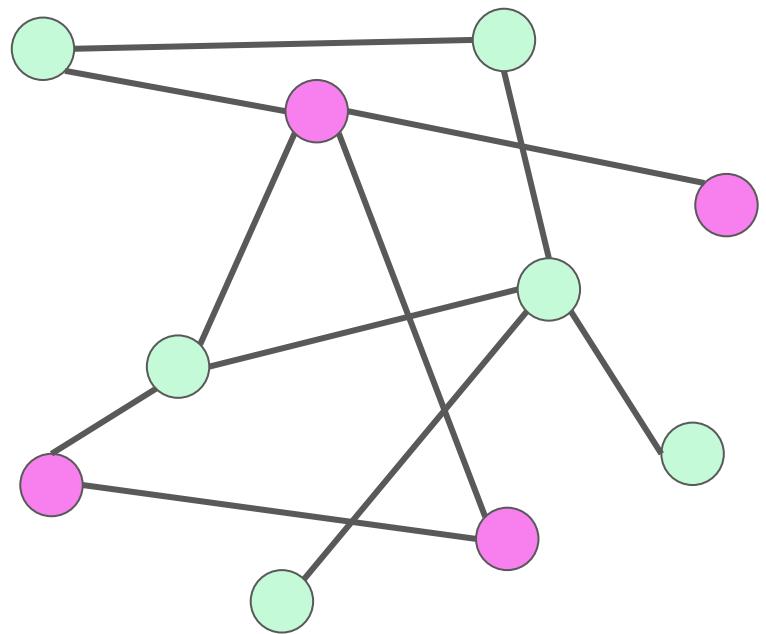


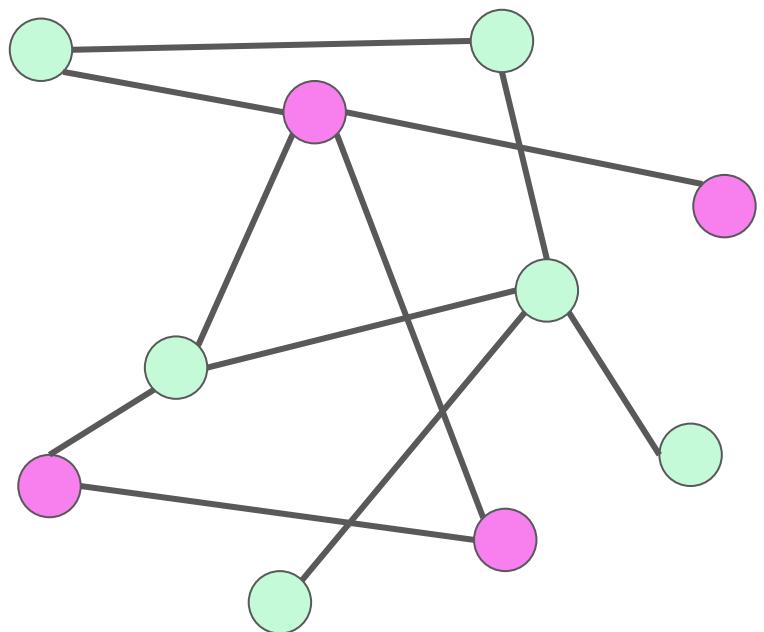
 Home



**Table 2: Table summarizing 1000 simulations, for each network.** Persistent nasal carriage determined by direct culture and enrichment. Significant p-values indicate non-random spread *S. aureus* through the social networks.

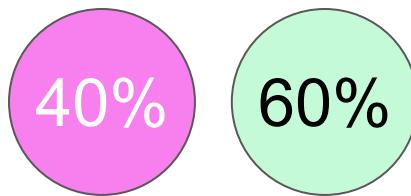
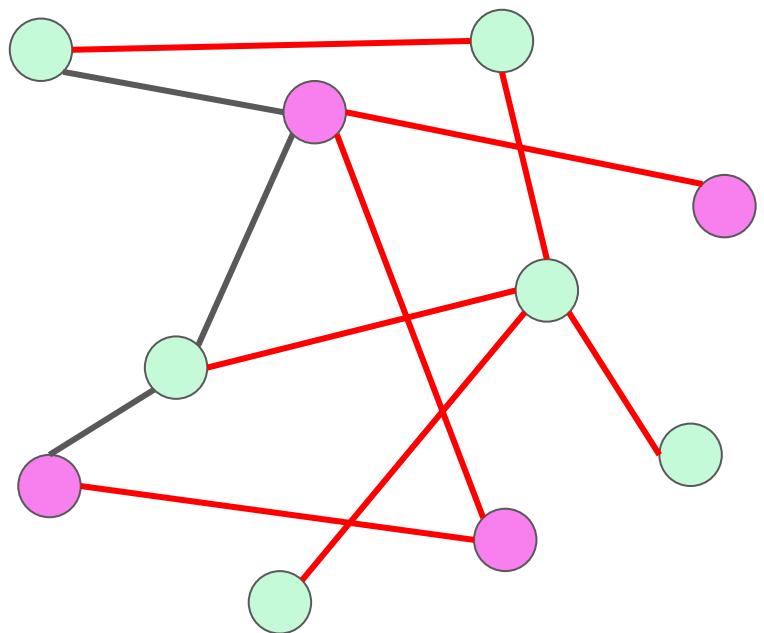
Network	Direct culture P-value	Enrichment P-value
Overall	0.07	* <b>0.02</b>
Physical	0.06	* <b>0.04</b>
School	* <b>0.02</b>	** <b>0.01</b>
Sports	0.12	0.29
Home	0.34	0.39
Other	0.08	0.06





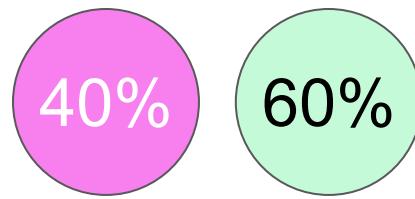
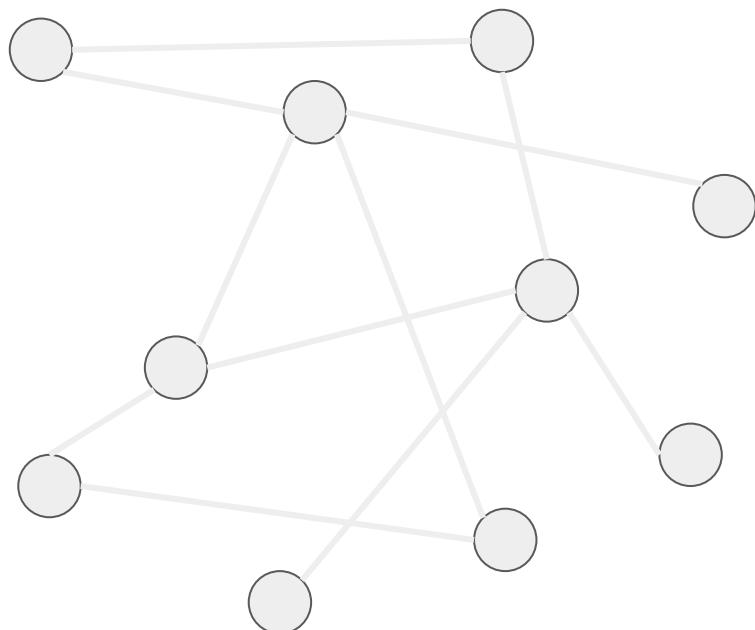
40%

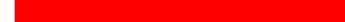
60%



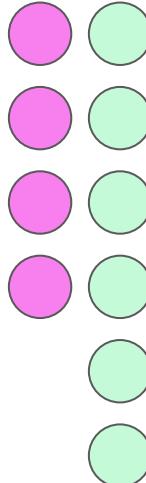
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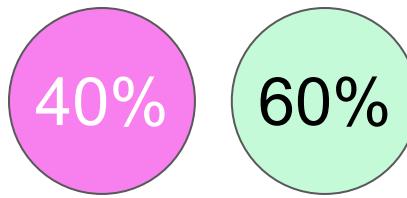
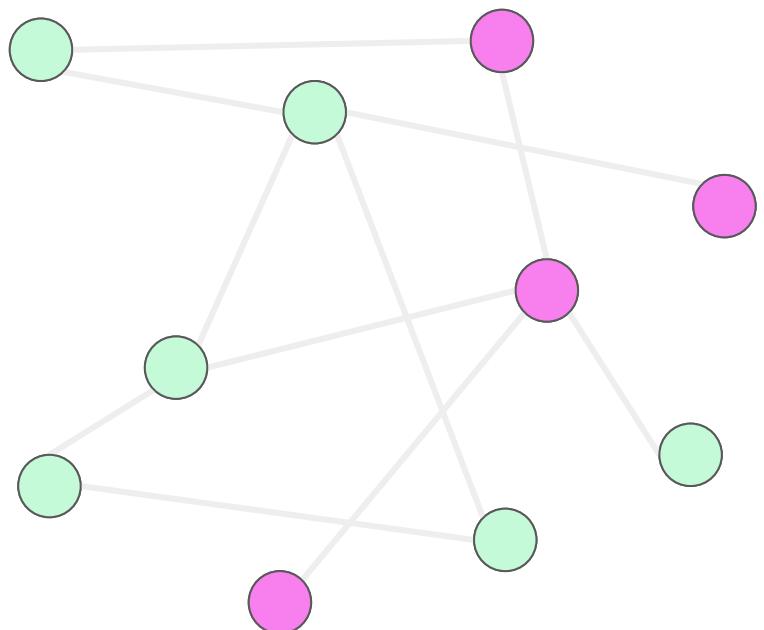
3 ——————

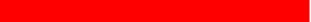


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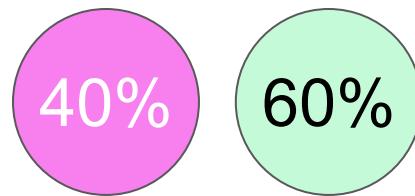
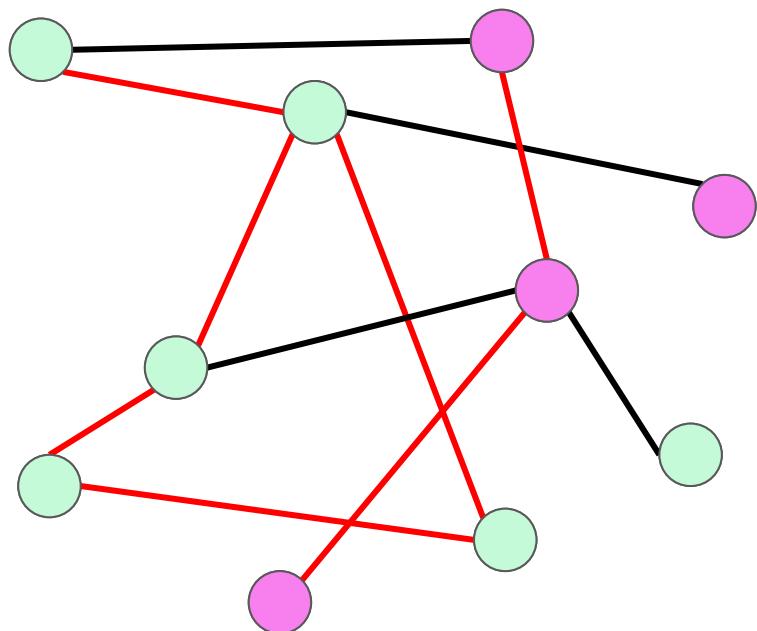
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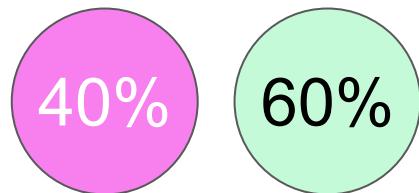
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7 

4 

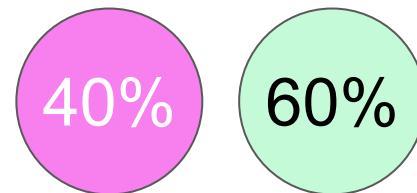
Original Network



8 

3 

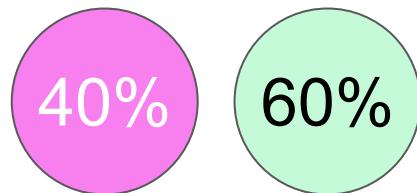
Random Network



7 

4 

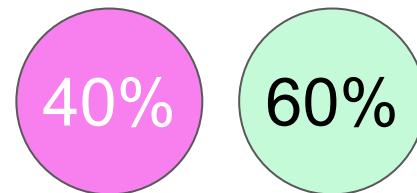
Original Network



8 ————— >

3 ————— <

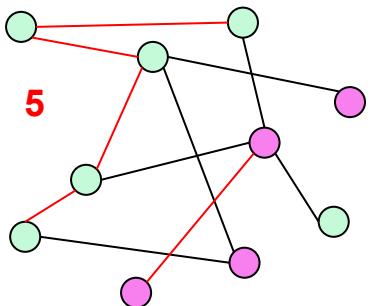
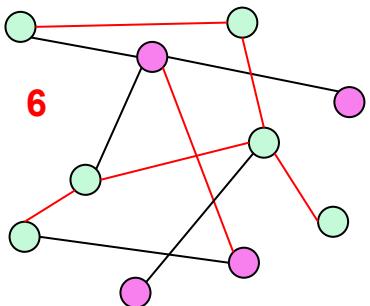
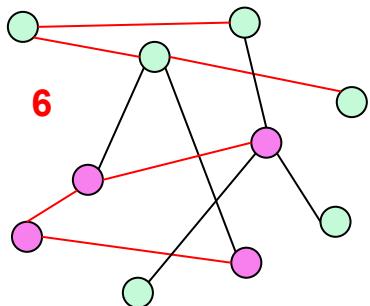
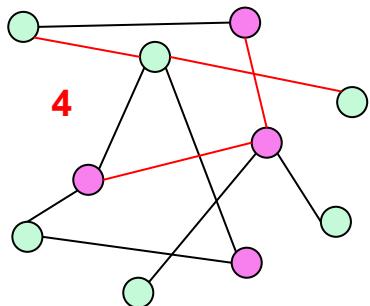
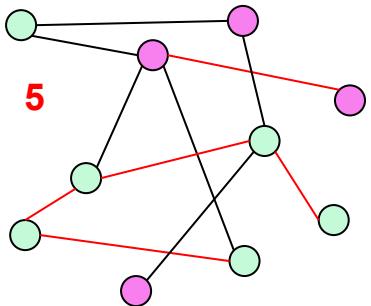
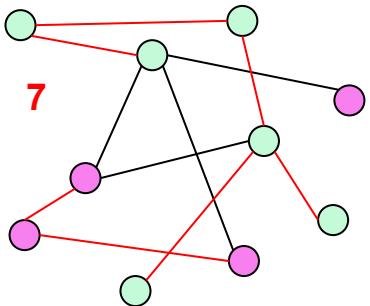
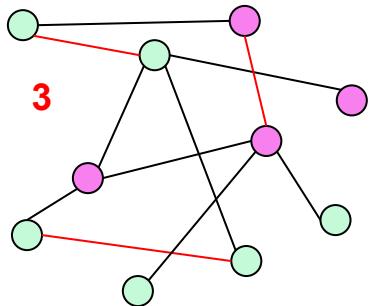
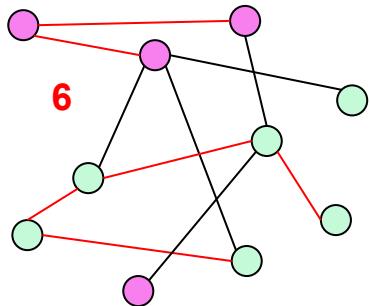
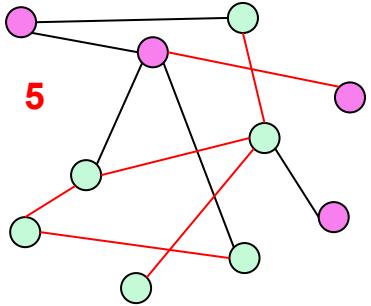
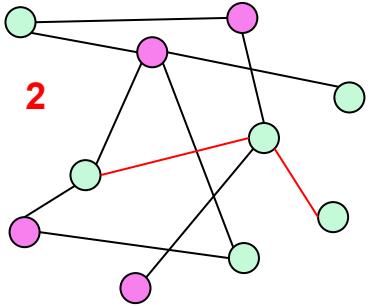
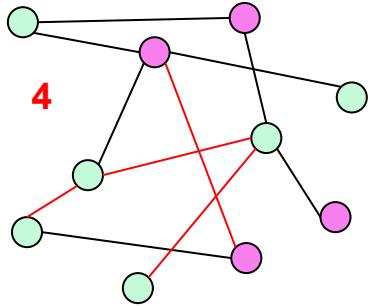
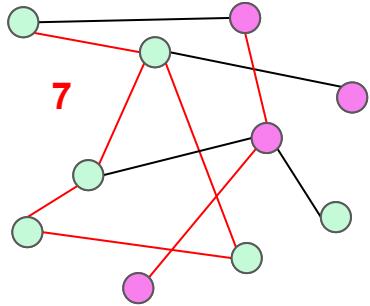
Random Network



7 —————

4 —————

Original network is not random, and is  
bias towards higher “same to same”  
relationships



**7**

**4**

**2**

**5**

**6**

**3**

**7**

**5**

**4**

**6**

**6**

**5**

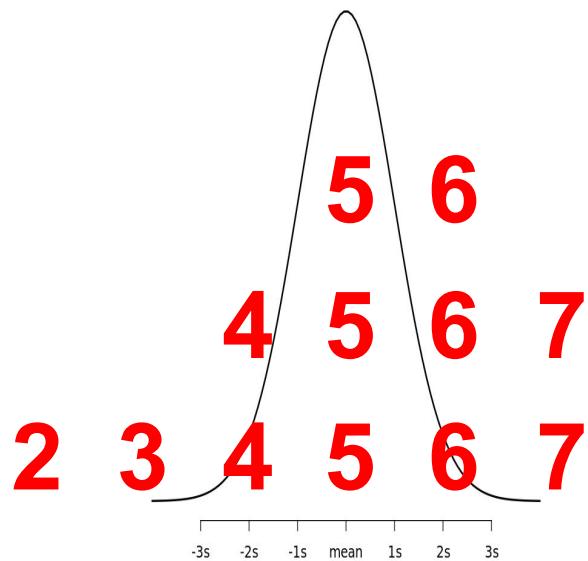
**5 6**

**4 5 6 7**

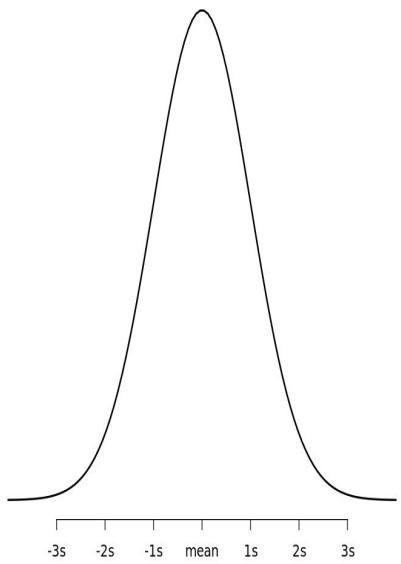
**2 3 4 5 6 7**

Mean = 5

Standard Deviation = 1.54

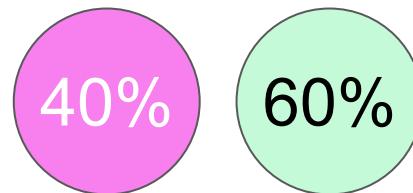


Mean = 5  
Standard Deviation = 1.54



2 3 4 5 6 7

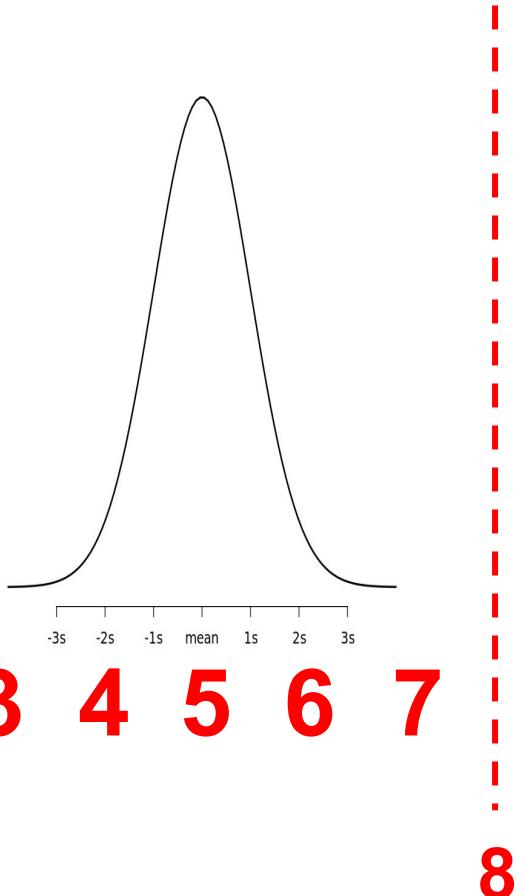
Original Network



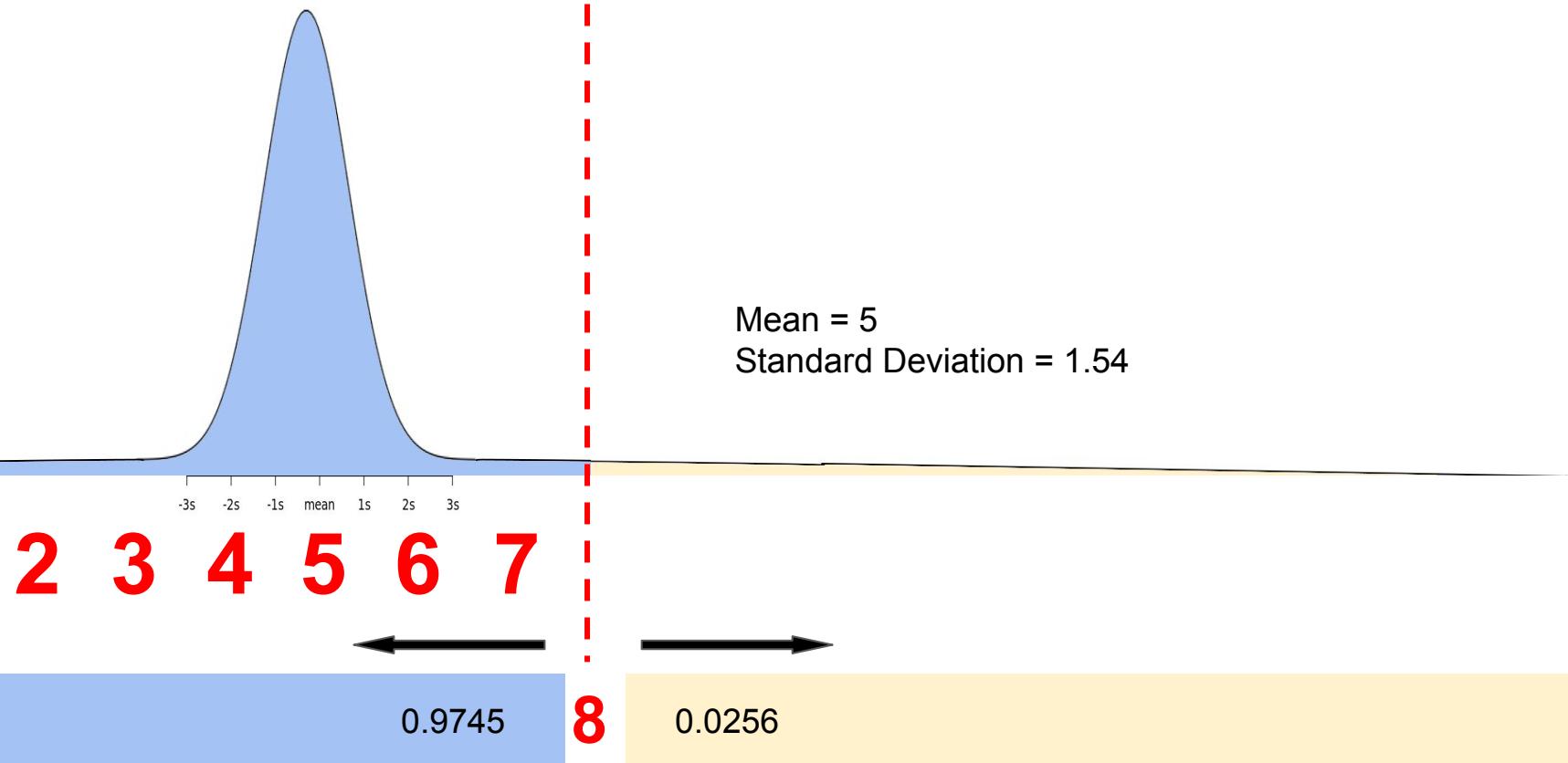
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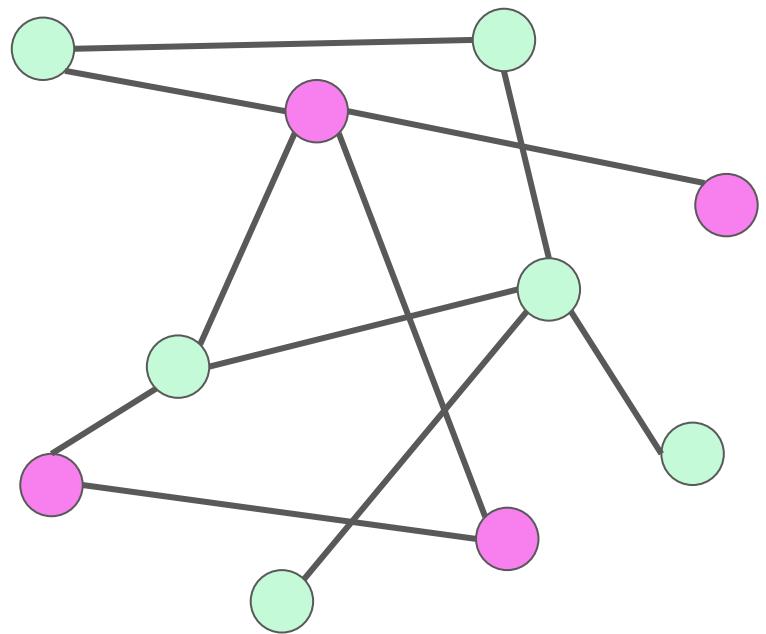
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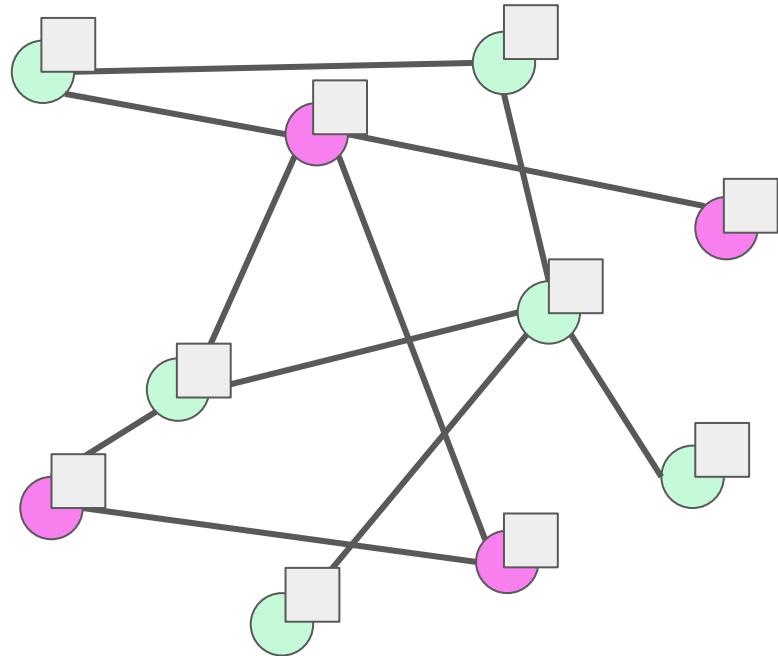
Original Network

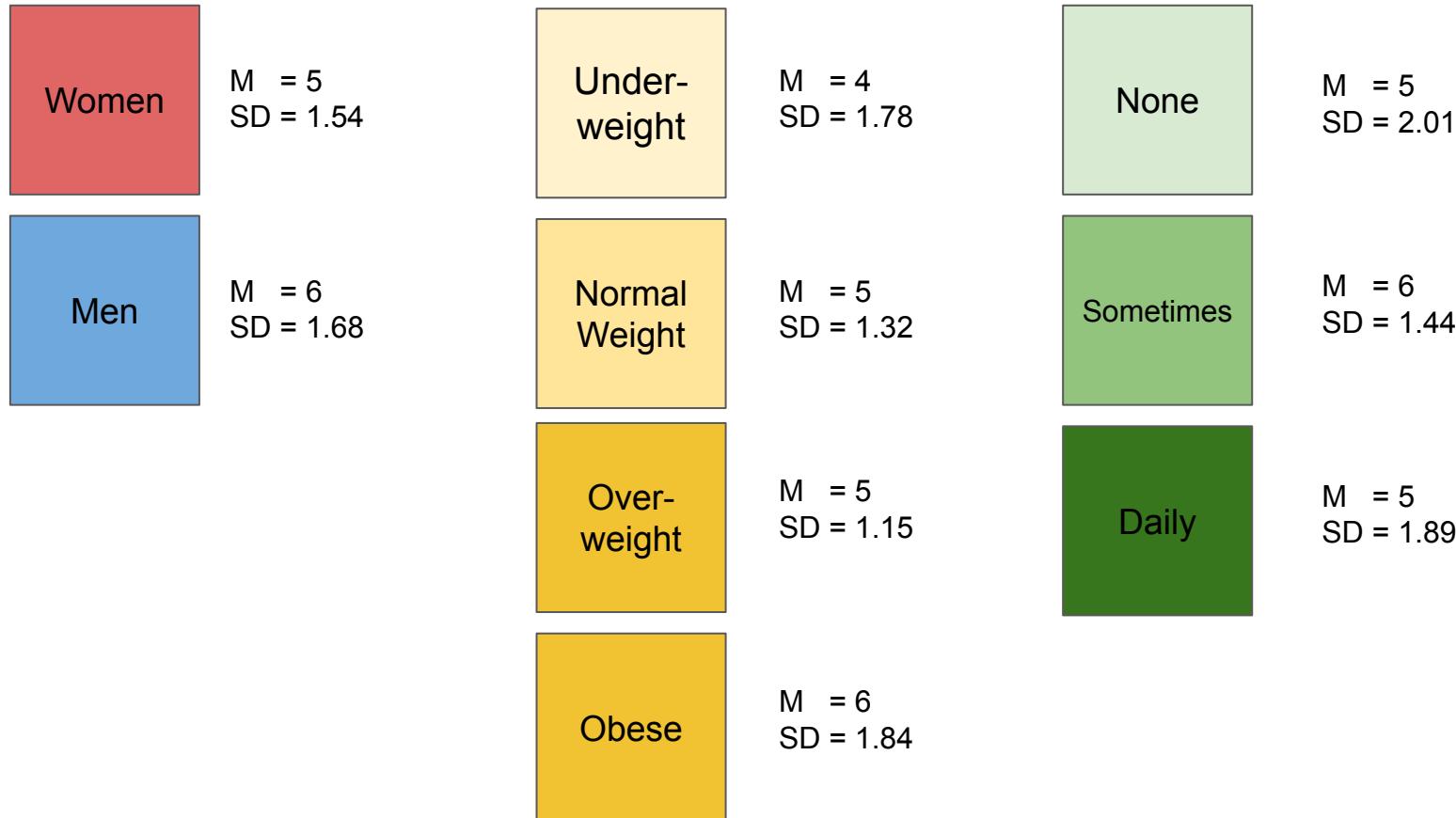
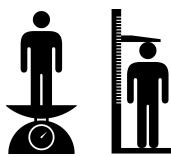


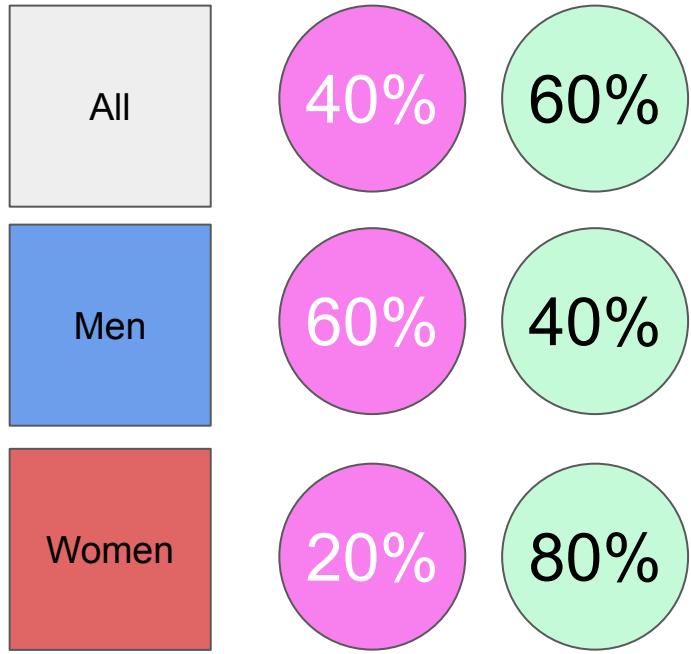
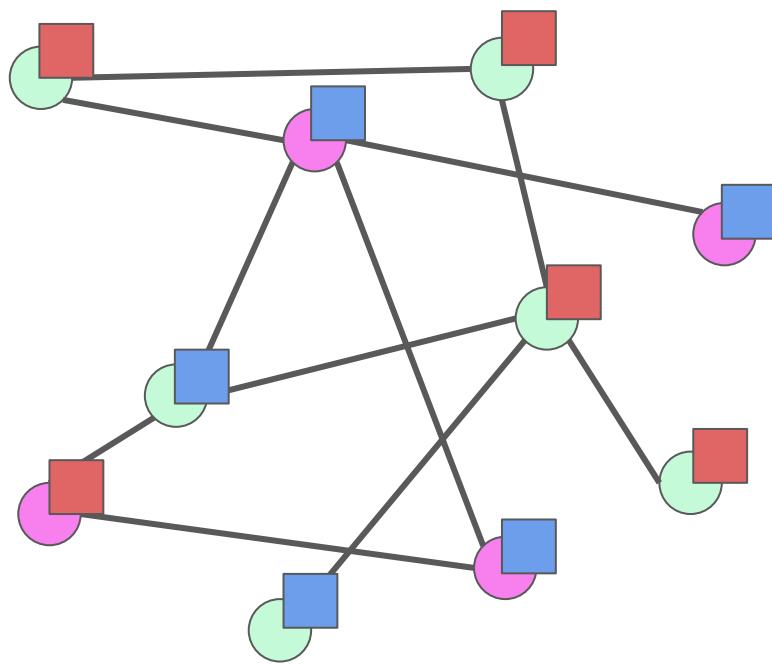
Original Network

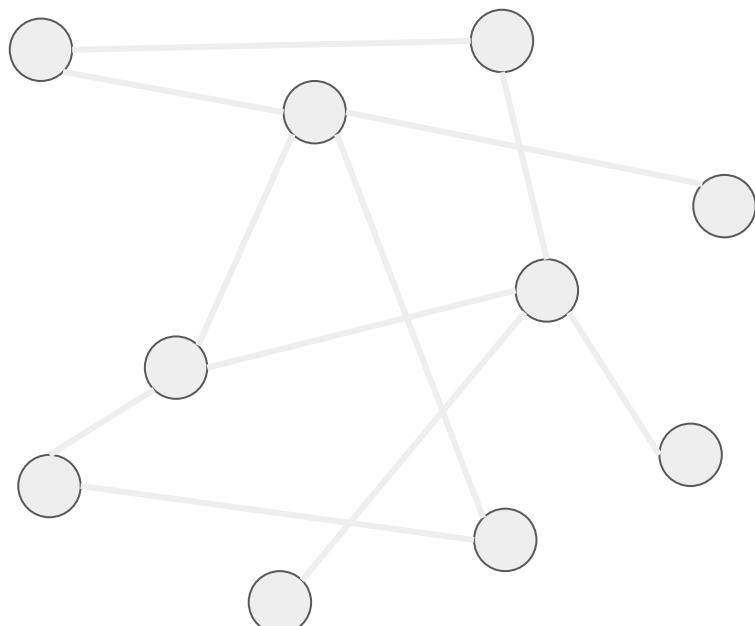












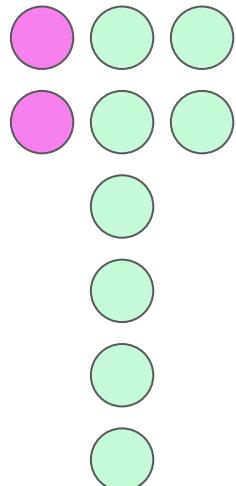
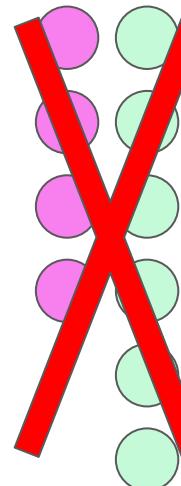
Women

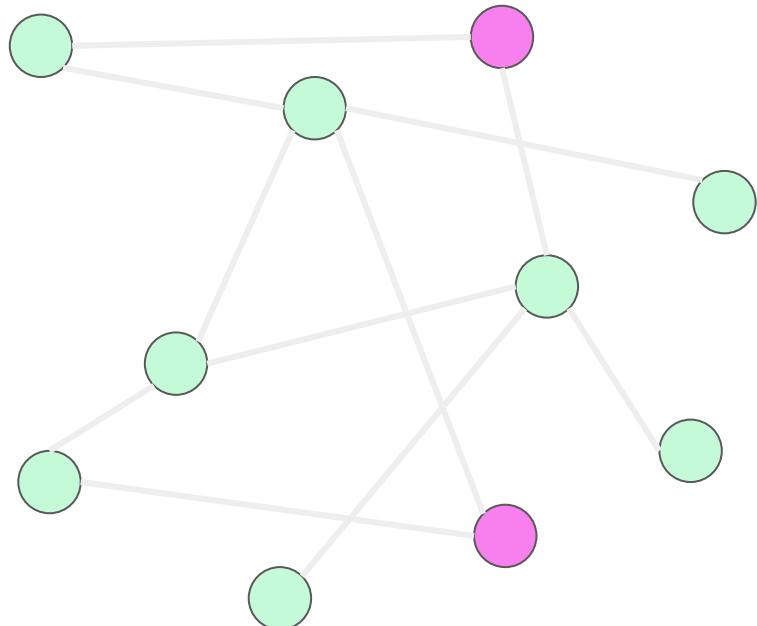
20%

80%

? —————

? —————

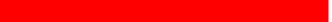




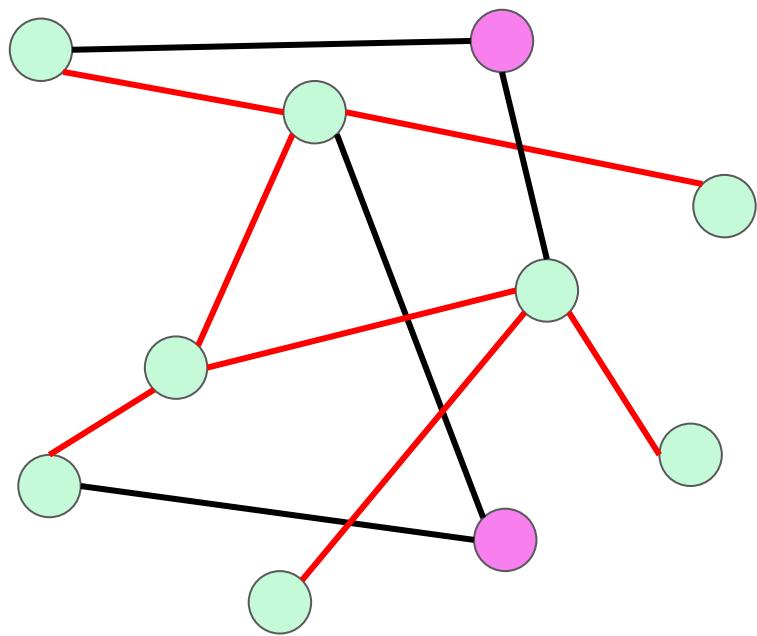
Women

20%

80%

? 

? 



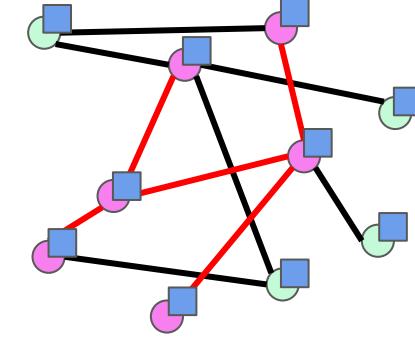
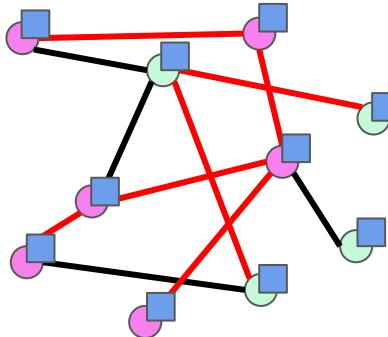
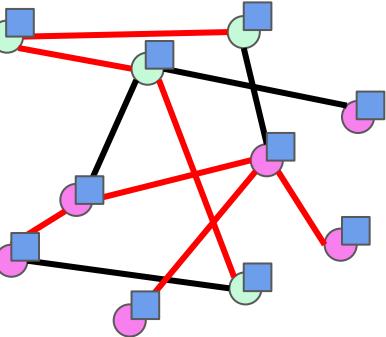
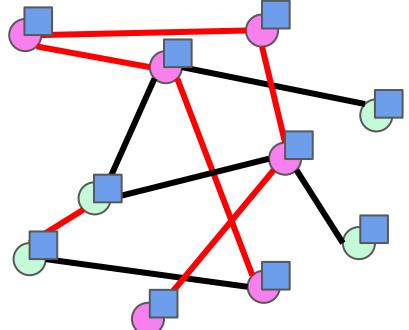
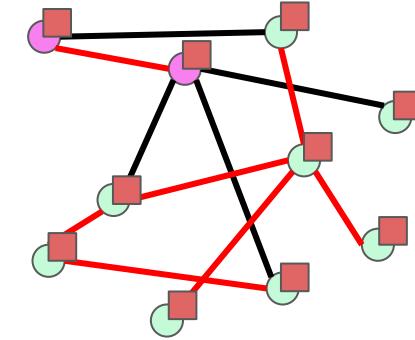
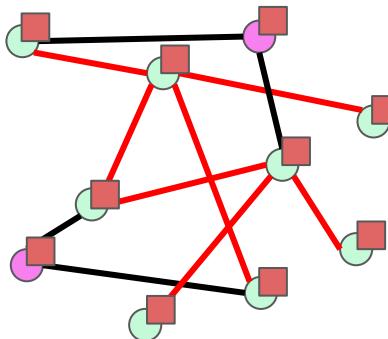
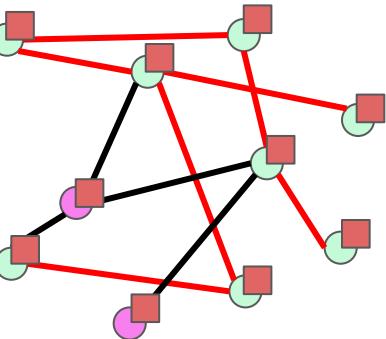
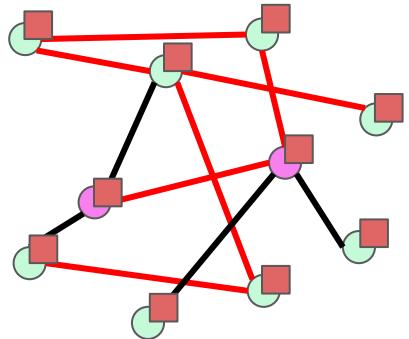
Women

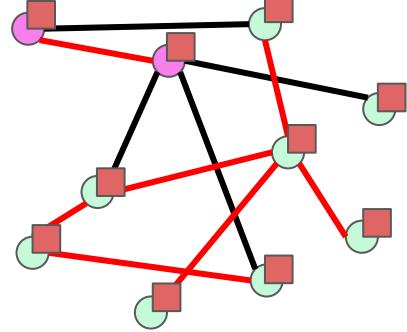
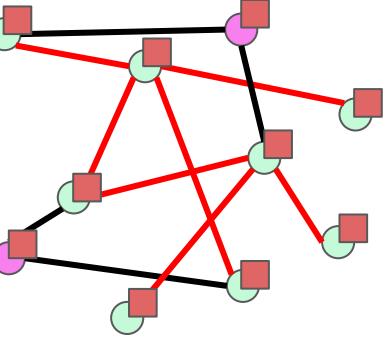
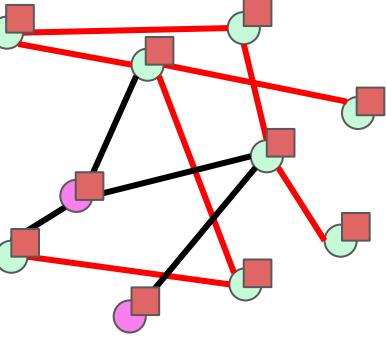
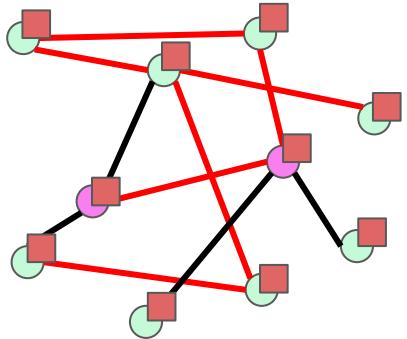
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80%

7 ——————

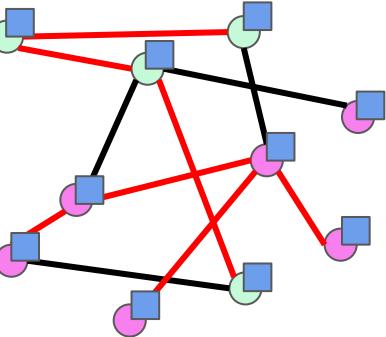
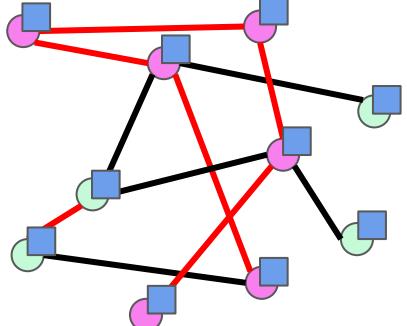
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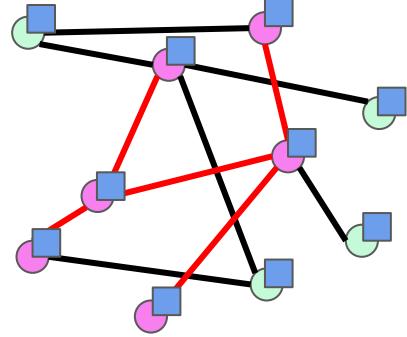
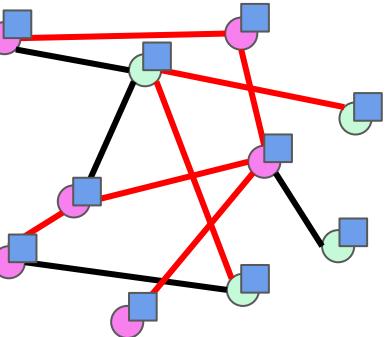
Women

Mean = 12



Men

Mean = 6

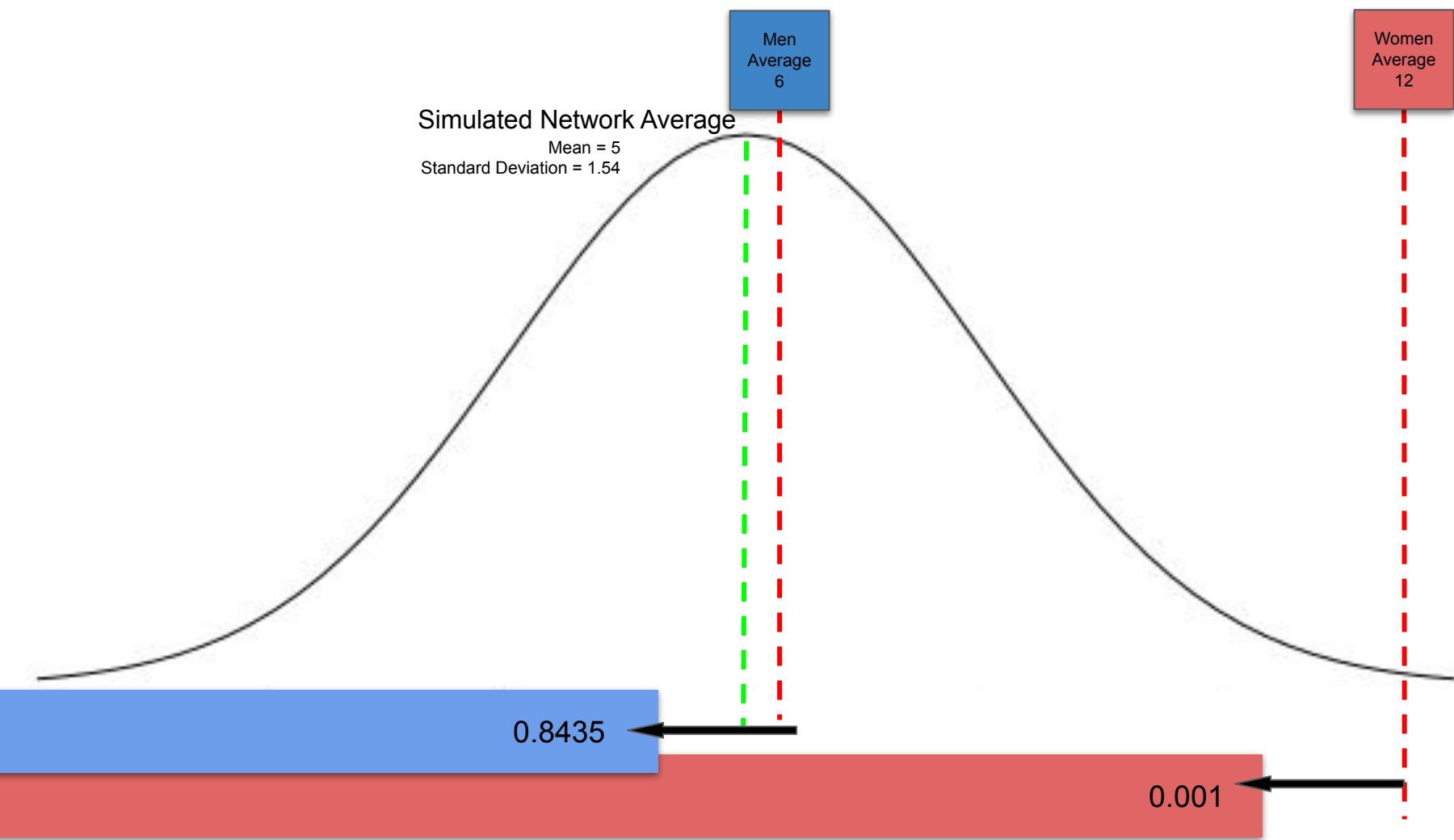


Women  
Average  
12

Men  
Average  
6

### Simulated Network Average

Mean = 5  
Standard Deviation = 1.54

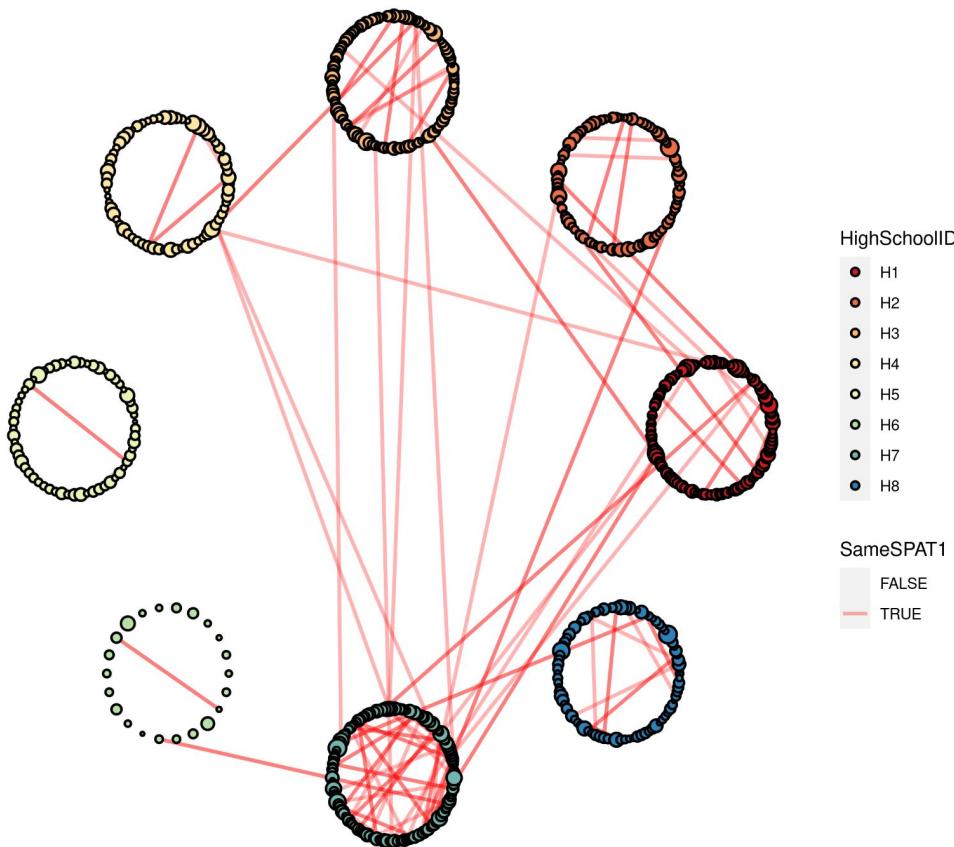


**Table 3 Known host risk factors for *S. aureus* carriage in relation to the overall social network for persistent nasal carriage by direct culture and enrichment culture. The Tromsø Study Fit Futures 1.**

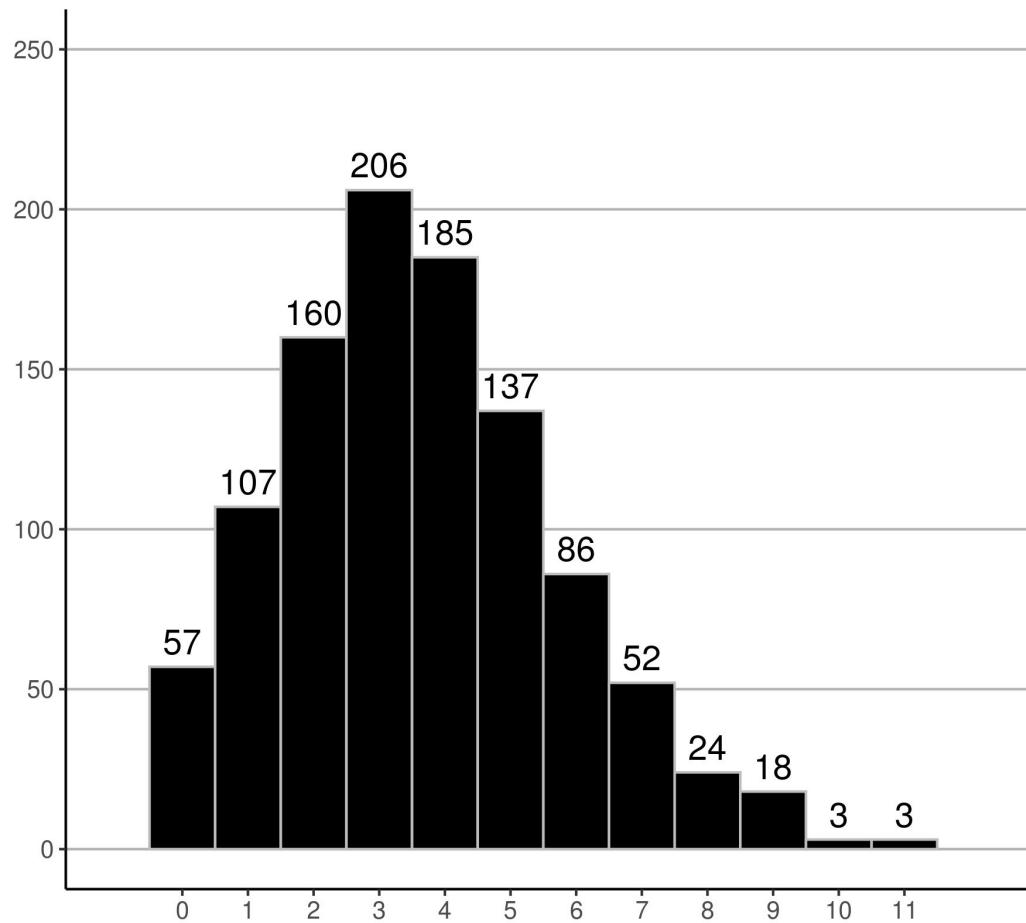
		Direct culture			Enrichment culture		
Variable	Category	P-value	Base Risk	CI 95%	P-Value	Base Risk	CI 95%
Sex	Woman	<b>0.0002</b>	1		<b>0.027</b>	1	
	Man	0.999	0.845	<b>0.805 - 0.884</b>	0.843	0.937	<b>0.900 - 0.974</b>
School	Vocational	0.548	1		0.353	1	
	General	0.510	1.002	0.950 - 1.054	0.410	0.996	0.954 - 1.038
	Sport	0.403	1.009	0.960 - 1.059	0.811	0.974	0.935 - 1.013
BMI <sup>a</sup>	Healthy	0.150	1		0.301	1	
	Underweight	0.793	0.953	0.905 - 1.001	0.841	0.968	0.928 - 1.008
	Obese	0.914	0.941	<b>0.896 - 0.987</b>	0.246	1.003	0.959 - 1.047
	Overweight	1	0.901	<b>0.860 - 0.943</b>	0.763	0.974	0.935 - 1.012
Smoke	Daily	0.294	1		0.855	1	
	Never	0.503	0.986	0.937 - 1.034	0.486	1.022	0.978 - 1.066
	Sometimes	0.723	0.971	0.922 - 1.020	0.262	1.036	0.991 - 1.081
Snuff	Daily	0.406	1		0.596	1	
	Never	0.414	0.999	0.949 - 1.049	0.310	1.017	0.973 - 1.060
	Sometimes	0.900	0.962	0.915 - 1.010	0.831	0.986	0.947 - 1.025
Alcohol	> 2 month	<b>0.035</b>	1		0.434	1	
	<=1 month	0.806	0.933	<b>0.885 - 0.980</b>	0.602	0.991	0.948 - 1.034
	Never	0.739	0.938	<b>0.890 - 0.986</b>	0.323	1.006	0.964 - 1.049
Physical Activity <sup>b</sup>	Light	0.301	1		0.089	1	
	None	0.994	0.930	<b>0.886 - 0.975</b>	0.803	0.952	<b>0.914 - 0.990</b>
	Medium	<b>0.008</b>	1.053	0.999 - 1.107	0.267	0.982	0.941 - 1.023
	Hard	0.883	0.959	0.913 - 1.005	0.817	0.951	<b>0.913 - 0.989</b>
Hormonal Contraceptives <sup>a</sup>	Non-user	0.444	1		0.494	1	
	Progestin	0.369	1.126	-0.230 - 2.482	0.392	1.239	-0.576 - 3.054
	Low Estrogen	0.430	1.024	-0.414 - 2.264	0.475	1.046	-0.840 - 2.932
	High Estrogen	0.476	0.940	-0.546 - 2.425	0.483	1.027	-0.862 - 2.916

Relationships of students with same SPAT1.

Only nodes with valid SPAT1 are shown.



Popularity in the overall network  
( how many people likes you )



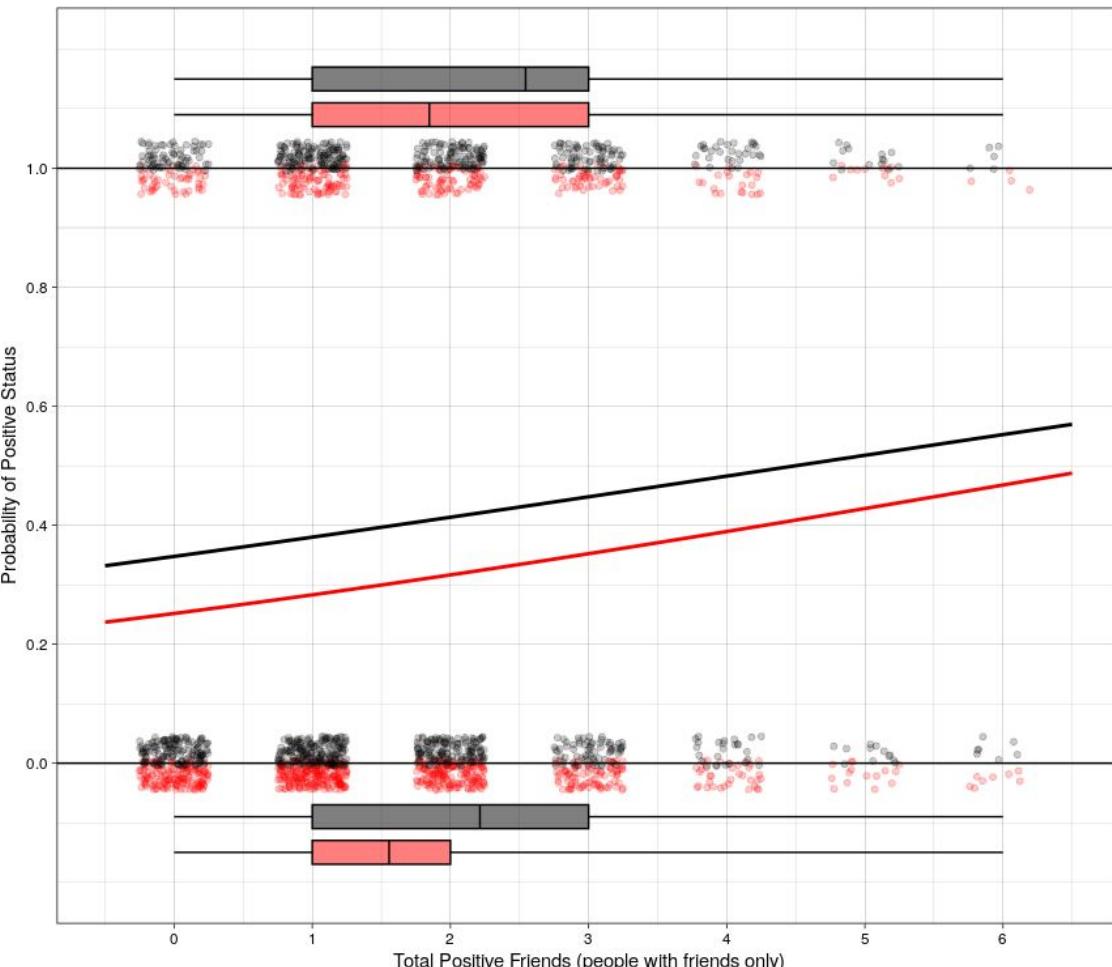
**Table 4 Average popularity in the overall network for each variable.** The Tromsø study Fit Futures 1.  
Participants with missing data are excluded from the analysis.

	Average Popularity (3.62)	Relative physical isolation (%)	Relative frequency all (%)
<b>Sex</b>	<b>** 0.008</b>		
Male	3.46	70	51.1
Female	3.81	30	48.9
<b>BMI-category<sup>a</sup></b>	<b>** 0.001</b>		
< 18.5 kg/m <sup>2</sup>	3.61	9.23	10.60
18.5- $\leq$ 25 kg/m <sup>2</sup>	3.72	62.31	68.40
25- $\leq$ 30 kg/m <sup>2</sup>	3.63	14.62	14.16
> 30 kg/m <sup>2</sup>	2.64	13.08	6.45
<b>Smoking</b>	<b>** 0.005</b>		
Daily	2.75	10	4.62
Sometimes	3.90	13.85	18.11
Never	3.60	72.31	75.34
<b>Snuff use</b>	<b>** 0.005</b>		
Daily	3.82	19.23	23.60
Sometimes	4.05	7.69	12.62
Never	3.45	69.23	61.85
<b>School-type</b>	<b>** 0.004</b>		
General	3.83	33.08	37.57
Sports	3.95	5.38	10.02
Vocational	3.43	62.31	52.41
<b>Physical activity<sup>b</sup></b>	0.329		
None	3.45	29.23	22.06
Light	3.56	30.77	32.56
Medium	3.73	21.54	24.95
Hard	3.80	14.62	18.69
<b>Alcohol habits</b>	<b>*** &lt; 0.001</b>		
Never	3.05	41.54	26.97
$\leq$ 1 Month	3.76	30.77	40.46
> 2 Month	3.93	23.85	30.64
<b>Direct culture persistent carrier</b>	0.347		
Positive	3.72	30	30.35
Negative	3.59	70	69.65
<b>Enrichment persistent carrier</b>	<b>** 0.006</b>		
Positive	3.87	38.46	42.58
Negative	3.47	61.54	57.42
<b>Hormonal Contraceptives (Women only, n = 505)<sup>c</sup></b>	Average Popularity (3.81)	Relative physical isolation (%)	Relative frequency all (%)
	* 0.016		
Non-user	4.00	58.97	64.95
Progestin only	2.65	12.82	3.96
Low Estrogen	3.60	12.82	10.50
High Estrogen	3.54	15.38	19.01

**Supplementary table 7 Average number of positive friends with respect to *Staphylococcus aureus* carrier status.** The results indicate that people who are carriers tend to have a significantly greater number of friends who are also carriers, in comparison with people that are not carriers. The Tromsø Study Fit Futures 1.

Direct culture	** 0.002
Persistent carrier	1.85
Non-carrier	1.56
Enrichment culture	*** < 0.001
Persistent carrier	2.54
Non-carrier	2.21

Logistic Regression between total positive friends and probability of positive status



Direct culture	** 0.002
Persistent carrier	1.85
Non-carrier	1.56
Enrichment culture	*** < 0.001
Persistent carrier	2.54
Non-carrier	2.21

- Through social interaction, people change each other belief/behaviour.
- **By similarity:** A wants to be like B  
(ie: gain social acceptance, everybody is buying toilet paper, so I should do the same!)
- **By distinction:** A want to distance from B  
(ie: gain social status, I want a super-sport car so everyone is envious of me!)

$$Y^{(1)} = X\beta$$

$$Y^{(1)} = X\beta$$

$Y^{(1)}$  = N x M matrix of initial opinions on M issues for N actors

$X$  = N x K matrix of K exogenous variables that affect Y

$\beta$  = K x M matrix of coefficients relating X to Y

Your initial beliefs

$$Y^{(1)} = X\beta$$

The kind of person you are

A set of coefficients

$Y^{(1)}$  = N x M matrix of initial opinions on M issues for N actors

$X$  = N x K matrix of K exogenous variables that affect Y

$\beta$  = K x M matrix of coefficients relating X to Y

Your initial beliefs

The kind of person you are

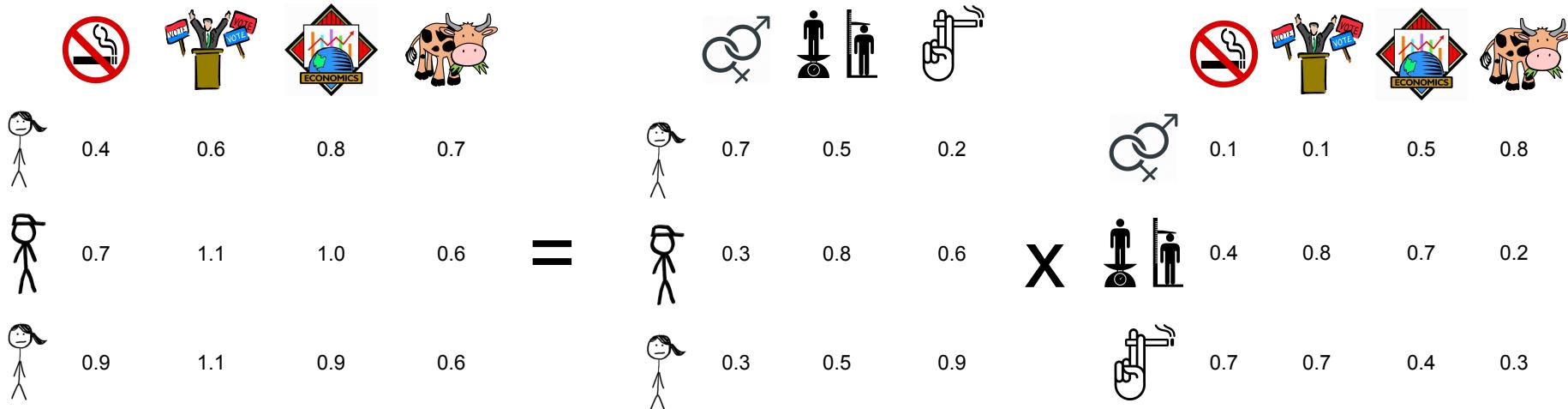
$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$  = N x M matrix of initial opinions on M issues for N actors

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Your initial beliefs

The kind of person you are

$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$  = N x M matrix of initial opinions on M issues for N actors

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$\beta$  = K x M matrix of coefficients relating X to Y

$$Y^{(t)} = \alpha W Y^{(t-1)} + (1 - \alpha) Y^{(1)}$$

Your initial beliefs

The kind of person you are



$$Y^{(1)} = X\beta$$



A set of coefficients

$Y^{(1)}$  = N x M matrix of initial opinions on M issues for N actors

$X$  = N x K matrix of K exogenous variables that affect Y

$\beta$  = K x M matrix of coefficients relating X to Y

$$Y^{(t)} = \alpha W Y^{(t-1)} + (1 - \alpha) Y^{(1)}$$

$Y^{(t)}$  = N x M matrix of current opinions on M issues for N actors

$W$  = N x N matrix of interpersonal influences

$\alpha$  = a weight of the strength of endogenous interpersonal influences

Your initial beliefs

The kind of person you are



$$Y^{(1)} = X\beta$$



A set of coefficients

$Y^{(1)}$  = N x M matrix of initial opinions on M issues for N actors

$X$  = N x K matrix of K exogenous variables that affect Y

$\beta$  = K x M matrix of coefficients relating X to Y

Your initial beliefs

$$Y^{(t)} = \alpha W Y^{(t-1)} + (1 - \alpha) Y^{(1)}$$

$Y^{(t)}$  = N x M matrix of current opinions on M issues for N actors

$W$  = N x N matrix of interpersonal influences

$\alpha$  = a weight of the strength of endogenous interpersonal influences

Your initial beliefs

The kind of person you are

$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$  = N x M matrix of initial opinions on M issues for N actors

$X$  = N x K matrix of K exogenous variables that affect Y

$\beta$  = K x M matrix of coefficients relating X to Y

Your initial beliefs

$$Y^{(t)} = \alpha W Y^{(t-1)} + (1 - \alpha) Y^{(1)}$$

The opinions of others

Your opinions

$Y^{(t)}$  = N x M matrix of current opinions on M issues for N actors

$W$  = N x N matrix of interpersonal influences

$\alpha$  = a weight of the strength of endogenous interpersonal influences

Your initial beliefs

The kind of person you are

$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$  = N x M matrix of initial opinions on M issues for N actors

$X$  = N x K matrix of K exogenous variables that affect Y

$\beta$  = K x M matrix of coefficients relating X to Y

How stubborn / naive you are

Your initial beliefs

$$Y^{(t)} = \alpha W Y^{(t-1)} + (1 - \alpha) Y^{(1)}$$

The opinions of others

Your opinions

$Y^{(t)}$  = N x M matrix of current opinions on M issues for N actors

$W$  = N x N matrix of interpersonal influences

$\alpha$  = a weight of the strength of endogenous interpersonal influences

Your initial beliefs

The kind of person you are

$$Y^{(1)} = X\beta$$

A set of coefficients

$Y^{(1)}$  = N x M matrix of initial opinions on M issues for N actors

$X$  = N x K matrix of K exogenous variables that affect Y

$\beta$  = K x M matrix of coefficients relating X to Y

How stubborn / naive you are

Your initial beliefs

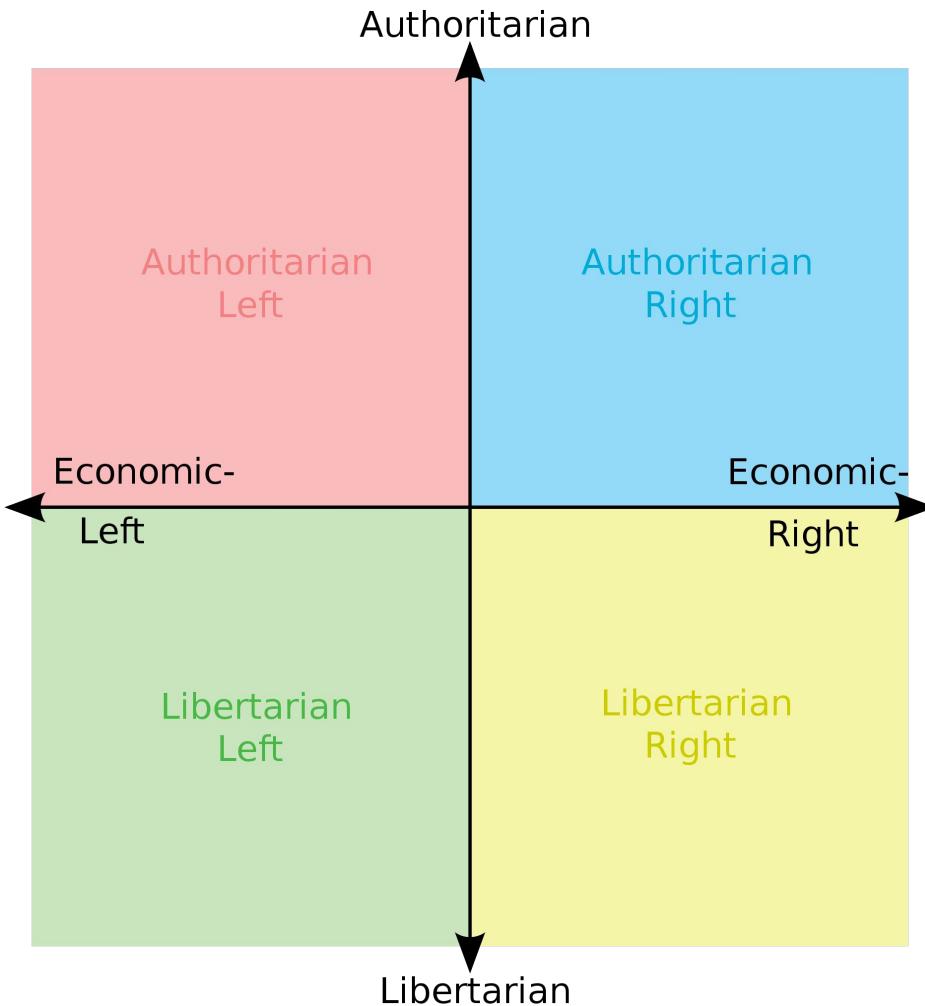
$$Y^{(t)} = \alpha W Y^{(t-1)} + (1 - \alpha) Y^{(1)}$$

How much do you value the  
opinion of each friend

$Y^{(t)}$  = N x M matrix of current opinions on M issues for N actors

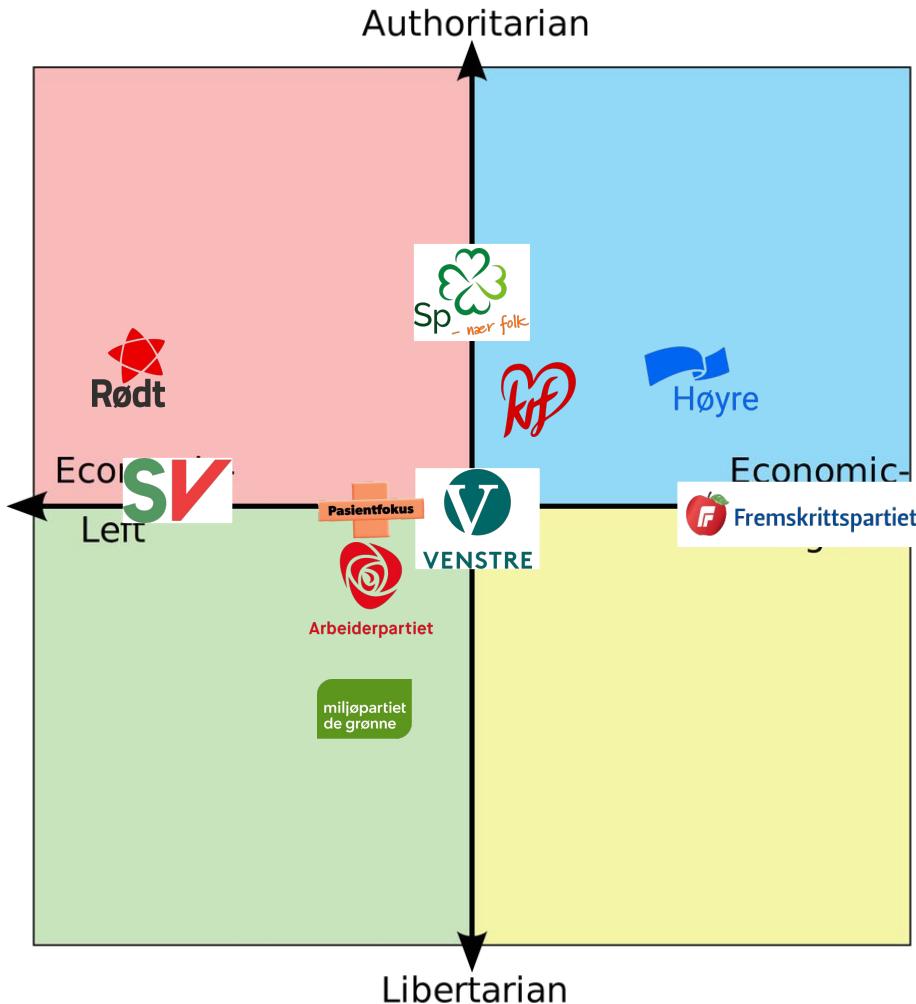
$W$  = N x N matrix of interpersonal influences

$\alpha$  = a weight of the strength of endogenous interpersonal  
influences

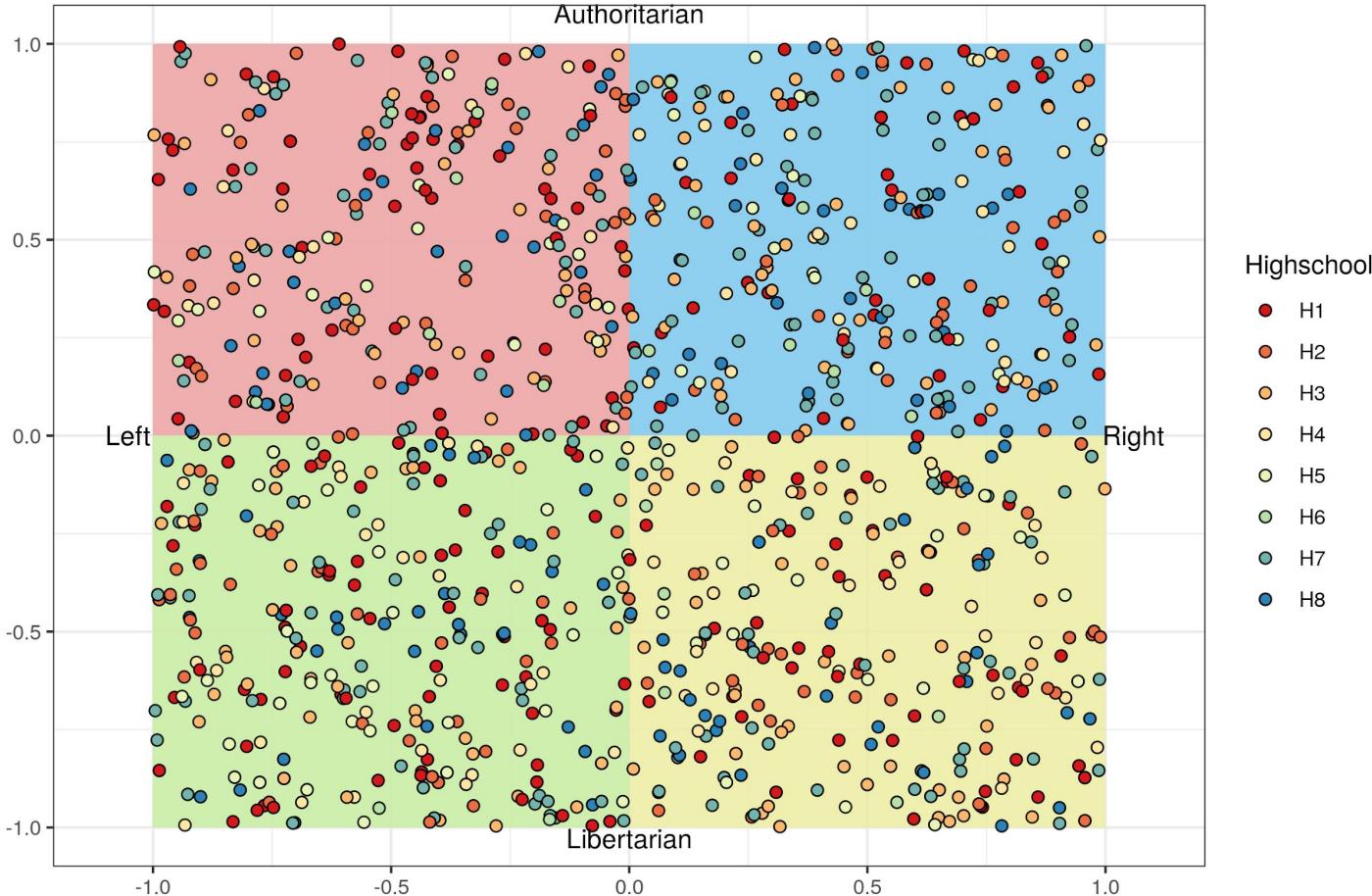




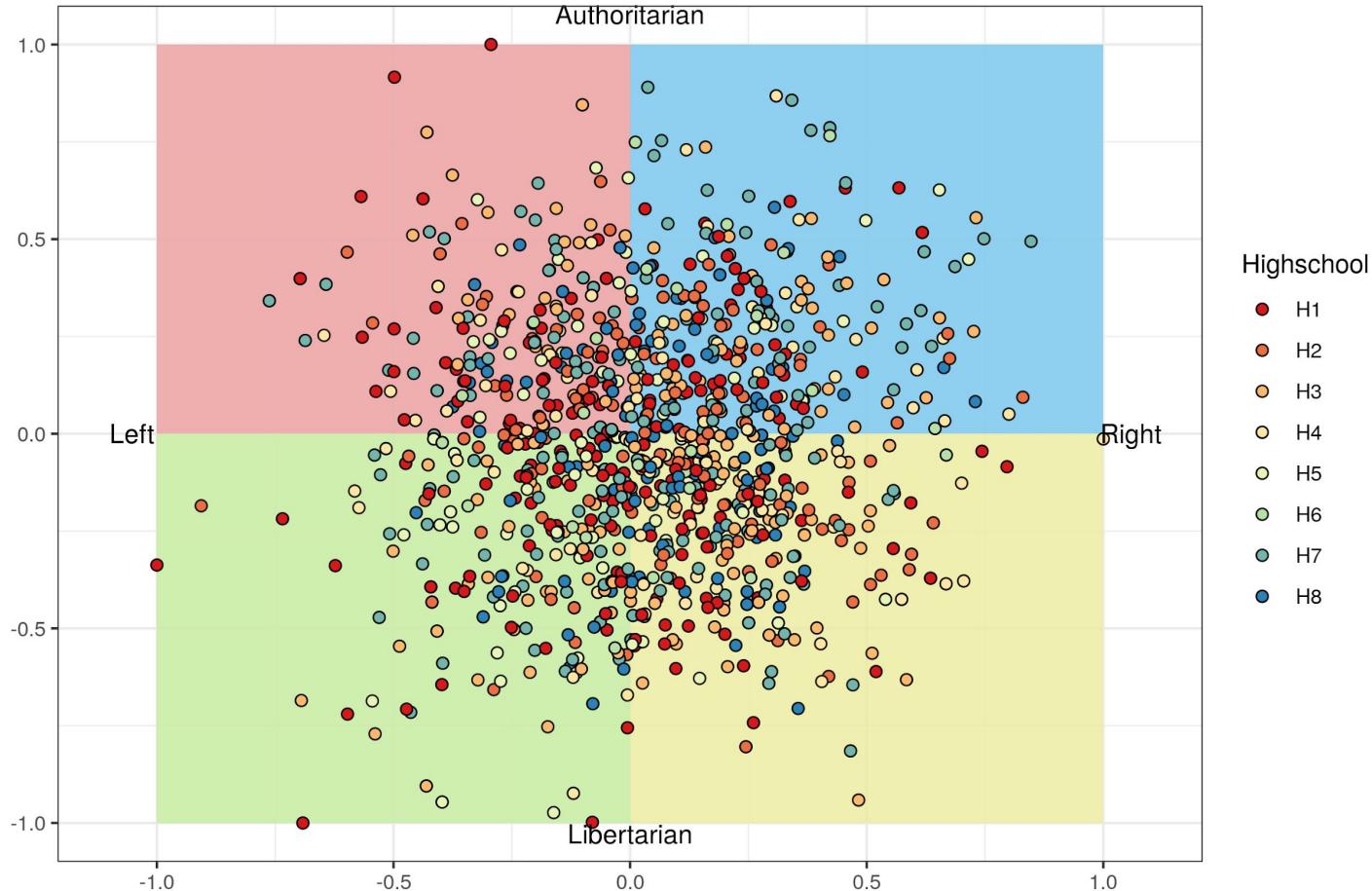
STORTINGET



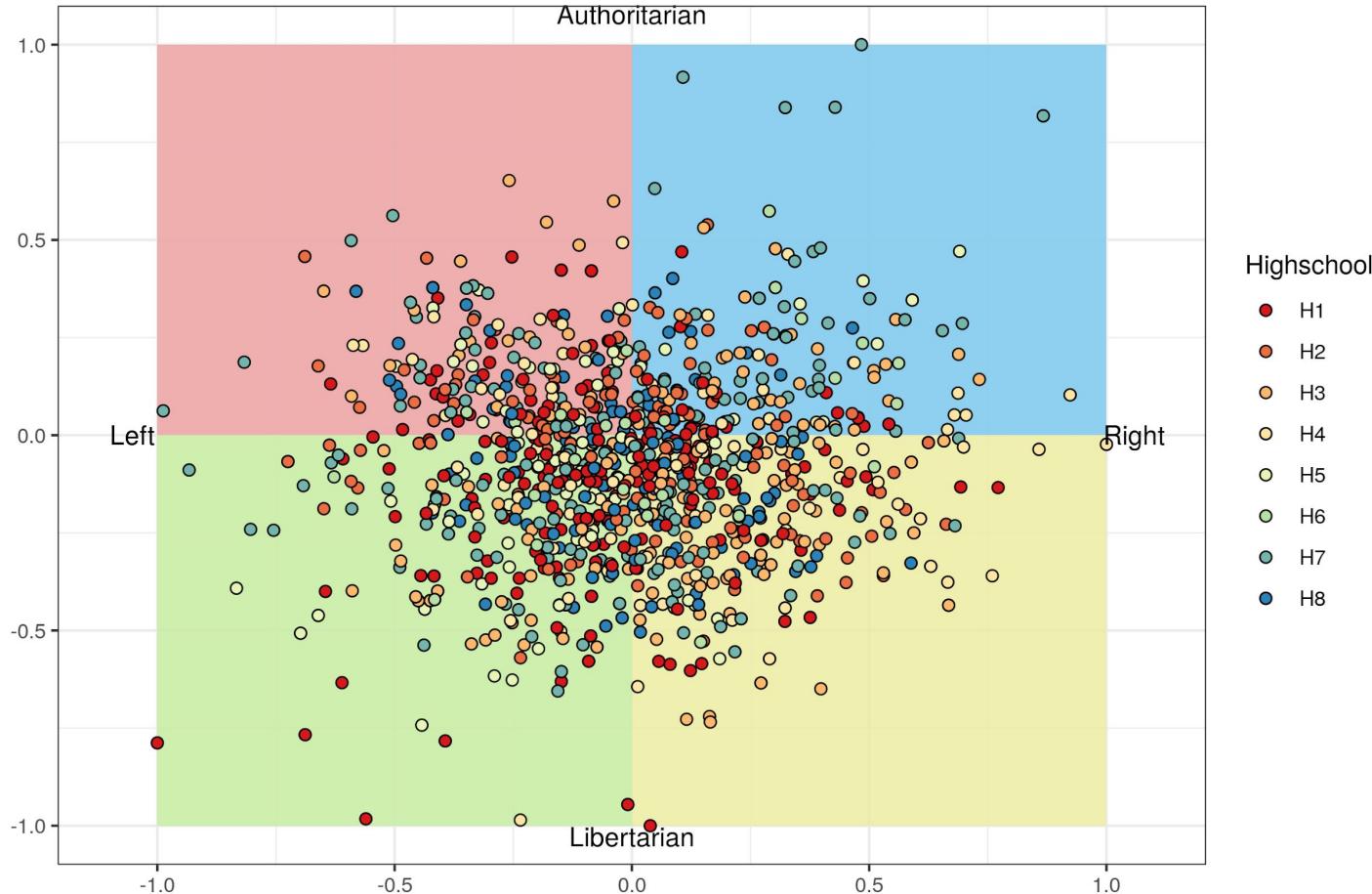
# Original Random Believes



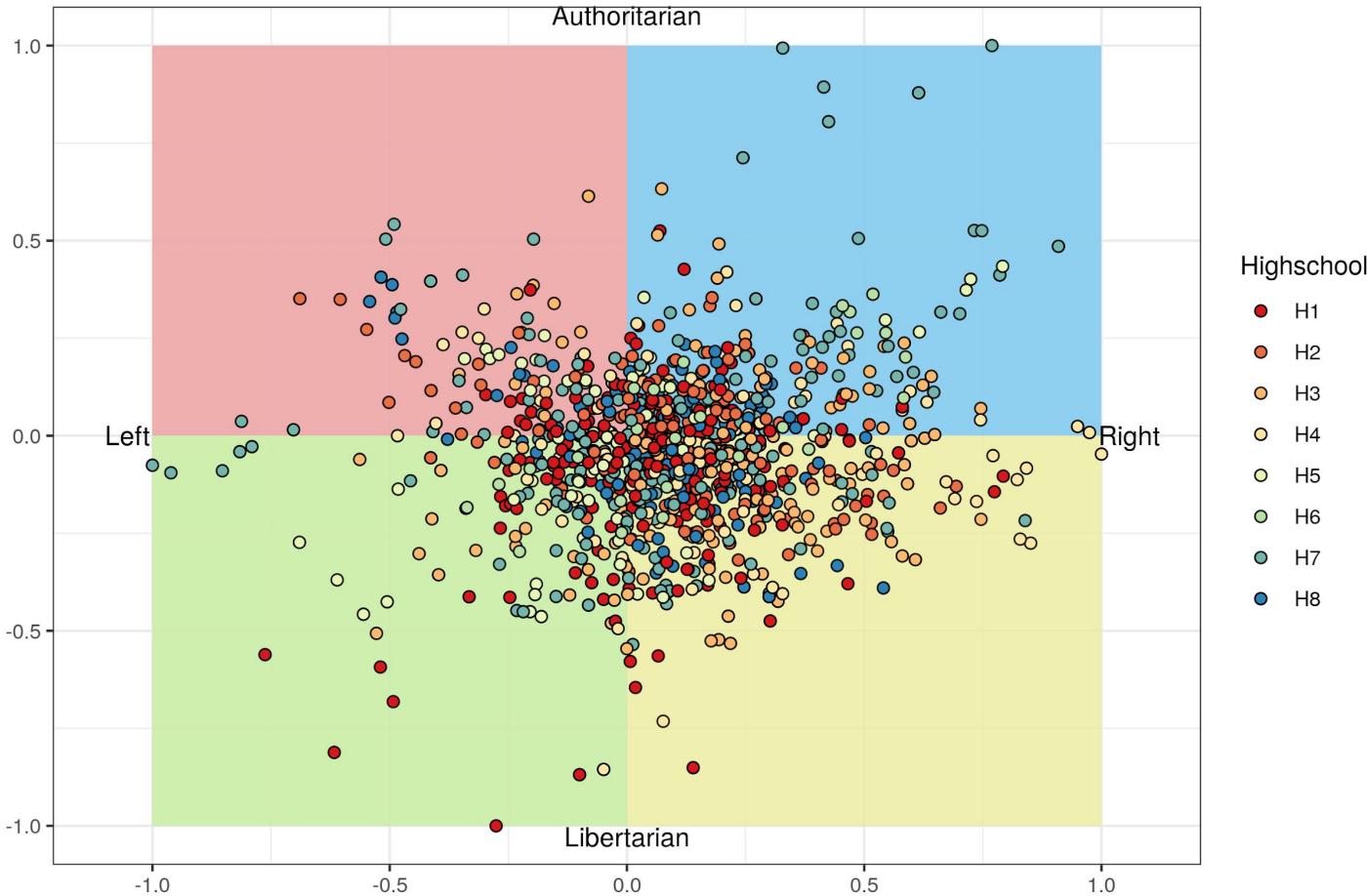
# Political believes at time 1



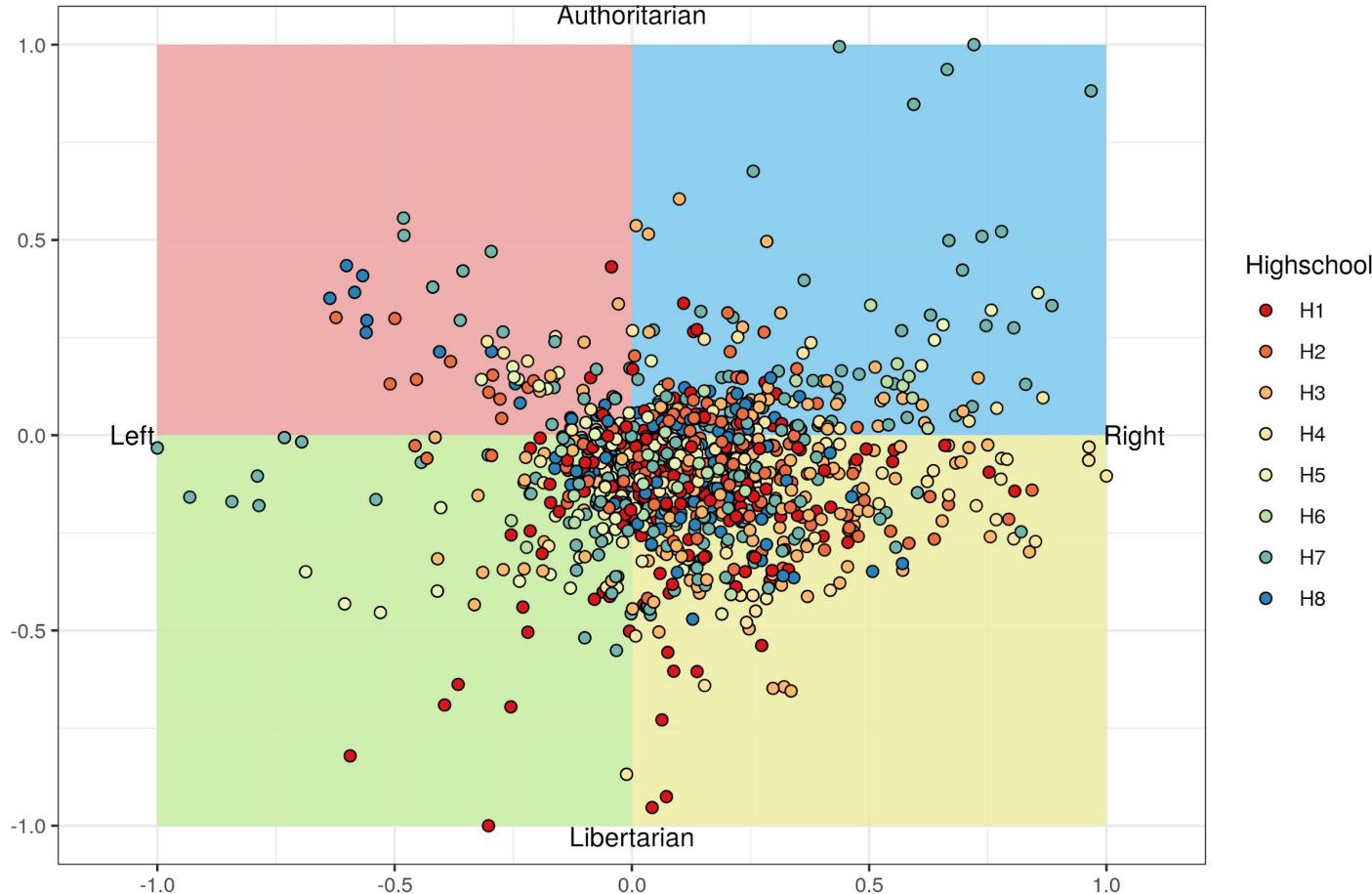
## Political believes at time 2



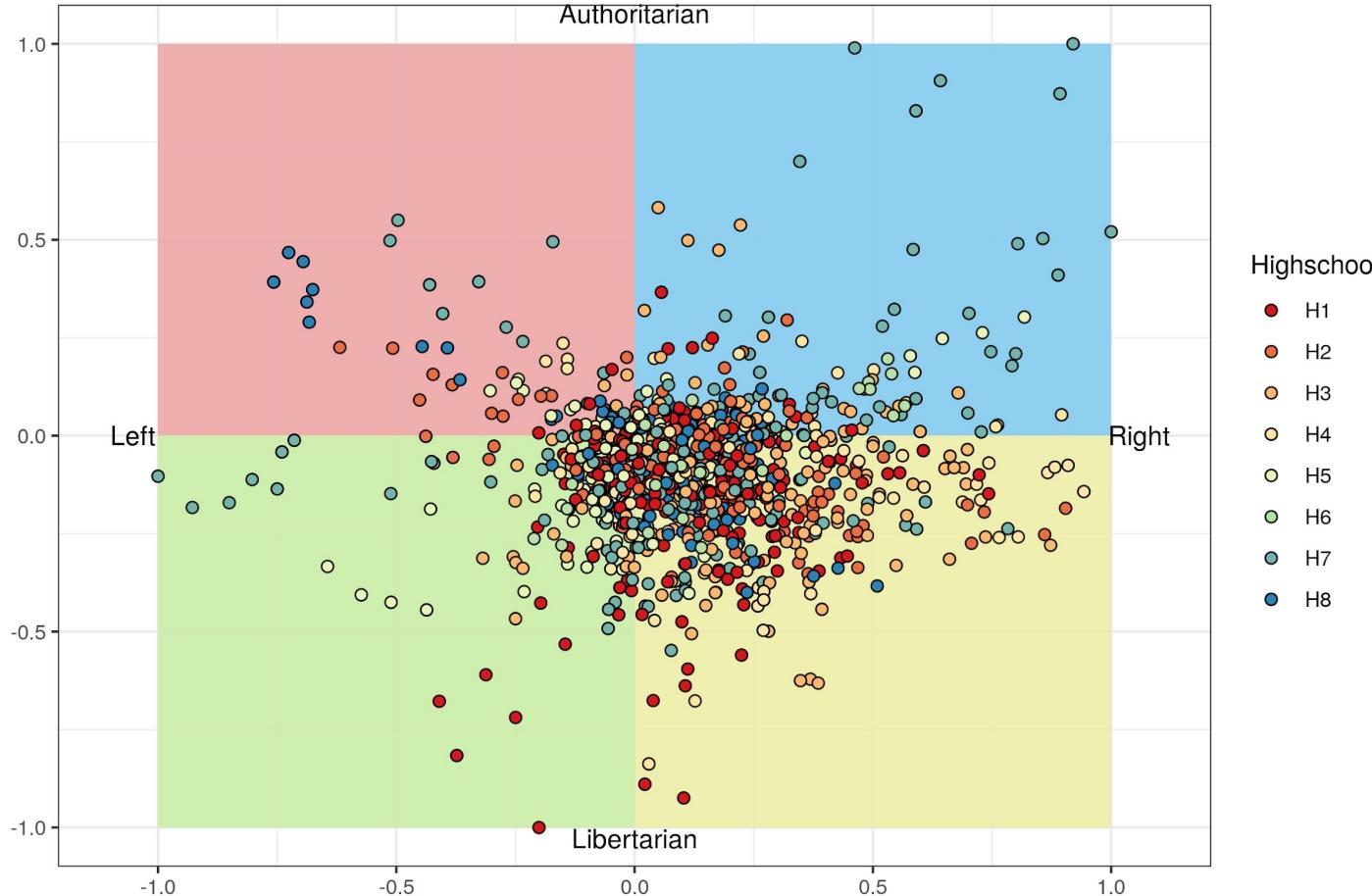
# Political believes at time 3



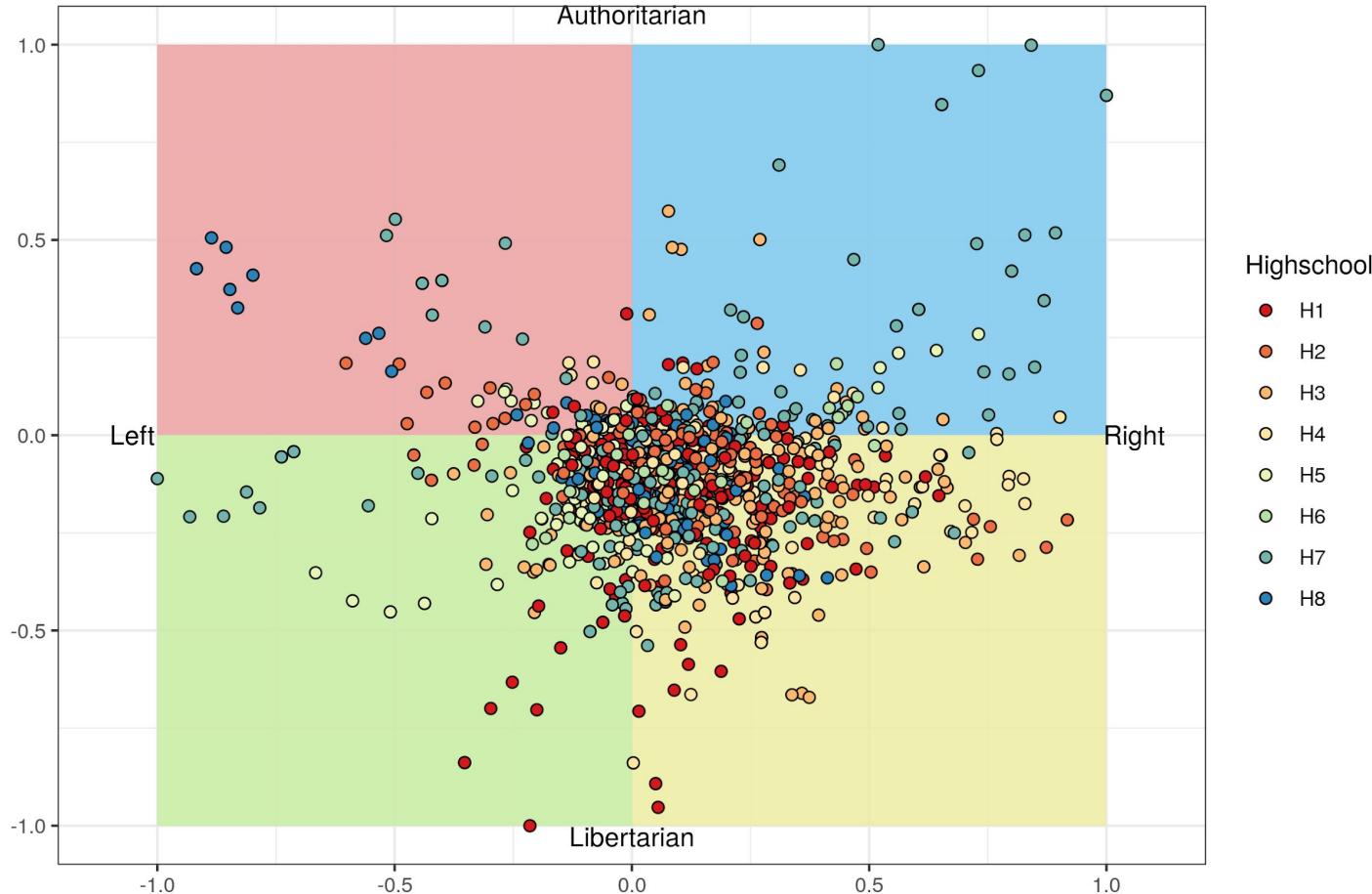
Political believes at time 4



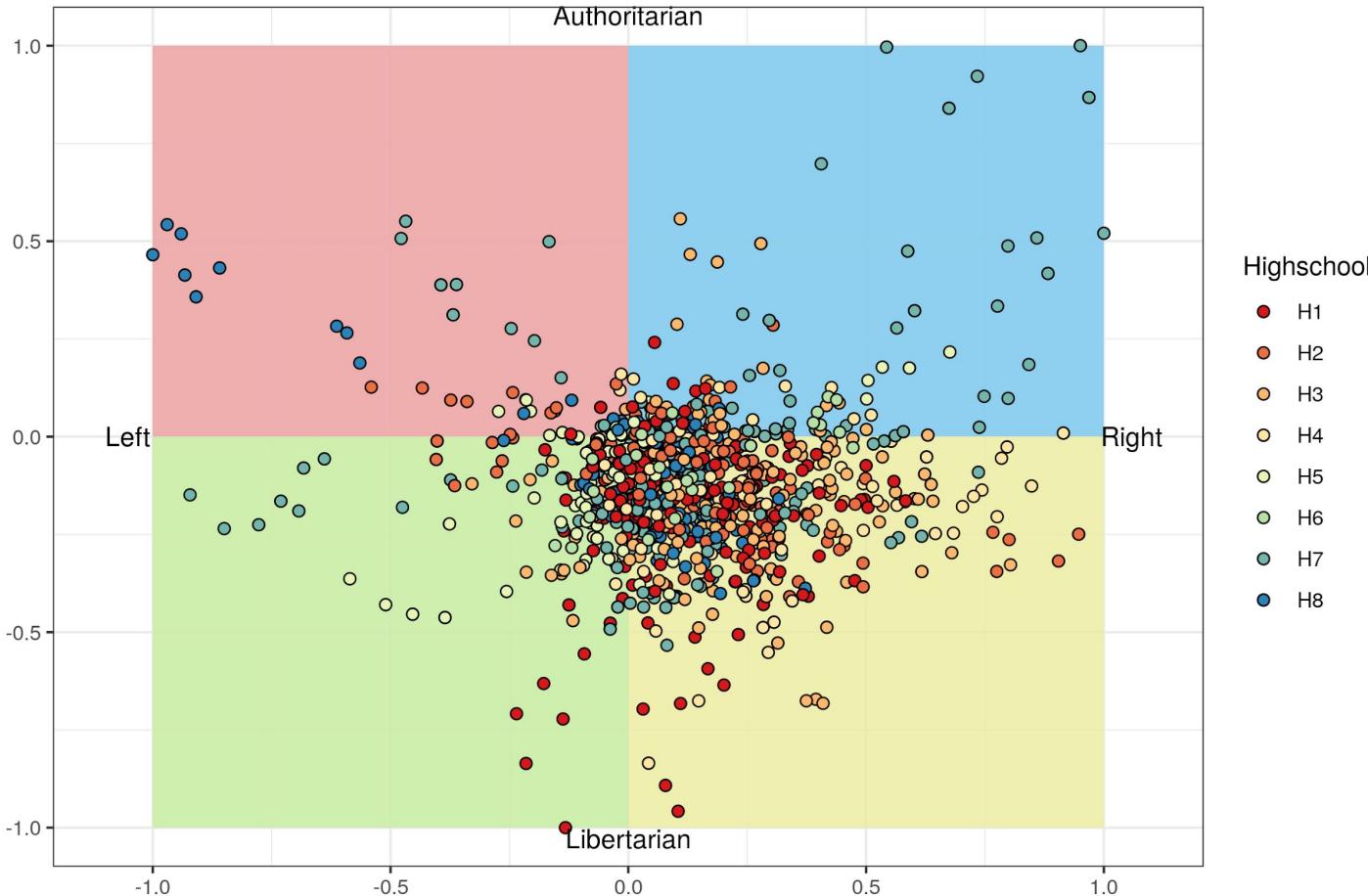
# Political believes at time 5



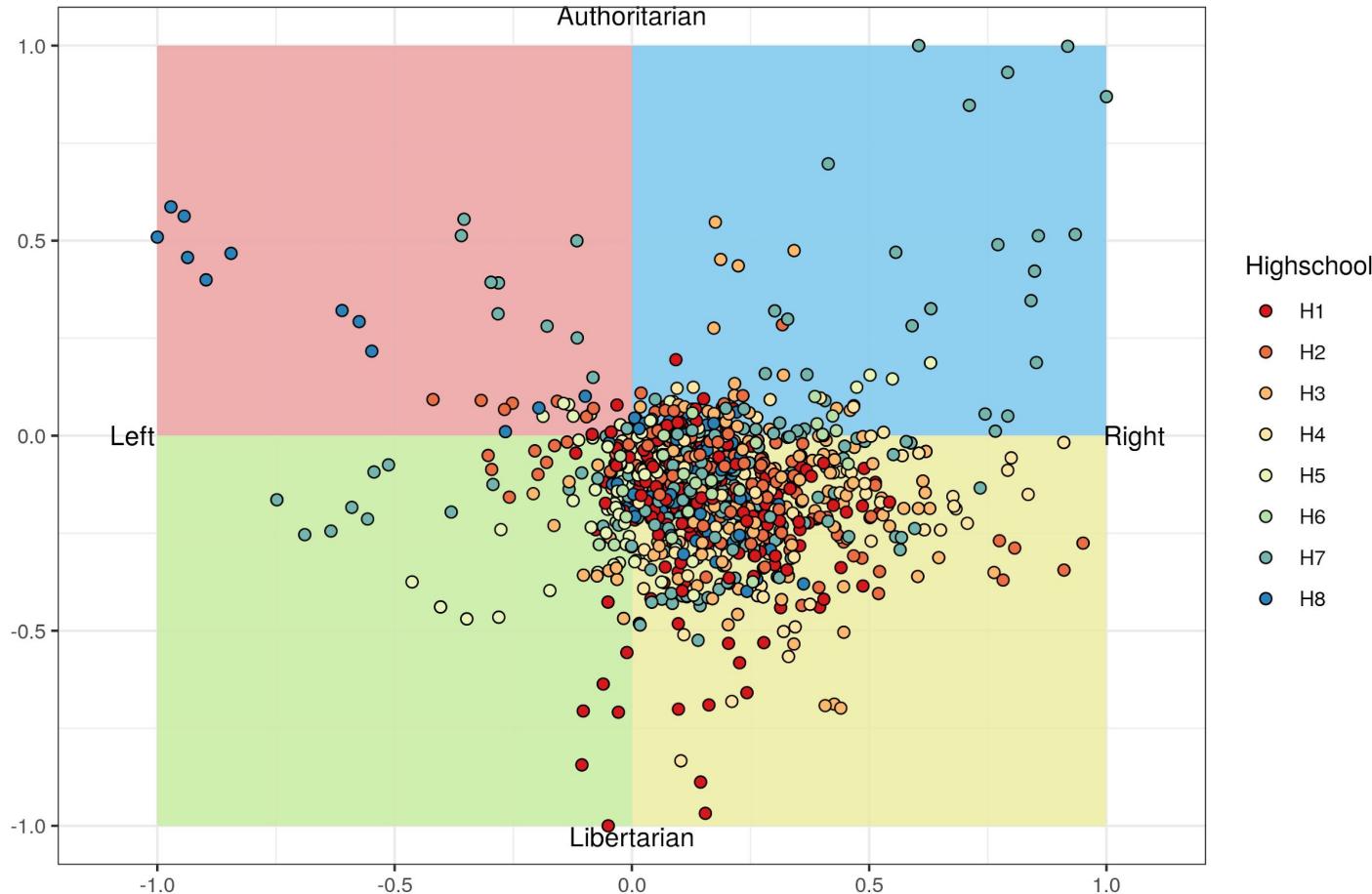
Political believes at time 6



# Political believes at time 7



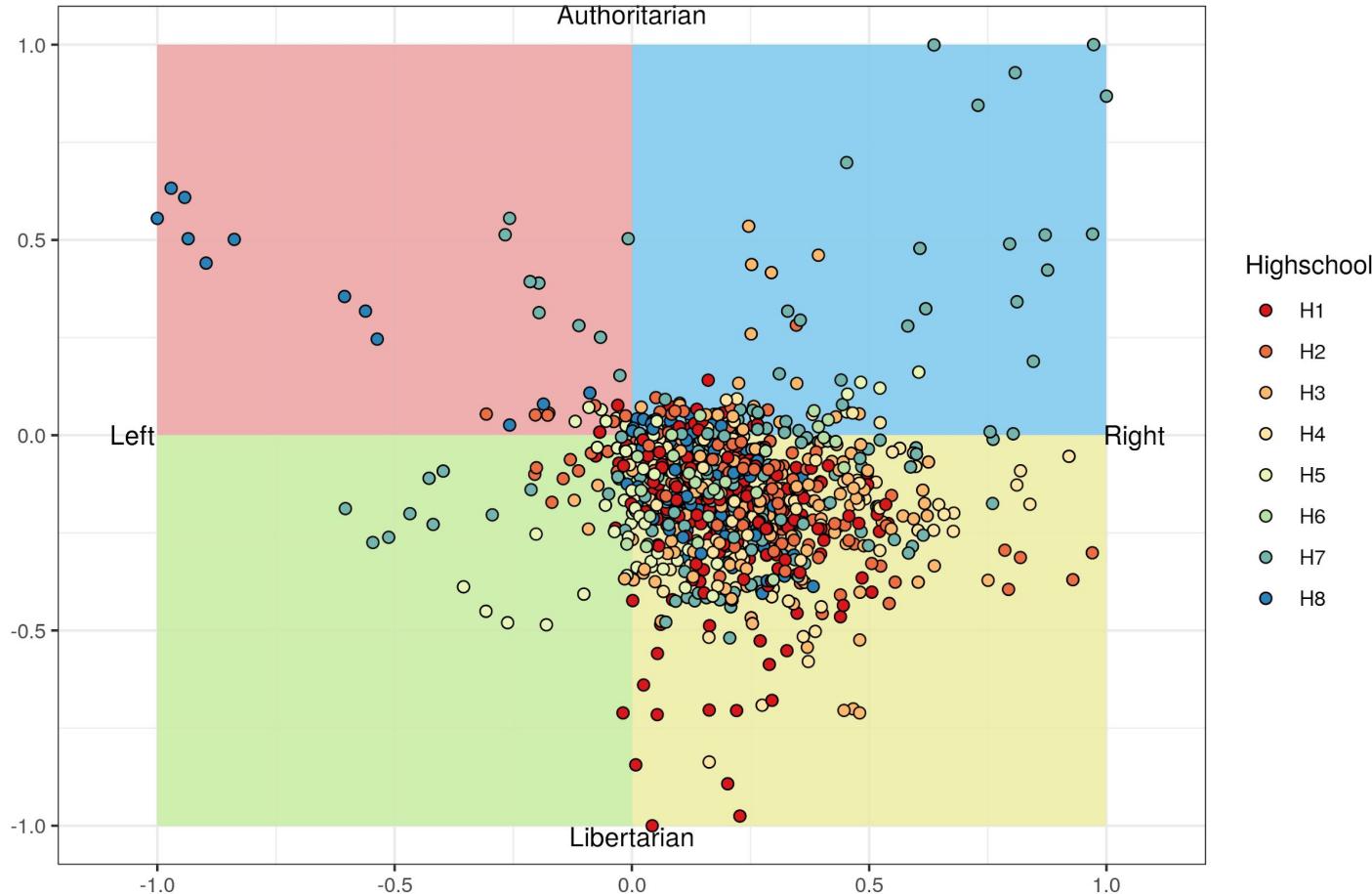
# Political believes at time 8



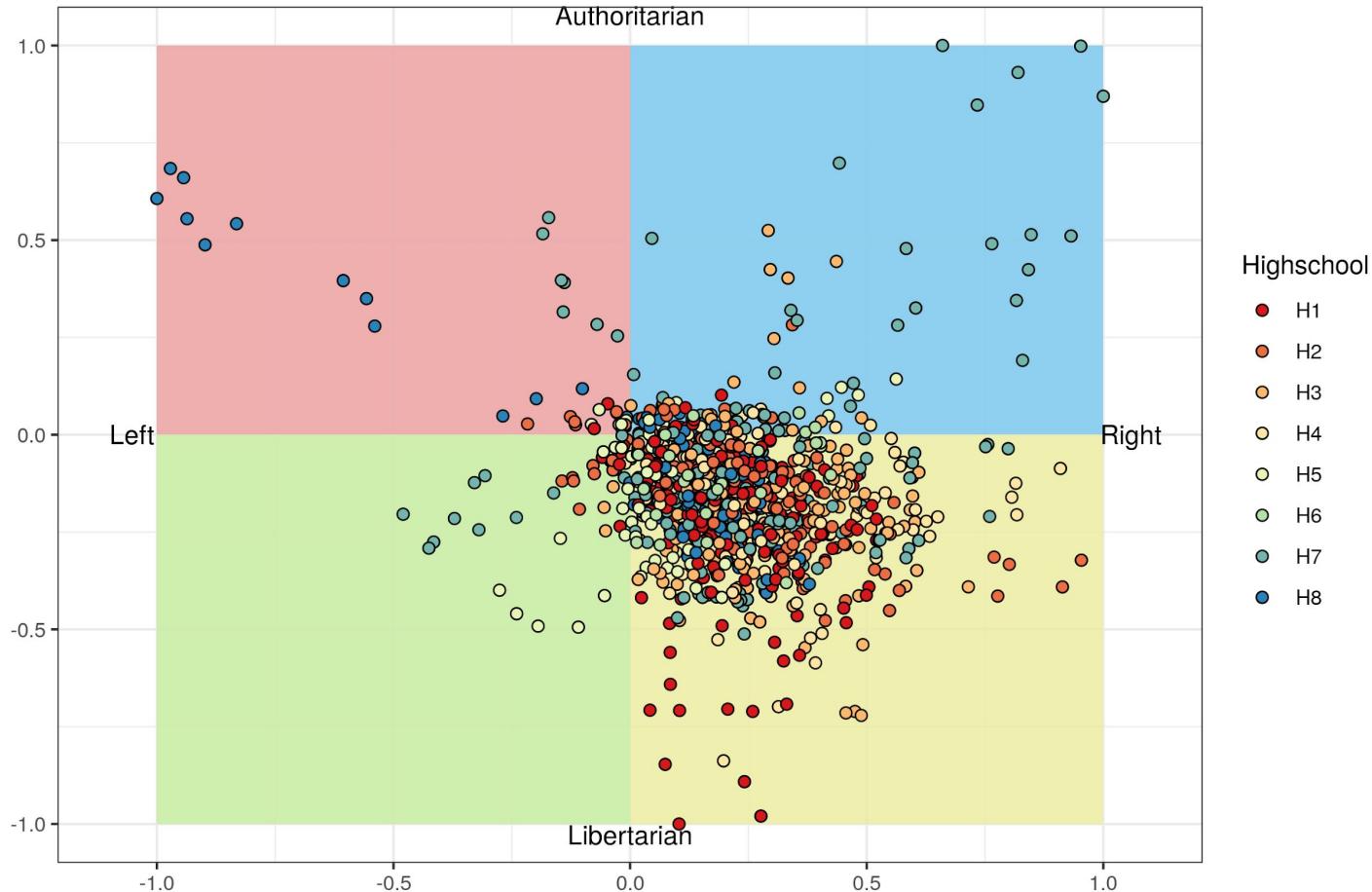
Highschool

- H1
- H2
- H3
- H4
- H5
- H6
- H7
- H8

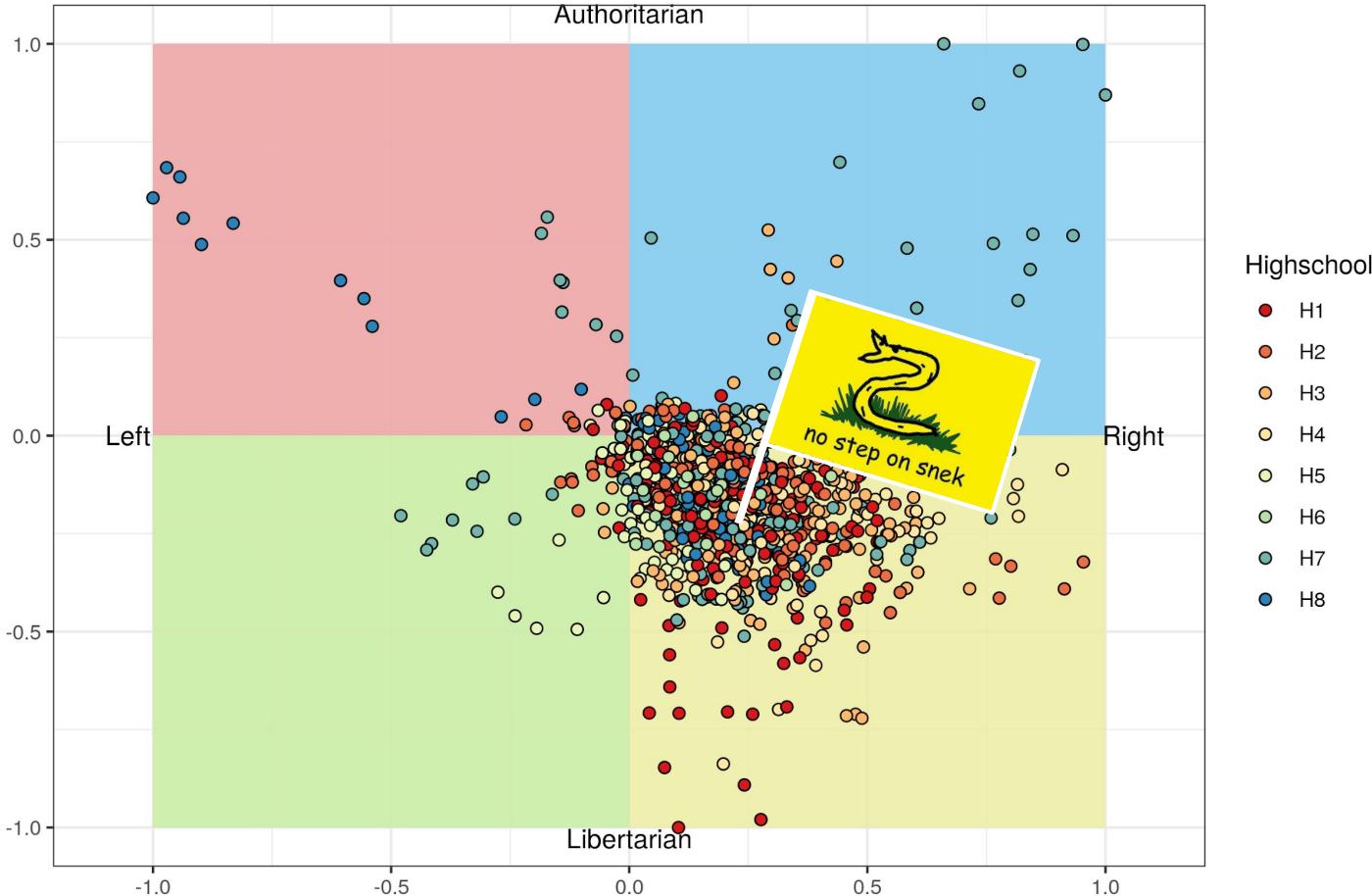
# Political believes at time 9



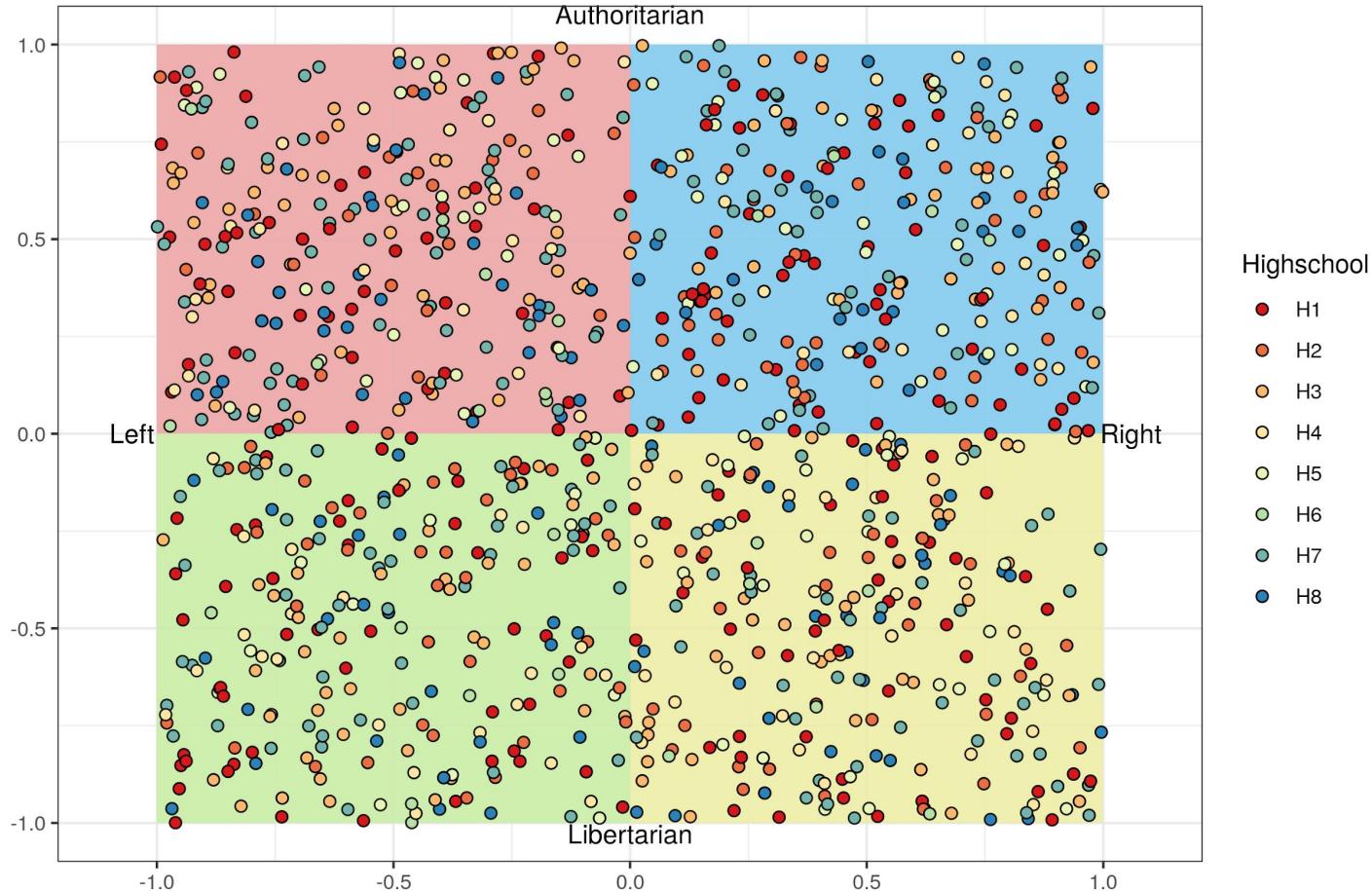
# Political believes at time 10



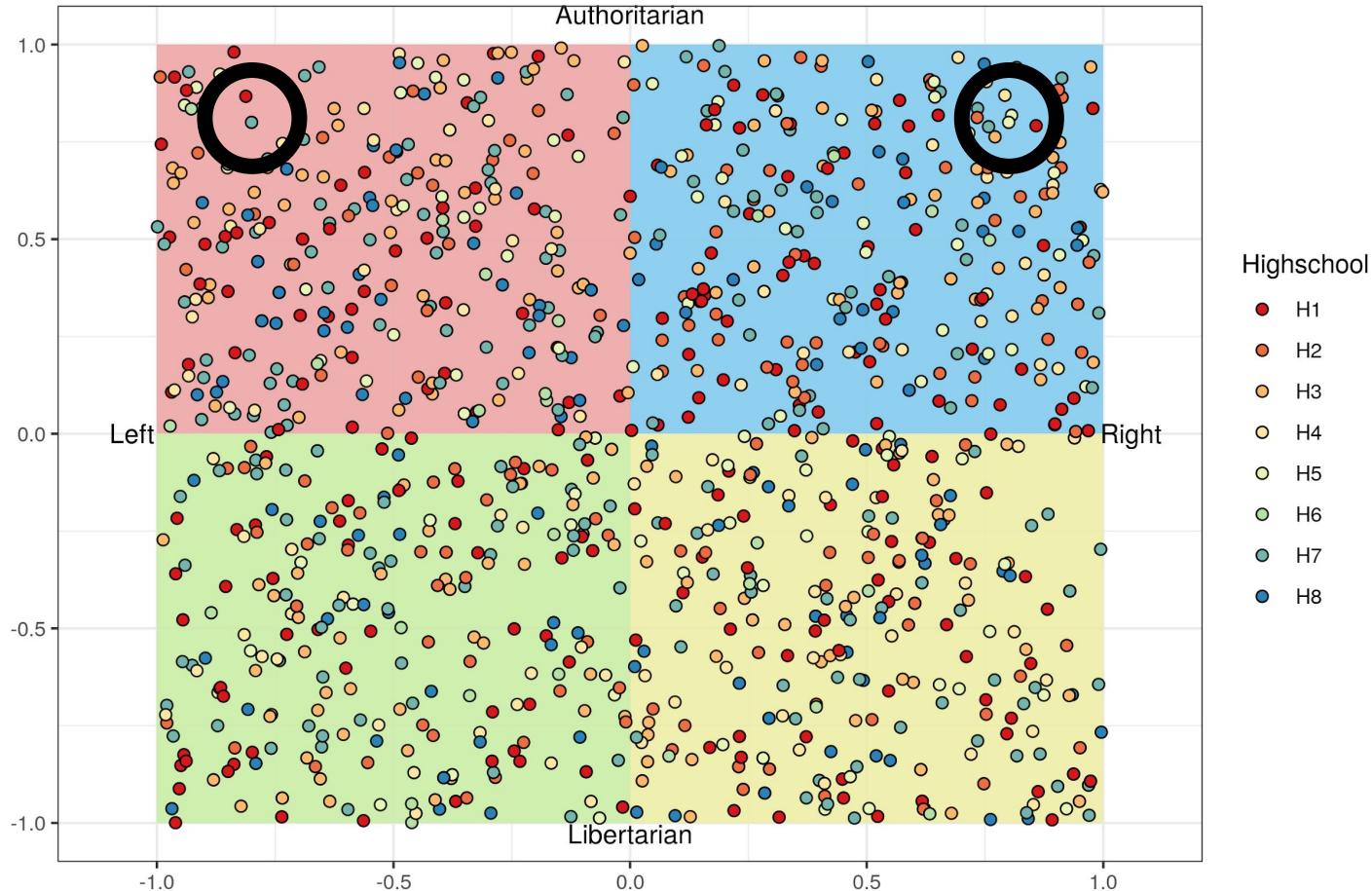
# Political believes at time 10



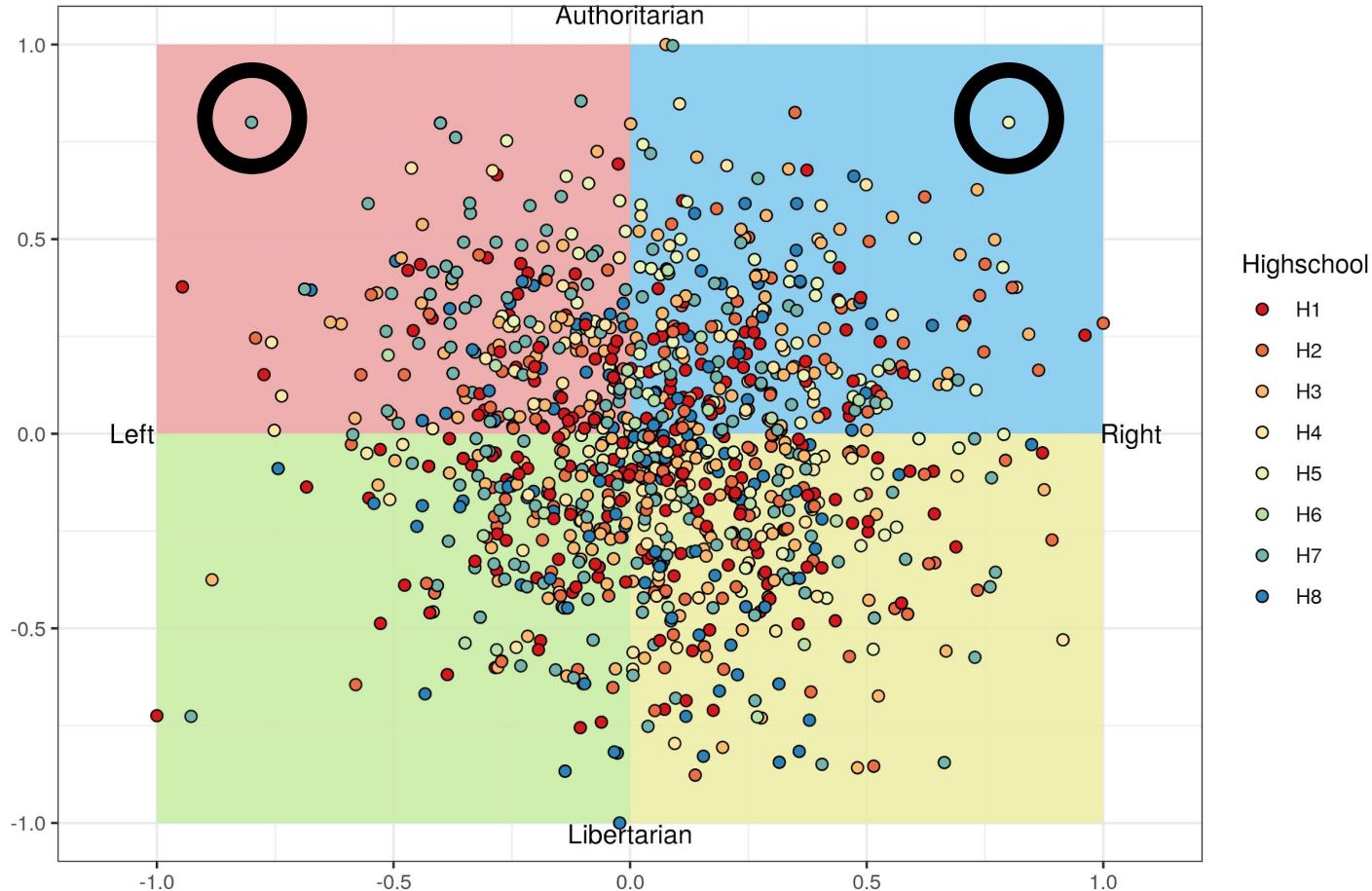
## Original Random Believes



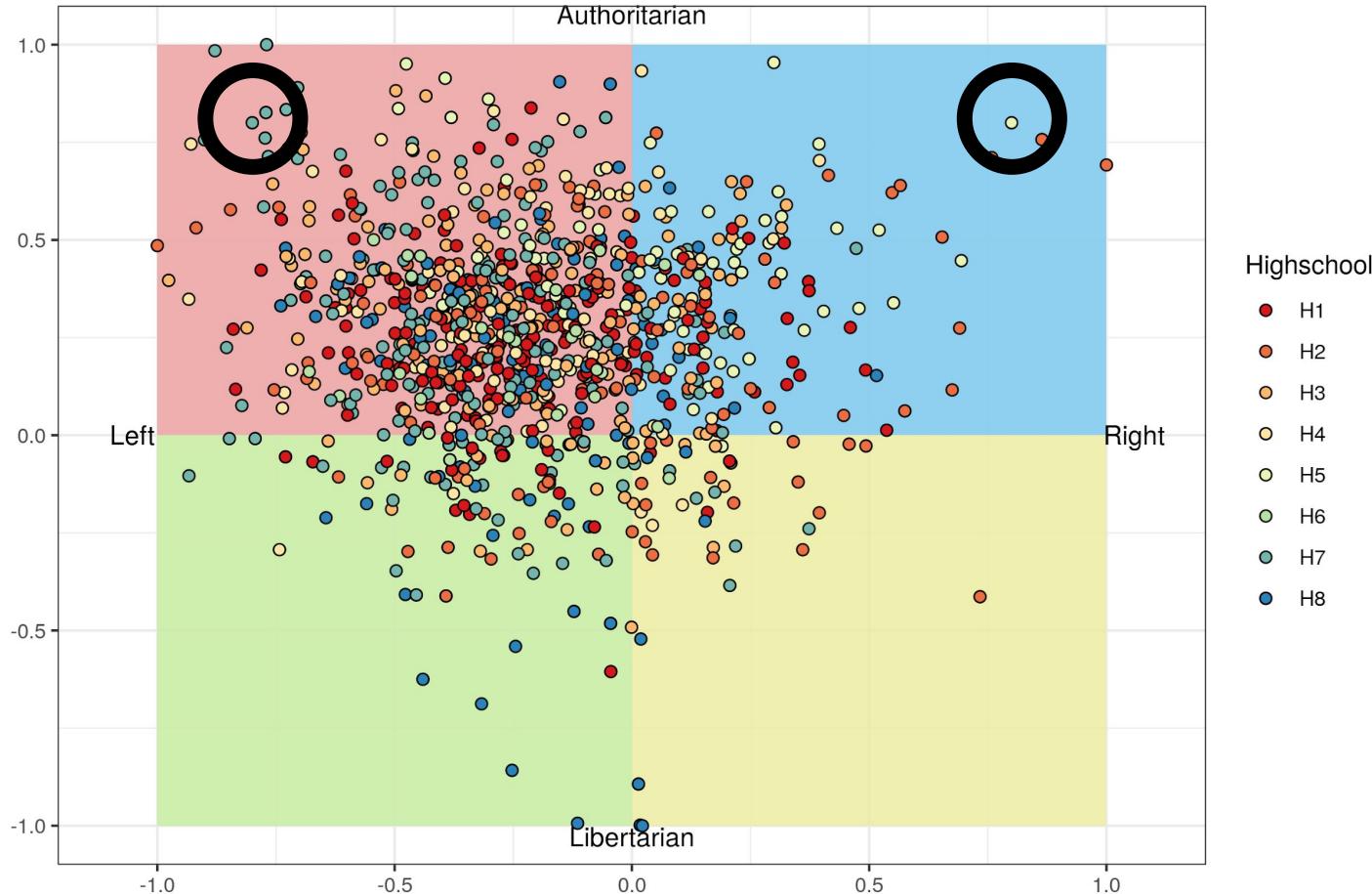
## Original Random Believes



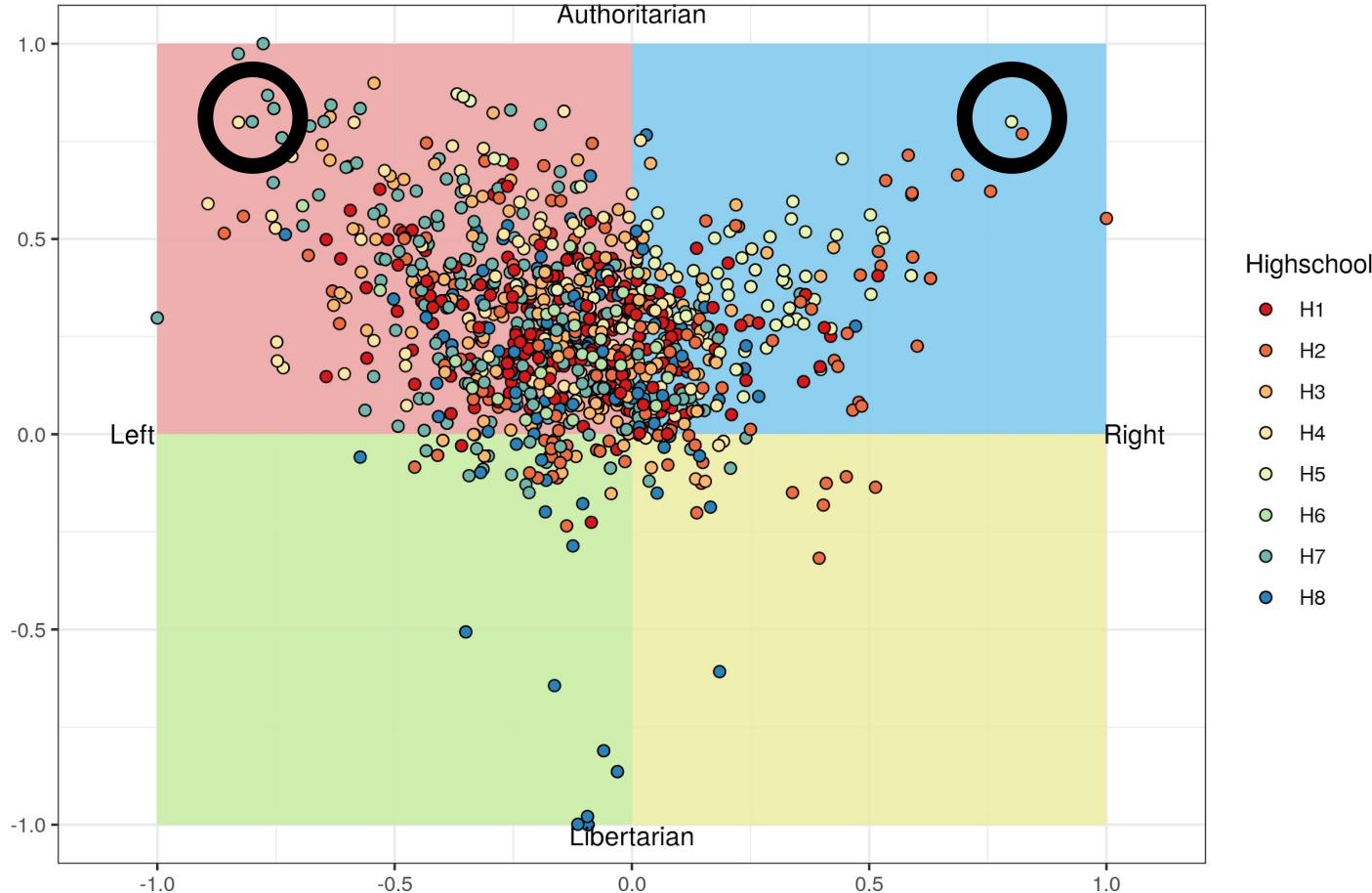
# Political believes at time 1



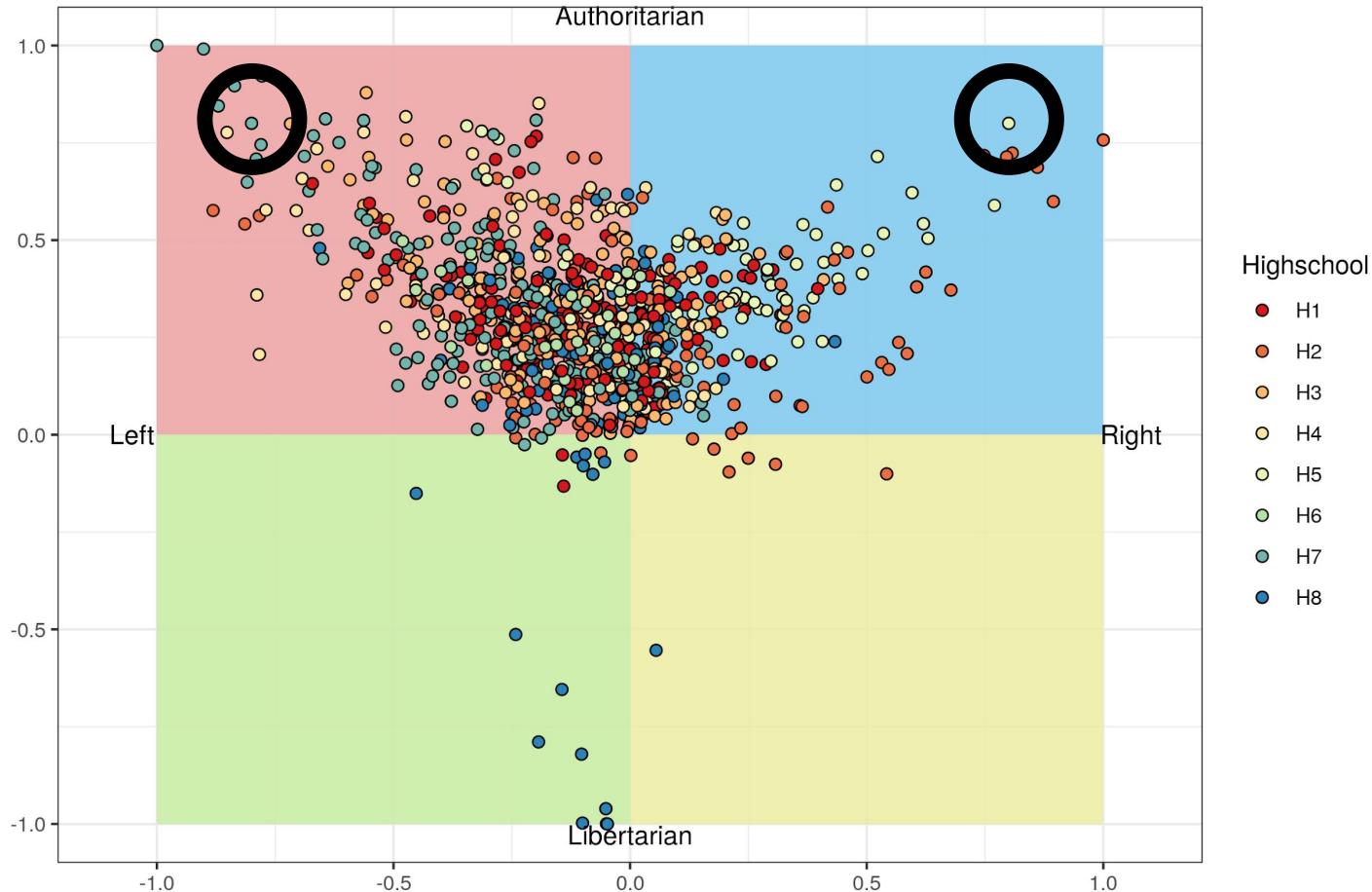
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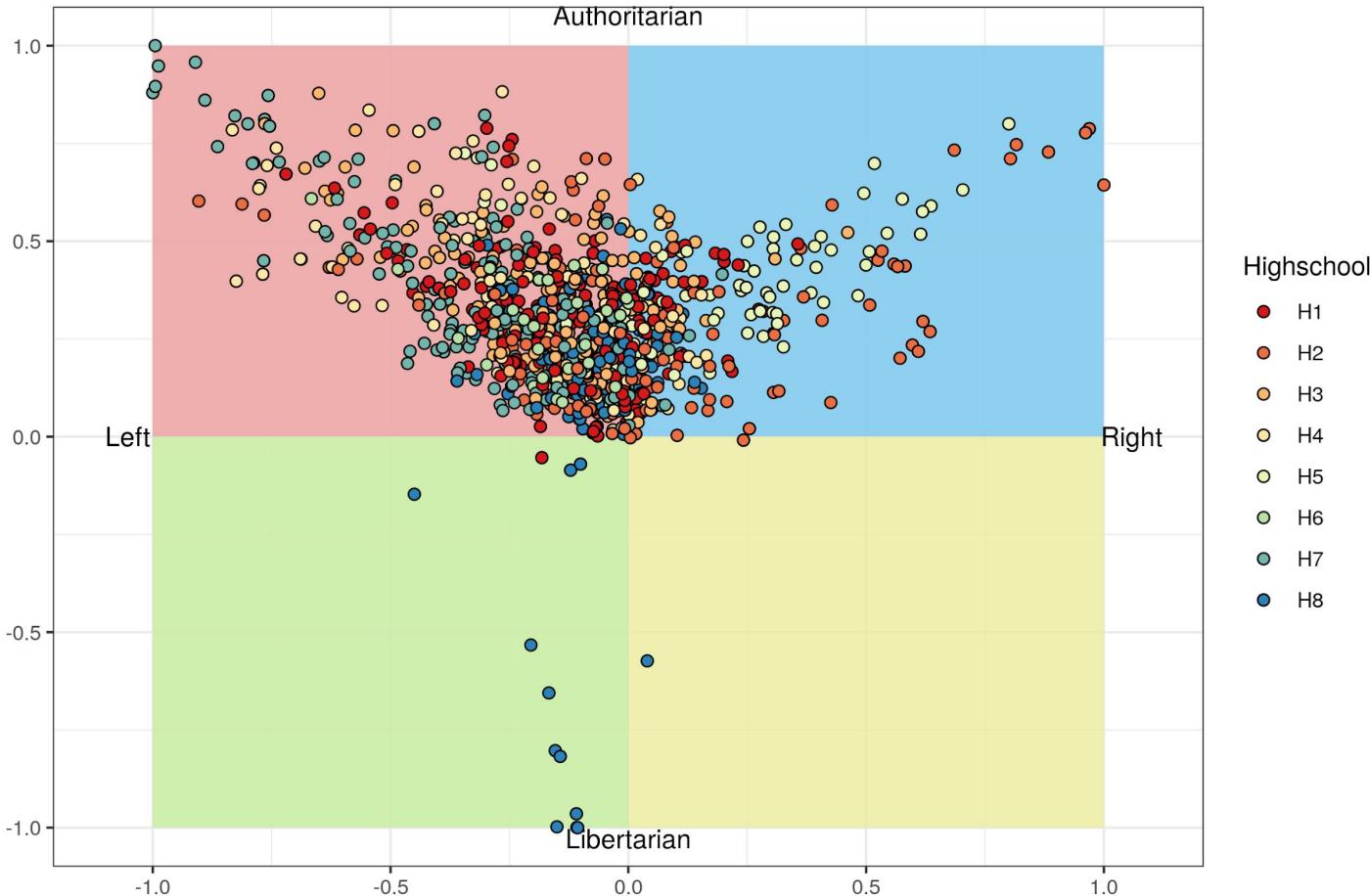
Political believes at time 3



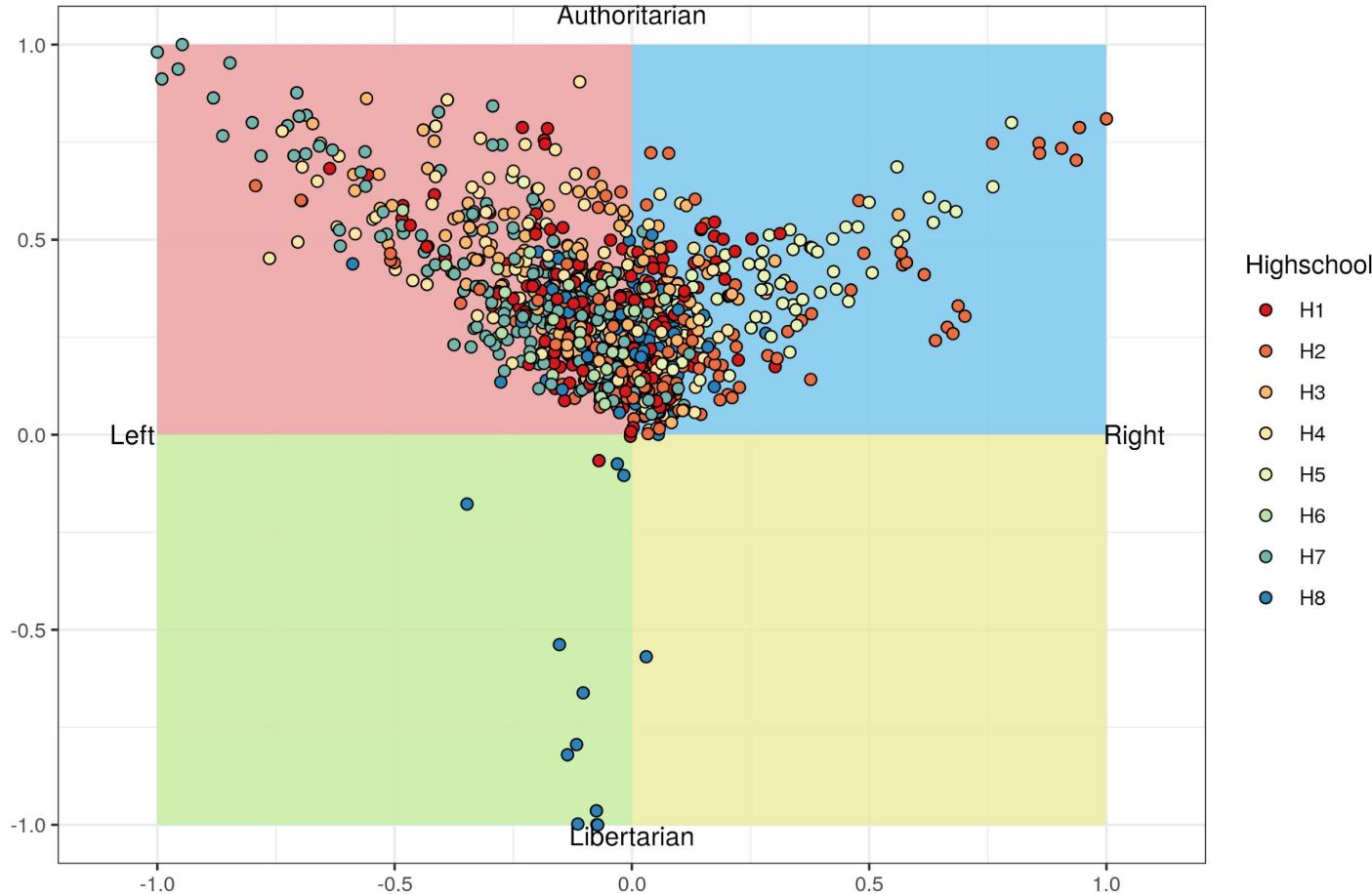
Political believes at time 4



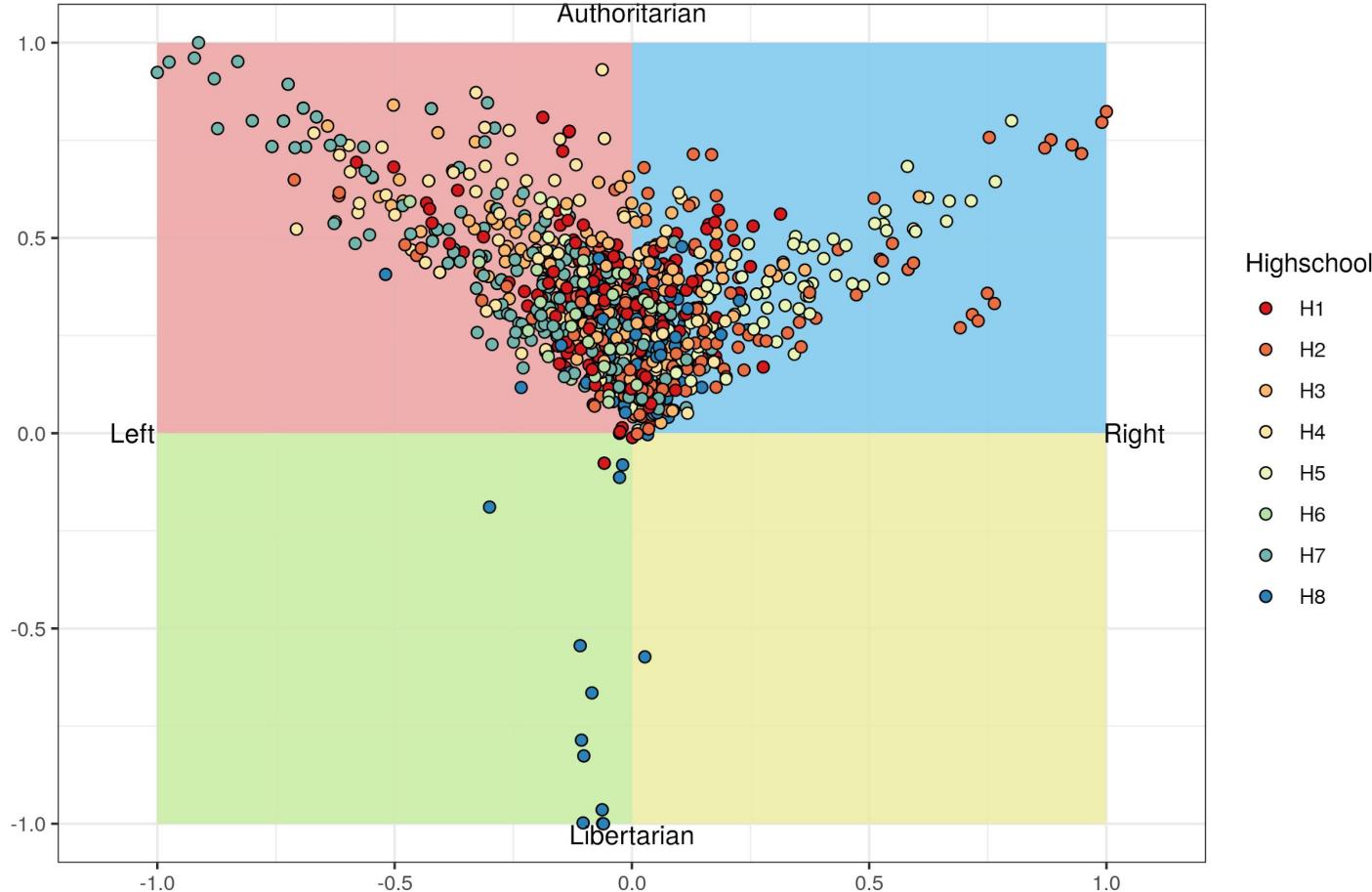
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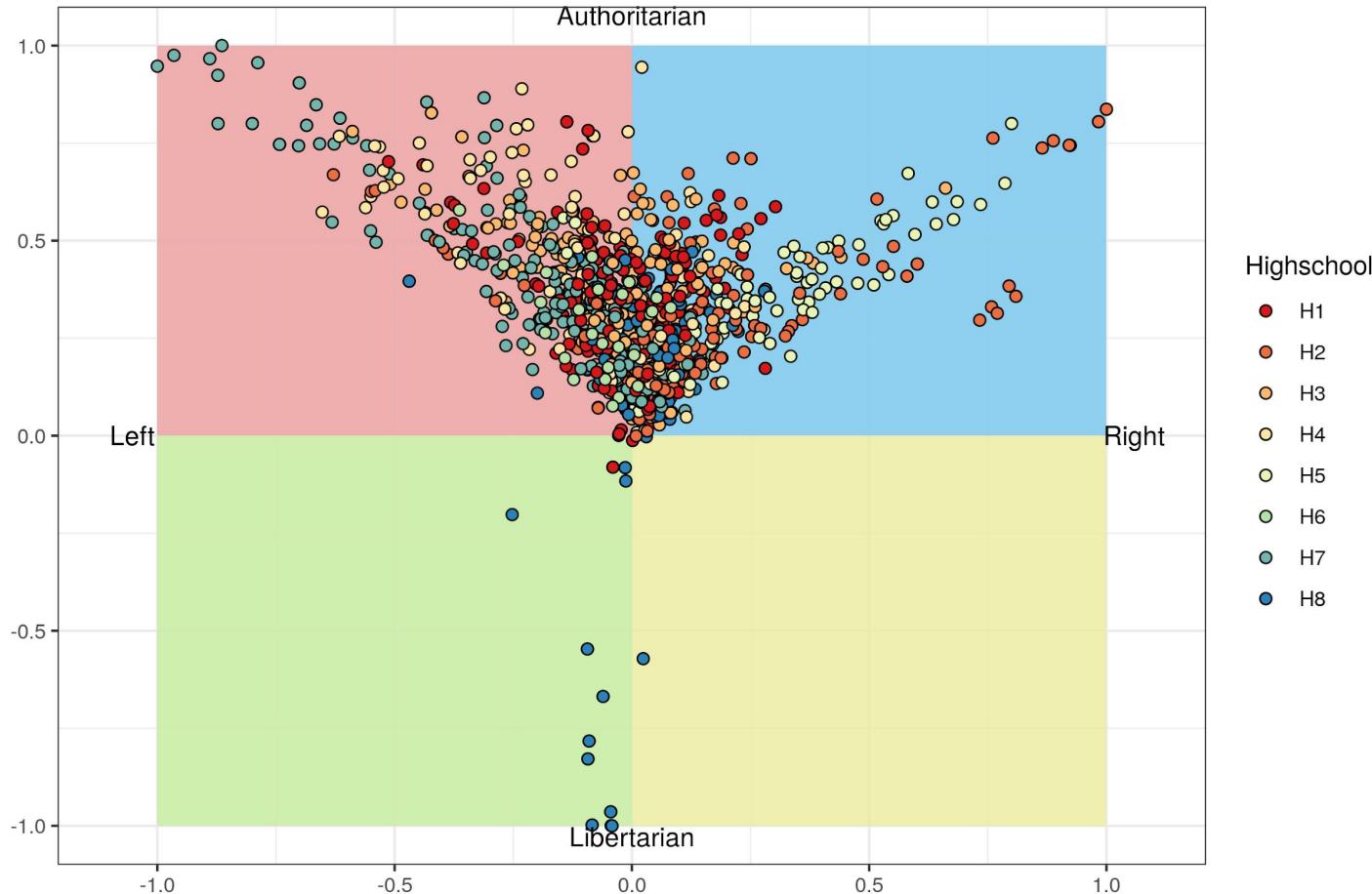
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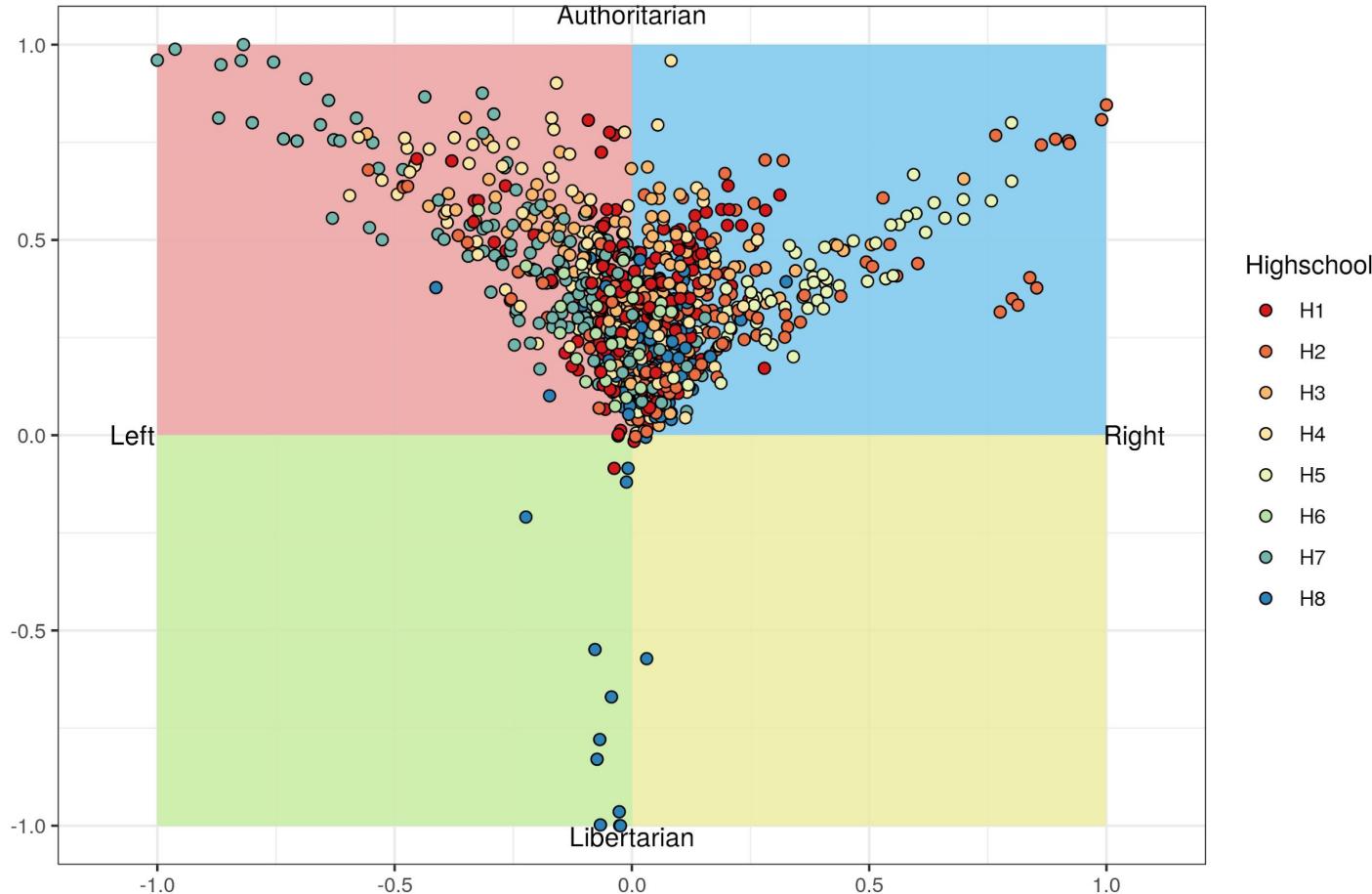
# Political believes at time 7



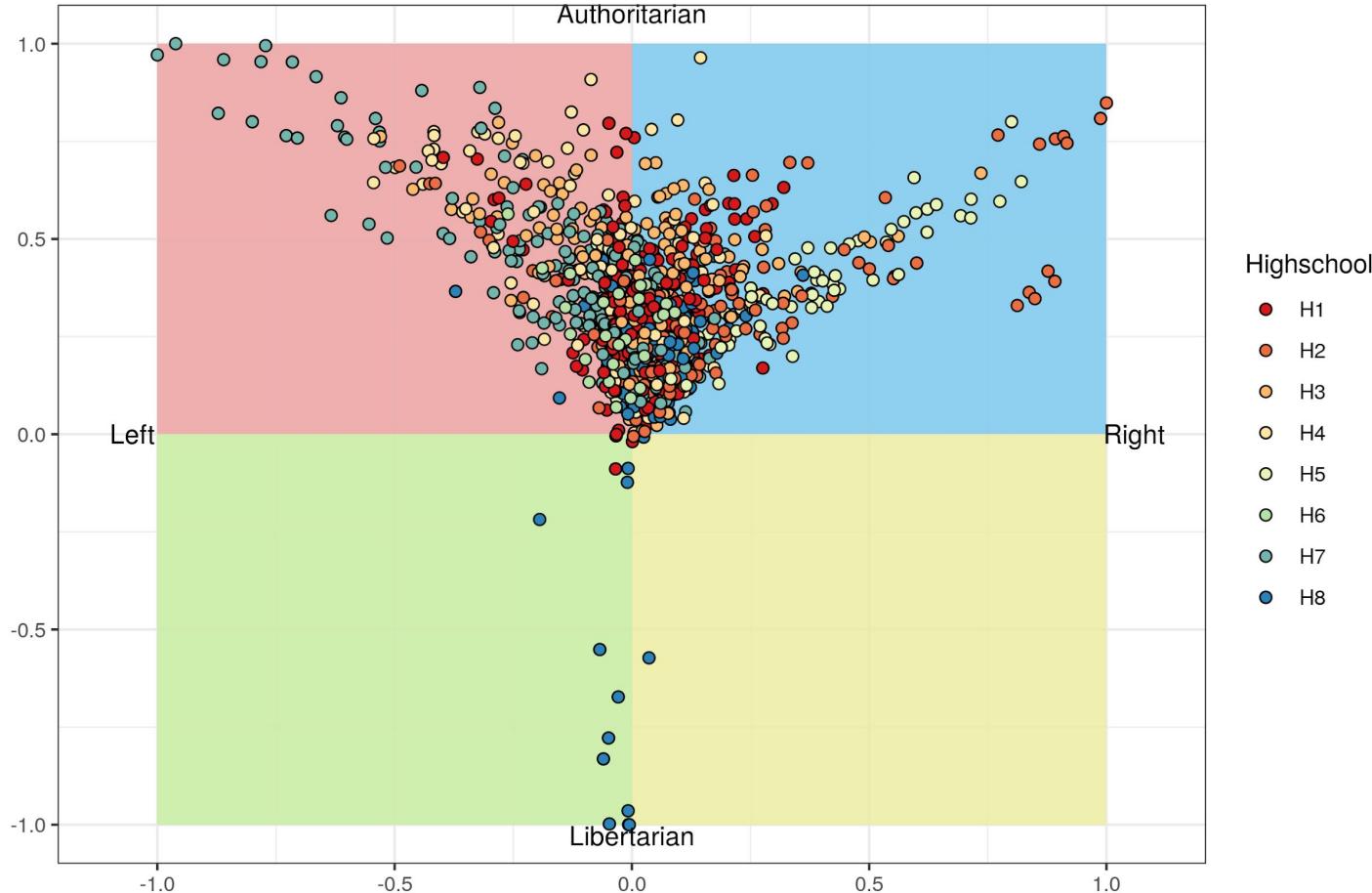
# Political believes at time 8



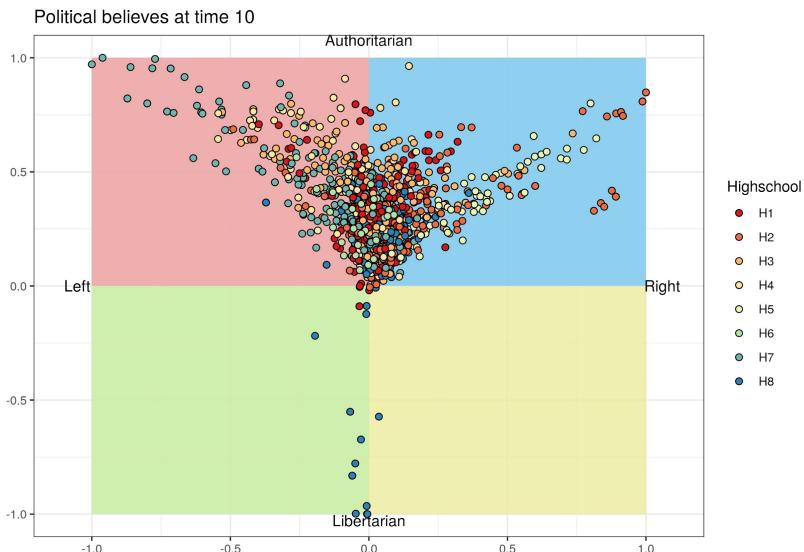
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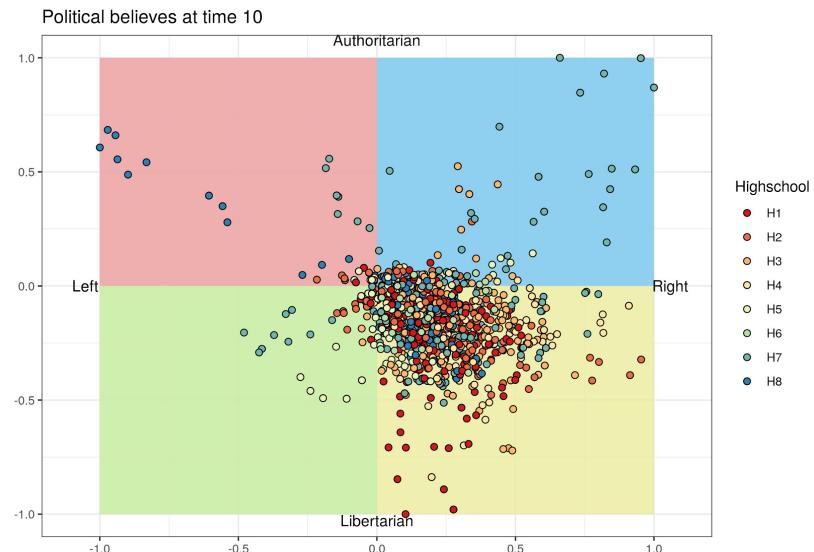
# Political believes at time 10



## With radicals



## Without radicals



# THE END

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