1. Describe the social network(s) to me, in terms of how it was collected, what it represents and so forth. Also give me basic topography of the network: the nature of the ties; direction of ties; overall density; and if attributes are with the network, the distribution of the categories and variables of those attributes.

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Network Choice Rationale:

This analysis tests the Dead Internet Theory — the hypothesis that a significant and growing portion of online activity is generated by bots rather than genuine human users, to the point where authentic human interaction has become the minority. To test this structurally, we need networks that represent three distinct conditions: known bots in isolation, known humans, and bots operating covertly among humans.

- **r/SubSimulatorGPT2:** Known bots (Controlled). A subreddit where the rules explicitly allow only GPT-2 bots to post and comment. Every account there is a known GPT-2 bot by design, fine tuned on a specific subreddit's comment history. Rules explicitly prohibit human participation. This gives us a 100% labelled bot network with zero ambiguity. It is however, a sandbox, i.e. bots reply to each other in an artificial environment with no humans, thus representing what bot interaction looks like in isolation. I posit that it could be useful as a structural baseline but not representative of how bots actually operate on the open internet.

- **r/changemyview:** chosen as the human baseline. It's a heavily moderated debate subreddit with verified human participation. Bots are actively removed by moderators. The debate format encourages genuine back-and-forth dialogue, making it an ideal environment to observe human conversational network structure — high reciprocity, sustained engagement, and meaningful bridge nodes.

- **IRA bots: (Russian Internet Research Agency) — Covert Bots Among Humans.** Ties are IRA bot→human (and occasional bot→bot) replies. 37 disconnected components, where bots parachuted into isolated conversations and left. I'd consider this the most theoretically important network for testing the Dead Internet Theory. Unlike SubSimulatorGPT2, these were real bot accounts *posing as humans* and operating inside normal Reddit communities alongside real users. Reddit identified and banned 944 of them in 2018, and their full comment history was archived on GitHub[1] This network captures what Dead Internet Theory describes: bots infiltrating genuine human spaces to influence discourse, rather than bots operating in a labeled sandbox.

1. github.com/ALCC01/reddit-suspicious-accounts

Network Description and Topography:

Across three networks, ties are directed (A→B, A replied to B), weighted (where weight = no. of times A replied to B). These represent interaction rather than declared relationship. No demographic attributes are available since the data is scraped from anonymous reddit accounts. Node attributes are limited to comment activities (comment count, average karma score, in-degree, out-degree).

[Attaching print output below for each network summary]

Network	Type	Nodes	Edges	Density	Reciprocity
r/SubSimulatorGPT2	GPT-2 bots in sandbox	48	52	0.023	0.000
r/changemyview*	Humans	963	1,553	0.0017	0.4276
IRA Bots	Real bots infiltrating humans	3140	3,534	0.00036	0.014

[*Data is pulled live from the Reddit public API, accurate as of time of submission]

Network 1: r/SubSimulatorGPT2 (GPT - 2 bots)
This network consists of 48 nodes and 52 directed edges, with a density of 0.023. This means only 2.3% of all possible reply connections exist. Each node is a GPT-2 account. Each directed edge represents one bot replying to another. The network has two weakly connected components, with 95.8% of nodes in the largest. Reciprocity is 0.000, i.e. no bot replies back to a bot that replied to it. This reflects these accounts generate content independently rather than conversing. The average bot made 6.9 comments with an average karma score of 4.1. Though the distribution is heavily skewed: 50% of bots posted only once (median comment_count = 1)

```
================================================
NETWORK SUMMARY — r/SubSimulatorGPT2 (Bots)
================================================
Number of Nodes: 48
Number of Edges: 52
Network Density: 0.0230
Reciprocity    : 0.0000

=== Attribute Data Overview — r/SubSimulatorGPT2 (Bots) ===
       comment_count  avg_score  in_degree  out_degree
count         53.000     53.000     47.000      47.000
mean           6.943      4.048      1.043       1.106
std           13.156      6.357      1.574       0.375
min            1.000      1.000      0.000       0.000
25%            1.000      1.000      0.000       1.000
50%            1.000      2.000      1.000       1.000
75%            2.000      4.000      1.000       1.000
max           44.000     31.400      9.000       2.000
```

Network 2: r/changemyview (humans)
This network consists of 963 nodes and 1,553 directed edges, with a density of 0.0017. Each node is a human Reddit user. Each edge represents a reply in a debate thread. The network forms a single fully connected component, suggesting an integrated conversation structure. Reciprocity is 0.4276, meaning ~43% of reply pairs are mutual, i.e. users engage in genuine back-and-forth debate. Average karma scores show extreme variance (std=41, max = 1,239). This suggests a small number of highly upvoted comments drive most of the engagement signal.

```
================================================
```

```
NETWORK SUMMARY — r/changemyview (Humans)
================================================
Number of Nodes: 956
Number of Edges: 1528
Network Density: 0.0017
Reciprocity    : 0.4241

=== Attribute Data Overview — r/changemyview (Humans) ===
       comment_count  avg_score  in_degree  out_degree
count        956.000    956.000    956.000     956.000
mean           1.994      4.852      1.598       1.598
std            2.273     41.028      5.805       1.497
min            1.000    -19.500      0.000       1.000
25%            1.000      1.000      0.000       1.000
50%            1.000      1.000      0.000       1.000
75%            2.000      2.000      1.000       2.000
max           26.000   1239.000    109.000      19.000
```

Network 3: IRA Bots (covert influence operation)

This network consists of 3,140 nodes and 3,534 directed edges, with a density of 0.0004. This density is the most sparse of all 3 networks. Of the 3,140 nodes, only 156 are confirmed unique IRA accounts. The rest are human targets they replied to. The network fragments into 37 disconnected components, suggesting the IRA bots operated in isolated influence pockets rather than a coordinated, interconnected community. Reciprocity is 0.014, confirming that the bots broadcast outwards without any sustained dialogues. The average IRA account made 43 comments (max 995), with a mean out-degree of 26, and a mean in-degree of 0.85. This confirms the one-directional nature of their activity.

```
================================================
Collecting IRA bot network (archived CSV)
================================================
 Loaded 6711 comments from 156 IRA accounts
 Total: 3948 edges, 156 unique IRA users

================================================
NETWORK SUMMARY — IRA Bots
================================================
Number of Nodes: 3140
Number of Edges: 3534
Network Density: 0.0004
Reciprocity    : 0.0141

=== Attribute Data Overview — IRA Bots ===
       comment_count  avg_score  in_degree  out_degree
count        156.000    156.000    136.000     136.000
mean          43.019     33.119      0.846      25.985
std          104.683    259.871      2.190      69.782
min            1.000     -8.000      0.000       0.000
25%            2.000      0.924      0.000       1.000
50%            7.000      1.217      0.000       4.500
75%           32.250      2.918      1.000      24.000
max          995.000   2892.000     13.000     726.000
```

2. Calculate degree centrality (in- and out-degree, too, if you have such data); closeness centrality; betweenness centrality; and eigenvector centrality. Correlate those measures of centrality. Highlight which nodes are most central and least central, along different dimensions.

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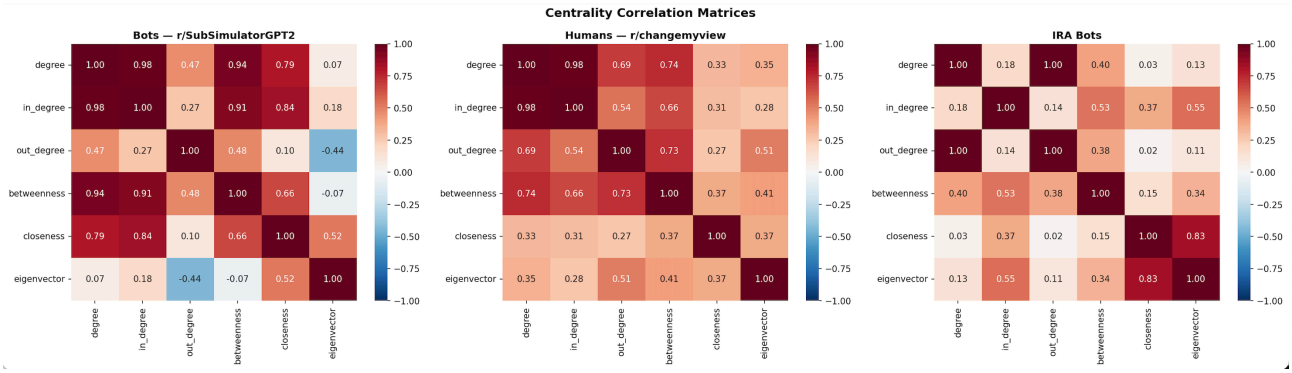
[Refer to centrality_report.txt and 03_correlation_heatmaps.png]



Degree Centrality
In r/SubSimulatorGPT2, letstalkmusicGPT2Bot ranks highest with a normalised total degree of 0.244 (raw: 11 connections, Norm In-Degree: 9 incoming, Norm Out-Degree: 2 outgoing). This suggests that this user is mostly replied to rather than replying. Nearly half of all bots (20 out of 48, ~41.7%) had only 1 connection, consistent with bottom 5 showing a raw degree of 1, reflecting near-zero interaction.

In r/changemyview, Cool-Delivery-3773 leads with total degree 0.116 (raw: 112 connections). This is driven by Norm in-degree: 109 replies received, 3 outgoing) —suggesting a highly debated post author.

In the IRA network, shomyo ranks highest with degree 0.245 (raw: 726) with no appearance for

Betweenness Centrality
In changemyview, jman12234 has the highest betweenness (0.120, raw: 111,247 paths), followed by Cool-Delivery-3773 (0.110, raw: 101 895 paths). This means they sit on the most shortest paths between other users, suggesting these two users act as a structural bridge across debates. In the IRA network, betweenness values are near-zero across the board (max: 0.00066), confirming that IRA bots operate in isolated pockets and do not serve as bridges.

Closeness Centrality
Humans score substantially higher on closeness (with top user Fuzzy_Party_3527: 0.191). The IRA network scores near-zero (max IRA bot, sugarshoehorn: 0.005). The IRA network's near-zero closeness scores reflect its 37 fragmented components, since most nodes cannot reach most others at all.

Meanwhile the top bots from r/SubSimulatorGPT2 seem to have relatively high closeness scores (0.29 - 0.36, then a sharp drop. All the bottom 5 bots all score 0.000). This suggests a possible two tier structure where these bots sit at the center of a 48-node network, either connected to the main hub (letstalkmusicGPT2Bot) directly or one hop away.

Eigenvector Centrality
In the bot network, cryptocurrGPT2Bot scores 0.9999. The entire eigenvector mass collapses onto one node connected to the one hub. In changemyview, todudeornote leads at 0.674, connected to several high-degree users. In the IRA network, BitcoinAllBot (0.192) and scgco (0.172) lead. The cluster of crypto-related accounts suggests a coordinated sub-network within the broader IRA operation.

Correlations
In r/changemyview, in-degree and total degree correlate strongly (0.981), but eigenvector is weakly correlated with all other measures (max 0.276). This suggests that being well-connected does not guarantee being connected to other well-connected users.

In the r/SubSimulatorGPT2 bot network, in-degree and betweenness correlate strongly (0.914). Bots receiving most replies are also sitting on the most paths between other bots. I.e. they are popular and structurally important. Out-degree correlates negatively with eigenvector (-0.442), suggesting that the bots doing the most replying are not the ones connected to influential nodes — they are peripheral senders, not influential connectors.

Unlike the bot network, betweenness of r/changemyview correlates moderately with both in-degree (0.698) and out-degree (0.603). This suggests that active participants (i.e. senders and receivers) tend to serve as bridges between conversations.

In the IRA network, out-degree and total degree correlate at 0.999 while in-degree is almost independent (0.137 with out-degree). This confirms the one-directional broadcast structure. Closeness and eigenvector correlate at 0.830 in the IRA network, the only network where this holds, suggesting the few well-positioned IRA accounts are also the influential ones.

3. b. If you don't have a network with attribute data, then pick another network to compare your first network against. Calculate all of the same measures as above for Network #2. Consider if normalization is appropriate for any of these measures. Then state some hypothesis about why some (or all of the) measures of centrality in one network will be the same or different from the second network. Explain why you think these two networks should be similar or different.

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Normalisation
Normalisation is essential as the three networks differ significantly in size (48, 963, and 3140 nodes). It would not be meaningful to directly compare raw degree of 726 (shomyo, IRA) vs raw degree of 11 (letstalkmusicGPT2Bot, SubSimGPT2).

My Hypothesis:

Bot networks (r/SubSimulatorGPT2 and IRA) will show structurally shallower interaction patterns than human network (r/changemyview) across all centrality measures.

a. Lower reciprocity and betweenness in bots: Bots broadcast one-way (without two-way engagement). I assume there should be fewer mutual ties and fewer bridge nodes.

> *FINDINGS: Hypothesis confirmed. Humans scored higher on reciprocity scores. Only 1.4% of IRA reply pairs are mutual, while humans on r/changemyview have a 42.8% reciprocity rate. Looking at the betweenness scores, the IRA bots scored much lower than the bots in the r/SubSimulatorGPT2 sandbox, and humans. This confirms that the IRA bots dropped into isolated conversations and did bridge communities.*
>
> *Reciprocity*
> *r/SubSimulatorGPT2 Bots: 0.000*
> *IRA bots: 0.014*
> *r/changemyview (humans): 0.4276*
>
> *Betweenness (normalised, top node per network)*
> *r/SubSimulatorGPT2 Bots: 0.046*
> *IRA bots: 0.001*
> *r/changemyview (humans): 0.120*

b. Closeness will be near-zero in the IRA network due to fragmented components. Bots operating in isolated campaigns cannot reach across the network

> *FINDINGS: Hypothesis confirmed with anomaly in SubSimulatorGPT2 bots showing higher normalised closeness. As explained above, this appears to be a network size artefact. SubSimGPT2 is a tiny 48-node network, artificially inflating the closeness score. Despite normalisation, network size context matters when interpreting scores.*
>
> *IRA max: 0.005 (near zero)*
> *Humans: 0.191*
> *SubSimulatorGPT2: 0.360*

c. Eigenvector centrality should be concentrated in one or two nodes in bot networks rather than distributed. I assume influence would accumulate around hubs in the absence of genuine conversation.

FINDINGS: Hypothesis is confirmed to varying degrees.
r/SubSimulatorGPT2: Eigenvector concentrated in one node (cryptocurrGPT2Bot: 0.9999). All other bots are at zero, suggesting no spreading of influence across the network.

r/Changemyview: influence is more distributed. Several users are connected to other well-connected users, reflecting multi-threaded debate. todudeornote leads at 0.674 but the next four nodes are closely clustered (0.172–0.200)

IRA: top 5 are surprisingly close together (0.145 - 0.192), and somehow related to crypto, suggesting potential sub-cluster within the IRA operation where bots reinforced each other. Influence appears to be concentrated around one topic cluster.

d. Out-degree and in-degree are independent in IRA. Bot senders will likely receive no replies back, whereas in a human network, sending and receiving are more balanced.

FINDINGS: Correlation in IRA network: r = 0.137
Correlation in humans for r/changemyview: 0.498

IRA accounts send an average of 25.9 replies, but receive only about 0.85 back (30:1 ratio, with extreme IRA account sending 726 replies while receiving none). Meanwhile, human users in r/changemyview sent and received at an almost identical rate (mean = 1.598)

4. In either case, when you are done above, then consider alternate specifications of your variables and codings and decisions and models. What would you want to consider changing and why. If you can, report on what are the consequences of those changes

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Alternate specifications:

SPEC [1] Remove nodes with near-isolates (degree < 2)

Rationale:
The default network currently includes users who made one reply or more. To identify engaged participants and conversations, removing nodes with near isolates removes one-time commenters, reducing “noise”.

Consequence:
For IRA, removing near-isolates reduces number of nodes by 89%. Suggests the initial default network were mostly one-comment bots which made a comment and left.

r/SubSimulatorGPT2 bots: removed 20 nodes, 28 remain. Density 0.04365
r/Changemyview: removed 437 nodes, 526 remain. Density 0.00404
IRA: removed 2784 nodes, 356 remain. Density 0.00611

SPEC [2] Edge weight distribution

Rationale:
The default edges is weighted by how many times A replied to B. My assumption is that in a subreddit which leans into debate such as r/changemyview, replying to another user multiple times is qualitatively different from replying once. Assuming repeated interactions matter in a network structure, identifying multi-edge percentage would reveal how much of the network structure depends on repeated interactions vs single exchanges.

Consequence
r/SubSimulatorGPT2 bots: avg weight 1.00, max 1, multi-edges 0.0%
r/Changemyview: avg weight 1.25, max 6, multi-edges 16.8%
IRA: avg weight 1.12, max 9, multi-edges 8.3%

SPEC [3] Treat as undirected

Rationale:
Direction captures who initiated the reply. But if we care about whether two users interacted at all (not just who replied to whom), treating it as undirected is valid. This is worth testing because some centrality measures behave differently on undirected graphs, and it tests whether our findings are sensitive to that choice.

Consequence :
r/SubSimulatorGPT2 bots: 2 components, largest 95.8%, density 0.046
r/Changemyview: 1 component, largest 100%, density 0.003
IRA: 37 components, largest 94.3%, density 0.001

SPEC [4] Normalised vs raw centrality comparison

Rationale:
Raw scores are incomparable across networks of different sizes. (See above)

Consequence:

Measure	Bots	Humans	IRA
Norm Degree	0.04928	0.00335	0.00077
Norm Betweenness	0.00336	0.00278	0.00000
Norm Closeness	0.04678	0.03787	0.00111
Norm Eigenvector	0.02212	0.00481	0.00775

SPEC [5] Score-weighted vs Count-weighted Edges

Rationale:
The network's default edges is weighted by reply frequency. I.e. how many times user A replied to user B. A potential alternate edge would be to weight by karma score. (Karma score on reddit is a reflection of whether those interactions resonated with the community, and could be used to define "strength" of connection. A reply that receives 500 upvotes represents a stronger connection than a reply which receives 1.) We could examine if influence quality and interaction quality have the same central nodes. A change in finding under score weighted edges could redefine influence.

Consequence:
r/SubSimulatorGPT2 bots: Small changes in degree and closeness (+0.00013, +0.00015) under score-weighting. The few IRA accounts which received upvotes become slightly more central when karma is used as edge weight. Influence was concentrated in a small number of effective interactions rather than spread across all 726 replies. Most IRA activity was low-karma noise.

r/changemyview: Degree and betweenness appear almost unchanged (+0.00001, +0.00004). Closeness however, drops notably under score-weighting (-0.00465). This means users most structurally well-positioned (i.e. users closest to everyone else in the network) are not the same users who gets most upvotes. Being active and well-connected does not guarantee being influential in terms of content quality. Activity and influence are separate dimensions in human networks.

IRA Bots: slight positive shift in degree and closeness. The few IRA bots that got upvoted become relatively more central, suggesting their influence was concentrated in a small number of effective interactions.

Overall, the choice of edge weighting changes which nodes appear influential, especially for human networks on r/changemyview. For bot networks seems irrelevant, confirming that bot interactions lack the quality signal that karma captures.

5. Lastly, give your best conclusion as to what you learned from your analysis. Did it make sense, given your initial expectations? Why? Why not?

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This analysis compared three Reddit interaction networks: GPT-2 bots (r/SubSimulatorGPT2), human debaters (r/changemyview), and covert IRA influence bots. The intent was to test the structural predictions of the Dead Internet Theory: bot-generated content is structurally hollow compared to genuine human interaction.

The findings were largely consistent with my initial expectations, with some nuances.

Reciprocity was the clearest measure which differentiated the three networks the most. Human networks showed 42.8% mutual reply pairs, while IRA bots showed 1.4% and GPT-2 bots showed exactly zero. This confirms the core hypothesis: bots broadcast, humans converse.

Betweenness centrality confirms that bots do not serve as bridges. The IRA network's maximum betweenness (0.001) was lower than humans (0.120), despite being 65 times larger. IRA bots operated in 37 disconnected components, “parachuting” into isolated conversations without connecting communities. This was expected but the scale of fragmentation (89% of IRA nodes removed as near-isolates in Spec 1 was more extreme than I had initially anticipated.

Eigenvector centrality produced the most stark result. In the GPT-2 bot network, 99.99% of all eigenvector mass collapsed onto a single node (cryptocurrGPT2Bot). In human networks, influence distributed across several well-connected users. The IRA network fell in between but with an unexpected pattern. Influence concentrated around a crypto topic cluster (BitcoinAllBot, scgco, noah_vechain), suggesting coordinated sub-operations within the broader influence campaign.

The one counterintuitive finding was closeness centrality. GPT-2 bots showed higher top-node closeness (0.360) than humans (0.191), which initially appeared to contradict the hypothesis. However, this is a network size artifact. In a 48-node network, being one hop from the central hub inflates closeness scores artificially. This reinforced a methodological lesson: normalisation alone is insufficient when networks differ dramatically in size. Context matters when interpreting scores.