Peer-review report of

Yang, X., Albert, R., Molloy, L.E., & Ram, N. (2024). Modeling and managing behavior change in groups: A Boolean network method. *advances.in/psychology, 2*, e55226. https://doi.org/10.56296/aip00009

Round 1

Dear authors,

I have now received two reviews from experts in the field of network science/network psychometrics.

Reviewer 1 provides a generally positive assessment of the manuscript, appreciating its introduction of the Boolean network for modeling social behavior, specifically self-disclosure. The reviewer acknowledges the manuscript's alignment with the special issue's focus, its methodological soundness, and clarity in most parts. However, several points of critique and suggestions for improvement are raised:

1. Clarification of Available Models: The reviewer suggests expanding on the current models in the field (like those by Snijders and Veenstra), their limitations, and how the proposed model differs or relates to them.

2. Dynamical System Methods: The manuscript needs more references and clarity on what is meant by dynamical system methods and how the approach fits into this category.

3. Central Nodes and Centrality: The manuscript should acknowledge the complexity and ongoing debates about centrality in social network analysis, providing more citations and discussion on these concepts.

4. Clarifying Assumptions: A clearer explanation is needed regarding the relaxation of the second assumption mentioned on page 7.

5. Attractor States: The concept of attractor states and its relation to control theory requires more detailed explanation and references.

6. Overlapping Sections: The initial paragraphs in the "Boolean Network" section appear redundant and should be integrated for better flow.

7. Consistency in Boolean Functions: Clarification is needed on apparent inconsistencies in Boolean functions as illustrated in Figure 1a.

8. Explanation of the 'Fingerprint Function': The manuscript should include references and a detailed explanation of the "fingerprint function."

9. Enhancing Table Clarity: Suggestion to use color coding in Table 2 to better indicate attractor states.

10. Clarifications in Figures and Text: Requests for clarifications in the manuscript's text and figures, particularly regarding Figure 1d and the depiction of attractor states.

11. Discussion on Attractors: The manuscript should reflect more on the practical implications of different attractor states, their feasibility, and the possibility of creating ideal attractors within the system.

12. Interpreting Error Rate: The author(s) are advised to provide more context and interpretation of the term 'error rate.'

13. Typographical Error: The reviewer points out a minor typographical error on page 28.

The review overall commends the innovative approach of the manuscript while suggesting significant enhancements for clarity, depth, and context in discussing the proposed model and its theoretical underpinnings.

Reviewer 2 also provides a positive evaluation of the paper, with suggestions for minor revisions to enhance its quality. Key points include:

1. The reviewer suggests clarifying the use of Markov chain dynamical systems in modeling social groups, emphasizing the need for more detail on repulsive and assimilative behaviors within this framework.

2. The reviewer notes the assumption of mono-layer social ties, proposing the consideration of multiple layers in social interactions to more accurately represent complex social dynamics.

3. The reviewer recommends frontloading citations related to control theory, especially Barabasi’s work, and acknowledging its application mainly to simpler organisms.

4. The manuscript's description of the Boolean network as an edge-colored graph is noted, implying a multiplex network.

5. Concerns are raised about the choice of using means instead of medians for binarizing time series data. The reviewer suggests a more thorough explanation or justification for this choice, considering the potential loss of information.

6. The reviewer points out that while the Boolean network method is not formally used in modeling self-disclosure behavior, it is not new to psychologists. A more careful rewording of this section is recommended.

7. Corrections: Suggestions include correcting typographical errors (e.g., "1d" to "Figure 1d") and rounding consistency in statistical reporting.

8. Consideration of Longer Memory in Social Systems: The manuscript is encouraged to explore the possibility that social systems may have longer memories than what a Markov chain can explain, and the implications of this on the dynamics modeled by higher-order Markov processes.

9. The reviewer advises adding more on how social desirability might influence self-disclosure strategies over time.

10. The reviewer emphasizes the need for more discussion on why each group displayed unique dynamics in the Boolean networks, questioning whether this is due to data noise or the effects of binarization.

Overall, the reviewer appreciates the manuscript's clarity and accessibility, recommending acceptance after addressing these points.

I agree with all points raised by the reviewers, and urge the authors to submit a revised manuscript addressing each one of them.

Best wishes,

Hudson Golino

Reviewer 1

This manuscript introduces a new topic, the Boolean network, which may be unfamiliar to most psychologists. It serves as a network for modeling and influencing social behavior, particularly self-disclosure behavior. This innovative approach is based on the assumption that the data is binary. The manuscript not only presents this method but also illustrates it with an empirical example. I appreciate that the model is integrated within and expands upon a simple yet plausible theoretical framework, the threshold theory. Furthermore, well-annotated code is provided. The manuscript aligns well with the scope of the special issue as it pertains to networks, introduces a novel method, and contributes to the field's knowledge. The manuscript is nuanced, methodologically sound, and often written clearly. However, there are specific points in the manuscript that could benefit from increased clarity.

Comments:

- A more substantial comment relates to page 5, where the author(s) state that there is currently a lack of available models. However, as a reviewer from outside this field, it is not clear which models are available and why they are considered insufficient. In the sentences preceding this one on page 5, the author(s) only briefly mention some models by Snijders and Veenstra. Do these models also address dynamic longitudinal data? I would expect that there are more models in the field, and it would be beneficial to have a dedicated section or a couple of paragraphs discussing these existing models. This would help explain the standard models in the field and why they may be inadequate. Additionally, it would be useful to explore the similarities between this model and others, as one might anticipate some commonalities.

- You also mention dynamical system methods, but there are hardly any references provided, and it is not clear how this approach is dynamic or what is meant by a dynamical system method. This term is quite broad and somewhat ill-defined.

- You discuss central nodes on page 7; however, centrality and the concept of a central node are complex and have been extensively debated in social network

analysis (e.g., Freeman, 1991). It would be beneficial to acknowledge this ongoing discussion and, in general, include more citations when introducing concepts, including potential discussions surrounding these concepts.

- Again on page 7, I found it unclear how one can relax the second assumption. It would be helpful to have a more explicit discussion of this point in the manuscript.

- Similarly, on the next page, page 8, you mention "attractor states" without providing references or explanations, nor how it is related to control theory. It would be beneficial to explain this concept here.

- Furthermore, the first two paragraphs of the "Boolean Network" section appear to be overlapping and should be integrated.

- On pages 9 and 10, you explain Figure 1 and the Boolean functions. However, upon examining Figure 1a, it seems that the Boolean functions do not consistently hold. For example, Function 1 states: 'Only when member 3's self-disclosure is OFF, member 1's self-disclosure can be ON.' In the example provided in Figure 1a, x3 is always 1 (ON), so it's ON, but x1, which represents member 1, is also 1 (ON) at time point 4. The same issue applies to Function 2. In general, it is unclear from this example how seemingly opposite functions can all be holding simultaneously. I hope the author(s) can clarify this discrepancy.

- On page 15, you mention the "fingerprint function." Could you please provide references and an explanation of what this function is?

- In Table 2, you could enhance clarity by explicitly indicating attractor states, such as by using color coding.

- The text on page 19 was not entirely clear to me. I'm not sure how one can see in Figure 1d if x3 is off, as it appears to have the same values. Could this be related to the self-loop?

- On page 21, you mention the different attractors one and two. However, upon critical reflection, neither of them seems like a great option. Ideally, a great option would be for all of them to be ON. Moreover, upon further reflection, is attractor 2 really that much worse, having three nodes versus five nodes? It would be beneficial to reflect on this aspect in the manuscript.

- On page 21, you mention that group members' sex should be a reminder to shorten the self-disclosure time to allow others to self-disclose. However, this doesn't seem to be evident from Figure 2d. It may be helpful to adjust the text accordingly to clarify this aspect.

- On page 22, it would help if the error rate was interpreted. What does this term mean, and is it considered a good or bad error rate? In general, it's essential to provide some context around this term for better understanding.

- In the discussion section, you mention multiple attractors. It would be beneficial to also discuss the idea that an ideal attractor has to already exist in the system and cannot be created. For example, if we want all people to engage in self-disclosure, this can only happen if this behavior is already present in an attractor. It would be

valuable to reflect on why it may not be theoretically possible to simulate what needs to happen if this behavior is not already within an attractor in the system.

- Page 28, you have twice “can” (efficiently…).

References

Freeman, L. C., Borgatti, S. P., & White, D. R. (1991). Centrality in valued graphs: A measure of betweenness based on network flow. *Social networks*, *13*(2), 141-154.

Reviewer 2

The manuscript titled "Modeling and Managing Behavior Change in Groups: A Boolean Network Method" explores the dynamics of behavior change within social groups through a novel Boolean network method. The manuscript delves into psychological theories of how individuals modify their behavior, either conforming to or differing from their social circle, and how this behavior adaptation can be conceptualized as a group process. This is a rather delicate point but the authors do an interesting job of documenting well enough the psychological literature motivating their individual-to-group attention shift. The initial sections discuss the theoretical underpinnings related to behavior change, conformity, and social influence, referencing established theories and models to set a contextual foundation for the study. Methodologically, the paper introduces a novel framework based on Kauffman’s Boolean networks, originally introduced to investigate gene interaction networks. The manuscript uses empirical data from a longitudinal study of disclosure behavior in therapy groups, applying the novel Boolean network method to infer social influence and manage group dynamics towards certain desired behavioral outcomes. The authors’ writing style is solid, clear and concise. They set the manuscript aims very early in the introduction and produce a solid quantitative investigation. The authors also uploaded a well-commented code on an OSF server, fostering the reproducibility of the methodology introduced here. There are a few elements that, if polished, might strengthen the manuscript. For these reasons, I recommend acceptance but after minor revisions.

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Page 5 - In a dynamical system, … - No, the dependency of the group/individuals’ states at t+1 on their states at time t is not a general feature of dynamical systems but rather only a convenient modelling approach relative to a Markov chain process, where the behaviour of a system at time t+1 is determined by its condition at time t. Markov processes of order n extend the memory of the system to n time steps before t+1. Further generalisations of chaotic dynamical systems possess even longer memory (see drunk games in Antonioni et al. PRE 2019). It would be better to clarify this part so that the authors explicitly acknowledge whether they are modelling a given social group as a Markov chain dynamical system. This whole paragraph should be further reworded to provide some details of what repulsive and assimilative behaviours would be in this Markov chain approach.

Page 6 - This group managemetn… - There is also a third assumption: social ties are mono-layer. There could be instead multiple channels of social interactions, some supporting assimilative and some others supporting repulsive social influence mechanisms, across two different layers of a multiplex network. People might dislike each other (one layer) or like each other (another network layer), see also Wasserman and Faust, 1994. This point can nicely follow the first point raised by the authors.

Page 7 - When mentioning control theory it would be better to frontload the citations of Barabasi's work and highlight that they were applied mostly to nematodes or simple organisms.

Page 10 - Indeed the description of the Boolean network is the one of an edge-coloured graph, i.e. a multiplex network.

Page 13 - When the authors use means to binarise the time series of individuals' session benefits, it is unclear why they selected the mean rather than the median. The latter would be less fragile to extreme fluctuations over time. A better specification of the selection of the threshold is important, since changing the threshold can greatly change the binarized time series. It would be better to acknowledge limitations in this approach, i.e. might applying a binary filter might get rid of additional information in terms of social interactions?

Page 13 - The Boolean network method might not have been formally used to model self-disclosure behaviour but this model is not new to psychologists, e.g. https://www.tandfonline.com/doi/abs/10.1080/00221309.1947.9918144. Please reword that passage more carefully.

Page 19 - 1d should be Figure 1d

Page 22 - 1.6 with an SD of 1.22 should be rounded to the same figure, e.g. 1.6 with an SD of 1.2.

Page 26 - It should be noted that it might be that social systems possess a longer memory, i.e. the Markov chain cannot entirely explain the whole dynamics but higher-order Markov processes might. This is important because in higher-order processes attractors might drastically change.

Page 27 - When discussing self-disclosure it might be worth adding a few more sentences about how social desirability might indeed alter or uniform over time self-disclosure strategies.

Discussion - More emphasis should be given to the fact that each group had its own unique dynamic, showcasing different Boolean networks, as mentioned on Page 22. Why so? Is this relative to noise in the psychometric data adopted here? Or is this an effect of the binarisation around the mean? A bit more discussion around the topic would make the manuscript even more interesting than it is now. I would like to underline also that the authors did an impressive work at making the manuscript as understandable as possible to a wide audience and should thus be praised for their efforts.

Round 2

Dear Dr. Yang, Dr. Ram, Dr. Albert, and Dr. Elreda,

It is my pleasure to inform that your manuscript titled "*Modeling and Managing Behavior Change in Groups: A Boolean Network Method"* is conditionally accepted for publication at Advances.in/Psychology, in our first special issue on network psychometrics.

After reading your revised manuscript, and receiving the feedback from the reviewer, I would only ask you to implement the last suggestions pointed out by the reviewer before we can finally accept your manuscript. It is important to note that the papers will be published in a rolling basis after acceptance.

Thank you for your innovative new method and for contributing to our special issue.

I'm looking forward to seeing your paper published in the near future.

Best wishes,

Hudson Golino

Reviewer 2

This revision has greatly improved, and I believe the authors did a commendable job addressing my comments.

While reviewing the code again, I noticed that, if not too much work, it would be helpful to have a simple R file with just the code parts or the .Rmd file. This is because of the set.seed(); in this case, it is particularly useful to have all the code in one place so you can run it at once, instead of having to copy and paste.

Small spelling errors:

Can it be that there is a bracket missing in this sentence on page 9? (also called "network control")

"socail" should be "social P." on page 30

"functiosn" should be "functions" on page 31

"in state-transition graph" should be "in a state-transition graph" on page 31

"as seen in 3,group" should be "as seen in Figure 3, group" on page 31

"choices, In sum:" should have a dot instead of a comma on page 31.