

Profiling *in vitro* Neurogenesis Using Mass Cytometry to Compare the Intermediate Populations of Neural Differentiations in the Context of Retinoic Acid Titrations
(Technical Paper)

Investigation of the Technological Determinism Characteristics and Political Consequences of Content Filtering by TikTok's Algorithm
(STS Paper)

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On my honor as a University Student, I have neither given nor received
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Introduction

TikTok is the fastest growing social media platform in the world, and with the broadening reach of technology, it is important to consider the societal implications of this platform (Asquith, 2020). The success of TikTok is mostly attributed to its “addictive” algorithm that predicts which videos users will enjoy watching to keep users engaged (Fischer, 2020). It is critical society understands how this particular technology can impact people since the algorithm interacts with over 800 million active users and support for the technology is growing exponentially (Mohsin, 2020). The sociotechnical project in this portfolio will examine how the TikTok algorithm is able to make profound impacts on society. The most unique and defining aspect of the algorithm is its method of grouping users with similar interests into clusters so that the technology can target specific videos based on those interests (Fischer, 2020). This project will examine the TikTok algorithm in the context of technological determinism and political technology to uncover the relationship that the algorithm has with society and the effects of that relationship.

This method of grouping data into clusters is not specific to TikTok, but is also utilized in the field of biomedical engineering. The technical project in this portfolio is a biomedical engineering project which aims to establish a novel data generation and analysis method for in-depth characterization of cell populations over time. Currently, the field lacks a standardized method to characterize cell populations in-depth and this project will combine high dimensional mass cytometry and clustering algorithms to fill this gap (Mishra et al., 2018). The project will use this method to show how varying levels of retinoic acid, a molecule implicated in several neurological disorders, affects neural cell development (Gooch et al., 2017). Further, this project will identify the critical cell populations of neural development and how retinoic acid levels affect these populations based on clustering methodologies. Each of these projects will analyze or use

clustering algorithms to develop new ideas in the fields of science and technology and biomedical engineering.

Profiling *in vitro* Neurogenesis Using Mass Cytometry to Compare the Intermediate Populations of Neural Differentiations in the Context of Retinoic Acid Titrations

Neurological diseases had been diagnosed in almost 100 million Americans as of 2011 (Gooch et al., 2017). Several diseases are linked to retinoic acid (RA), which plays an integral role in neural development (Rhinn & Dolle, 2012). This independent technical project seeks to define how varying concentrations of retinoic acid affects the development of cell populations over a 14-day time course. Previously, researchers have studied the development of neurons by analyzing only a few (less than 10) cellular markers and using methods like immunofluorescence and polymerase chain reaction (PCR) to measure their markers (Zhou & Li, 2018; Kam et al., 2012). These methods do not allow for large numbers of cellular markers to be examined simultaneously, which causes researchers to extrapolate their findings by inferring cell population identified based on only a few markers (Mishra et al., 2018).

To reduce this gap in knowledge, this project aims to develop a robust pipeline for generating and analyzing the effect of RA on mouse *in vitro* neural development at the single-cell level with a novel panel of 40 multiplexed antibody measurements. This project will use mass cytometry to be able to measure 40 different cellular markers on each cell in the neural differentiations. A panel of cellular markers will be optimized during the fall 2020 semester to identify key characteristics of different cell populations expected to emerge during the neural time course. Markers in the panel will be indicative of stem cell populations, neural cell progenitors, glial progenitors, and mesoderm progenitors in order to be able to describe the cells in depth (Ko et al., 2020).

In the spring of 2021, three separate neural differentiations (the process of culturing stem cells to neurons) will be performed at the 1 micromolar RA, 1 nanomolar RA, and 0 molar RA levels. The differentiations will last 14 days to ensure the development of neurons in each culture. At each time point, the markers will be applied to the cells and then read out on the mass cytometer. This data will be analyzed using high dimensional computational methods, including uniform manifold approximation and projection graphs (UMAPs) and dendrograms, the graphical outputs of clustering techniques, that will directly compare cell populations between different RA concentrations. The methods will be used visualize the development of the cells over time indicated by the emergence of neural markers and disappearance of stem cell markers (Ko et. al, 2020). Cells will be clustered within their respective differentiations based on similar marker intensity and cluster comparison will be critical when investigating how RA concentration affects the timing of neural development (Zunder et al., 2015).

The methodological and scientific findings will be significant for this field. The methods proposed in this project will serve as a standardized platform for studying neural development which, in the future, can be applied to specific disease states of neurological disorders to obtain thorough characterization of cell development through the application of 40 markers. As far as significant findings, full 14-day neural time courses have never been performed at the 1 nM RA level and that comparison to the 1 uM RA and 0 M RA differentiations will be informative as to what extent the concentration of RA hinders neural development.

Investigation of the Technological Determinism Characteristics and Political Consequences of Content Filtering by TikTok's Algorithm

TikTok is a social media platform used primarily by younger people with 41% of users between the ages of 16 and 24 (Mohsin, 2020). Users spend an average of 52 minutes on the technology per day, with 9 out of 10 users frequenting the technology multiple times a day

(Mohsin, 2020). When users interact with the social media platform, they interact with the application's built in algorithm that is able to curate a stream of videos that the algorithm predicts the user will like. However, since the technology is such a recent addition to the world of social media, only publicly available since September of 2016, the societal implications have not yet been studied (Mohsin, 2020). With a large proportion of the global population spending significant time using the technology, it is important to know how the technology is impacting society.

TikTok uses a specific algorithm to ensure that its users continue to use the technology. The algorithm is able to “map a user's preferences in relation to similar users and group them into clusters.” These clusters are known as filter bubbles, which “[reinforce] users’ existing preferences” (Fischer, 2020). The filter bubble phenomenon is critical to the success of the algorithm, and since TikTok is a new platform with a large audience, the effects that these filter bubbles have on society have not been studied with reference to TikTok. Since filter bubbles are a relatively new concept, research on the topic is limited. However, available research suggests that these bubbles are damaging because the user is not aware that the information available to them is censored by algorithms (Holone, 2016).

As mentioned previously, the technology is utilized mostly by the younger generation. The age of the users makes them especially sensitive to external forces, which are created by the filter bubbles and essentially inescapable if the user has interacted with enough criteria that qualify them for the bubble (*Institute of Medicine (US) and National Research Council (US) Committee on the Science of Adolescence*, 2011; Holone, 2016). Richard Huang, a product manager at TikTok who oversees the algorithm, concedes that “within a filter bubble, there’s an informational barrier that limits opposing viewpoints and the introduction of diverse types of content” and claims the company is trying to mitigate this effect (Newton, 2020). This research project will explore how

content filtering is a technological artifact that influences society, and has potential political implications.

To analyze this problem, the first science, technology, and society (STS) theory that will be applied is technological determinism. This theory asserts that technology is solely responsible for affecting society and society plays no role in affecting technology in any way. Merrit Roe Smith, an American historian, analyzes the theory and asserts that technology has absolute power over society which provides the foundation for technological determinism (Smith, 1994). This theory will be used to analyze the connection between the TikTok algorithm and how it affects TikTok users. A major critique of this theory is that its approach is too simple in that it uses technology as a scapegoat for causing all social change (Hess, 2015). One critic, David Chandler, a British academic in sociology, argues that technological determinism becomes a “self-fulfilling prophecy” since people may feel like technology is driving society so they never attempt to intervene. He also argues that “political control, class interests, economic pressures, geographical access [and] educational background” affect society, which Smith does not consider (Chandler, 2000). In order to combat these critiques and mitigate the downfalls of technological determinism, this research will focus on the non-human aspect of the technology. Instead, the analysis will focus on the nuances of the algorithm and how it creates filter bubbles unsupervised (*TikTok, 2019*).

The second STS theory to be used in this research is the concept of technology being political. The theory emphasizes two ways that technologies can be political. The first states that the process in which the technology is developed will determine the politics of the technology. Alternatively, technology can be inherently political if the technology itself is correlated with specific political relationships (Winner, 1980). When researching the aforementioned research question, this project will analyze the technology in the context of the technology having inherently

political properties. The political ideologies that will be considered in future analysis are those that promote a singular set of desirable, or popular, characteristics since the algorithm is built to promote popular, uncontroversial content. The political technology theory is critiqued similarly to technological determinism in that scholars consider that while technology may perpetuate a political agenda, it is the politics of the creator of the technology that are put forward, not the politics of the technology (Rowland, 2019). To mitigate this critique, the intent of the creator of the technology will be considered and analysis of how the politics of the creator align with the politics of the technology will be completed to ensure that the politics of each entity are examined.

Research Question and STS Research Methodologies

Research Question: What effect does content filtering in TikTok have on society, and how is this relationship political?

To pursue this question, documentary research will be performed in conjunction with discourse analysis. These methods will work to gather information that is pertinent to the technology, which the documentary research will address, and that is pertinent to the user of the technology, which the discourse analysis will address. The research and analysis needed to investigate the research question will be performed over the 2020-2021 academic year.

The documentary research will include a literature review of the aforementioned theories as well as a technical background on the algorithm itself. The research will provide context for the technologies and prepare the reader for application of the theories to the research question. Beer, an academic in sociology, discusses how it's necessary to "understand what algorithms are and what they do in order to fully grasp their influence and consequences," so this analysis will reveal exactly how the algorithm works to be able to uncover its influence (Beer, 2017). Key words such as "TikTok algorithm," "filter bubble," and "content filtering," along with the theories will be used

to search for relevant information. Due to the relatively short history of the technology, sources will be gathered with the intent of focusing on the algorithm and filter bubbles; however, other sources that provide additional reliable information about the algorithm will be analyzed in order to gain a holistic perspective on the topic. Additional research on the historic biases and their effects previously displayed in algorithms will be completed to give this analysis more context (Sîrbu et al., 2019). This analysis method will establish the connection between the TikTok algorithm and the key elements of the STS theories.

The discourse analysis will identify TikTok phenomena that highlight content filtering and showcase troubling effects on society. Winner's argument that technologies have politics will be used to explain how the phenomenon discovered in the discourse analysis may have a political basis. Furthermore, this method supports answering the research question as the nature of discourse analysis reveals how the technology is able to influence society to where the technology's effects are being discussed in the news, other social media platforms, and the TikTok platform itself (Asare, 2020; Grant, 2020; Wescott & Liao, 2019). Together, documentary research and discourse analysis will provide the necessary background information needed to apply the STS theories.

Conclusion

The STS project will provide an analysis of the TikTok algorithm in the context of technological determinism and the political implications of technology. This analysis will illuminate the ways in which the TikTok algorithm affects society through content filtering and enforcing political perspectives. Additionally, the technical project will establish a method to culture full neural differentiation time courses and employ high dimensional mass cytometry technology to analyze each cell in 40 dimensions. The project will utilize a novel analysis method and clustering techniques to draw conclusions regarding how varying concentrations of retinoic

acid affect the timing of neural development. Thus, these projects investigate the benefits and downfalls of using clustering capabilities in science and technology.

References

- Asare, J. G. (2020). *Does TikTok Have A Race Problem?* Forbes. Retrieved October 8, 2020, from <https://www.forbes.com/sites/janicegassam/2020/04/14/does-tiktok-have-a-race-problem/>
- Beer, D. (2017). The social power of algorithms. *Information, Communication & Society*, 20(1), 1–13. <https://doi.org/10.1080/1369118X.2016.1216147>
- Chandler, D. (2000). *Technological or Media Determinism*. https://www.researchgate.net/publication/265101073_Technological_or_Media_Determinism
- Fischer, S. (2020). *TikTok reveals details of how its algorithm works*. Axios. Retrieved October 8, 2020, from <https://www.axios.com/inside-tiktoks-killer-algorithm-52454fb2-6bab-405d-a407-31954ac1cf16.html>
- Gooch, C. L., Pracht, E., & Borenstein, A. R. (2017). The burden of neurological disease in the United States: A summary report and call to action. *Annals of Neurology*, 81(4), 479–484. <https://doi.org/10.1002/ana.24897>
- Grant, C. (n.d.). Uncovering the TikTok Algorithm and the app's Racial Bias. *The Oarsman*. Retrieved October 12, 2020, from <https://veniceoarsman.com/10142/uncategorized/uncovering-the-tiktok-algorithm-and-the-apps-racial-bias/>
- Hess, D. J. (2015). Power, Ideology, and Technological Determinism. *Engaging Science, Technology, and Society*, 1(0), 121–125.
- Holone, H. (2016). The filter bubble and its effect on online personal health information. *Croatian Medical Journal*, 57(3), 298–301. <https://doi.org/10.3325/cmj.2016.57.298>

- I. of M. (US) and N. R. C. (US) C. on the S. of. (2011). *The Influence of Environment*. In National Academies Press (US). <https://www.ncbi.nlm.nih.gov/books/NBK53409/>
- Kam, R. K. T., Deng, Y., Chen, Y., & Zhao, H. (2012). Retinoic acid synthesis and functions in early embryonic development. *Cell & Bioscience*, 2, 11. <https://doi.org/10.1186/2045-3701-2-11>
- Ko, M. E., Williams, C. M., Fread, K. I., Goggin, S. M., Rustagi, R. S., Fragiadakis, G. K., Nolan, G. P., & Zunder, E. R. (2020). FLOW-MAP: A graph-based, force-directed layout algorithm for trajectory mapping in single-cell time course datasets. *Nature Protocols*, 15(2), 398–420. <https://doi.org/10.1038/s41596-019-0246-3>
- Mishra, S., Kelly, K. K., Rumian, N. L., & Siegenthaler, J. A. (2018). Retinoic Acid Is Required for Neural Stem and Progenitor Cell Proliferation in the Adult Hippocampus. *Stem Cell Reports*, 10(6), 1705–1720. <https://doi.org/10.1016/j.stemcr.2018.04.024>
- Mohsin, A. (2020). *10 TikTok Statistics That You Need to Know [September 2020]*. Retrieved October 12, 2020, from <https://www.oberlo.com/blog/tiktok-statistics>
- Newton, C. (2020). *Three takeaways from a visit to TikTok's new transparency center—The Verge*. (n.d.). Retrieved October 12, 2020, from <https://www.theverge.com/interface/2020/9/11/21430822/tiktok-transparency-visit-tour-algorithms-for-you-page>
- Rhinn, M., & Dollé, P. (2012). Retinoic acid signalling during development. *Development*, 139(5), 843–858. <https://doi.org/10.1242/dev.065938>
- Rowland (2019). Do artifacts (still) have politics? *The Information Society*, 35(4), 244–249. <https://doi.org/10.1080/01972243.2019.1618058>

- Sîrbu, A., Pedreschi, D., Giannotti, F., & Kertész, J. (2019). Algorithmic bias amplifies opinion fragmentation and polarization: A bounded confidence model. *PLOS ONE*, *14*(3), e0213246. <https://doi.org/10.1371/journal.pone.0213246>
- Smith, M.R. (1994). Technological Determinism in American Culture. *Does Technology Drive History?: The Dilemma of Technological Determinism*. (pp. 1-17). Cambridge, Massachusetts. London, England. The MIT Press.
- Westcott, B. Liao, S. (2020). *TikTok beauty video with a hidden anti-China message goes viral*—*CNN*. Retrieved October 12, 2020, from <https://www.cnn.com/2019/11/27/tech/tiktok-xinjiang-eyelash-curling-scli-intl-hnk/index.html>
- Winner, L. (1980). Do Artifacts Have Politics? *Daedalus*, *109*(1), 121–136.
- Zhou, W., & Li, S. (2018). Decreased levels of serum retinoic acid in chinese children with autism spectrum disorder. *Psychiatry Research*, *269*, 469–473. <https://doi.org/10.1016/j.psychres.2018.08.091>
- Zunder, E. R., Lujan, E., Goltsev, Y., Wernig, M., & Nolan, G. P. (2015). A Continuous Molecular Roadmap to iPSC Reprogramming through Progression Analysis of Single-Cell Mass Cytometry. *Cell Stem Cell*, *16*(3), 323–337. <https://doi.org/10.1016/j.stem.2015.01.015>