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A Letter from the Editors-in-Chief

Readers,

It has been a joy to produce the third volume of the Arbor Journal of Undergraduate Research. Despite the challenges of a hybrid year, the quality of submissions has allowed us to curate a brilliant selection of articles from students across the Faculty of Arts & Sciences.

In line with the interdisciplinary mission of this journal, you will find that while our articles are divided into each of the Humanities, Social Sciences, and Sciences, our authors have produced research that stretches traditional disciplinary boundaries. Whether it's normative critiques of mathematical utility theories, or scientific attempts to mechanize and formalize complex human reasoning, you will find within this volume intersections of various disciplines. As you read along, we hope you feel inspired to think about connections between and across the fields you have encountered.

This volume would not have been possible without our team of thirteen dedicated students. We thank our editors for the numerous hours they committed to select, edit, and polish the submissions. This journal would not have been completed without your work.

Warmest,

Basmah Ramadan and Fatemeh Nami

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HUMANITIES

"Using the Maronite mountaineers against the Druzes": The Overlooked Role of Egyptian Policies in the Formation of Sectarianism on Mount Lebanon, 1831-1840

Timothy Boudoumit is a fourth-year History and Political Science student.

The Egyptian invasion of Ottoman Syria in 1830 was pivotal for the development of the sectarian governance of Mount Lebanon. Misconceptions about the nature of the region's sectarian political system have led many, such as Ottoman Foreign Minister Fuad Pasha (1858-1860), to conclude that the conflicts on the Mountain were "age-old struggles between tribal communities whose ignorance had [stifled] reform."[1] Such misconceptions have been challenged by contemporary historiographical trends. While modern Arab historiography emphasizes the primary cause of sectarianism to be Ottoman policies of 'divide and rule,' modern Turkish historiography instead attributes it to European clientelist policies which pitted ethnoreligious groups against each other.[2] However, few historians have emphasized the role of regional actors, such as Muhammad Ali's Egypt, in the creation of these inter-communal divisions. This paper presents evidence to fill this gap in the academic literature by analyzing the implementation of Egyptian 'divide and rule' policies in Mount Lebanon and how this strategy complicated subsequent attempts to restore Ottoman sovereignty. Overall, it argues that the Mountain's first multi-confessional sectarian political system, created in 1843, was in large part a response to Egypt's divide and rule policies between 1831-1840, which created important divisions between the Mountain's communities.

Before the Egyptians occupied Mount Lebanon, religious divisions held little political importance. Military rank within the Ottoman army determined which local elites would govern the Mountain. This military hierarchy that shaped the Mountain's preceding political system likewise determined social distinction.

1. Quote: Fuad Pasha, July 24, 1860, available in Ussama Makdisi, *Culture of Sectarianism: Community, History, and Violence in Nineteenth-Century Ottoman Lebanon* (Berkeley: University of California Press, 2000) 3, 177 n3.
2. Makdisi, *Culture of Sectarianism*, 5-6.

Mount Lebanon's society was divided largely in the same carrying a revolution so revolutionary as to outshine their Caucasian Mount Lebanon's society was divided largely in the same way as the rest of the empire: between local notables (*'ayan*) and the peasant class (*ra'aya*).[3] Most of the region's high-ranking military officers were of the Druze and Sunni sects with few Maronites. Officially, the Mountain was divided between two Ottoman *eyalets* (also called *beylerbeyliks*) along the Beirut-Damascus Road: between the *eyalets* of Sidon, to the south, and Tripoli, to the north.[4] Practically, however, Mount Lebanon was ruled relatively independently from these eyalets due to the region's complicated and unique features. As Mount Lebanon is the region with the highest average elevation in the Ottoman Eastern Mediterranean, its geography complicated any attempt at long-distance governance and administration. Consequently, a tradition emerged whereby the respective *eyalets* ceded de facto governance of their portion of the Mountain to the highest-ranking local officials Mount Lebanon, who held close ties to the Ottoman government. These elites, espousing different religious beliefs, ruled Mount Lebanon between brief and limited conflict, caused by political rather than religious feuds.[5]

The Mountain's complicated demography also contributed to its de facto autonomy. The largest portion of the Mountain's population identified as Maronite, a Christian sect following the West Syriac Catholic rite. They lived alongside the Druzes, followers of a unique belief system with Isma'il, Christian, Gnostic, and Neo-Platonist elements, some of whom helped the Ottomans conquer the region in the 16th century. While numerically smaller than the Maronites overall, the Druze were the dominant population of certain villages in the southern half of the Mountain, known as the *Shuf*.[6] Several other smaller groups included Sunni Muslims, Shia Muslims, Greek Catholics, Greek Orthodox, Armenians, and Jews, each with

3. Makdisi, *Culture of Sectarianism*, 6.
4. Kamal S. Salibi, *The Modern History of Lebanon* (Delmar, N.Y: Caravan Books, 1977), xi, 24.; Makdisi, *Culture of Sectarianism* 28, 30.
5. Makdisi, *Culture of Sectarianism*, 29.
6. Dick Douwes, *The Ottomans in Syria: a History of Justice and Oppression* (London: I.B. Tauris, 2000), 88-89, 101, 113.

larger populations in the Mountain's neighbouring regions.[7] Like all the other people of Ottoman Syria, Mount Lebanon's people identified strongly with their religious identities, but, according to Ussama Makdisi, "subsumed [these] identities within a political and public space that accommodated differences of faith."[8] The Mountain's people shared a common culture, as they were bound by the same customs and hierarchies, and they submitted to the same elites regardless of religious affiliation. The rugged terrain forced all the peasants to also occupy similar economic activities and hold a common respect for agricultural cycles.[9] Overall, religious identities were not reflective of the Mountain's political patterns, with tribal and kinship ties holding sway over political considerations.

The Egyptian conquest of Ottoman Syria marked a discontinuity in the old Ottoman administrative system. Muhammad Ali's army, commanded by his son, İbrahim Pasha, captured the city of Acre in 1831, capital of the Sidon *eyalet*, opening the way to conquer all of Ottoman Syria.[10] Between 1831 and 1833, İbrahim Pasha quickly established control over Mount Lebanon and dismantled the decentralized pattern of politics that previously prevailed.[11] In its place, İbrahim Pasha centralized the governance of Ottoman Syria into one centre in Damascus, where he established an Egyptian-model civil government.[12] The new government reformed the management of finances in the Syrian lands, including Mount Lebanon, by replacing the tax farming system (*Iltizam*), from which local notables traditionally drew their revenues, with a system of salaried tax collectors that brought revenue directly to the state.[13] This

7. Leila Tarazi Fawaz, *An Occasion for War: Civil Conflict in Lebanon and Damascus in 1860* (Berkeley: University of California Press, 1994) 223-224.
8. Makdisi, *Culture of Sectarianism*, 29.
9. Ibid., 29.
10. Tuğçe Kayaal, "The issue of Ottoman centralisation and local reactions: political and ideological transformation of mount Lebanon between 1858 and 1900." (Master of Arts (History), Sabanci University, 2013), 23-24.
11. Dick Dowes, *The Ottomans in Syria*, 91.
12. Moshe Maoz, *Ottoman Reform in Syria and Palestine 1840-1861: The Impact of the Tanzimat on Politics and Society* (London: Clarendon Press, 1968), p.12, 15-17.; Kayaal, "Ottoman Centralization," 24.
13. Maoz, *Ottoman Reform*, 16-17.

degree of centralization was unprecedented in the Mountain's recent history.

Egyptian officials repressed any dissent against their centralizing policies. As a region that previously enjoyed substantial independence, the old elite families of the Mountain objected to centralization. Their resistance to reforms led İbrahim Pasha to confiscate their properties and lands, and he forced many into exile. İbrahim Pasha warned the elite of Mount Lebanon, "Woe to you who disobeys me or who delays in doing my bidding."[14] Yet, this strategy prevented İbrahim Pasha from establishing control on the Mountain since, due to its remoteness, he needed to foster local alliances to facilitate his plan for centralization. Muhammad Ali consequently proposed to İbrahim Pasha that the task of "eradicating the rebels" on the Mountain could be made easier if he were to use the "Maronite mountaineers against the Druzes."[15]

Following this suggestion, İbrahim Pasha requested, in a letter to the Maronite Patriarch, Youssef Boutros Hobaish, that the patriarch help select three hundred young Christian men from Jubbat Bsherri who were "famed for their bravery," but he also stressed the necessity of their "obedience."[16] With his Christian troops ready, İbrahim Pasha gave them sixteen thousand rifles and ordered them to "[fight] the traitorous infidel Druze sect which denies the existence of God and his prophets. God willing, they and their property will become plunder for you, and you are to keep the weapons for eternity."[17] İbrahim Pasha appealed to the faith of the Maronites to win them as allies, despite being himself a Muslim, thus differentiating loyalties based on religious sect. İbrahim Pasha used religious distinction to fulfill his political objectives, labeling the Druze as "infidels," and blessing the loyal Christians with the Pasha's "eternal" blessing.

The following decade expanded and cemented the growing division between the Maronites and the Druzes. As part of İbrahim Pasha's divide and rule policies, he instated Bashir Shihab II, a

14. Makdisi, *Culture of Sectarianism*, 53, 192 n11.
15. Ibid., 54, 193 n18.
16. Ibid., 56, 193 n26.
17. Ibid., 56, 193 n27.

Maronite convert from a Druze-Sunni family, as the *emir* of the entire mountain.[18] In so doing, İbrahim Pasha encouraged non-Muslim political participation to break the old pattern of Druze governance in Mount Lebanon.[19] This became the first official mono-confessional system established between the Mountain's communities as the *emir* had to be a Maronite.[20] The Druze elites became increasingly marginalized, killed, or forced into temporary exile by İbrahim Pasha's administration.[21] The elites connected to Shihab, who were mostly Maronites, obtained the confiscated or abandoned Druze properties as a reward for their loyalty.[22] Thus, in attempting to produce a loyal regime, the consolidation of Egyptian power sectarianized the government of Mount Lebanon.

This decade of Egyptian occupation saw an increase in tensions between the politically-favoured Maronite elite and the politically-disadvantaged Druze elite. In 1833, after the Druze rebellion had been put down, İbrahim Pasha instructed Shihab that, "as regards the [returning] Druzes, let bygones be bygones. Do not harm them when they return to their homes. Allay their fears and set their minds at rest."[23] Shihab consequently allowed the Druze leaders to return, although he did not aid the Druze in the restoration of their privileges. Due to the Egyptian tax reforms, Druze elites lost their traditional *Iltizam* revenues and did not have the coercive power to fully restore their former positions. İbrahim Pasha simultaneously attempted to restore the old order by disarming Christian loyalists, a decision that was heavily resisted.[24] Thus, tensions between the Maronite elite, who sought to retain their dominant positions, and the Druze, who hoped to restore both Ottoman rule and their traditional privileges, escalated during the remaining years of Egyptian occupation.

After Egypt lost Mount Lebanon in 1841, both the Maronite

18. Fawaz, *An Occasion for War*, 15-16, 19, 26.
19. Maoz, *Ottoman Reform*, 17-20.
20. Makdisi, *Culture of Sectarianism*, 52, 54, 60-61, 63.
21. Ibid., 56.
22. Kayaal, "Ottoman Centralization," 25-26.
23. Makdisi, *Culture of Sectarianism*, 56, 193 n28.
24. Kayaal, "Ottoman Centralization," 25.; Makdisi, *Culture of Sectarianism*, 57.

and Druze elites attempted to fill the power vacuum left in its wake. The loss of Egyptian power on Mount Lebanon began in 1838 when Druze and Maronite peasants rose in rebellion against Shihab, united by their common disdain for Shihab's heavy tax collection and heavy exploitation of the Mountain's resources.[25] Initially, the majority of the elites, including the Maronite Church, joined the rebellion.[26] However, in 1839, international interventions fractured solidarity among the elites. The Ottomans, encouraged both by French and British pledges of military assistance as well as by the weakened state of Egyptian rule, decided to recapture the Syrian lands. The two elite factions of the Mountain saw an opportunity to advance their own interests by aiding the European and Ottoman reconquest, although they aided different powers: the Maronites aided the military efforts of Catholic France while the Druze opted to support their old Ottoman overlords and the British efforts. Division among the local elites resulted in a low-level civil war that became characterized by sectarian overtones. For instance, Druze elites who chose not to fight were called "traitors" by their co-religionists, and the language of "*Ta'if*" (religious community) became commonly used to differentiate the two factions.[27] Thus, immediately following Egypt's retreat, sectarian strife began characterizing the Mountain's elite politics, although it had not yet become widespread.

This sectarian strife plagued Ottoman attempts to re-establish order upon their reconquest of Mount Lebanon in 1841. The Ottomans received substantial help from the French and British armies during the war to recapture the Syrian lands from the Egyptians, which gave France and Britain significant leverage in the postwar negotiations that brought all the Great Powers to the table. There were competing settlement proposals emanating from the Maronite and Druze camps. Although the Maronites requested the continuation of the Emirate that favoured their numerical superiority, Ottoman authorities

25. Fawaz, *An Occasion for War*, 21-23.; Makdisi, *Culture of Sectarianism*, 60, 195 n41.
26. Kayaal, "Ottoman Centralization," 28.
27. Makdisi, *Culture of Sectarianism,* 65, 198 n64-n65.; Salibi, *The Modern History of Lebanon*, 53.; Fawaz, *An Occasion for War*, 26-28.

initially implemented the Druze request to restore their old estates.[28] The Ottomans agreed to also restore their traditional political and financial prerogatives under the condition that the Druze elite comply with the Tanzimat reforms intended to modernize the governance of the Empire. Among other reforms, the Tanzimat promise of equality between Muslims and non-Muslims present in the Gülhane Edict of 1839 resonated strongly with the Mountain's large Christian population.[29] Consequently, Druze elites resisted the Ottoman's Tanzimat reforms and claimed that, since "it was by [their own] effort [that] the Shihab government was overthrown," they were unwilling to bend to Ottoman Tanzimat initiatives.[30] Thus, the continuing tension between Maronite and Druze elites was not alleviated by the settlement of 1841, which demonstrates the lasting impact of Egyptian policy on the development of sectarianism.

The final settlement of the elites' political divisions would enshrine sectarianism as the Mountain's dominant political model. In 1842, the Ottoman foreign ministry and the ambassadors of Ottomans' European allies convened a conference in Istanbul to find a compromise that suited each community. Three distinct and contradictory settlements caused an impasse during this conference, with the French supporting the Maronite cause, the British supporting the Druze cause, and Istanbul's desire to centralize the Ottoman Empire. Austrian Chancellor, Klemens von Metternich managed to overcome this impasse by dividing the Mountain into two self-governing districts: Northern (*Kiserwan*) and Southern (*Shuf*). Each district would be governed by a *Qa'ym Maqam* (Ottoman Turkish: قائم مقام, Anglicized: Qaimaqam) who was a military-ranking official that would act as governor. This official would be appointed according to the demographic weight of the ethnoreligious groups for each district and their loyalty to the Sultan. On October 29, 1842, Metternich's suggestions were implemented in a system known as the Double Qaimaqamate; a Maronite governor was appointed in

28. Makdisi, Culture of Sectarianism, 67.; Salibi, *The Modern History of Lebanon*, 53-55, 58-60.
29. Maoz, *Ottoman Reform*, 30-32.
30. Kayaal, "Ottoman Centralization," 30.; Salibi, *The Modern History of Lebanon*, 59.

Kiserwan and a Druze governor in *Shuf*. Each was given an advisory council composed of one of Druze, Maronite, Sunni, Greek Orthodox, Greek Catholic, and Shia representatives of the minority communities present in each half of the Mountain.[31] The Double Qaimaqamate system, formed directly out of the turmoil caused by Egyptian policy, would be the first political system of a sectarian nature instituted on Mount Lebanon, and one to which Great Powers would often make recourse.

Ultimately, the foundation for the ethnoreligious division between Druze and Maronite elites and the resulting Double Qaimaqamate system can largely be attributed to the policies implemented by Egyptian officials between 1831 and 1840. Egyptian divide and rule policies, which were used to establish control over Mount Lebanon, simultaneously ended the traditional Ottoman class divisions and created division between the Druze and Maronite elites. The subsequent decade of occupation saw the suppression of Druze elites and assertion of Maronite dominance over the Mount Lebanon emirate, deepening inter-communal resentment and creating the first mono-sectarian political system between the communities. When the Ottomans reasserted their sovereignty in Mount Lebanon, competition for power among the elites became dressed in sectarian rhetoric, labeling co-religionists who opted out of the fighting as "traitors" and the opposite camp as "infidel". The final compromise imposed on the region permanently legislated these sectarian divisions, becoming the first sectarian-style political system between the Mountain's communities. This paper thus highlights the often overlooked role of Egyptian divide and rule policies in the growth of sectarianism among Mount Lebanon's elites. It demonstrates that the region's distinctive sectarian system–along with the gridlock politics that plague its people–is far from an 'inevitable' development.

31. Kayaal, "Ottoman Centralization," 30-31, 37.; Salibi, *The Modern History of Lebanon*, 67-72.

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Unsettled Utility: A Critique of the Expected Utility Theory as a Normative Theory for Decision-Making Under Uncertainty

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Abstract: The expected utility theory (EUT) is a normative theory for rational decision-making under uncertainty. EUT defines utility as a measure of personal preference by the decision-maker when given a set of options to choose from (Briggs, 2019). Expected utility is the weighted average of utility values, weighted by the probability of each outcome. EUT argues for the maximization of the expected utility for a rational agent to make the optimal decision. Although being regarded as the orthodox theory for decision-making, EUT creates problems interpreting utility as preference. Firstly, the assumption of rationality in EUT provokes inconsistencies in its axioms. Secondly, quantifying utility as a scalar number does not account for its multidimensionality, potentially leading to indecision. Thirdly, EUT fails to address the influence of emotions as a part of rationality. Hence, this essay critiques the expected utility theory (EUT) as a normative decision theory because of unsettled problems in assigning utility as personal preference.

1. Introduction

It is estimated that human adults typically make around 35,000 conscious decisions each day, including about 227 decisions on food alone (Wansink & Sobal, 2007). We recognize that decision-making, the act of choosing, is a crucial part of our everyday life made possible by our cognition. Intuitively, we often consider the consequences of each alternative option that we could choose from before deciding on the one with the most ideal outcome. However, sometimes we may not have access to sufficient information that allows us to develop an accurate prediction of its consequences at the time of the decision and we are forced to make the decision in uncertainty. Thus, the study of decision-making under uncertainty has emerged to account for the unobservable consequences of each action (Briggs, 2019).

Normative theories for decision-making propose optimal choices and policies that people should obey to make decisions, often justified by philosophical and mathematical arguments (Baron, 2012). The expected utility theory (EUT) is a prominent normative theory for decision-making under uncertainty. Expected utility (EU) refers to a weighted average of utilities, or a measure of preference, weighted by the probability for each possible outcome (Briggs, 2019). EUT argues for the maximization of the EU when making decisions. EUT is considered to be the orthodox normative decision theory as it provides rational rules and mathematical formulations, as well as its popular usage and proven benefits in economics (Kochenderfer, 2015). However, this essay will critique the EUT as a normative theory for decision-making under uncertainty due to inherent problems in the definition and assignment of utility as personal preference.

The structure of this essay is outlined as follows. Section 1.1 will further elaborate on the definitions, axioms, and claims of EUT, providing the necessary background and understanding for the rest of this essay. Section 2 will explain problems with utility being the DM's personal preference in EUT, which is further divided up into three subsections. Section 3 will address the counterargument, which will be followed by a conclusion in Section 4.

1.1 Expected Utility Theory

EUT was first formulated by Daniel Bernoulli in 1738 to help gamblers maximize their gains (Tversky, 1975). EUT then became a normative theory of decision-making under uncertainty, focusing on what a free and rational decision-maker (DM) should do in every decision-making context (Zappia, 2018). EUT assumes rationality in decision-making, meaning the DM would analyze facts and information and follow a step-by-step procedure to arrive at a decision (Uzonwanne, 2016). There are different options, called *acts*, that the DM can pick . Each act has consequences that lead to changes in the situation, referred to as the *outcomes* (Briggs, 2019). One act may have multiple outcomes, each with an associated probability P that represents the chance of the outcome occurring. This probability is usually thought of in terms of a conditional probability, which is the likelihood of the outcome, given that the DM chooses an act A

(Briggs, 2019). EUT also introduces utility functions U that assign a scalar value to each outcome. The utility value represents how valuable an outcome is to the DM, typically interpreted as a measure of personal preference by contemporary research (Peasgood, 2014). Combining the utility and probability of the outcome, we calculate a weighted average as the expected utility (EU) for an act A as follows, where O is the set of all outcomes o (Briggs, 2019). EUT argues that the DM should pick the act with the maximum EU in order to obtain the most satisfaction out of the decision.

$$EU(A) = \sum_{o \in O} P_A(o)U(o)$$

2. Unaccountable Utility

As discussed in Section 1, EUT produces the optimal decision for the DM by maximizing the EU. Since the EU is directly calculated by taking a weighted average of the individual utilities of each outcome, EUT relies on the acquisition of clear and concrete mathematical values of utility. However, this section will address the problems with the utility function that assigns utility values as a measure of preference by the DM. Section 2.1 will discuss concerns with the inconsistencies in the assumptions of EUT. Section 2.2 will argue that utility as a numerical value for preference does not account for the multidimensional nature of utility. Section 2.3 will present the lack of consideration for emotions in EUT while the DM remains rational.

2.1 Inconsistencies in the Assumptions of Utility

EUT was axiomatized by von Neumann and Morgenstern in 1944 (Tversky, 1975). The four axioms of EUT on the DM's preferences of outcomes are completeness, transitivity, independence, and continuity (Steele & Stefánsson, 2020). The axioms are assumed to be true as the basis for EUT (Levin, 2006). As EUT is a normative theory, it also assumes the DM to be rational and ideal. However, in certain situations, the rationality assumption seems to cause violations of the axioms and allow preferences that cause inconsistency within EUT (Briggs, 2019). If rationality implies the falseness of the axioms, but EUT requires the axioms for it to be a normative theory

for rational decision making, there would be a contradiction. Thus, the assumptions about the utilities or the DM's preferences in EUT are flawed, causing problems in EUT being a normative theory. In the following sections, we will give two situations where rationality leads to a violation of transitivity and completeness axioms. We introduce the notation $\leq$ to represent the relation of a less or equal preference of the former option compared to the latter by the DM (Levin, 2006).

2.1.1 Rationality Violating Transitivity. Quinn's puzzle of the self-torturer is an example of rationality violating the transitivity axiom (Andreou, 2015). The transitivity axiom defines that given three options *X, Y*, and *Z*, if $X \leq Y$ and $Y \leq Z$, then $X \leq Z$ (Levin, 2006). Quinn's puzzle features a self-torturer (ST) who has an electric device attached to them that they can operate to shock themselves. The device has settings from 0 to 1000 with increasing electric current shocking the ST. The ST is told that 0 is painless and 1000 triggers excruciating pain (for pain caused by the electric current). However, each time the setting increases only by 1, the difference in pain level is almost undetectable, meaning the ST will only be able to experience real pain if they make a big jump between settings. In addition, the ST is offered $100 every time they move up 1 in the setting. Rationally, the ST would want to maximize their financial gain while considering the pain level. The ST recognizes that if they increment only by 1 every time from 0 to 1000, the difference in pain with an incremented setting is imperceptible, but they are able to receive money with each increment. Thus, it is rationally permissible for the ST to give preference to the n+1 level over n for all n between 0 and 999. By the transitivity axiom, this pattern of preference implies that the ST prefers level 1000 to level 0. However, when choosing only between level 0 and level 1000, the ST is likely to give preference to level 0 as it is a big jump that would bring them unbearable pain that no amount of money can make up for, violating the transitivity axiom. Therefore, Quinn's puzzle of the ST demonstrates that cyclic preferences can be rational while causing a violation of the transitivity axiom, which makes EUT inconsistent.

2.2.2 Rationality Violating Completeness. When the DM rationally finds two options incomparable or has different preferences based on different criteria, the completeness axiom may be violated

(Wątróbski et al., 2019). The completeness axiom states that given two options X and Y, either $X \leq Y$ or $Y \leq X$ (Levin, 2006). Let us consider a scenario where the DM has to choose between an omelette and pancakes for breakfast. The DM may prefer omelette to pancakes for health considerations, but pancakes to omelette for taste. The DM is rationally allowed to care equally about their health and the taste of the food. However, the two considerations result in two contradicting preferences, which violates the completeness axiom. Therefore, the DM can be rational but have incomplete preferences considered by different criteria.

2.2. Problems in Quantifying Multifaceted Utility

As evident in Section 2.1.2, the DM's preferences are subject to change when compared with different perspectives or against different criteria. Revising the example introduced in Section 2.1.2, other than health and taste, there are even more factors to consider when making the decision, such as what the DM has planned for the day, who the DM is with, what the DM had the previous day. It is totally rational that the DM arrives at different preferences or utility values for the options with each of the mentioned factors in mind. In fact, most decision problems in the real world require consideration from multiple perspectives because of their complexity and large dimensionalities (Wątróbski et al., 2019). However, the utility value is a numerical number that neither accounts for the multidimensionality of the utility nor provides methods to analyze trade-offs, making EUT theory inadequate while contributing to the violation of the completeness axiom.

2.2.1. Indecision. One problem with defining the utility as a single value without multidimensional consideration is that it could result in indecision. As discussed in Section 2.2, using different criteria could cause the DM to have incomplete or contradicting preferences, but EUT does not propose a solution to resolve the conflict or a rule for further decisions for trade-offs. Meanwhile, if the DM thinks rationally of everything worth considering when deciding, it can be time-consuming which would prevent the DM from coming up with the utility values until they no longer have the chance to decide. The frame problem is observed in artificial agents that an agent's

inability to consider the relevant consequences of their behaviours leads to failure to decide on actions. Although humans can realize the relevance of each consequence, the frame problem still gives an idea of the danger of having too many things to consider. It also suggests that EUT is likely to fail in rational artificial agents due to indecision, indicating that EUT is not well-formulated as a theory for rational decisions. Similarly, for a human DM, it could also take a long time to arrive at a single utility value as they examine a potentially infinite number of aspects of the decision (Chow, 2013). Therefore, the utility value may be undefined either due to contradicting preferences or the large amount of time needed for computation. In these situations, maximizing the EU is impossible, so EUT does not help the DM to make the optimal decisions, or any decisions at all.

2.2.2. Multidimensional Consideration & Trade-offs. Since utility is multifaceted, it is overly restrictive and suboptimal for the utility to be quantified merely as a scalar value as defined in EUT. As a human with different needs, the DM would and should have different objectives with different criteria when making a decision. Maslow's hierarchy of needs attempts to explain human motivation and desires by categorizing human needs into a pyramid, suggesting that humans generally have more than one tier of essential need (Mcleod, 2007). Although the pyramid idea implies that there is an order of importance for human needs, the needs at the same level of the pyramid still seem equally meaningful. For example, the third level at the top of the pyramid is the need for belonging, which includes intimate relationships, friendships, and family (Mcleod, 2007). Consider a situation where the DM needs to choose a city to live in and they want to be close to their partner, friends, and parents, who all live in different cities. It is then necessary for the DM to take into account all of their three goals to make the most satisfying decision. However, it would be extremely difficult and nearly impossible to identify the best trade-offs or compress the multidimensional consideration into a number that is completely representative of the DM's preference (Steele & Stefánsson, 2020). Therefore, the theory that allows the DM to make an optimal choice should not quantify utility as a single value. Alternatively, the decision theory could provide rules to combine preferences based on different criteria to acknowledge

different aspects and resolve the conflicts. For instance, the multiple criteria decision framework proposes a rule-based method that takes the DM's preferences to be a mathematical aggregate of the preferences corresponding to all pertinent dimensions (Wątróbski et al., 2019). EUT requires the utility to be quantified as a scalar value and does not include a method to numerically incorporate different preferences depending on the objectives. As a result, it overlooks the importance of the DM's multifaceted preferences, rendering itself inadequate as a normative theory for decision-making.

2.3. Consideration of Emotions

People always question whether they should "follow their head or follow their heart" when deciding, with "head" referring to rationality and "heart" representing emotions. However, many philosophers grew to believe that there are direct causal relations between emotions and rationality, in which emotions enable the causes of rational decision-making (Kirman et al., 2010). Thus, not only are rationality and emotions not mutually exclusive, but rationality also requires and allows emotions. Although EUT assumes rationality in the DM, it is permissible for their preferences to be emotional. Nonetheless, research reveals that emotions can be both beneficial or harmful for decision-making depending on the circumstances (Lerner et al., 2015). For example, fear of dying may stop the DM from jumping from a ledge, but fear of failure may hold the DM back from taking on a demanding task, which prevents them from growing and improving. Hence, it is unclear if the most preferable choice will grant the DM the most satisfaction in the long term. Furthermore, EUT does not provide rules to make the distinction between the DM utilizing helpful emotions for their benefit and the DM being misled or overwhelmed by emotions, at which point they may even stop being a rational agent. Therefore, although the objective of the EUT is to find the optimal decision for the DM based on their preferences, the lack of consideration of emotions prevents it from guaranteeing the best choice for the DM.

3. Counterargument

This section will address some possible counterarguments in response to the critiques made in the previous section.

3.1. Completeness Axiom

There are many studies that investigate the constraint relaxation of EUT. Specifically, a study over lotteries shows that EUT can be modified and reformulated without the completeness axiom utilizing the mathematical properties of the metric space containing all outcomes (Dubra et al., 2004). If the completeness axiom ceases to be a necessary condition for EUT, it will no longer create a contradiction with the rationality assumption as discussed in Section 2.1.2. However, the elimination of the completeness axiom is not widely accepted as it relies on other assumptions and requires the situation to satisfy additional requirements, such as the outcome space being compact (Dubra et al., 2004).

3.2. Bounded Rationality

Bounded rationality was proposed by Herbert Simon in 1975 that rejects the assumption of perfect rationality (Campitelli & Gobet, 2010). Bounded rationality suggests that when making decisions, the DM's rationality is limited by many factors, such as the difficulty of the decision, the cognitive capacity of the DM's mind, and time constraints on the decision. There have been studies that incorporate the notion of bounded rationality into EUT along with changes made to the axioms (Wheeler, 2020). Hence, the relaxation of bounded rationality in EUT potentially resolves the problem for indecision discussed in Section 2.2.1, although it is more empirically based rather than having philosophical foundations.

3.3. Alternative Definitions for Utility

Although EUT advocates for the maximization of utilities as a personal preference, there have been other proposals of alternative definitions for the utility that may eliminate problems associated with the original definition regarding emotions discussed in Section 2.3. Classic utilitarians interpret utility as a measure of pleasure or happiness (Briggs, 2019). This definition of utility touches on the emotional aspect of utility, as happiness is characterized by feelings

including joy, satisfaction, well-being. EUT with utility as a measure of happiness implies that all negative emotions that do not provoke happy feelings are undesirable; however, as discussed in Section 2.3, there are beneficial choices even behind negative emotions. Moreover, this definition also faces the problem of trade-offs as there can be more than one source for happiness (Briggs, 2019). Another definition for utility is the objective betterness and worseness instead of subjective preferences, as there is nothing in the formalism of EUT that requires subjective rather than objective values (Broome, 1991). This definition eliminates the necessity to consider personal emotions associated with preferences, as it only concerns the objective truth. However, it does not resolve the problems outlined in Section 2.1 regarding inconsistency, and Section 2.2 about the consideration of multiple aspects. In addition, there have yet to exist universally approved definitions for object goodness and badness (Schroeder, 2021).

4. Conclusion

This essay critiques EUT as a normative theory for decision-making under uncertainty due to problems in the definition of utility as a measure of the DM's personal preference. Firstly, the assumption of rationality in EUT causes contradictions in the transitivity and completeness axioms, which are the basis for EUT. Secondly, the assignment of utility as a single value is not representative of the DM's preference that corresponds to multiple dimensions, potentially also leading to indecision. Thirdly, EUT does not take the DM's emotions into consideration, as rationality also involves emotions. Although EUT is widely accepted as the orthodox normative theory for decision-making, it still has flaws that need to be addressed for it to be able to constitute a guideline for optimal rational decision-making.

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Say Yes to Access:
Ethical Considerations of Conscientious Objection in the Domain of Healthcare

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The right to freedom of conscience is considered elemental to upholding liberty and autonomy in a pluralistic society. However, this is not a sweeping declaration that can be unquestionably applied to every facet of society—Schuklenk and Smalling argue that physicians do not have a right to conscientious objection within the domain of healthcare. In this essay, I will critically analyze their view. First, I will provide a framework for our discussion by defining conscientious objection and situating it in political philosophy. Next, I will present Schuklenk and Smalling's view under this framework, focusing on the argument that healthcare practitioners are obligated to provide services expected from a profession to which they voluntarily join (2016, p. 234). I will then present the objection that the patient's legal entitlement to a medical service does not imply the doctor's moral obligation to provide that service when it pertains to certain types of procedures. Finally, by appealing to reformed medical values, I will argue that conscientious objection should not be allowed in *any* cases for services within the scope of medical practice.

Constructing an Ethical Framework

Conscience can be understood as the conviction to act according to an individual's own understanding of what is good and right (Schuklenk & Smalling, 2016, p. 235). Conscientious objection is defined as opposing to carry out an act that violates one's sense of conscience. Accordingly, conscience and respect for conscientious objection are taken to be necessary for citizens of a pluralistic society to maintain autonomy and tolerance (Schuklenk & Smalling, p. 235). Conscience does not require sound reasoning to support what an individual feels is right. Considering this, the content of one's conscience does not have to be objectively or morally legitimate to be respected in a liberal society.

Though morality or reasoning is not necessary for an

individual's right to conduct their actions according to their conscience, these rights must also function within the 'rules' of a liberal society. Actions can be categorized into three classes:

1) Negative duties are acts that are legally and morally impermissible, which individuals are required to refrain from.
2) For acts that are both legally and morally permissible, there is no obligation to refrain from or do them. Within this category, individuals are free to exercise conscientious objection.
3) Positive duties are acts that are required of an individual (Wiebe, 2021, slide 5).

The second category encompasses most actions in a liberal society, in which the individual is free to exercise autonomy over career, religion, health, and other aspects of their life. The difficulty of conscientious objection arises in medical practice when society cannot agree on which category an act fits into. Conscientious objection in the medical realm often concerns medical assistance in dying (MAID), along with abortion, contraceptives, and patients that do not fit in heteronormative categories (Schuklenk & Smalling, p. 235). For the purposes of this essay, we will be restricting our discussion of conscientious objection to procedures pertaining to reproductive health and end-of-life care.

The Radical View against Conscientious Objection

Schuklenk and Smalling argue that, since people have a right to healthcare, physicians have a positive obligation to provide that good when they enter the medical profession, regardless of whether it aligns with their own conscience (p. 234). Positive duties are less common in a liberal society and only arise during specific circumstances in which:

1) Someone willingly adopts a role and thus accepts the obligations of that role.
2) People in that role hold a monopoly over the provision of specific goods and services.
3) The goods and services are things that citizens have a *right* to access (Wiebe, slide 5).

Schuklenk and Smalling argue that individuals who voluntarily choose to enter the medical profession have no right to withhold services that patients are legally entitled to receive (2016, p. 237). Being a medical practitioner itself is not a right, as one must meet rigorous requirements in order to enter the profession in the first place. It is fair that people who cannot meet the academic requirements of medical school are not allowed to become physicians. Correspondingly, physicians who cannot perform procedures required of them do not meet the standards of the profession. According to Schuklenk and Smalling, this is unacceptable, for professionals are responsible for the obligations that come with the *voluntary choice* to become a medical practitioner (p. 238).

Doctors hold a monopoly over the services they provide, which can generate significant consequentialist concerns when they are unwilling to provide them. This is exemplified in areas in which the majority of providers conscientiously object to a procedure. In Italy, 70% of gynecologists object to performing abortions, resulting in shocking rates of backstreet abortions (Schuklenk & Smalling, p. 238). It is clear that accommodating conscientious objection can result in suboptimal access, inequitable workloads for doctors, and an unreliable and unfair delivery to care (Schuklenk & Smalling, p. 237-38). This comes at a dire cost to patients trying to access medical goods and services that they are legally entitled to access (Schuklenk & Smalling, p. 234). Refusal to provide services that cannot be safely or easily attained elsewhere is no less immoral than a parent who neglects to provide adequate food and care to their child.

Objection: What do patients have a *Right* to?

Schuklenk and Smalling argue that physicians who willingly step into the role have a positive duty to provide medical services that patients are legally entitled to access (p. 234). However, in order for something to be mandated as a positive duty, a premise requires that citizens have a *right* to the good. One objection to their argument proceeds as such: if by establishing that the procedures are not something a patient has an intrinsic right to, it is no longer a positive duty that the physician is obligated to service. This means the service is categorized in the class of actions that are both legally and morally

permissible, wherein physicians have the liberty to conscientiously object to providing.

In Canada, healthcare is acknowledged as a right. The accepted intention of healthcare encompasses the prevention, treatment, or cure of physical impairments such as disease and injury. Provided that people have this right, it would be morally impermissible and prohibited for a physician to limit access to an essential health service, such as refusing to vaccinate someone on a racially discriminatory basis. Abortions and MAID however, are notoriously polarizing in pluralistic societies. For instance, some people may see medically assisted dying as a direct violation of the negative duty not to kill another person while others see it as an act of beneficence. In less extreme views, it is unclear whether certain medical procedures fit within the "therapeutic" model of healthcare. Contraception is preventative to pregnancy but pregnancy, in most cases, is not detrimental to one's health in the same way that diseases are. These procedures are often treated more as a commodity, in the sense that people have to pay for elective surgeries for conditions that are not central to one's health. Patients are entitled to access morally and legally permissible procedures, but *legal entitlement does not entail the physician's obligation to provide a good if it is not a fundamental right*.

Why is the doctor's right to conscientious objection important? An emphasis of pluralistic societies is the respect for different moral and religious views, for the "preservation of freedom of conscience" is argued to be a moral right and core value of liberal states (Schuklenk & Smalling, p. 235). Failing to do so incites a psychological cost to the conscientious objector. In order to preserve the liberal integrity of a pluralistic society, freedom of choice must be protected within the bounds between negative and positive duties. It is not necessary to verify the epistemic basis or veracity of the doctor's conscience, for the need to respect conscience in a liberal society is independent of those reasons. Seeing that certain procedures lie both outside of the realm of healthcare and inside of the realm of acts which are neither compulsory nor prohibited, medical practitioners have a moral claim to conscientious objection accommodation in liberal democracies.

The Reformed Landscape of Medical Care

The objection seeks to preserve the liberty of medical practitioners with little regard to the moral liberty of patients that depend on the services. I will now refute the objection by demonstrating that 1) prohibiting conscientious objection in medical contexts does not infringe on the doctor's moral liberty and that 2) policies must change in response to the paradigm shifts in medicine in order to uphold liberty in a pluralistic society.

First, moral aversion to performing certain procedures does not have to incite physiological harm nor limit an individual's choice to be a doctor. Schuklnek and Smalling point out that doctors are at liberty to pursue a specialty that does not require them to perform procedures which contradict their conscience (p. 239). For instance, there is nothing preventing a medical practitioner from becoming a dermatologist instead of a gynecologist. Doctors that object to providing procedures that are within the scope of their practice should choose a suitable subfield or be replaced by someone who is willing to so that patients can receive the care they need. Objections may be brought up that some doctors may have voluntarily joined at a time in which the scope of practice did not include procedures that they would conscientiously object to. This is not a valid objection, however, for all professionals must adapt to the changing nature of societal demands. Teachers cannot refuse to do their job during the pandemic because they were not aware that they would be required to adapt to an online learning curriculum. *The needs of society are not stagnant, therefore policies cannot remain so.* Medicine is an "ever-evolving scientific cultural pursuit," and thus the contract between society and medical practitioners must be revised accordingly (Schuklenk & Smalling, p. 239).

This leads to the second contention: that social policy must change in response to reforms in medical practice. Conscientious objection to abortion or MAID often appeals to the traditional core values of medicine which endorses the preservation of life at all costs. However, the values of medicine have been changing to defend the quality, and not just quantity of life (Schuklenk & Smalling, p. 239). The quality of life can be appreciated as the type of life that aligns with

an individual's values. For instance, women are no longer obligated to follow a traditional role in society as mothers, so contraception and abortion allow a woman to safely carry out that choice. Similarly, a couple who is infertile should be able to access assisted reproduction without being turned away because of a practitioner's moral qualms. Some people may seek MAID to avoid suffering from a terminal illness and to end their life on their own terms. In each of these examples, it is apparent that a competent patient decides that they would endure greater physical and/or psychological trauma without the procedure—these procedures allow individuals to have the kind of life that is the most valuable to them. Doctors promised to promote the interests of patients, and the interests of the patient must be *defined by the patient*, rather than the doctor's idiosyncratic views of what the patient's interests should be (Schuklenk & Smalling, p. 239).

A shift in the medical paradigm is *morally essential to liberty* for it enables individuals to better pursue and realize their choices in a liberal society. On this basis, I maintain that healthcare must include procedures such as reproductive health and MAID, which would then entail that patients have a right to the unfettered access of these procedures. Physicians have a positive duty to provide healthcare, therefore conscientious objection is morally impermissible for any service within the scope of medical practice (Schuklenk & Smalling, p. 234). To summarize, inhibiting conscientious objection does not infringe on the liberty of medical practitioners, yet allowing it drastically infringes on the liberty of patients.

Closing remarks

In this paper, I have presented both negative and positive arguments against conscientious objection to medical procedures and conclude that adopting policy against conscientious objection accommodation is morally, and consequently, the best option to promote liberty in a pluralistic society. Expanding our definition of healthcare to reflect our continuously changing values will ultimately further autonomy. It is obvious that procedures such as abortion and MAID are critical services that a patient cannot easily go without. In a world where medical practitioners hold the only safe means to healthcare, we can only hope that they will not deny us.

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The Intersections of Blackness and Queerness: Why Queer Is Not Revolutionary

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Introduction

Within gender and sexuality studies, the term 'queer' denotes an individual's departure from heteronormative ideals of gender and sexuality (i.e., heterosexuality and cisgenderneity) (Sedgwick, 1994). Queerness portrays itself in one's ability to love freely and express oneself outside the confines of gender norms. Consequently, many people believe that declarations of queerness are revolutionary; that the word Queer is revolutionary. This belief in Queer's power is rooted in its history of weaponization by those who are homophobic and its reclamation by non-heterosexual and gender-nonconforming individuals. This paper will argue that Queer is not revolutionary because it fails to acknowledge the intersections of race and sexuality. This argument will be supported through references Michèle Pearson Clarke's articulation of the Black queer experience. Queer makes the complex experiences of Black queer people invisible, resulting in Queer's complete loss of liberatory power.

How Queer Makes Black Queer Experiences Invisible

Queerness as a Monolithic Experience

In her essay "Queer and Now," Eva Sedgwick (1994) explains that Queer refers to the countless ways in which a person's gender and sexuality cannot be made monolithic. Queerness is intended to represent all who do not conform to heteronormative ideals of gender and sexuality. Therefore, Queer is inherently vague and undefined. The term is disseminated so vastly that it loses any notion of representation for specific subgroups of the queer community.

In its attempt to represent identities that cannot be made monolithic, Queer makes the queer experience monolithic. It attempts to extend itself to discourses of race and ethnicity without acknowledging how those identities influence the queer experience (Sedgwick, 1994). In doing so, it makes invisible the unique experiences of racialized queer people and becomes counter-

productive to its goal. To better conceptualize this, consider the following scenario:

> A social justice advocate (Person A) dedicates their time to ten different organizations. Their time with each organization is limited, so they cannot establish meaningful relationships with the individuals in the organizations. Their impact on each organization is minimal. Another social justice advocate (Person B) appreciates all social justice organizations but decides to dedicate their time to one organization. They create connections with everyone in the organization and help run events. Their work is appreciated, and their impact on the community is visible.

Through their attempts to help several organizations, Person A cannot meaningfully help any of the organizations. They spread themselves out so much that presence within each organization is unnoticeable. Person B, on the other hand, identifies one cause to commit to. They can create meaningful relationships and change within the lives of those they are helping.

Queer loses its ability to represent anyone by attempting to represent everyone. It becomes especially harmful to racialized people, specifically Black people, who must contend with historic experiences of erasure within the queer community.

The Intersections of Blackness and Queerness

In her essay "Parade of Champions: The Failure of Black Queer Grief," Michèle Pearson Clarke articulates her own experience with invisibilization in the Queer community as a Black queer woman. In 2011, Clarke (2017a) lost her mother to pancreatic cancer. Her death meant an immense loss for Clarke, and she was consumed by grief. Clarke was left feeling vulnerable to racism and homophobia that her mother had protected her from her whole life (Clarke, 2017a). Being a Black queer woman, Clarke has faced unique experiences that have made her both hypervisible and invisible within society.

Clarke's personal experiences of loss inspired her project *Parade of Champions* in which she interviewed Black queer people

experiencing grief. The intersections of their racial and sexual identities created unique experiences of grief for each of them that mainstream medias fail to represent. Clarke explains that "as black queers, we exist in a space of irresolution: too queer for blackness and too black for queerness. In failing to meet the normative ideals of either, our black queer lives are most often ignored within the visual and discursive spheres of both blackness and queerness" (Clarke, 2017a, p. 94). Queerness and Blackness intersect to create experiences of displacement from communities and failure in conformity. The intersections of these identities are complex, and they cannot be watered down to one-word articulations of experience.

During a lecture, Clarke explained that she cares more about the processes and relationships built during her projects than their concluding results (Clarke, 2021). Community building, creating relationships, and finding solidarity among Black queer people are most important. This is because these projects give visibility and voice to her experiences as a Black queer woman. She felt understood and acknowledged when she found similarly identified people experiencing a trauma such as her own. She created her own visibility. For Clarke, the term 'Queer' is not representative of her experiences nor is it revolutionary. Her own projects and explorations are.

Liberation cannot be achieved for marginalized communities when the terms used as tools do not represent intersectional and marginalized experiences. Queer attempts to equate a white gay man's experience with sexuality to Clarke's experiences with queerness, Blackness, and womanhood. These two experiences are not the same, and Queer leaves no room for expression and identity beyond sexuality. It works to erase the intricacies within Black queer experiences.

Black Erasure within the Visual World

Clark (2017b) explains how the Black experience is manipulated and constructed within visual mediums, such as photography. Photography has been used to reinforce values of white superiority while degrading Black people, telling a story of deviance and criminality. Photography is a tool of colonialism, intended to oppress all others (Clarke, 2017b). For this reason, Black experiences

cannot be accurately portrayed through photography.

As an artist, Clarke combats this inherent nature of photography by bringing representation to queer Black people. She photographs herself to allow others to stare at her body for as long as they need while diverting their direct gaze. Her photos give representation to the Black queer body and the ways it is visualized.

During her lecture, Clarke explained how her androgyny often puts her in a vulnerable position (Clarke, 2021). People mistake her for a Black man, and their racial prejudices become a risk to her safety. This experience contradicts the notion that queer people are generally very visible within society. Queer visibility is highly dependent upon one's other intersecting identities. For Clarke, her queerness is made invisible when others identify her as a man. Her identity as a Black person is more visible than her identity as a queer woman, and this can create dangerous situations for her in ways that it would not for a white queer person. For example, if Clarke is pulled over by police while driving, the police will likely assume she is a Black man before they assume she is a queer woman. Clarke's Blackness is more visible than her queerness, and her experience as a queer person in the world are made complicated by this truth.

Understanding how Blackness and queerness intersect is vital in understanding how a Black queer person experiences the world. The term Queer posits sexual identity before racial identity, and this fails to represent the experiences of many racialized queer people. Queer cannot possibly embody the complex and intricate experiences that Black queer people encounter in the world. The term fails to recognize how race can be more visible than queerness, and the history of Black demonization through visual mediums influences interactions between Black people and non-Black people.

Lack of Race in Queer Studies

José Esteban Muñoz (1999) furthers this discussion of race and sexuality by explaining that queer and race studies have historically been treated separately from one another. This results in queer studies assuming whiteness in discussions matters of sexual and queer experiences. Stories of Black queer people are discussed so infrequently that many people believe that “the queer is a white

thing" (Muñoz, 1999, p. 9).

In his article, Muñoz (1999) includes a section from a book written by Marlon Riggs, a Black gay man. Riggs discusses his experiences in California after coming out and explains that he "pretended not to notice the absence of black images in this new gay life…[that] the few images of black that were most popular: joke, fetish, cartoon caricature" (Riggs, 1989 as cited in Muñoz, 1999, p. 9). Riggs expresses how invisible he felt as a Black man in the gay community. Visual mediums of photography and film treated Black gay men in disdainful ways, making their experiences invisible.

Clarke (2017b) articulates this observation of Black representation within photography, and she uses her own work to combat it. Even a subtle inclusion of racialized queer people within queer studies and media cannot make that discourse progressive (Muñoz, 1999). Queer cannot capture the experiences and lived truths of Black queer people. The history of queer studies and the treatment of Black queer people in media demonstrates how the queer community has repeatedly rejected Black and other racialized queer individuals. Evidently, Queer cannot liberate those it has oppressed.

Conclusion

The term Queer is overly vague, and it attempts to represent an entire community of differently identifying queer people. Its attempts to recognize all of its members led to the erasure of Black people from queer narratives. Blackness and queerness intersect in unique ways such that Blackness is often more visible than queerness within Black queer individuals. Historic visualization of a queer subject has been whitewashed within mainstream media, and Black queer people have historically been erased from queer archives. Consequently, Queer fails to capture the lived realities of Black queer individuals. Therefore, it cannot be revolutionary.

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Realities of Resistance and the Haitian Revolution

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In writing *The Infamous Rosalie*, Évelyne Trouillot managed to craft a fictive historical narrative on the subject of enslavement whose pages are lined not only with the violence and inhumanity that one might expect to encounter in a novel set in colonial Saint-Domingue but also with equally evocative expressions of resistance, both subtle and overt. Through the eyes of a young Black Creole woman named Lisette, Trouillot depicts various acts of subversion directed towards the institutions of slavery and its perpetrators that only grow more pronounced as the story progresses. Following the flight of her maroon lover Vincent, Lisette's friend and mentor Michaud offers her solace by remarking that the desire for freedom persists in the hearts of the enslaved much like fog ceaselessly permeates the natural world.[1] Trouillot's poetic portrayal of marronage as a form of resistance to enslavement manifests itself most vividly in the novel's conclusion. Having recognized that she is, "nothing but an object at the mercy of whites," Lisette ultimately seeks to emancipate herself by pursuing marronage, resolving to liberate her unborn child from the prospect of enslavement in doing so.[2] While Lisette will only ever exist in the minds of those of us who have interacted with *The Infamous Rosalie*, the spirit of resistance that characterizes her journey from maid to maroon—from a state of physical and mental enslavement to one of both spiritual and corporeal freedom—manifests itself with comparable force throughout the histories of colonial Saint-Domingue and revolutionary Haiti.

The Haitian Revolution of 1791-1804 is remarkable both in its significance as a monumental manifestation of resistance to enslavement and in its lasting legacy as an event beyond belief. In the French colony of Saint-Domingue, the enslaved acted to undermine the authority of their supposed masters for decades before carrying a revolution so revolutionary as to outshine their

1. Évelyne Trouillot, *The Infamous Rosalie*, trans. M.A. Salvodon (Lincoln and London: Nebraska University Press, 2013), 91.
2. Trouillot, *The Infamous Rosalie*, 112, 126-29.

Caucasian contemporaries overseas and leave countless perpetrators of Atlantic World colonialism either dead or dumbfounded. Haitian historian Michel-Rolph Trouillot went to great lengths to emphasize the inconceivable nature of the revolution and the manifold reactions of disbelief to its permanent successes, stating that, "The Haitian Revolution thus entered history with the peculiar characteristic of being unthinkable even as it happened."[3] Notwithstanding the widespread sense of disbelief that accompanied and followed its successes, the armed revolt that spread throughout the Caribbean colony had countless antecedents. From the inescapable threat of poisoning to the persistent prevalence of marronage, encounters with resistance were part and parcel of the colonial experience long before the rise of Haiti. It follows that this paper will seek to counterbalance if not outweigh the dominating views about the lack of agency of the enslaved held by white planters, colonial authorities, and metropolitan intellectuals alike with the undercurrents and overt acts of resistance that shaped eighteenth-century Saint-Domingue and would ultimately culminate in a successful revolution effected by the formerly enslaved.

Juxtaposing the enduring resistance against enslavement visible throughout the histories of colonial Saint-Domingue and revolutionary Haiti with the reactions of disbelief and denial to said resistance requires an investigation of the pro-colonial mentality exemplified by the writings of exiled colonist Médéric Louis Élie Moreau de Saint-Méry. Published in Philadelphia as the Haitian Revolution violently asserted its presence in the Atlantic World, de Saint-Méry's dual descriptions of the colonies of French Saint-Domingue and Spanish Santo Domingo serve as a testament to the disbelief and reactionary revisionism that dominated pro-colonial discourse in the years surrounding the revolution.[4] The opening

3. Michel-Rolph Trouillot, "An Unthinkable History: the Haitian Revolution as a Non-event," in *Silencing the Past: Power and the Production of History* (Boston: Beacon Press, 2015), 73.

4. M.L.E. Moreau de Saint-Méry, *Description topographique et politique de la partie espagnole de l'isle Saint-Domingue* [. . .] (Philadelphia, 1796); M.L.E. Moreau de Saint-Méry, *Description topographique et politique de la partie française de l'isle Saint-Domingue* [. . .] (Philadelphia, 1796).

passages of both works call forth a striking sense of colonial nostalgia that appears to be representative of the author's inability to come to terms with the subversive realities of the historical moment in which he lived. Perhaps the most telling sign of his longing to return to an elusive colonial past lies in the tone that de Saint-Méry adopted whilst describing the crown jewel of the French Empire, repeatedly alluding to the notion that its glory was in the midst of receding into the annals of the Atlantic World; he spoke of Saint-Domingue as the most brilliant colony of the Antilles, a prized French possession whose "past splendour" inspired a reasonable sentiment of envy among the so-called Great Powers of the early modern era.[5] Upon examining historical manifestations of slave resistance witnessed throughout the colonial period, it soon becomes apparent that Moreau's words ran counter to reality—and somewhat ironically to his own lived experience.

In "Spectres of Saint-Domingue," historian Laurent Dubois argues that Moreau de Saint-Méry treaded a path characteristic of the colonial-in-exile, endeavouring to return to the familiarity of the colonial world in the process of illuminating its storied past.[6] In opening the first volume of his duology on Saint-Domingue, Moreau claimed that it would be "bizarre to abandon an authentic and interesting model" of the island's history in favour of struggling to capture the ever-changing essence of its present condition.[7] He likened such a pursuit to that of an artist commissioned to paint a portrait who, upon its completion, resolved not to present the work without first tampering with the original, marring the image of the refined individual whom it sought to portray by covering up their beautiful features with those of a person affected by a "convulsive malady."[8] De Saint-Méry's own experience in Saint-Domingue,

5. My translation, adapted from the French; de Saint-Méry, *La partie française de l'isle Saint-Domingue,* iii-iv.
6. Laurent Dubois, "Specters of Saint-Domingue," in *Avengers of the New World: The Story of the Haitian Revolution* (London and Cambridge, Mass.: Harvard University Press, 2005), 11.
7. My translation, adapted from the French; de Saint-Méry, *La partie espagnole de l'isle Saint-Domingue*, 1.
8. *La partie espagnole de l'isle Saint-Domingue*, 1.

however, seems to confirm that the colony was beset with such a malady long before the eve of the revolution. Referencing the writer's description of a cemetery situated beside a lovely fountain marking the entrance to a town in the French colony, Dubois remarks that de Saint-Méry was well aware that "The dead were inescapable in Saint-Domingue."[9] Needless to say, the enslaved populace of the treasured Caribbean colony were afforded neither security nor prosperity. And yet, in the face of unending depravity, the enslaved masses did not simply concede defeat.

A turn towards the underside of colonial Saint-Domingue reveals not resignation among the enslaved when denied their humanity by the institutions of slavery but instead a collective determination to undermine and uproot those very institutions. The eighteenth century saw opposition to enslavement through marronage develop in tandem with the intensification of colonial exploitation in Saint-Domingue.[10] Linking the rising success of marronage in the colony to the outbreak of the Haitian Revolution, Crystal Nicole Eddins stresses that the pursuit of marronage and its growing viability in Saint-Domingue were informed and facilitated by the development of networks of resistance.[11] Speaking of the "collective revolutionary potential" of enslaved people and maroon communities, Eddins asserts that the establishment of resistance networks working both within and beyond the direct reach of colonial institutions signalled the initiation of the process of mobilization that led to revolution in

9. Dubois describes Saint-Domingue as a graveyard for three populations: the indigenous peoples slaughtered by the Spanish, the colonizers whose settlements were periodically beset with flu epidemics, and the countless enslaved people tortured and exploited in pursuit of profit and domination (see Dubois, "Specters of Saint-Domingue," 11). Dubois, "Specters of Saint-Domingue," 13.

10. Crystal Nicole Eddins, "Runaways, Repertoires, and Repression: Marronnage and the Haitian Revolution, 1766–1791," *Journal of Haitian Studies* 25, no. 1 (spring 2019): 8.

11. Eddins suggests that marronage was part of the "*contentious repertoire of action*" of the enslaved population; that is to say, oppressed communities developed forms of opposition to enslavement such as marronage that endured and evolved over time, inspiring future acts of resistance guided by a collective consciousness of resistance (see Eddins, "Runaways, Repertoires, and Repression," 10). Eddins, "Runaways, Repertoires, and Repression," 6.

1791.[12] In examining the history of colonial Saint-Domingue, the prevalence of marronage emerges not only as incontrovertible proof of resistance to enslavement but also as an indicator of the subversive spirit that would ultimately uproot the ideological and institutional structures of slavery in revolutionary Haiti.

Given the existential threat that opposition to enslavement posed to the Atlantic system, resistance was recognized in practice regardless of its dismissal in colonial discourse. Those on the ground who managed and controlled the plantations of Saint-Domingue found it impossible to ignore the prospect of subversion at the hands of the enslaved; time and again, planters and managers contradicted the theoretical denial of resistance that dominated contemporary discourse on the agency of the enslaved by taking a number of steps to suppress its manifestations in the real world.[13] As Michel-Rolph Trouillot noted, colonists clung to ludicrous notions of loyalty and contentment among the enslaved not because they believed that such rationalizations were reasonable but rather because trivializing the realities of resistance was the only way to address the unthinkable in a manner that would not call into question the normalized framework of colonial domination.[14] The rise of Mackandal as a symbol of the fear of slave resistance through poisoning that pervaded colonial Saint-Domingue accentuates this fundamental contradiction.

The mid-eighteenth-century poisoning conspiracy surrounding the maroon Mackandal provoked a severe response from those in positions of power in colonial Saint-Domingue that exemplifies the extent to which the fear of retribution plaguing the white planters ran counter to colonial discourses that sought to strip the enslaved of their agency. From May 1757 to January 1758, the white colonists of Saint-Domingue were beset with hysteria,

12. Eddins notes that many of the Creole *commandeurs* who would lead the African-born *bossale* population in open revolt from 1791 to 1804 also organized rebellions carried out by enslaved people alongside maroons in the years leading up to the revolution, emphasizing the connection between maroon and enslaved labourer (see Eddins, "Runaways, Repertoires, and Repression," 27). Eddins, "Runaways, Repertoires, and Repression," 27.
13. Trouillot, "An Unthinkable History," 83.
14. Trouillot, "An Unthinkable History," 84.

convinced that malicious elements within the enslaved population had set in motion a scheme to eradicate them using mystical poisons; a crippling sense of peril prompted the colonists to convict and execute several supposed poisoners, pursuing a frantic nine-month campaign of repression and torture until Mackandal, the suspected leader of the conspiracy, was captured and burned at the stake on January 20, 1758.[15] Trevor Burnard and John Garrigus argue that the real cause of the untimely deaths of countless enslaved labourers and several white colonists during the years surrounding the conspiracy was likely the consumption of spoiled grain products smuggled into the North Province in an attempt to stave off famine in the French colony during the Seven Years' War.[16] In the eyes of the white colonists, however, Mackandal's apparent spiritual powers—evidenced by the charms that he had crafted using a blend of West Central African religious symbology and Christian iconography—posed an irrefutable threat to their survival.[17] In light of the likelihood that the conspiracy itself was not nearly as wide-reaching as the colonists of Saint-Domingue came to believe, the Mackandal case serves not only to contradict the discourses of pro-colonial contemporaries who judged the enslaved to be infallibly faithful 'servants' but also to highlight yet another way in which the enslaved reasserted their agency in the face of oppression.

While white planters dealt firsthand with the realities of resistance in eighteenth-century Saint-Domingue, the sense of dislocation between colony and metropole meant that even the most 'progressive' thinkers of the Enlightenment could conceive of large-

15. Moreau de Saint-Méry himself seems to have shared the colonists' fear of Mackandal (see Burnard and Garrigus, *The Plantation Machine,* 105). Trevor Burnard and John Garrigus, *The Plantation Machine: Atlantic Capitalism in French Saint-Domingue and British Jamaica* (Philadelphia: University of Pennsylvania Press, 2016), 103-05.

16. Burnard and Garrigus note that the death toll among the enslaved population continued to rise until December 1759, nearly two years after Mackandal was burned at the stake, by which time the North Province was once again able to trade with the North American merchants who supplied the colony with smuggled flour (see Burnard and Garrigus, *The Plantation Machine*, 119). Burnard and Garrigus, *The Plantation Machine,* 103, 105, 112-13, 119.

17. Burnard and Garrigus, *The Plantation Machine*, 108-11.

scale slave resistance only as a vague and distant threat to the colonial project. Michel-Rolph Trouillot identified French philosopher Denis Diderot as one such intellectual. Trouillot argued that Diderot's vocal distaste for colonial exploitation and the institutions of slavery was inevitably tied to an ulterior motive, namely the philosopher's desire to undertake "a project of colonial management."[18] Historian Yves Bénot remarked that Diderot seemed to formulate a number of "humanitarian maxims" in a 1781 piece on French colonial policy such as "take care of the indigenous" after adopting an entirely different tone in opening his work.[19] The French philosopher introduced the topic at hand by making a series of scathing remarks about the "injust, cruel, and inflexible tyrants" who he argued would rather perpetuate colonial oppression than attempt to befriend colonized peoples.[20] As Trouillot rightfully concluded, the ultimate aim of highlighting the moral muddiness of Enlightenment thought is not to insinuate that thinkers such as Diderot should have been more progressive in their thinking but rather to emphasize that they were incapable of imagining true human equality; it follows that according to the principles of contemporary Western discourse, the prospect of a revolution led by the enslaved transpiring in colonial Saint-Domingue, much less succeeding, was inconceivable.[21] The influence of the fabrication and entrenchment of the Enlightenment era notion of "Man (with a capital M)" appears to have been so pervasive that even those who recognized the depravity of the institutions of slavery could not truly conceive of the enslaved as their equals.[22]

The revolution would begin regardless. In its formative years, most of the narrators of the Haitian Revolution were white colonists,

18. Trouillot, "An Unthinkable History," 81.
19. My translation, adapted from the French; Yves Bénot, *Diderot: de l'athéisme à l'anticolonialisme* (Paris: F. Maspero, 1970), 187.
20. Diderot also suggested that resistance to a "'distant revolution'" would be futile given that such a revolution would unfold regardless of the aforementioned tyrants' efforts to maintain control over the colonial world (see Bénot, *Diderot*, 187). Bénot, Diderot, 187.
21. Trouillot, "An Unthinkable History," 82.
22. Trouillot tells us that at the turn of the 1800s, the dominant strains of Western thought universally concurred that "Man (with a capital M) was primarily European and male" (see Trouillot, "An Unthinkable History," 76).

and as such they sought to produce narratives stressing the unyielding loyalty—and at times affection—expressed by certain enslaved people who chose to stand by their masters in lieu of joining the rebellion.[23] Jeremy D. Popkin suggests, however, that the decision to remain in the company of white planters was a calculated choice made by a number of enslaved people before the revolution escalated into a monumental struggle for emancipation; cognizant of the inhumane retribution that would likely await them in the event that the rebellion were to be suppressed and wary of the food insecurity that appeared to plague the rebels, some enslaved people deferred their decision to rebel until the prospects of the revolution became more promising.[24] Those who did not rebel immediately therefore appear to have been exercising the same kind of agency and intelligence that the pro-colonial planters sought so desperately to refute in producing narratives emphasizing enslaved subservience.

Even after the enslaved masses of Saint-Domingue began to mobilize in a mass demonstration of resistance that would leave the Atlantic World in a perpetual state of disbelief, white colonists attempted to reassert their most ludicrous claims about the lack of agency of the enslaved. In *The Black Jacobins*, Trinidadian historian C.L.R. James' seminal work on the Haitian Revolution, James cited a speech given at the Legislative Assembly in Paris on behalf of the Colonial Assembly of Saint-Domingue on November 30, 1791, as a striking example of such a claim.[25] Having finished delivering a fantastical account of Atlantic World slavery to the metropolitan revolutionaries of the Legislative Assembly, the white colonists' delegate could not help but utter the following: "These coarse men [the blacks] are incapable of knowing liberty and enjoying it with wisdom, and the imprudent law which would destroy their prejudices

23. Jeremy D. Popkin, "Masters and Their Slaves during the Insurrection," in *Facing Racial Revolution: Eyewitness Accounts of the Haitian Insurrection* (Chicago and London: University of Chicago Press, 2007), 174.
24. Popkin, "Masters and Their Slaves," 176.
25. C.L.R. James, *The Black Jacobins: Toussaint Louverture and the San Domingo Revolution*. Second Edition, Revised (New York: Vintage Books, 1963), 112-14.

would be for them and for us a decree of death."[26] Of course, this remarkably inflammatory statement about the dangers of emancipation for planters and enslaved people alike would have no bearing on the success of the Haitian Revolution, which concluded triumphantly on January 1, 1804, with the proclamation of the independent Black Empire of Haiti. But it is quite revealing. Clinging to their arguments about the impossibility of slave resistance until the bitter end, the white planters of Saint-Domingue were ultimately forced to flee the island lest they be killed as the free Haitian populace made it clear that they were capable of far more than blind servitude.

The histories of colonial Saint-Domingue and revolutionary Haiti thus collectively emerge as a testament to the spirit of resistance wielded by the enslaved that no amount of colonial depravity could ever hope to suppress. In light of the manifold manifestations of coloniality that continue to create deep rifts within modern society, the relevance of narratives that shed light on the countless atrocities that shaped the Atlantic World seems undeniable in the current moment. Nonetheless, it is also worthwhile to explore the many ways in which the enslaved consciously subverted the very systems that sought to deny their humanity at all costs. Coming to terms with historical realities of resistance allows us to appreciate the gravity of the past in a manner that is conducive to hope rather than despair. In the face of the overwhelming weight of colonial history, academic Saidiya Hartman emphasizes the value of "counter-histories of slavery," narratives that abandon the constraints of contemporary historiography and seek to break the oppressive silences of the archive, offering us a more human image of the enslaved.[27] As Michel-Rolph Trouillot asserted, "We all need histories that no history book can tell, but they are not in the classroom—not the history classrooms, anyway. They are in the lessons we learn at home, in poetry and childhood games, in what is left of history when we close

26. The delegate, a man by the name of Millet, declared that until recent events brought chaos to the idyllic colony of Saint-Domingue, "The most sincere attachment bound the master to the slave; we slept in safety in the middle of these men who had become our children and many among us had neither locks nor bolts on our doors" (see James, *The Black Jacobins*, 113). James, *The Black Jacobins*, 114.
27. Saidiya Hartman, "Venus in Two Acts," *Small Axe* 12, no. 2 (June 2008): 4.

the history books with their verifiable facts."[28] We all need these counter-histories, and Lisette's perilous yet hopeful march towards freedom in *The Infamous Rosalie* seems to be one of them.

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28. Trouillot, "An Unthinkable History," 71-72.

What's Really in the Water
There's Something in the Water Film Analysis

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Introduction

There's Something in the Water, a documentary directed by Elliot Page and Ian Daniel, addresses environmental racism, injustices, and their impacts on Canadian—specifically Nova Scotian, waters as well as Indigenous and Black communities. The documentary builds on Ingrid Waldron's novel, *There's Something in the Water: Environmental Racism in Indigenous & Black Communities* and aligns many of the theories in the book, such as the ongoing effects of environmental racism, to practice by visiting and interviewing the actual communities and families affected. The documentary creates its own space for stories, experiences, and worldviews of marginalized Indigenous and Black communities to be heard in environmental and social justice conversations. By doing so, the film rejects the notion that "their challenges will never be written in environmental policies" (Page & Daniel, 2019).

In this film analysis, I summarize and highlight both the contents of what is literally in Nova Scotian waters, such as bacteria and toxins, as well as what is thematically in Nova Scotian waters, such as inequality, intergenerational trauma, and ongoing Western colonialism. Then, I examine the important role of environmental relations in each community, from taking care of neighbours, seeking truthful relationships, to being responsible for, but not righteous to, the gift of water. By doing so, I draw on how settler colonialism and environmental racism undermine such relations and worldviews, working to sustain Canada as a corporation, instead of sustaining the gifts of Mother Earth. It is through analyzing these layers of the documentary that allows one to see what is *really* in the water—not just bacteria, toxic waste, and dead fish, but ongoing settler colonialism and environmental racism in a country that holds its breath underwater and hides behind the façade of 'truth and reconciliation.'

What's in the Water – The Literal and Thematic Spills of Settler Colonialism and Environmental Racism

Shelburne, Nova Scotia

To begin, the first place that Page and Daniel visit is the town of Shelburne, a predominantly Black community in Nova Scotia. Resident and activist Louise Delisle reveals how the town remains largely affected, and haunted, by a dump that was placed there in the 1940s and closed in December of 2016 (2019). Although the dump has been closed, there is still great concern about "what's still in the ground," (Page & Daniel, 2019) that is affecting the water and soil. As a small town that depends on residential wells for clean water, well tests have come back with dangerously high levels of E.coli bacteria and coliform which are associated with illnesses and diseases like multiple myeloma (Page & Daniel, 2019). The film then follows Delisle on a drive around Shelburne, where she points out that almost every home has either lost someone to cancer or has someone who is currently battling it. Here, it becomes clear that it is not only bacteria that is in the water, but also illnesses, traumas, and losses.

Adding to that list are racial inequality and injustices. Delisle notes that predominantly white neighbouring towns and the mayor of Shelburne are unconcerned about Shelburne's lack of access to clean water because they themselves have water towers, and therefore, are not faced with the same health risks (Page & Daniel, 2019). When being asked for better water resources in 2017, Shelburne Councillor told a Black resident to "Stop playing the racism card," (Page & Daniel, 2019). This 'racism card', however, is difficult to be dismissed when the town refuses to invest in a community well that would cost approximately $10,000, but is willing to invest $35,000 for the town's annual Founder's Day festival. Aside from heavy funding on a colonial celebration, this decision, more importantly, highlights government and decision-maker priorities. The question Delisle raises—"why are we less in this community than people in that community?" (Page & Daniel, 2019)—proposes that environmental racism, whether it is the planned-placing of the dump in the past or the lack of clean water and accountability in the present, is one of the blockades to upholding the human right to have access to clean water. What's in Shelburne's water?: dangerously high levels of bacteria,

generational and community-wide illnesses, and racial inequality.

A'Se'K, Nova Scotia

Next, the site of A'Se'K (known in the mainstream as Boat Harbour) in Pictou County, Nova Scotia, a predominately Pictou Landing First Nation community, deals with water contamination from the Scott Paper Company mill placed in 1965 and its destructive leak later in 2014 (Page & Daniel, 2019). Ingrid Waldron's *Re-thinking Waste: Mapping Racial Geographies of Violence on the Colonial Landscape* reveals that since the 1960s the mill has been dumping about 25 million gallons of toxic wastewater per day into A'Se'K waters, a "toxic cocktail of zinc, cadmium, mercury, dioxins, furans, and hydrocarbons," (Waldron, 2018). The mill's dumping releases toxins quickly, and in turn, destroys ecosystems quickly. Older members of Pictou Landing First Nation recall that within a week after the plant start-up, copious amounts of fish died and washed up on shores: "they killed them right away, overnight," (Page & Daniel, 2019) highlighting the expedited damages of toxic wastewater on the fish, and the overall ecosystem of the lake.

The documentary goes on to meet with Michelle Francis-Denny, Mi'kmaq, the granddaughter of the late-Chief of Pictou Landing who signed the agreement to the Scott Paper Company. Francis-Denny vulnerably tells the story of how Scott Paper deceived her grandfather to sign; they brought him to the water plant for domestic sewage instead of the actual mill to show him there was "no discolour or odour," (Page & Daniel, 2019) and no environmental concerns. By doing so, they received his signature of agreement. However, Francis-Denny's truth reveals the history of manipulation and deceit employed by corporations like Scott Paper, tactics that have existed since first contact and perpetuates ongoing Western colonialism. On relations, she links this manipulative piece of history to her family trauma. The way in which her grandfather possessed the guilt of signing A'Se'K away and "died thinking it was his fault," (Page & Daniel, 2019) became the root of their family trauma, intimately poisoning minds, emotions, and relationships alike. Like water, trauma has the ability to flow into new bodies, and new generations. As a longstanding historical issue in Canada, much

of the intergenerational trauma Indigenous peoples face stem from cultural genocide, closely associated with residential schools and land dispossession, the latter exemplified in A'Se'K. It is this trauma that drives present-day colonialism and puts power in settler erasure (Simpson, 2017). What's in A'Se'K water?: a toxic cocktail, a history of manipulation and deceit, and ongoing cycles of intergenerational traumas that contribute to Western settler colonialism.

Stewiacke, Nova Scotia

The last place visited in *There's Something in the Water* is Stewiacke, where another predominately Mi'kmaq community fights to oppose the Alton Gas pipeline proposal. The extensive project, estimated to last 50 years, is to flush out large salt beds to hold gas and dump the hard salt and brine into the freshwater of Shubenacadie River (Tress, 2017). Putting this into perspective, this 'flushing' is equivalent to dumping 3,000 tons of hard salt into the Shubenacadie river daily, over a course of approximately 50 years (Stop Alton Gas). Taking into account that Shubenacadie River is naturally a freshwater ecosystem, this plan would damage the river by introducing an overwhelming amount of high salt content that would worsen the deteriorating situation of the already-endangered Atlantic salmon and breeding grounds for the native striped bass (Woodford, 2020). This would disturb and disrupt food sources for the other species in the water, the community, local businesses, and not to mention, the traditional practices with fish the Mi'kmaq have a right to exercise on their traditional, *unceded*, land.

Digging deeper, the film showcases how the Canadian government, on municipal, provincial, and federal levels, actively chooses to dismiss the concerns and protests of the Mi'kmaq, and especially the Grassroot Grandmothers: a group of traditional, Indigenous, women-led water protectors (Page & Daniel, 2019). Since contact, Western heteronormativity has been a way for Canada to displace the power of Indigenous women, those who are Two Spirit, and their crucial roles in environmental relations, in order to colonize land and distribute power on Western terms—or in other words, to men (Simpson, 2017). Born as a colonial tactic, its effects are ongoing and contributes to larger issues like the human rights crisis

of Missing and Murdered Indigenous Women and Girls in Canada (Simpson, 2017). By the Grassroots Grandmothers gaining solidarity with women in community and seeking environmental justice on their own terms, they have begun to reclaim the knowledges and agency that have been taken away from them. As one of the Grandmothers states, "[we see the] river as a superhighway of our nation," (Page & Daniel, 2019) highlighting the importance of understanding how sacred water is to the land, ecology, aquatic wildlife, and humans—and how we must interact with it in a responsible, conscious manner. What will be in the Shubenacadie water unless the Alton Gas plan is rejected?: the destruction of a natural, freshwater ecosystem and the perpetuation of Western colonial heteronormativity in critical environmental conversations.

The Flow of Environmental Relations and Worldviews

Understanding what is 'in the water' of three Nova Scotian communities comes with the environmental relations and worldviews that are specific to each place, nation, and community. Environmental relations involve the relationship *and* kinship between humans, animals, and the land on which they reside on, and worldviews include the concepts and knowledges—often generational and passed-down in Indigenous Knowledge Systems (IKS)—that frames how one sees the world. Environmental relations and worldviews are especially important in aligning how one thinks to what one does. It is this process of learning and unlearning, and putting theories within IKS into practice that center on effective and sustainable change.

Flowing back to Louise Delisle's activism and work in the town of Shelburne, one her last narrations in the documentary is, "If you can't take care of your neighbour, your people, or family, what good are you? What do you get up for everyday?" (Page & Daniel, 2019). There is a lot to unpack in these two questions, creating an opportunity for one to reflect on their relationship to other humans, and by extension, all living beings—including the land. Delisle later answers her own question 'who do you get up for everyday' with "Yourself? Must be awful lonesome," (Page & Daniel, 2019) and in this seemingly simple statement, invites one to dig even deeper and explore what it means to be selfish versus selfless, to take action

versus to stay inactive, in terms of environmental consciousness and work. By doing so, Delisle showcases the environmental relation of taking care of each other, and the worldview of doing things for more than oneself. Like a popular environmental saying goes, sustain what sustains you.

A'Se'K, translated to 'the other room,' is a name that I explicitly chose to use throughout this paper instead of Boat Harbour, because of its history in environmental relations and worldviews to the Pictou Landing First Nation community. As Michelle Francis-Denny retells, it was a place that community members ran to when the Canadian government would come to collect kids (Page & Daniel, 2019). A'Se'K was also the place where her community found shelter, felt protected, and was fed—in a way, A'Se'K became "like parents," (Page & Daniel, 2019). Relating this to environmental relations, the bond between the community and A'Se'K is close; the same way one takes care of their parents, the community takes care of A'Se'K. This close relationship also shapes the worldview of interacting and caring for the land like it is one's own kin. As Francis-Denny shares her story about losing most of her family and losing the "chance to live in a way where we could grow old together," (Page & Daniel, 2019), one may use this relationship and worldview to reclaim the ability to at least 'grow old' with A'Se'K as kin.

Revisiting Stewiacke, there are environmental relations and worldviews that are rooted in the Grassroots Grandmothers as water protectors. One of the main environmental relations covered in the documentary is how the Grandmothers conceptualize water, "we are given a gift, but also a responsibility," (Page & Daniel, 2019). This conceptualization is notable because it does not only focus on all the ways one may profit from water, but rather all the ways one may care for, and tend to, water as kin (Page & Daniel, 2019). The work of the Grandmothers also ties in closely with Deborah McGregor, Anishinaabe, 's work, *Traditional Knowledge and Water Governance, The Ethic of Responsibility*, in which she proposes that Traditional Knowledges of Indigenous peoples is crucial because it distinguishes and bridges the gap between "'rights-based' and 'responsibility-based' approaches to water governance," (McGregor, 2014). The distinctive view of water governance from Western and Indigenous

frameworks may be centered on profit and rights, versus care and responsibilities, respectively. It is important to acknowledge this distinction as it has the ability to change and re-imagine present-day environmental worldviews and practices. The presence and work of the Grassroots Grandmothers also sustain and recognize traditional Indigenous worldviews as they reject the notion of heteronormativity (Simpson, 2017) and reclaim the traditional power and roles of Indigenous women as waterkeepers.

Conclusion

One of the foundations of *There's Something in the Water* is Ingrid Waldron's idea that "Where you live has bearing on your well-being. Your postal code determines your health," (Page & Daniel, 2019). Thus, Elliot Page and Ian Daniel's documentary follows Waldron's findings that landfills and pipeline sites are not 'randomly' placed geographically, but rather strategically planned to be situated in Indigenous and Black communities, enforcing settler colonialism and environmental racism.

By looking closely at how places like Shelburne, A'Se'K, and Stewiacke have been, and continue to be, infected by the literal and thematic toxins infiltrating their communities, it is clear that healing is needed now more than ever—for humans and the waters alike. Water must be able to heal from histories of environmental traumas, just like how Indigenous and Black communities in Nova Scotia must be able to heal from emotional and intergenerational ones, in order to recover, to be well, and to flow, like before (McGregor, 2013). There is also importance drawn on those communities, and all communities, to join social and environmental justice conversations and fight for social and environmental justices, *together.* Within IKS, the social and the environmental have always worked hand in hand, and especially must do so now, in a better way, with climate change on the horizon.

Whether one is Indigenous or non-Indigenous, situated in Nova Scotia or wherever else, in the words of McGregor, "it is not enough just to know; one has to 'do something,' or 'act responsibly' in relation to the knowledge," (McGregor, 2014). With this knowledge now, one must amplify it, and work towards dismantling Canada as a

corporation (Page & Daniel, 2019) so it may revert back into a nation where real truth, resilience, solidarity, and responsibilities may take place.

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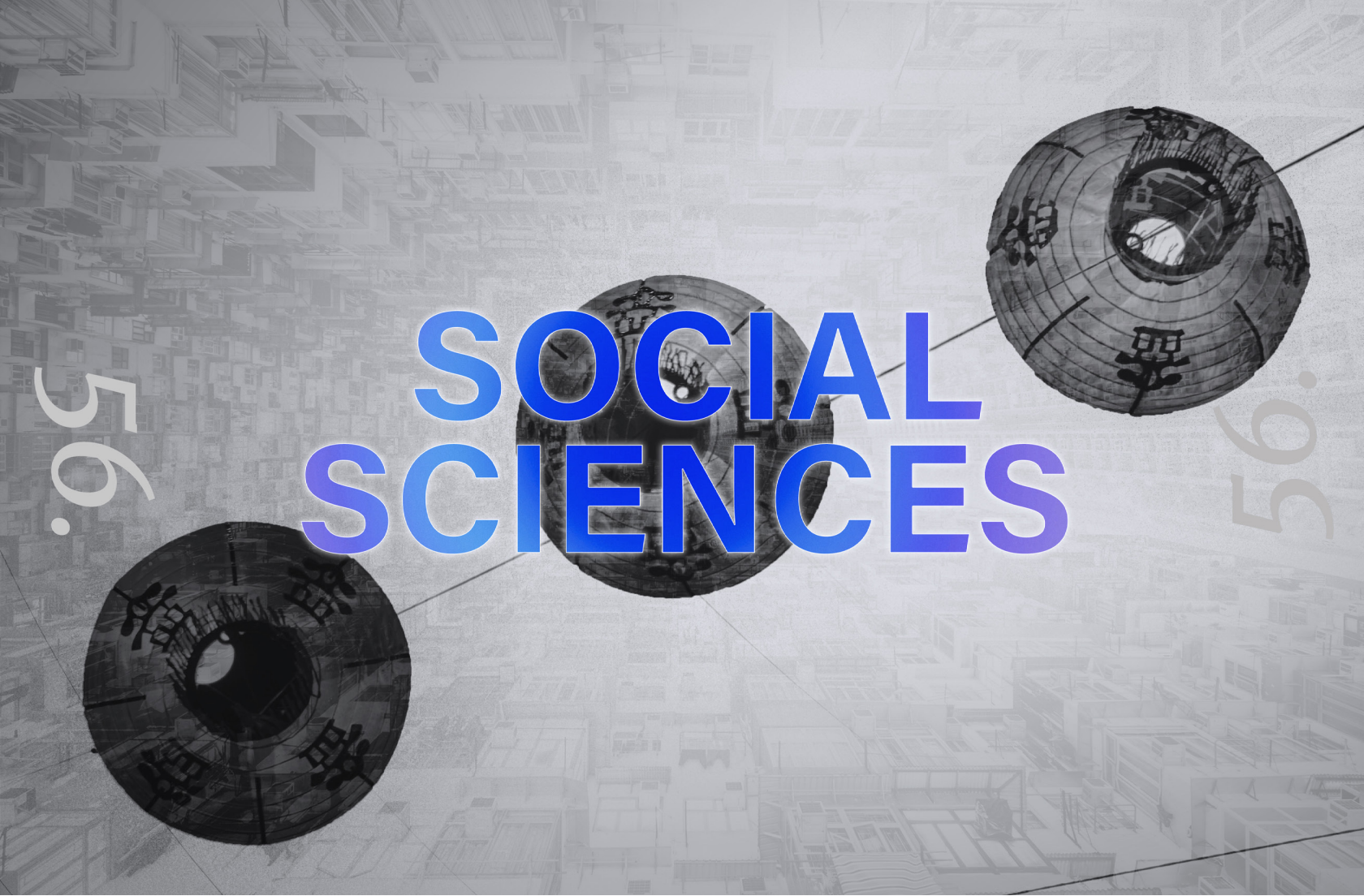
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No Two "Tigers" Have the Same Stripes: A Case Study of South Korea and Singapore

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When testing the validity of Dependency Theory in developmental politics, academics are often inclined to present the case of the "Four Asian Tigers". These Sovereigns are outliers—periphery countries that have developed and industrialized rapidly between the 1960s and 1990s to emerge at the forefront of world economies. Both South Korea and Singapore are "Asian Tigers", but when one examines their place in world economics, there are stark differences. The former has a strong manufacturing base, and the latter has transformed itself into a prominent financial center. Therefore, even if it is noted by scholars that the neoliberal framework was employed in all four "Asian Tigers", it is evident that there remains a variable outcome. One may be inclined to look for where in the process these nations diverged to get to their final result, but this paper argues that it is factors long before the rise of globalization that ultimately impacted the economic outcome and policies of these two "tigers". While South Korean development and policy is greatly influenced by their unique cultural history and war, Singaporean development is centered in colonialism, diversity, and land allocation. This paper is organized as follows: First will be the highlighting of neoliberalism, its prevalence, and its key characteristics that have been credited for exponential growth in the 1990s. Then, this paper will present the historical context of South Korea in order to specify what has affected its economic development. This context will then be applied to modern economic policies. The same process will be repeated for Singapore in order to showcase the stark differences in development and policy priority. This will be done to an end to highlight the importance of context and show that there is no single unifying equation that explains and promotes the development of every nation.

The globalization of neoliberalism can be largely attributed to the Regan and Thatcher administrations of the 1980s (Williamson, 1990). They achieved this through the mechanisms of the World Bank (WB) and the International Monetary Fund (IMF), which, though

supposedly objective, was largely sponsored by the United States and British governments (Williamson, 1990). Conditionalities were given to developing nations in need of a loan which stipulated the adoption of neoliberal policies that promoted free markets, free trade, a lack of government intervention, encouragement of entrepreneurial development, and the purchase of heavy machinery among a few other factors (Williamson, 1990). This venture yielded a variety of results—which, due to a relative rise in global GDP, was generally accepted as successful. Yet, Nobel laureate Joseph E. Stiglitz (2013) in his work *The Roaring Nineties: A New History of the World's Most Prosperous Decade* outlines the long-term economic impact that the adoption of these policies would have on developing economics. These reasons vary from the lack of government intervention during recessions to the myth of great executive leadership that spurred global economic development. However, the analysis of Stiglitz does little in explaining how the "Asian Tigers" maintained and came to prominence. In fact, his work suggests ill-effects on developing nations which make countries like South Korea and Singapore further outliers.

This paper posits history as the determinant of how these nations became outliers. Research suggests that the roots of South Korea's form of government and various economic policies can be traced back to the Joseon dynasty which placed importance on harmony and the collective—thus reinforcing subordination to the governmental authority (Yang & Torneo, 2015). Within the next hundred years came annexation from the Japanese during the second world war that subsequently led to a United States occupation of the South and a Communist-influenced regime in the North (Yang & Torneo, 2015). As the United States established a heavily centralized democracy in the South, elements of governmental dominance were combined and resulted in the crystallization of a military dictatorship (Shin & Stevens, 2013). This military dictatorship would finally be overthrown in 1987 and the current, formal modern democracy would be formed within the following decade (Shin & Stevens, 2013). Within this progression of events, one can see how modern-day policies around civil society and centralization came to fruition within the climate. These same sentiments extend far into their current

economic condition within the nation—concerning how they conduct themselves, how they evaluate performance, their socio-demographic changes, their welfare systems, and the potential plagues on their economy and how they react to it.

As noted by Yang and Torneo (2015), a large majority of society in South Korea still adheres to the Confucian-based concepts of harmony and collective and therefore, are very subservient to governmental authority. However, they would be remiss to ignore how much these notions have been diluted over time. Here, we see what Shin and Stevens (2013) have analyzed with regard to how Korea has developed economically through and around civil society. On one hand is the traditional willingness to adhere to government policy and on the other is the desire to move away from a past marred with military dictatorship—an imperfect compromise between adherence and prevention of potentially dangerous levels of centralization (Yang & Torneo, 2015). A great example of this can be seen in Gwangju, where a settlement greatly impacted by centralization and military rule underwent an economic and urban restoration in the 1990s in which civil society actors and bureaucrats attempted to work in tandem to economically develop the city (Shin & Stevens, 2013). They suggest that this is an empirical and great example of development of economy through culture due to the overall effectiveness of the initiative (Shin & Stevens, 2013). The power of civil society also extends to a vast network of initiatives in order to provide citizens with welfare, such as the National Basic Livelihood System, which serves to provide basic needs to qualified South Korean citizens (Bidet & Eum, 2011). This system is prudent considering their disproportionate number of low-skill workers and elderly working in what they refer to as "non-salary" jobs—part time or temporary (Bidet & Eum, 2011). This paper would go as far as to suggest that it is rampant globalization and the establishment of factories that have contributed to the high levels of low-skill workers. With companies like Samsung electronics, LG electronics, Hyundai motors, Kia motors, and Hynix semiconductors being such a large contributor to the economy, the bulk of the available jobs in South Korea would naturally be in factories (Cheng et al., 2005). As low-skill workers are statistically likely to be paid less, this would increase

the efficiency and success of the South Korean economy. To conclude, South Korea's bulk of economic and urban development stems from a combined traditionalism, a desire for government protection, and the capitalist-neoliberal framework bequeathed by the Americans—but with a decidedly Korean base of sensibilities (Yang & Torneo, 2015).

The history of Singapore, unlike South Korea, suffers from what one may aptly refer to as colonial erasure. Outside of acknowledging a small fishing establishment in what is now the city-state, historical context predating its usage as an English trading post is highly limited (Song, 2007). Eventually, as more traffic flowed through the trading port, Singapore developed into a bustling settlement attracting migrants throughout Asia due to a perceived opportunity for wealth. This resulted in a large influx of different demographics—ranging from the pre-existent Islamic population, an influx of Hindus, Chinese workers from the Fujian province, and various ethnic groups within the region of Malaya (Song, 2007). Again, due to the pro for colonial erasure, these changes in demographic were of little consequence to the English government at the time—but, going into the 20th century where the English began to lose their influence over colonial interests, it has been reported by primary sources that there was another large influx of Chinese immigrants (Song, 2007). Though it is not mentioned, the assumption can be made that this demographic is more affluent than the original migrants seeing as China was undergoing some civil unrest during the 1950s leading into the 60s. Finally, its existence as a colonial property essentially came to an end after its fall to Japan during the 2nd world war (something they had in common with the South Koreans) (Song, 2007). However, it was not until 1959 when they achieved true self-governance. By this point in time the Chinese elite had become so prominent that they began to write their own versions of Singaporean history, as noted by Song in his study of the historiography in the region. This would be indicative of the massive role the Chinese contingent, among other significant demographics, would play later in Singaporean development.

The colonial history of Singapore is what developed the large, demographic variance in the city-state. Among these people were followers of Islam, who are recognized as one of the longest

standing demographics in Singapore (Brown, 2008). Brown (2008) himself acknowledges that there is existing literature to suggest that Islamic law in the Middle East is a contributing factor to the lack of healthy capitalism in the region . However, Brown (2008) makes a supposition that it is the Islamic laws within Singapore, which were fervently fought for as the demographic was diluted, that make a conducive environment for finance and property. These laws are derived from the idea of *Waqf*—essentially traditional endowment and land allocation. These laws also made moneylending and remittances instruments in the financing of traders and developers that made up the initial economic base of Singapore (Brown, 2008). After achieving independence in 1959, Singapore was highly dependent on land allocation and housing (Phang, 2001). Governmental property and housing policies were specially designed to advance social and economic growth to the point where the government was able to purchase 80 percent of land on the peninsula within 4 decades at more than optimal prices (Phang, 2001). Naturally, having such a large share of the land allows maximum output of industry and economic activities for the government, propelling them into the top of the modern-day GDP per capita rankings worldwide (Istiak, 2020). Istiak also points out that the largest economic trade partners of Singapore are Hong Kong (another "Asian Tiger") and China (Istiak, 2020). This is where one can see the influence of the other significant demographic affecting development in Singapore: those referred to as the landed Chinese elite whose population rose during the 1940s when fleeing the communist transition in China (Koh, 2007). After having fled their homeland, these prominent individuals are those who invested in property and industry and dictate terms of trade—which explains the current emphasis on trade with Hong Kong and China through policy (Istiak, 2020). Unlike South Korea which was deeply rooted in uniformity, harmony, and tradition influenced by external powers, Singapore finds itself the product of diversity and savvy land allocation, possibly inspired by the Islamic traditions and laws pertaining to *Waqf*.

Neoliberal concepts and ideals have supplanted itself as the paradigm when pertaining to the nature of economics over the past 4 decades in no small part due to the combined efforts of the

English and Americans (Williamson, 1990). However, just as Stiglitz outlines in his work on the myths of the "roaring nineties" (2003), its globalization was actually generally ineffective for most nations. Thus, its overall popularity and viability as a blanket-policy in the development of economies is rather baffling. Through examining historical context, adopted policies, and current economic focuses, this paper has illustrated how context and decision-making result in adjustments to a non-universal blueprint. Just as England did in the beginning of development itself, Singapore and South Korea had pre-existing, conducive environments which allowed them to flourish in the way that they did. Even Hong Kong and Taiwan, not discussed in this paper, have unique histories tied to economic juggernauts atypical in the rest of the "undeveloped" world. This, in turn, would be a refutation against any idea of a single framework of development conceived and put forth. If no two "tigers" have the same stripes, then it is fair to say that concepts of development are case specific.

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IFIs, MNEs, and National Sovereignty: A Study of Globalized FDI and its Consequences in Guyana

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In our increasingly globalized world, the relationship between private and public spheres is being wholly transformed. Alongside erosion of the nation-state and empowerment of non-state actors, chronic underdevelopment has persisted in the Global South, placing ailing nations at the mercy of global markets. Foreign direct investment (FDI) is a frequently proposed solution to this ailment, heavily endorsed by international financial institutions (IFIs) to provide cross-sectoral development through targeted private investment. However, FDI's application in developing countries often becomes an acquisitive control mechanism, permitting a multinational enterprise (MNE) to command a national economy. This raises an essential question: how have international efforts to mitigate global underdevelopment through FDI affected the sovereignty of developing countries? While liberal internationalist IFIs presume the developmental benefits of FDI structured by a collaborative framework, decentralized state, and deregulated economy, MNEs exploit this context for profit maximization. I draw on the international relations theories of neoclassical realism and transformationalism to illustrate that globalization has allowed MNEs to deploy their substantial power for the advancement of self-interest at expense of the state. Transformationalism contends that a globalized world has changed the dynamics of the international state system by introducing private companies whose influence and wealth can exceed that of nation-states. Neoclassical realism builds upon this theory by asserting that powerful international actors, whether states or private agents, will always privilege their own interests by seeking power in global networks of capital and authority. Thus, I argue that the crippling effects of FDI on national sovereignty in developing countries, and their facilitation by IFI ideology, are made evident in the case of Guyana, through minimization of the state's economic authority, disempowerment of its political apparatus, and entrapment in exploitation dependency.

In the 1970s and 1980s, the developing world was plagued by

a series of national economic catastrophes. These crises prompted an extensive bailout campaign by IFIs, which offered states enormous loans contingent upon adopting neoliberal economic policies which extricated them from private markets (Baker, 2014, p. 124-125). FDI was especially encouraged, as a developmental methodology premised on the seemingly vast mutual benefits of cooperative investment in a deregulated economy (Thomas, 1982, p. 50-57). Guyana was but one country pressured into decentralization and FDI, with its sizeable mining, forestry, and agricultural industries acquired by foreign corporations (Clegg, 2014, p. 400-401). This included a deal signed in 1999 with ExxonMobil for offshore oil exploration (Wilburg, 2018). While FDI induced significant economic growth across the world, it often left income levels, employment, education, infrastructure, and public services stagnant, as was the case in Guyana (United Nations Development Programme (UNDP), 2020, p. 2-7). Nevertheless, ExxonMobil's 2015 announcement that they had discovered massive offshore oil reserves in Guyana sparked hopes for national prosperity (ExxonMobil, 2020). With the 1999 concession expiring, ExxonMobil signed a new Public Sharing Agreement (PSA) with the Guyanese government in 2016, which was publicly excoriated for its exploitative terms (Sanzillo, 2020, p. 3-6).

The most immediate consequence of FDI in developing countries lies in the total subordination of the sovereign nation's economic authority, as abetted by IFIs. Following liberal internationalist ideology, IFIs contend that maximal economic growth necessitates minimal state intervention, which will expedite global market integration and public-private cooperation (Villafuerte et al., 2008, p. 4-6). FDI perfectly fulfills liberal development, by compensating for monetary and infrastructural constraints of underdeveloped nations with the capital, funding, and technical skills of private MNEs (Durham, 2004, p. 287). However, in failing to incorporate transformationalist or neoclassical realist logic, IFIs assume that MNEs and government are equals pursuing cooperative benefits in FDI. Because MNEs are rational actors and often wield more market power than developing countries, they prioritize profit and power maximization over development (Faeth, 2009, p. 171-176). The deregulatory demands of IFIs are conducive to such

monopolization, particularly in undiversified economies in which MNEs may use core industries to command sovereign economic instruments such as GDP, trade flows, resources, inflation, and employment levels (Baccini et al., 2014, p. 979-990). This hierarchy has become apparent in Guyana, where foreign corporations direct major economic arteries in mineral and agricultural exports, but government revenues remain low, consolidating economic power and wealth in private hands (International Monetary Fund, 2017, p. 4-5). Nevertheless, the IMF asserts that deregulation and partnership with ExxonMobil portend unprecedented prosperity for Guyana, ignoring ExxonMobil's self-interest and disproportionate power (International Monetary Fund, 2019, p. 4-6). The government's estimated share of oil profits is a paltry 12.5%, as ExxonMobil may charge 75% of revenues to the government as "annual recoverable costs", which comprise all explorative, developmental, operational, and abandonment costs (International Monetary Fund, 2017, p. 4). Even assuming that the government minimizes public spending, Guyana will likely require massive external loans to repay oil deficits in subsequent years (Sanzillo, 2020, p. 15-19). These results deprive the government of economic or resource control. Corruption, exacerbated by ExxonMobil's proclivity towards immediate aggrandizements over long-term supports, is evident in the clandestine PSA's $18 million USD signing bonus, which the government did not disclose until details publicly leaked (Crowley, 2019). Soaring housing prices in Guyana since 2015 despite marginal increases in per capita income also reflect a proliferation of foreign-dominated elites (Chow, 2020, p. 2-8). Rampant corruption characterizes FDI in many other underdeveloped states such as Iraq, where IFI-sponsored neoliberalism has allowed MNEs to exchange personal favours for economic authority (Costantini, 2013, p. 264-270). In both countries, a delegation of revenue and resource management to unelected MNEs and elites nullifies popular sovereignty by eliminating the citizenry's ability to demand and actualize economic policy. Guyana's government is equally powerless over economic functions, unable to even access oil facilities unless ExxonMobil receives advance notice under "appropriate" conditions (Wilburg, 2018). The comprehensive subjugation of national economic sovereignty in MNEs resource

management, wealth accumulation, and fiscal control through FDI is evident of MNE self-interest and market power, in Guyana and elsewhere. Nevertheless, IFIs promoting foreign development continue to propound liberal internationalism. These IFIs assume that cooperation, derived from mutual interests and organized through FDI, will empower the decentralized state, rather than sanctioning foreign rapacity and sovereign dispossession.

The elevation of MNE authority under FDI additionally constrains the executive and legislative prerogatives of the underdeveloped sovereign state. IFIs insist that disempowering the state's role in private activity is crucial to global market participation and attraction of developmental FDI (Razin & Efraim, 2007, p. 5-7). This approach is ironically entrenched in the liberal belief that equal public-private interaction in global markets requires public-private separation, despite transformationalist arguments that private actors often attain more authority than sovereign states under globalization (Faeth, 2009, p. 172-179). Liberal internationalism also disregards neoclassical realist indicators that the private sector would naturally leverage advantages over the public to extend its power (Razin & Efraim, p. 2-5). In attempting to avoid the statism that stifles FDI, IFIs inversely permit private investors to assault state sovereignty through its legislative organs. In Guyana, the government can barely regulate labour practices amidst IMF deregulation and the emergent economic centrality of oil. Workers on oil facilities are heavily underpaid, operate in unsafe conditions, and are reportedly ordered to work 24-hour shifts (*Kaieteur News*, 2019). There is no regulatory oversight committee for working conditions, and both labour and minimum wage legislation have languished since 2015 (Crowley, 2019). Government attempts to address these needs have recurrently met threats of project abandonment from ExxonMobil, predicated on the contractual provision that Guyana cannot enact or alter legislation that affects the terms of the PSA ("Petroleum Agreement", 2016, p. 68). Furthermore, the PSA forbids any government actions that have "materially adverse effects on the economic benefits" of ExxonMobil's operations (p. 68). In view of oil's expanding economic and social role in Guyana, this provision severely circumscribes government jurisdiction. It could automatically void environmental protections,

labour policies, and corporate regulations if they appeared to impede ExxonMobil's profits or authority. By consequence, a fully representative government in Guyana, and thus popular sovereignty, is far less tenable (Baccini et al., p. 979). FDI has similarly degraded popular sovereignty in Iraq, where policymaking is largely supervised by unaccountable bureaucrats, local elites, and foreign corporations, with even security forces becoming privatized (Baker, 2014, p. 125-135). For both Guyana and Iraq, the IMF predictably concludes that regulatory policies create imbalances between state and private power that hampers FDI-driven cooperation and growth (Gnangnon, 2017, p. 79). It does not consider the pre-existing power disparity in developing countries, which is cemented by decentralization and augmented by FDI. The MNE preys upon IFIs concern for liberal internationalism over transformationalist realism in order to preclude any executive actions that contradict its interests. In so doing, state sovereignty becomes a nominal authority, depriving government of its prerogatives and people of representative institutions.

Perhaps the most devastating consequence of IFI-sanctioned FDI in developing countries is its inescapability and coercive exploitation dependency, which undermines sovereign independence. As an MNE is self-interested and profit-maximizing, a developing country's appeal derives from its exploitability: that is, from cheap labour, scant regulations, pliable institutions, and lucrative resources (Blonigen & Piger, 2014, p. 776). Though IFIs adhere to the liberal belief in FDI's capacity for distributive development, even they acknowledge the realist paradigm that developing countries must compete to maximize their investment appeal, or exploitability, through decentralization (Wei & Balasubramanyan, 2004, p. 2). Once established, FDI maintains exploitation through concentrated investments that spawn resource dependency (Frynas, 2017, p. 124-125). ExxonMobil's heavy investments have driven oil to account for nearly 40% of GDP in Guyana, while other principal revenue streams such as bauxite mining and rice farms have progressively lost government funding and economic relevancy (*Budget Speech*, 2021, p. 21-31). As it evolves into Guyana's central source of government revenues, employment, and development, the oil industry risks national economic ruin in the event of collapse, ensuring that the country

cannot exit the PSA or oil trade (Frynas, 2017, p. 125). ExxonMobil's relatively stable financial position and contractual right to recoup costs of abandonment, however, shield it from any serious imperilment (Sanzillo, 2020, p. 6). FDI has had similar outcomes in several other developing countries, such as Nigeria, where oil recently reached 95% of exports following investment by Shell Corporation (Hannah et al., 2014, p. 140-145). Through FDI, Guyana's government and people have lost their sovereignty in becoming largely dependent on foreign actors for revenues and stability, a relationship irreconcilable with state primacy. Furthermore, their dependence is on blatant exploitation due to IMF deregulation: Guyanese oil workers are paid marginally more than the $1.32 USD minimum wage for hazardous labour, given negligible training by ExxonMobil, and systematically excluded from executive positions (Chabrol, 2020). Even after a new government was elected in 2020, their promise to equitably renegotiate the 2016 PSA and an upcoming PSA was met with refusal by ExxonMobil and thinly veiled threats that if the company did not "get the agreement as we are looking for… the investment money will go elsewhere in ExxonMobil's portfolio" (*The Caribbean Council,* 2020). In doing so, the company leveraged the authority endowed by their investment to preserve dependency and negate popular sovereignty. Just as Guyana only attracted ExxonMobil's interest by presenting an exploitable government and populace, the country depends on continued exploitation to maintain that interest and avoid economic devastation. The pervasive exploitation dependency instituted by FDI paralyzes government and denies public mechanisms to institute political demands, simultaneously targeting state and popular sovereignty. In elucidating the tendency of MNEs to exert power to this end, transformationalism and neoclassical realism have triumphed over liberal internationalist development. Propped up by IFI-sponsored deregulation, FDI renders sovereignty effectively meaningless, paradoxically inferior to the decree of the self-serving foreign actor.

In drawing power away from the underdeveloped sovereign state, FDI effectively establishes an external pseudo-state, which commands many privileges ostensibly exclusive to government. Within liberal internationalist logic, IFIs perceive FDI as a superlative

form of assistive development that demands a liberalized state structure. Their shortcomings are demonstrated in transformationalist and neoclassical realist doctrine, in which an MNE's abuse of authority is expected. It is evidenced in Guyana, where ExxonMobil has parasitically drained institutions of state sovereignty, by way of economic authority, executive prerogatives, and exploitation dependency.

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An Ecofeminist Approach to Domination and Hierarchy in Times of Climate Crisis

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Introduction

The climate crisis is an existential threat, but one characteristic often overlooked is the role of nature and women, and how the climate crisis relates to socially constructed hierarchies based on domination. Through an ecofeminist perspective, this paper poses the question: how has the concept of nature been impacted through hierarchy and domination in times of climate crisis? This paper will argue that understanding the appearance of human-nature hierarchy and domination is crucial to comprehending how the climate crisis exemplifies the damaged perception of women and nature in the contemporary world. This argument will evaluate three supporting points. First, this paper will explore how nature has been gendered. Why do we use the term "mother nature" in referring to nature? Was it a coincidence that mother is feminine or are there underlying factors? Second, this paper will examine the role of masculinity and its influence on culture, which contains certain dominant ideals determined by masculine perceptions. Finally, this paper will reconceptualize the idea of environmental justice from an ecofeminist perspective. This approach on environmental justice not only examines the misperceptions of women and nature but also challenges it, and guides us in evaluating the climate crisis and considering our planet's future. Rather than following mainstream literature, which focuses on the climate crisis through political perspectives, this paper will explore the field of ecofeminism and its underestimated role in the creation of a more sustainable environment.

Ecofeminism

Moving forward, it is necessary to grasp the ideology of ecofeminism. The term was first used by Francoise d'Eaubonne in the 1970s, when she connected the destruction of Earth's environment to a prevailing masculine culture of dominance in society, and called

for an "ecological revolution to save the planet."[1] Since then, the ecofeminist approach has gained traction in classrooms, and various organizations have been created to combine the notion of feminism with environmental issues. In her book, contemporary ecofeminist scholar Carolyn Merchant identifies four key types of feminism at play in environmentalism: Liberal, Marxist, Cultural and Socialist. Liberal feminism touches mind/body dualism and the male domination of nature where males act in their self-interest, Marxist feminism describes the exploitation of nature by means of technology and science where feminists critique capitalist modes, cultural feminism highlights the unawareness of the interconnectivity between male domination of women and nature, and finally socialist feminism identifies nature as the material basis of life and why women's roles are overlooked.[2] However, there are more different approaches to ecofeminism. One such approach comes from Janis Birkeland who views ecofeminism as an useful analysis tool to challenge the role of patriarchal dominance where masculine characteristics place you at the top of the hierarchy while the association of feminine and nature place you elsewhere.[3] To break this hierarchy, ecofeminists such as Val Plumwood suggest that the dualized conception of human identity must be challenged in order to relate human identity with nature, "not alienate from it."[4]

Here, it is important to note that this paper will primarily rely on the liberal, cultural and socialist feminist aspects of ecofeminism to explain the points of gendering nature, masculinty and culture, and environmental justice. Through an ecofeminist perspective, this paper evaluates nature, its limitations and its relationships with

1. Carolyn Merchant, *Radical Ecology: The Search for a Livable World*, 2nd ed (New York: Routledge, 2005),https://books-scholarsportal-info.myaccess.library.utoronto.ca/uri/ebooks/ebooks4/taylorandfrancis4/2018-06-05/2/9781136190155, p. 194
2. ibid., p. 198-199
3. Janis Birkeland, "Ecofeminism: Linking Theory and Practice," in *Ecofeminism: Women, Animals, Nature*, ed. Greta Gaard (Philadelphia: Temple University Press, 1993), p. 18-19
4. Val Plumwood, *Feminism and the Mastery of Nature* (Routledge, 1993), https://books-scholarsportal-info.myaccess.library.utoronto.ca/uri/ebooks/ebooks4/taylorandfrancis4/2018-06-03/10/9781134916696) p. 36

humans. The significance of using the ecofeminst lens is that it highlights how forms of domination and hierarchy can be overcome while questioning the interdependence of humans and nature.

Genderization of Nature

In order to fully evaluate the human-nature hierarchy and domination, it is important to consider how humans have gendered nature. The ecofeminist perspective points out that relations and institutions in society are dominated by patriarchal assumptions and structures, which causes destruction of the environment through oppression.[5] It is apparent that nature has been categorized as feminine. The discourse of eco-maternalism and human/nature dualism exemplifies how nature has been dominated by patriarchal ideas of femininity, and has become how nature is perceived in times of climate crisis.

Eco-maternalism revolves around the concept of gendering nature as a female, as "mother nature" or "mother Earth." Eco-maternalism is a fairly new perspective that has been built upon in the last couple decades. One of the most central scholars in developing this new concept is Sherilyn MacGregor, who defines ecomaternalism as making "explicit links between women's mothering and caring disposition and their unique propensity to care for nature."[6] But how do maternalism and nature intersect? Maternalism has generally shaped the struggle for women in acquiring motherhood and citizenship,[7] and by touching on this, nature has been linked by the male-dominated world to mother the world and its global citizens. However, cultural feminists believed that it was more important to act upon the language of nurturing and maternal beliefs rather than citizenship. As MacGregor argues, the maternal practice which was characterized by preservation, growth and social acceptance (all

5. Bob Pease, "Recreating Men's Relationship with Nature: Toward a Profeminist Environmentalism," *Men and Masculinities* 22, no. 1 (2019): p. 114-115
6. Sherilyn MacGregor, *Beyond Mothering Earth: Ecological Citizenship and the Politics of Care* (Vancouver: UBC Press, 2006), https://books-scholarsportal-info.myaccess.library.utoronto.ca/uri/ebooks/ebooks3/upress/2013-08-25/1/9780774855310, p. 20
7. ibid., p.23

derived from motherhood) is important to understand feminist theories of peace and justice for society and the environment.[8] Along with this, ecomaternalism also frames women's environmental concern and activism through the language of caring, nurturing, or concern for the future."[9] Again, here it is important to stress the language. "Caring," "nurturing" and "concern" are characteristics that are not attributed with males because a patriarchal society considers these traits to be a weakness. By setting the stage that ecomaternalism is about these three words, a system of oppression begins to develop in how we discuss and view nature. Ultimately, nature is gendered as female in our overall perceptions. This reinforces the passive role the environment plays in our patriarchal status quo, which leads to the massive exploitation of nature.

Using human/nature dualism, another example of the genderization of nature can be derived from the term "mother nature." Plumwood argues that the study of dualism in ecofeminism results in a finding of "a certain kind of denied dependency on a subordinated other"[10] meaning that a domination/subordination structure is existent. Drawing from this conclusion, the domination/subordination structure is equivalent to the human/nature structure where humans are dominating the subordinate nature. But what if the term "mother nature" is more sexist than one might think? It is important to consider that the masculine approach of being the so-called "saviour" resonates with traditional patriarchal exploitation. Thus, it shapes our perception of mother nature as defenseless and vulnerable. It seems like this characterization is harmless, as it appeases humanity's protection instinct. However, this nonetheless portrays a somewhat damaging view of nature and women. Pease makes this argument when he states that men have exceeded their traditional patriarchal roles by protecting nature in order to nourish their families.[11] The

8. ibid., p.27
9. Mark Stoddart and D. B. Tindall, "Ecofeminism, Hegemonic Masculinity, And Environmental Movement Participation In British Columbia, Canada, 1998–2007: 'Women Always Clean Up The Mess'," *Sociological Spectrum* 31, no. 3 (2011): p. 353
10. Plumwood, *Feminism and the Mastery of Nature*, p. 41
11. Pease, "Recreating Men's Relationship with Nature," p.119

point about "mother nature" depicts that during the climate crisis, there is an urgency to protect the environment which furthers sexist sentiments. In order to overcome sexism apparent climate dialogue, humans need to dismantle the human/nature hierarchy and rather see nature as a partner, an equal.[12]

This genderization creates a damaged perception of nature as we are dealing with the climate crisis. Through evaluating the process of genderization by means of eco-maternalism and human/nature dualism, it can be concluded that nature is viewed as feminine and subsequently seen as requiring protection from patriarchal constructs. This perception is highly apparent during the climate crisis and a viable option for the future cannot be achieved until the domination of patriarchy is addressed.

Masculinity and Culture in a Climate Crisis

The role of hierarchical culture in societies imposes damaged perceptions about women and nature, and this is especially prevalent in the current climate crisis. In a society where certain groups or individuals are seen as more important than others, the dominant and powerful will always have their voices heard over the subordinate. In evaluating masculinity and culture, this point will further the main argument of this paper by exploring how the promotion of ideas in culture such as hyper-separation and egocentrism led to a misrepresented conceptions of humans and nature. This will shed light on the background of negative perceptions regarding nature, because it is derived from not only how we view women, but also how we treat them.[13]

Plumwood in her work puts forth the rejection of radical exclusion which is often regarded as hyper-separation in academic literature, and associates this with her culture/nature dualism. Hyper-separation has been apparent since the industrial revolution and takes place when the "the master tries to magnify, to emphasize and to maximize the number and importance of differences and to eliminate

12. Merchant, *Radical Ecology*, p. 196
13. Stoddart and Tindall, "Ecofeminism, Hegemonic Masculinity, And Environmental Movement Participation," p. 345

or treat as inessential shared qualities, and hence to achieve maximum separation."[14] For years, the patriarchal structure has backed this, but are women challenging this as a collective in the contemporary world? Before women can challenge this narrative, it is imperative that the masculine power of hierarchical culture is firstly understood. Goldgaber approaches power by referring to Foucault as she argues that in order to reshape culture/nature dualism, it is important to emphasize cultural power as "constituting or producing what it regulates."[15] Re-centering hyper-separation, the reactions of cultural and liberal feminists are equally significant: liberal feminists would argue that culture has labelled women as outsiders in men and nature relations while cultural feminists would approach it by stating that society is unaware of interconnectivity of women and nature while men retain their hierarchy.[16] What the culture of hyper-separation is really doing is that it is disassociating women from nature as if they have no place in it. Overall, hyper-separation is a masculine approach to understanding the role of culture with regards to ecofeminism and the climate crisis. It is quintessential as it displays how hierarchical culture has shaped damaged perceptions about nature and the role of women.

Another approach to the masculinity of hierarchical culture can be traced back to egocentrism. Egocentrism can be seen as paternalistic in nature where the good for one is good for all, but in environmental terms, it implies that the exploitation of nature for one's benefits supposedly benefits society as a whole.[17] So does the good of the dominant equate to the good of nature and women (who are seen as subordinate)? Today, egocentrism can be associated with the negative perceptions of nature and women in times of climate crisis. Egocentric culture has made it so that nature and women have "bolstered masculinity and ego-massaged" of the dominant[18] by displaying their role of the nurturer—women by cooking food

14. Plumwood, *Feminism and the Mastery of Nature*, p. 49
15. Deborah Goldgaber, "Return to the Repressive: Re-thinking Nature- Culture in Contemporary Feminist Theory," *Open Philosophy* 1, no. 1 (2018): p. 251
16. Carolyn Merchant, *Radical Ecology,* p.198
17. ibid., p. 64-65
18. Plumwood, *Feminism and the Mastery of Nature*, p. 66

and taking care of children while nature by providing them with necessary resources. Ecofeminists like to essentialize that nature is closer to women while men are closer with culture and by this logic, since male culture and hegemonic masculinity are social constructs, they can be transformed to be more inclusive.[19] Brett Pelham's set of studies regarding climate change skepticism highlights that due to egocentrism, people "base important judgments about climate change on information they ought to disregard."[20] In other words, cultural egocentrism prevents people from recognizing reality which is crucial in overturning negative perceptions, especially during a climate crisis.

The culture of hyper-separation and cultural egocentrism are two different pieces of the puzzle in solving how the role of women has been articulated in times of climate crisis. It answers why there is a hierarchy of men over women over nature and how it is still maintained in times of climate crisis. Without understanding the "why" and "how" factors, it is hard to have a firm grasp as to why negative perceptions of women and nature are harming the solution process for the climate crisis.

Environmental Justice

By touching on the genderization of nature and masculinity in hierarchical culture thus far in regards to climate change, this paper has demonstrated a clear understanding of the human domination of nature. Now, this paper will now transition towards evaluating the role of environmental justice. Kiran Asher argues that gender, race, history and political economy are overlooked in mainstream solutions for a path for sustainable development.[21] This paper will focus on the "gender" aspect of this argument and how it can be associated with sustainable development, in issues of environmental justice. This paper will further highlight how the existence of hierarchies

19. Pease, "Recreating Men's Relationship with Nature," p.114-115
20. Brett Pelham, "Not in My Back Yard: Egocentrism and Climate Change Skepticism across the Globe," *Environmental Science & Policy* 89 (2018): p. 426
21. Kiran Asher, "Thinking Fragments: Adisciplinary Reflections on Feminisms and Environmental Justice," *Catalyst: Feminism, Theory, Technoscience* 3, no. 2 (2017): p. 3

and ideas of domination in the creation of environmental solutions hinders the ecofeminist approach to the climate crisis.

It is important to consider environmental justice in regards to gender with a historical and political context. The climate crisis has severely impacted women in the Global South as they still face the consequences of "colonial marginalization and ecologically unsustainable development."[22] The causation of this impact is traced back to the Industrial Revolution in Europe and the emergence of capitalism as a driving force behind behaviour. Merchant calls this a "capitalist ecological revolution" where the extraction of crops that are used for commercial rather than its conventional value had been accelerated which inevitably led people in the Global South to live on marginal land.[23] But where do women come in? Up until the latter half of the twentieth century, women were seen as "resource degraders" and/or "hapless victims of development," but this misperception is gradually being changed to women being regarded as "knowledgeable resource guardians."[24] Ecofeminists, whose literature mainly began to develop in the 1980s and 90s, began impacting the international arena with reports, conventions and conferences which have boiled over to the twenty-first century. This leads many in the political and public spheres to believe that not only are solutions being found to the climate crisis, but this solution process is also improving gender inequalities. This claim is false. Asher, evaluating the 2014 UN Women Survey, believes that attempts at addressing these inequalities in relation to the climate crisis to "empower women" and "mainstream gender" neglects institutional and structural factors and undermines progress for social and environmental justice.[25]

The evolving movement of environmental justice encompases the growing role of women as environmental activists. This is most apparent in the case study of Love Canal, which MacGregor describes as the "paradigmatic (if not the original) case of environmental justice

22. Carolyn Merchant, *Radical Ecology*, p. 213
23. ibid., p. 213
24. Kiran Asher, "Thinking Fragments," p. 14
25. ibid., p. 16

activism in the United States."[26] Up until this event, the discourse around environmentalism and climate change was dominated by male hegemonic masculinity. Lois Gibbs, the leading activist in Love Canal, began organizing and mobilizing the people of her community in a grassroots movement challenging various levels of government and corporations. Merchant, using Gibbs, demonstrates that women who have lived as ordinary housewives and disregarded the environment were politically forced to address an existential issue by applying their motherly instincts.[27] This is where ecofeminists point out female involvement in the climate crisis. It was not a choice, but rather by force. However, the fact that it was forced does not necessarily mean that it has a negative impact. This is because by the Love Canal incident, the damaged perception of women and nature had become the status quo. The unethical actions of Hooker Chemical Company by placing chemical waste in the canal allowed women to challenge the status quo. Throughout this paper, it has been identified that the climate crisis brings out damaged perceptions about women and nature. However, the case study of Love Canal embraces this and offers an example of women directly challenging hierarchy and addressing climate change.

The evaluation of environmental justice in examining the human-nature hierarchy and domination highlights a point about damaged perceptions of women and nature that is not offered by the genderization of nature and the role of masculinity and culture. Environmental scholars and ordinary women today are still feeling the cruelty of misperceptions about nature, but now, they are combating it. This ecofeminist approach to environmental justice displays how women began to emerge to challenge misperceptions and then gradually overturn them, simultaneously addressing climate change with grassroot activism.

Limitations and Criticism

Carolyn Merchant, in her chapter on Ecofeminsim in *Radical Ecology*, presents two major criticisms of ecofeminism which limits

26. Sherilyn MacGregor, *Beyond Mothering Earth*, p. 46
27. Carolyn Merchant, *Radical Ecology*, p. 203-204

the scope of this paper. The first is about how relating women to nature overlooks the possibility of males having a sense of care for nature, as if only what women do is good and what men do is bad for the Earth.[28] This criticism can be traced back to the dominance of patriarchy in the years leading to climate change. Now that climate change is in full swing, women tend to blame men. In other words, this criticism asserts that the ecofeminist perspective overlooks the interdependence of not only women, but of *humans* and nature. The second criticism Merchant puts forth is that the ecofeminist approach lacks a clear analysis of capitalism's relationship to nature.[29] This is a critical limitation of this paper. Because climate change is a result of capitalist ideals embraced by governments, this paper is unable to examine the full extent of how our perceptions of women and nature impact how we address climate change. Despite this limitation, social issues such as gender relations have a great impact on our views about climate change regardless of the impacts of capitalism.

Conclusion

In conclusion, this paper expands on the critical role of human-nature hierarchy and domination and how in times of climate crisis, exemplifies misperceptions of women and nature. In order to understand the significance of this role, this paper goes over how and why nature is gendered, the extent of influence masculinity has in culture, and by using environmental justice, how this role is being challenged. This paper also acknowledges limitations it may have, especially in the evaluation of capitalism and its impact on gender in times of climate crisis. It is undeniable that women have been impacted differently due to inequalities. Institutions must further empower women by recognizing structural limitations, and realize that a feminist perspective is the future for environmental solutions and justice. Ultimately, there are various sources of climate change, including how a patriarchal society portrays women and nature as intertwined. What is most important is that as humans and as a community, climate change must be recognized. The climate crisis is an existential threat and in order for a sustainable future, the world

28. Carolyn Merchant, *Radical Ecology*, p. 204
29. ibid., p. 204

must radically and swiftly address the human-nature hierarchy and domination of humans over nature.

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Protecting Low-Income Housing in Historically Low-Income Renter Neighborhoods

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Introduction

This paper will focus on how to protect low-income housing in historically low-income renter neighbourhoods in Toronto, Ontario, a city that is undergoing an affordability crisis. By investigating Toronto's post-1990 economic morphogenesis, I will trace how Toronto's lack of affordable housing has come to threaten the wellbeing of low-income renters. Moreover, I will examine the dynamics of neoliberalism in governmental and private sector housing policy to elucidate how they are the main causes of Toronto's affordability crisis.

From this, I will present a solution that can protect existing affordable housing. I will argue that community land trusts (CLTs) are an effective approach to protecting existing low-income rental housing. This essay illustrates that, through the transfer of land holdings from the traditional neoliberal capitalist speculative market into a CLT, low-income renter residents are empowered and insulated from private interests, which ultimately protects low-income housing. I will examine a CLT in Toronto's Parkdale neighbourhood to elaborate on how CLTs function and the certain obstacles that residents must overcome for CLTs to be established and successful.

My paper is guided by my main research question: *What are the benefits and barriers that community land trusts produce in protecting existing affordable housing in Toronto's low-income renter neighbourhoods?* Two sub-questions I aim to answer are: *How do land ownership methods in community land trusts differ from traditional methods of neoliberal land ownership,* and *What are the particular attributes that community land trusts need when operating in Toronto?*

Community land trusts have a variety of mechanisms and dimensions, so I will begin with a literature review to provide a framework of the different components and critiques of CLTs. Then,

I will situate the paper within Toronto's housing affordability crisis, then present an overview of what CLTs are and how they emerged. From there, I will present my main argument for the use of CLTs.

Literature Review

Authors such as Williams (2018) have investigated the internal socio-political tensions within CLTs. They examine how CLTs usually form through grassroots organizations but sometimes diverge into corporate mechanisms that protect affordable housing while also silencing community members. She also outlines how CLTs create power struggles between educated skill-based CLT operators and longtime residents. Moreover, Thompson (2015) examines how a historically marginalized British neighbourhood called Granby overcame institutional barriers to create a CLT. They paid particular attention to how contending radical and incrementalist approaches form a symbiotic relationship under the correct conditions—but much of it relies on government willingness. They illustrate that within Granby, a variety of residents wanted their CLT to produce different outcomes, but settled on collective land-ownership as the most essential end goal.

In other cases, authors like Alves et al. (1995) consider tensions within community mobilization and institutional factors differently. They show that historically disinvested minority neighbourhoods have not had the same mobilization power as affluent, predominantly White ones. They open up a broader conversation about how CLTs are rooted in racial and social justice. I will discuss this in more detail later.

Kelly (2015) provides a policy-oriented review of how a CLT can operate within a legal framework that protects existing housing while promoting 'neighbourhood development' so new, wealthier residents can move in. Kelly is optimistic that CLTs can ease the economic tensions that mixed-income neighbourhoods often have. Rowe et al. (2018) consider the philosophical groundwork that endows a CLT with longevity. They postulate that successful CLTs can create a neighbourhood ethos that values participation and activism, but this activity is conditional on the neighbourhood's composition and the CLT's main goal.

Each of these articles illuminates a critical feature of CLTs. My paper will build on this literature by drawing from some of the challenges they discuss regarding organizing and maintaining CLTs, while also presenting my own argument for the greater use of CLTs in Toronto. I will now situate, then examine, Toronto's housing market.

Situating Toronto's Housing Crisis

Before I discuss Toronto's affordable housing crisis in detail, I must define what 'affordable housing' is, as there are different definitions that tend to benefit different interest groups. The Canada Mortgage and Housing Corporation (CMHC) defines affordable housing as housing that costs no more than 30% of one's annual pre-tax income (2018). However, the City of Toronto defines affordable housing as "at or below average market price" (Pagliaro, 2018). Toronto's current mayor, John Tory, admits that the City may need to redefine what affordable is, as the average rental price for a one-bedroom apartment in the city is roughly $2000 (Pagliaro, 2018; Rentals, 2020). Moreover, it is important to mention that 'affordability' is relative. People with higher incomes have greater options when renting apartments. Low-income people do not have the same breadth of choice, as they are constrained to a lower price range. I note that I pay particular focus to low-income social housing in the section below; I do so to elaborate that the rollback in social housing supports my broader argument that neoliberal land and housing policy fails to produce and protect low-income dwellings.

Explaining Toronto's Housing Unaffordability

Toronto's housing crisis can be related to a myriad of fiscal policies from the federal and provincial governments of the 1990s and early 2000s that aimed to further privatize and deregulate social and private housing. Bendaoud (2017) writes that social housing is usually publicly owned and is "under the possession and control of public authority, whether at the provincial or municipal level" (p. 2). Social housing was once heavily funded by the federal government, until 1993, when Jean Chretien's Liberal Party decided to download many federal social housing expenditures to the provinces (Hackworth, 2006). Soon afterwards, Ontario elected an extremely

fiscally Conservative government that removed a substantial portion of provincial funding from social housing and cancelled 17,000 units "already in the pipeline" (Hackworth, 2006, p. 515). This reduction forced Ontario municipalities to quickly navigate new funding avenues that offered little funding.

Currently, Toronto has 97,000 households on a waitlist to move into social housing (City of Toronto, 2020). Additionally, a study conducted by the Canadian Urban Institute found that 87% of low-income renters spend more than 30% (and up to 50%) of their income on housing alone (City of Toronto, 2019). The Institute also projects that by 2030 there will be 600,000 low-income residences and overcrowding in dwellings will grow substantially (City of Toronto, 2019). Approximately half of Toronto's residencies are rental units (City of Toronto, 2019).

Additionally, David Hulchanski's (2010) longitudinal 'Three Cities' report (Fig. 1 and 2) presents economic socio-spatial data from 1970 to 2005 that proves that Toronto's historically low-income downtown renter neighbourhoods are becoming wealthier and less affordable. It also found downtown neighbourhoods like Parkdale, Queen Street West, and King Street are becoming Whiter and longtime minority residents are leaving (Hulchanski, 2010). I add that twice as many visible minorities live in low-income housing compared to non-visible minorities in Toronto (City of Toronto, 2019). There is not enough room in this essay to fully unpack these racialized trends, but it is essential to mention that affordable housing and racial discrimination are inseparable in the Toronto context. It is clear that the status quo housing trends are creating potential (and without intervention, inevitable) forced displacement concerns among low-income renters in Toronto. But how has this issue compounded to such a dire degree? What are *status quo* housing mechanisms? I must now examine and elaborate on neoliberal economic ideology to show that CLTs are mechanisms that can effectively combat neoliberal land and housing markets.

Neoliberal Capitalist Markets: Capital Above all Else

The term "neoliberal" remains ambiguous to a certain degree, as there are "differences of viewpoint in how neoliberalism is

defined, and how it manifests locally" (Hackworth, 2006, p. 510). This essay defines neoliberalism as an ideology which advocates that "the market is the most effective means through which individuals can maximize their own utility" (p. 511). In other words, in neoliberal thought, the 'market' is the best way to serve and solve people's needs and problems. Implementing neoliberal ideology in government institutions relies on a "roll-back phase which is followed by a roll-out phase" which first destroys 'Keynesian artifacts' like social-housing and redistributive welfare, then rolls out "government-business consortia" to secure economic 'freedom' (p. 513). As discussed previously, the federal and Ontario governments followed this process in the 1990s and early 2000s in developing their social housing policies.

In addition, neoliberal housing ideology is founded on the market principle of supply and demand; it is expected that the private sector can supply 'demand-side' housing. To incentivize private sector 'supply', neoliberal development encourages the sell-off of "social rental housing; reduced subsidies for rental housing construction" and switching to "deregulated rents" (Kadi, 2018, p. 270). Deregulating the housing market, or "relaxing constraints", will get at the "heart of the problem" by providing a "greater supply of housing" (Kung, 2018, p. 79). A neoliberal rationale *assumes* there is high elasticity in the housing market (Kung, 2018, p. 80). This is one reason why Toronto's historically less developed areas, like Parkdale and Queen Street West, are beginning to see development in and around their neighbourhoods.

I acknowledge that more housing must be built to meet demands in a growing city like Toronto; however, Toronto's increase in housing supply has been accompanied by a rise in housing costs. Between 2006 and 2018, Toronto's average rent increased by 30%, despite the fact that 186,094 housing units have been built in the past two decades (City of Toronto, 2019; Elliott, 2020). Furthermore, tenants have faced rent hikes because of Ontario's current government slashing rent controls on recent condos to promote housing construction (Elliot, 2020). Time and time again, neoliberal proponents argue that less 'interference' will create cheaper housing; in Toronto, as well as other metropolitan areas like New York, this

approach has yet to be proven effective (Kadi, 2014).

I also stress that under neoliberal capitalist housing ideology, it is in the property owner's right to evict tenants who cannot pay rent (AllOntario, 2020). Housing is "increasingly seen as an investment rather than a home"; therefore, a tenant who no longer supplies capital means that the property owner is a "loser to their investment" (Wetzstein, 2017, p. 3164). The COVID-19 pandemic has explicitly proven this, as private landowners seem to have failed to feel a moral obligation to provide a sense of wellbeing for tenants, even during a global crisis. In November 2020 alone, 2,500 tenants faced eviction by Toronto's Landlord Tenant Board (Miller, 2020). Many of these low-income tenants lost their jobs due to the pandemic (Miller, 2020). This reaffirms my broader claim that, as housing costs rise, especially in Toronto's low-income renter neighbourhoods, eviction and displacement are inevitable.

We have now examined the Toronto housing market and how its tumult is due mostly to neoliberal policy. Now, I will argue that CLTs are the best solution to protect low-income renter neighbourhoods from further neoliberal destruction in Toronto.

An Overview of Community Land Trusts: Strategies to Combat Neoliberalism

Community land trusts emerged in the 1960s Civil Rights era in the hope of changing the "near-feudal dependency" that African-Americans faced in the White-dominated economic and political sphere (Meehan, 2014, p. 120). Robert Swann, widely acknowledged as the 'inventor' of the CLT model, thought that enfranchising the land that marginalized groups lived on would create an enclave that was less dependent on the politics that intentionally neglected them (Meehan, 2014, p. 120). Community land trusts have evolved into multifaceted operations that address a variety of issues such as food security, economic development, and environmental stewardship, but they all depend on the CLT's foremost elements: *community activism* and *land ownership* (Alves et al, 1995; PCED, 2016; Rowe et al, 2018). Most often, contemporary CLTs are community based non-profit organizations that hold and protect land that is usually used for housing. They are an "innovation in real estate that separates

home ownership by individuals from land owned by the community" (Meehan, 2014, p. 114). They have become a popular model in the United States and are gaining attention in Canada and the United Kingdom (Rowe et al, 2018). It would be inaccurate to say that every CLT functions in the same way. To be successful, CLTs must operate within the framework of their particular municipality. That said, CLTs *do* often need private grants and funding from higher levels of government to purchase and maintain land to truly solidify the CLT. Moreover, most CLTs hold frequent participatory action meetings to ensure the "place-based population's decision-making power" remains relevant "through interactions with/in the CLT" (Williams, 2018, p. 462).

When the CLT secures land it is held by the non-profit, which handles finances and manages the residences. This means that once the land is 'entrusted' to the non-profit, it is removed from the speculative market. It is clear that CLTs and neoliberal thought hold opposing ideologies concerning housing and land; the former holds that place and space are meant to serve people, regardless of their income; the latter pursues land as a means of capital accumulation. Because CLTs have no active incentive to pursue private capital gain, they ensure that rents remain affordable and stable and protect low-income renters from increased development. This element of the CLT is at the core of this paper, as CLTs, when implemented correctly, can empower residents to take control of their neighbourhood and nullify the neoliberal concerns discussed above. CLTs are effective at protecting low-income rental housing because developers can neither control nor purchase the land from the city or property owners; the *community* owns the land. Throughout the global financial crisis of 2008-2009—the result of a failed neoliberal privatized housing scheme—there was not a *single* foreclosure in a downtown Boston CLT neighbourhood, despite its low-income status (Meehan, 2014, p. 114). No bank or government *owned* the neighbourhood's land, so the housing was not commodified (Meehan, 2014). The neighbourhood was insulated from private (predatory) interests through the CLT.

Moreover, CLTs are practical and *attainable*. CLTs are a political bargaining body *within* the hegemonic framework of capitalist neoliberalism. Instead of pursuing the daunting task of

systematic land policy reform, CLTs snuggle within the neoliberal infrastructure, then disarm it. To substantiate this claim in a local context, I will examine Parkdale's CLT. This will show how CLTs can form and operate in the Toronto context and elucidate the barriers that Parkdale's residents had to overcome to establish their CLT.

The Parkdale Community Land Trust: Pioneering Land Rights in Canada

Parkdale is a west-downtown Toronto neighbourhood that is historically home to low-income renters. Due to Parkdale's abundance of rooming houses that often accommodate assisted-living residents, the neighbourhood was stigmatized and deemed 'at-risk' and riddled with 'crime and drugs' (Ostantel, 2020, p. 2). However, the growing attractiveness of Toronto's downtown has led Parkdale to experience intense gentrification processes. Large rooming homes, which are abundant in North Parkdale, are being renovated into expensive 'family homes' (PCED, 2016, p. 13). Additionally, private rental asking prices have increased by 36% from 2015 to 2017 alone (Ostantel, 2020, p. 3). Over 90% of South Parkdale's residents are low-income renters who are at severe risk of displacement due to the neighbourhood's changing composition (PCED, 2016, p. 14).

In 2012, Parkdale's Activity-Recreation Centre (PARC) began exploring CLT models to actively combat 'market changes' (Ostantel, p. 4). PARC, through community participatory action meetings, found that residents were open to the idea of establishing a CLT (PCED, 2020). Parkdale's first CLT purchase was a community garden that was vulnerable to being sold and developed into new housing. Through *intensive* private and public fundraising, the Parkdale Neighbourhood Land Trust (PNLT) bought the Milky Way garden from two private land owners for $115,000 in 2017 (PCED, 2020). Today, Parkdale owns the land under the garden and can protect it from future development. In 2019, through the help of municipal, provincial, and private funding, the PNLT secured 71 low-income rooming units for $1.5 million, as well as $600,000 for building improvement (PCED, 2020). This purchase effectively thwarts some of Parkdale's "predatory corporate landlords" who want to displace low-income residents by either raising rent or evicting tenants and

then renovating said homes (PCED, 2020). Indeed, the tenants must continue to pay rent, but do so knowing that it will remain affordable and stable and their 'landlord' (the CLT non-profit) is working in their interests and not the 'market's'. The PNLT demonstrates that CLTs can effectively protect existing affordable housing for renters while also shielding land from prospective development that would increase the cost of living.

Concluding Remarks: Prescriptions and Challenges in Creating Successful CLTs

PNLT's success can be explained by its particular attributes in Toronto's context, as it has a city councillor who relentlessly advocates for his constituents, which helps secure municipal funding; strong community mobilization that bolsters confidence in private funding bodies; and private landowners who were *willing* to sell their land. These attributes will vary in each municipality, and indeed each neighbourhood. It is unlikely that a CLT will be successful, albeit even formed, unless an *entire neighbourhood* actively organizes and then mobilizes. Indeed, it is hard work, and frankly unfair that low-income residents must dedicate even more stress and devote so much time to ensure they can remain living where they are.

Although it may sound dismal, it is likely that social housing stock will continue to falter and neoliberal housing hegemony will remain dominant, as private "housing system insiders" have "further cemented" themselves since the global financial crisis (Kalman-Lamb, 2017; Wetzstein, 2017, p. 3163). This is why CLTs are needed. I have demonstrated that they are effective solutions to protect existing affordable rental housing, as they do not rely on the government or require funding *to the same degree* as social housing, and they are proven to *neutralize* and *work within* neoliberal market forces. I should note that another low-income Toronto neighbourhood, Bloordale, is in the primary organizational stage of exploring a CLT with help from PNLT operators (BBBD, 2020). Parkdale's CLT has solidified itself in Toronto's land market, so Canada now has an archetypal model for community-owned land. Hope exists for low-income renters. However, a great deal of work is on the horizon.

Figure 1

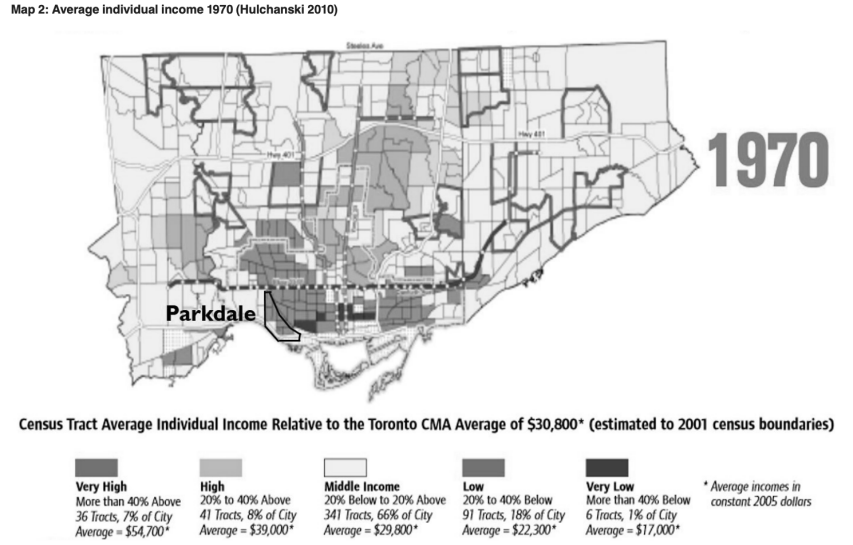

Figure 2

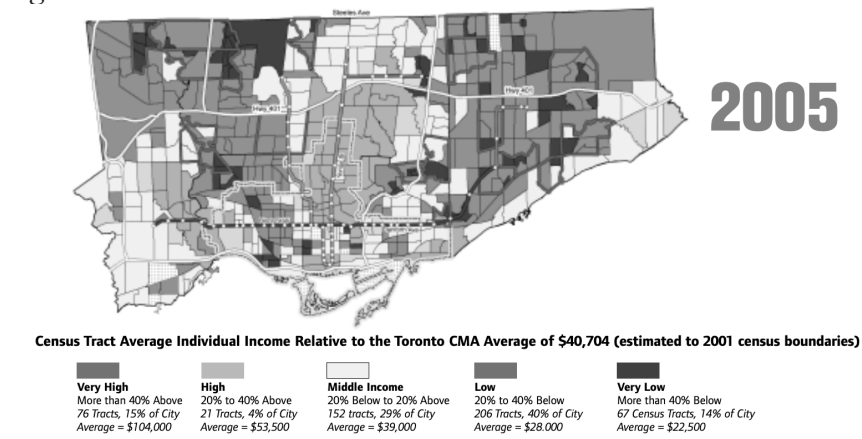

Figure 1 & 2. Both figures are from David Hulchanski's *Three Cities within Toronto* Report, see references for further information

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In what ways does language influence quantitative decision-making?

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The Sapir-Whorf hypothesis, also called linguistic relativity, creates a link between language and cognition (Danesi, 2016, p. 13). This bidirectional relationship suggests that language is influenced by its speakers' and receivers' thoughts, but language, in turn, can also influence speakers' and receivers' thoughts. For instance, concepts that have more societal value also tend to have more vocabulary in the society's language(s), indicating that perceptions can influence the formation and use of language (Danesi, 2016, p. 13). Similarly, the same language—be it verbal or written—can impact its speakers' and receivers' perceptions, as the brain processes the words' societal values along with its actual meaning (University of Göttingen, 2019). This theory is a principle of linguistic anthropology, which is relevant even today as language is ever-changing, and consequently, so are our perceptions (Danesi, 2016).

Cognition, as a whole, is not restricted to perceptions. It involves multiple mental processes, including but not limited to thinking, decision-making and memory. This paper will specifically focus on decision-making to quantify this hypothesis, arguing that language and decision-making (an aspect of cognition) are interconnected. Moreover, this paper will focus on the latter half of the Sapir-Whorf hypothesis—that language influences perceptions—to simplify the argument. To test the strength of this relationship, it is useful to examine if language can influence thoughts that appear to be unrelated to linguistics, such as mathematics; therefore, this essay will focus on quantitative decision-making. The primary argument of this essay is that language can influence quantitative decisions due the roles **vocabulary**, **syntax** and their consequent **biases** play in decision-making.

Vocabulary

Vocabulary is the "set of words and phrases in a language" and therefore, a key part of daily communication (Danesi, 2016, p. 34). Therefore, it can be assumed that vocabulary (aspect of language)

can impact decision-making (aspect of cognition), according to the Sapir-Whorf hypothesis. This impact is evident because decision-making is defined as choosing amongst options, but the expression of these options can be done only through language (Bickerton, 1990). Picking between "A" and "B" means understanding what "A" and "B" represent first, and then formulating choices; but to understand the referents and connotations, language is most certainly involved (Danesi, 2016, p. 35). Connecting this to numerical contexts, it seems unclear what effect qualitative vocabulary would have on quantitative decisions; if an effect is present, it would indicate a clear linkage between language and decision-making because it draws a relationship between two very different types of data (qualitative and quantitative), suggesting that language has extensive influence over thought.

A study by Loftus and Palmer (1974) investigates the role of word choice on subjects' perceptions of speed. The researchers showed participants a video of a car accident and then asked participants to estimate the speed the car was going. Although all 45 participants watched the same video, these 45 subjects were divided into 5 groups, in which the researchers changed the vocabulary for instructions for each group. For example, they asked one group to estimate how fast the car "smashed" while another group was asked how fast it "contacted". While both adjectives suggest the same action, at the denotative level, they are used to indicate a difference in intensity. They may even be considered a part of the same lexical field, as their referential range is similar—both denote speed. This minor difference caused a major change in participants' estimates—the "smashed" group estimated a mean speed of 40.8 mph, while the "contacted" group guessed, on average, 31.8 mph. Hence, a definite correlation between qualitative vocabulary (diction, in this case) and quantitative decision-making (estimating speed) is seen.

However, a key limitation of this study is its artificiality. Language is better investigated in natural environments as people communicate more habitually, instead of unnaturally. Many linguistic anthropologists make use of ethnography or fieldwork; experiments tend to be more controlled, but also artificial (Danesi, 2016, p. 15).

Another counterpoint to this argument lies in the use of solely English as a language. This experiment only made use of English, but intuitively, this study should obtain the same results with another language because all languages have their own vocabulary given their "finite set of distinctive sounds" (Danesi, 2016, p. 5) and therefore the brain must process a task (like the one mentioned in the study) similarly. However, if this is the case, then it suggests that *language* and decision-making are not related, but it is instead the mere *vocabulary* impacting decision-making. The theory proposes that language influences thought, and therefore, an implication arises: people speaking different languages think differently. Linguistic relativity does not account for bilingualism or multilingualism—would decisions be different for bilinguals compared to monolinguals?—which is increasingly prominent in a global world today (Athanasopoulos & Aveledo, 2012, p. 236-255). Brain scans have shown that people speaking more than one language process language in different regions of the brain, and that the addition of a new language can lead to neuroplasticity, essentially changes in the wiring of the brain (Lin et al., 2019, p. 122-134). This suggests that internally language *is* processed differently, but *externally*, may not impact decision-making (and implicitly cognition) as the end-result—the decision—is the same. It can be concluded that language has biological correlates, but its cognitive correlates (if any persist) are still undergoing research. Hence, the Sapir-Whorf hypothesis leaves out a key aspect of linguistic anthropology (bilingualism and multilingualism, and their effects on cognition), one that has been backed by empirical biological evidence, and is a crucial limitation of the theory.

Syntax

The arrangement of morphemes and lexemes that produce phrases in a language can be defined as syntax (Danesi, 2016, p. 51). Consistent with linguistic relativity, syntax can lead to altering perceptions, as Sapir proposed that changing the order of words in sentences changes its meaning and therefore, consequent thought (Danesi, 2016, p. 51). Many studies observe whether the framing of sentences has an impact on participants' reactions; an implication

that arises from this is the psychological theory of the "framing effect" (Busby et al., 2018, p. 67-90). This theory suggests that positive and negative 'frames' play a role in forming positive and negative perceptions, which can hence impact decisions (Tversky & Kahneman, 1986). For instance, if a friend asks you for a favour, they are more likely to describe the task pleasantly, so you are more likely to complete it; whereas, if someone wants to discourage you from an activity (e.g., smoking), they are more likely to exaggerate the negative consequences of the activity, so you do not engage in the activity. It is particularly interesting to investigate the framing effect with regards to numerical values because numbers are objective, unlike positive and negative frames which appeal to emotions.

Many studies investigate the 'framing effect', and one particular study was a breakthrough in cognitive psychology. Tversky and Kahneman (1986) studied the 'framing' effect on decision-making on 307 American undergraduate students. Participants were given a hypothetical scenario in which the US was preparing for an outbreak for a rare disease, and participants were asked to choose between certain 'programs' to combat this outbreak. The situation mentioned that the programs were to be tested on 600 people, and that certain risks would be involved. The study was split into two halves, with the first half testing the positive frame and the second testing the negative frame. In the first half of the study, participants were given the following choices: using Program A, "200 people will be saved" and using Program B, "there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved". 72% of participants picked Program A, compared to only 28% who chose Program B. In the second half of the study, the choices were negatively framed: using Program C, "400 people will die" and using Program D, "there is 1/3 probability that nobody will die, and 2/3 probability that 600 people will die". Given this information, 22% of participants chose Program C while 78% chose Program D. Syntax is integral in this decision, because each of these 4 programs was essentially the same (each resulting in 200 survivors and 400 deaths) but the sentence formation was different, which indicates for certain that this influenced participants' decisions. Without changing the quantitative values, and just by altering syntactic structure,

decision-making was impacted. The main conclusion to draw from this is that in the positive scenario, people chose the certain outcome (and avoided a potential loss) while in the negative scenario, people avoided the certain loss (and chose an uncertain gain). It sheds light onto a pattern of decision-making in scenarios where negative and positive results occur.

A weakness is that the study had low mundane realism, which means without a real outbreak, it is unwise to draw definitive conclusions because of its artificiality (Aronson & Carlsmith, 1968). The concern is that no research will be perfect, especially in linguistic anthropology. This is because measuring cognition is difficult to operationalise, as cognition is an abstract concept. While measuring decision-making makes finding evidence easier (because it is easier to quantify), the impact of syntactic structure on the very *process* of decision-making cannot be seen in this study. This leads to conclusions such as "language impacts thought", but with no physical evidence as to *how* language impacts thought. Hence, a causation is impossible to conclude, leaving simply a correlation between language and thought. However, many other studies support the conclusion that Kahneman and Tversky reached, and the "framing effect" has aided businesses in marketing and branding products in addition to pharmaceutical companies performing health campaigns (Finkle, 2019).

Biases

Showing that changing the order of words in a sentence affects decision-making may also imply that changing the order of sentences themselves can affect decision-making. One such cognitive bias is the anchoring bias. The anchoring bias is a person's tendency to hold on to the first piece of information they were provided with (Cherry, 2019). This suggests that decision-making is not just influenced by words (vocabulary) or formation of phrases (syntax) but also the overall communication that takes place prior to making a decision. Pragmatics, the study of communication, can help provide insight into this (Danesi, 2016, p. 143).

Englich and Mussweiler (2001) conducted a field experiment on 19 trial judges to test if the presence of an "anchor" would influence their decision of requesting a sentence length for a criminal.

The participants were divided into two groups, each group being told the same information regarding the case but a different prosecutor's "suggestion". Group 1 was told the suggested sentence length by the prosecutor was 12 months, while Group 2 was told it was 34 months. This was the first piece of information conveyed to the participants; the case was explained afterwards. In the end, when both groups were asked to suggest a sentence length, it was clear that Group 1 suggested lower sentences on average (18.78 months), whereas Group 2 suggested higher sentences (28.70 months). Although it can be concluded that the "anchor" played a role in this decision, it is not certain whether language was the key factor driving the decision.

Once again, the justification for the link between language and decision-making is missing. A major argument against this hypothesis is that the theory's foundation is cyclical—it is almost impossible to determine cause and effect with regards to language and cognition—because numerous factors are contributing together, and cannot be separated. While the numbers 12 and 34 definitely affected participants' cognition, it is unclear if this is because it was the first piece of information or whether it was about the numbers themselves. It is a possibility that this information could have been conveyed later and still had an effect on decision-making. Moreover, it is probable that the noun "prosecutor" influenced the choice, as this word carries authority. In this case too, language does affect decision-making, but which aspect of language specifically impacted this is too complex to be narrowed down. It causes the Sapir-Whorf hypothesis to be based on a fallacy, and not reflect accurate reasoning for the interconnection between language and cognition. Nonetheless, the fieldwork still clearly indicates that language and decision-making appear to be interconnected, and so does support linguistic relativity at least partially.

In conclusion, language and cognition are intertwined, with numerous factors working together to create this relationship. While this paper only explored certain aspects of this relationship, it provided insight into the ways in which this relationship affects decision-making. Factors such as vocabulary and syntax impact mental processes in the brain, thereby affecting decision-making. While this can be beneficial, these factors can also result in cognitive

biases such as the anchoring bias which was discussed previously. It is important to consider what other factors influence this relationship, particularly non-linguistic factors. For example, decision-making may be a cognitive process, but biological determinants such as hormones and emotions can also impact decisions (Dube, 2016).

This essay used a sociolinguistic approach and so did not take these other factors into account, but it is vital to draw conclusions after understanding them. The Sapir-Whorf hypothesis is overly simplistic as it fails to recognise the complexity of language and cognition; it attempts to draw a cause-effect relationship without accounting for biological and social factors. Another limitation discussed was the theory's lack of account for bilingualism and multilingualism—their role in linguistic relativity is still unclear. The major barrier is the difference between the kind of research into cognitive psychology and linguistic psychology as compared to mere science such as biology; there is a lack of concrete, tangible evidence when studying the "mind" and not the "brain".

However, the range of studies presented in the essay depicts that linguistic relativity is not restricted to the field of linguistics, but that this knowledge can be applied to other areas too. For example, the essay consistently referred to mathematics (i.e., speed, time, length) due to the subject being quantitative decision-making, and also made references to biology to question the role of brain functioning in language. Holistically, any field where decision-making is essential (practically every field) can utilize implications of the Sapir-Whorf hypothesis. Some implications are: businesses can make branding more efficient, pharmaceuticals can produce effective health campaigns and governments can increase their appeal to the general public. There is definitely a lot to take away from linguistic relativity, and perhaps with more research, there will soon be a greater understanding of it as well.

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Champion of Freedom: Locke's Condemnation of Socrates' City Creation

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In *A Letter Concerning Toleration*, John Locke is a champion for religious freedom, seemingly the saving grace for those who are persecuted by the intolerant. While he centers religion as its focus, the conversation can uniformly be extended toward the idea of expression as a whole. If Locke is the hero for the oppressed, is Socrates his sidekick or adversary? Does Socrates support Locke's open-minded position on toleration, or does he challenge it? Woefully, *Kallipolis*, the city constructed by Socrates and his interlocutors, is not interested in tolerating differences; instead, the city seeks to eradicate them. Consequently, Socrates represents a foe to Locke, not a friend. While Locke endeavours to negotiate individual liberty through toleration, Socrates's city represses the autonomous identity with the goal of manufacturing unity. The use of censorship, fabrication of human creation, abolition of private property, and newly allotted roles of women unveil Socrates' city as the antithesis of Locke's doctrine on toleration, even when considering Locke's exclusions.

Before considering the absence of tolerance from *Kallipolis*, I will expound on Locke's critical points in *A Letter Concerning Toleration*. Locke wastes no time getting to the purpose of his letter; within the first sentences, he claims toleration as the chief mark of the "True Church."[1] Individuals or groups who claim orthodoxy but "persecute, torment, destroy, and kill other men" in the name of religion are disingenuous with their faith.[2] As a result of their actions, they cannot bear the mark of the "True Church." These are not frivolous claims; Locke's accusations are grave. First, he is challenging the notion of one church, asserting that no such thing exists, alluding to a multitude of churches.[3] In doing so, he begins to break down the traditional hierarchical system of Western religious

1. John Locke, "A Letter Concerning Toleration," in *A Letter Concerning Toleration*, ed. James Tully (Indianapolis, IN: Hackett Pub. Co., 1983), 23.
2. ibid.
3. ibid.

practice. Second, he is explicitly critiquing the tyrannical zealots of religion, proclaiming that they are acting "contrary to the Glory of God, to the Purity of the Church, and the Salvation of Souls."[4] In sharing these thoughts, Locke claims that those who cloak themselves in religious rhetoric to persecute and impose their ideology on others cannot ever be a part of the "True Church," as their intolerance is the sin that omits them.[5]

Having identified that there is not one church, but many, Locke proceeds to ascertain the characteristics of these societies. On page 28, he writes that the church "is a free and voluntary society," a space where people can gather and worship God publicly as they see fit, in a way that is most beneficial to their salvation.[6] We can infer from his portrayal of the Church as a free space, that one cannot be born a member, for faith is not inherited, and people are not bound by any religious society.[7] That is to say that compulsion and persuasion through violent means, for the purpose of conversion, are actions taken in vain. Religion is deeply personal and reclusive, involving two: the individual and God. Hence, freedom remains a crucial aspect to Locke's depiction of religious society.

From the principles of toleration, freedom, and private faith, Locke implores civil society to preserve a separate church and state. A magistrate is tasked with securing civil interests: "life, liberty, health, and indolence of the body," including "money, lands, houses, furniture, and the like."[8] Conversely, religious leaders are assigned to church regulation and spiritual counsel.[9] So, while church leaders manage spiritual matters, the civil magistrate manages the temporal. Locke asserts that there should be no union among the two sectors; their power must remain separate.[10] Ecclesiastical authority "ought to be confined within the bounds of the church," and the power of the magistrate ought to be void in the church for the sake of securing

4. John Locke, 24.
5. John Locke, 23-24.
6. John Locke, 28.
7. ibid.
8. John Locke, 26.
9. John Locke, 28-29.
10. John Locke, 33.

civil interest.[11]

Finally, Locke grants certain conditions for intolerance. He states that we should not tolerate cases of religious intolerance, atheism, and actions that adversely impact the common good.[12] Intolerant religious people pose a threat to individual liberties and the freedom found in joining a church voluntarily, whereas atheists are not to be trusted because they "deny the being of God, Promises, Covenants, and Oaths," which Locke believes are key directives for a law-abiding society.[13] Without the conviction of God, who is to say that they can be trusted? For this reason, Locke labels their disbelief and lack of obligation to what is moral as dangerous to society.[14] Concerning the state's intervention in church matters, it is only acceptable if the actions of the church jeopardize civil interests,[15] such as taking away a member's property, or infanticide.[16] The government is suited to protect civil interests; liberty included, meaning that any unwarranted interference in spiritual matters would be overstepping the church's jurisdiction and infringing on the people's interest they swore to protect.

Against Locke's criteria concerning toleration are the rules and regulations of *Kallipolis*. The city is comprised of three classes: guardians, auxiliaries, and artisans.[17] Since the city is to be feverish, filled with relishes, its residents will need excess land to produce a generous amount.[18] However, the acquisition of land is not without its consequences; it will inevitably lead to war.[19] Ergo, *Kallipolis* will need an army; they will be called auxiliaries, from their class, guardians will be chosen to govern based on natural capabilities

11. John Locke, 31, 33.
12. John Locke, 23, 51, 39.
13. John Locke, 51.
14. ibid.
15. John Locke, 42.
16. ibid.
17. Plato, in *The Republic of Plato,* trans. Allan Bloom (New York: Basic Books, 1968), 415a.
18. Plato, 373d
19. Plato, 373e

and their performance throughout their education.[20] Consider the guardians and auxiliaries as drafted, for the people's future does not belong to them but to the city makers, who, with greater purpose, direct their path.

The first regulation exacted on the city is censorship. Socrates recognizes that in the early years of life, we are most impressionable.[21] As a result, he and his interlocutors resolve to censor the stories of the gods and Hades.[22] Instead of telling the children stories of "gods [making] war on gods" or lamenting wails echoing from the depths of Hades, they will share the finest tales with respect to virtue.[23] As Socrates said, the guardians must be "god-revering and divine."[24] Reading the children's poems from Hesiod or Homer will corrupt them and make them like the gods. To avoid that, they rewrite the tales, ultimately stripping them of the choice of religion.[25] With one narrative, there is nothing else to choose from, no freedom in faith, only a collective belief.

Although uniformity is a priority for Socrates, it challenges all conceptions of tolerance written by Locke. Censorship in *Kallipolis* is not a mother's way of guarding her child until they grow wise enough to decide for themselves what to believe. Instead, it is the expropriation of civil interest and the city makers' assurance that they can exact control without interference. Rewriting the gods' stories is an act of violence towards the people, not physically, but spiritually. They are incubated in an environment where their beliefs are provided, and they are prevented from challenging them. Nevertheless, it is what Socrates is willing to sacrifice for the sake of unity and for the function of greater society.

Let us consider the second rule, a lie masked as human beings' creation to ensure submission. Essentially, Socrates creates a narrative that functions as propaganda. In book three, Socrates suggests that he

20. Plato, 414b
21. Plato, 377a
22. Plato, see 378b, 386c
23. Plato, 378c, 387d, 378e
24. Plato, 383c
25. Plato, see 378d

and the others should "contrive one of those lies" in the case that their actions are challenged.[26] The lie is comprised of two consequential elements: being born of the earth and blood infused with a metal that delineates one's role in the city.[27] The story states that the censored education received, in actuality, was the children being fashioned and reared under the earth, only to be spat out when their mother, earth, had completed them.[28] Furthermore, their mother mixed the ground metals into their blood, predetermining the class in society they would be assigned to.[29] As a result, the guardian class is obliged to defend, for they are seen as chosen. Whereas craftsmen should be content as providers of the city because earth mother did not establish them as a protectorate. As long as the people of *Kallipolis* believe the lie of their creation, they will be hesitant to challenge their allocated role, regardless of their feelings towards it.

But there to oppose the despotism of Socrates' city is Locke. The victor of religious tolerance, along with liberty. The people of the city need to be free to choose their own path. So, Locke stands with his doctrine in hand, challenging the oppression in the city, proclaiming liberty as a right and not a privilege. Still, Socrates refuses to hear, sure that manipulating the people into positions of need: protector and provider, will produce the desired outcome of unity which implies peace. But as maintained by Locke, it is the right of government to secure civil interest, not to efface them.[30] Can one not claim that happiness adds years to one's life? Since health is a clause of civil interest, should it not be preserved? Joy cannot be found in a task that one has no interest in. Regardless of the lie, there will be ill feelings towards the life that the city's people are born into. But, alas, Socrates chooses the city's happiness – the functionality – over individuals, remaining unconcerned so long as there is no uproar.[31]

Another of the city's laws is the loss of personal belongings.

26. Plato, 414b
27. Plato, 414e-415c
28. Plato, 414e-d
29. Plato, 415a
30. John Locke, see 46.
31. Plato, 420b

To ensure no malice or negative emotions amongst the guardians, Socrates proposes the abolition of private property.[32] He remarks that "no one will possess any private property except for what's entirely necessary."[33] In the city of *Kallipolis*, a home and immediate family is seen as inessential.[34] To Socrates, the guardian class should be denied these interests and worldly luxuries because they will turn them savage and green with envy, to such an extent that they will turn against their comrade.[35] Since conflict within the city and amongst its protectorates would defeat the purpose of suppression for the sake of unity, it is decreed that all triggers of jealousy are to be removed. Having nothing will make all equal and, therefore, content.

Unfortunately for Socrates, such justifications do not persuade Locke, who emphasizes the importance of private property. In Locke's letter regarding toleration, he addresses the prohibition of property by the church.[36] Bishops and priests are not permitted to deprive a man of his liberty or worldly goods, including a home.[37] Equally, the city makers, who have imposed themselves on a community, are not authorized to take the private property of a man. Their power lies in security, not the seizing of belongings. In doing this, they extract all authority from their guardian class, transferring that power undemocratically to themselves, further infringing on their rights. It is imperative to note that what does not belong to the people will belong to the city makers, the bearers of all authority.

Turning to the fourth supervision for the city, women – the governors of the home at this time – will be considered viable participants in guardianship. Although it is agreed upon by Socrates and his interlocutors that women are weaker than men, they also agree that women are capable of being spirited and philosophical like male guardians.[38] Therefore, women "must also be chosen to

32. Plato, 416d
33. Ibid.
34. Plato, 416d, 457d
35. Plato, 416b
36. John Locke, 33.
37. Ibid.
38. Plato, 456a

live and guard with such men."[39] Despite the appearance of feminism and support for women in war, Socrates displaces women from their sphere of influence. He denotes that women will always be lesser than their male counterparts in guardianship, yet proceeds to extract them from the home, a place they have control. This is done in two ways: the new allotment of roles in the military and the heist of children. One implication of the new creation story discussed is the denial of family, particularly mothers.[40] If the earth is the creator, then no child will know their biological parents, nor will the mother's plight in child labour be acknowledged, and she will be forbode from knowing and loving her child as her own.

Perhaps the relationship between a mother and child is not directly parallel to any law regarding civil interest; however, implicit connections can be made. Life is a civil interest, and until the age of maturity, the life of a child is under their parents' care.[41] Yet, Socrates and the others have fled with the children bred by the guardians, taking the "offspring of the good and [bringing] them into the pen to certain nurses who live apart in a certain section of the city."[42] The life of the child belongs to the parent, and yet nurses ensure anonymity, using all sorts of devices to confuse the mothers about who their child is.[43] In this sense, having the supposed "security" of the collective ownership of children is a guise for taking children away from their families to indoctrinate them. Can one not consider the well-being of their child's life and the right to raise them a civil interest? In the legal sense, and according to Locke, children are worldly belongings. Therefore, the denial of motherhood is, yes, an intolerable act, but also a crime. Additionally, by separating mother and child, the city makers are taking up a post that is not theirs, educating infants with lies and fabricating reasons for them to remain loyal and compliant to the city as they grow.

Lastly, we turn to look at the final brawl between the two

39. Plato, 456a
40. Plato, 414e-d
41. John Locke, 26
42. Plato, 460c
43. Plato, 460d

philosophers, Locke and Socrates. At the beginning of *A Letter Concerning Toleration*, Locke condemned the tyrannical zealots for brutality and those who mistreat others in the name of God.[44] This time it is Socrates he turns to; Socrates he denounces for his despotic city creation. Locke's critique surpasses religion; it expands to include the civil interests left behind when building *Kallipolis*. His retort is much broader than it appears; it resists not only religious intolerance but the oppression of the individual and the loss of identity. In Socrates's city, all have become one. There is no independent body, only the artisan, auxiliary, and guardian, an amalgamated creature contrived of monotonous moving parts. There remains no delineation, and it is Socrates' who writes that, yes, this is just. Why? Because justice is the minding of one's own business, doing your part to keep the gears of the city turning peacefully.[45] The question remains, at what cost? The loss of identity, of true family, of independent thought. In *Kallipolis*, the people are not their own, and that is the central problem. The freedom described by Locke in a religious society, the voluntarism, cannot be found in any area of Socrates' city creation.

Although Socrates has won the battle in the city, he has lost the war. It is clear that Socrates is working towards ultimate conformity and unity, while Locke's ends are aimed at individual liberty. However, suppressing human desire and shielding people from the world for the sake of a harmonious society will always be unfruitful. For censorship narrows the lens through which we see the world, prohibiting us from engaging in the nuanced discourse around belief systems and identity. And the class system proposed would further exacerbate a lack of diverse conversation. It is human nature to inquire about the world surrounding us, whether it is to find a higher purpose or follow one's passions. Liberty provides that opportunity for individual goals in ways a uniform society could not. For this reason, Locke's negotiations of autonomy through means of toleration stand out as more appealing. Yes, there will be ideological disputes, but there can be peace through a mutual agreement to disagree. Rather than live in Socrates' city, where unity strips us of

44. John Locke, 24
45. Plato, 433b

our identity, Locke's conception provides freedom for self expression, and a community built on tolerance, making Locke, as opposed to Socrates, the ultimate champion of freedom.

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Consequences of the *Nosema* infection in Honeybees and the Physiological Aspects of Caste Determination

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Abstract: *Nosema apis* and *Nosema ceranae* are primary stressors of honeybees that induce the *Nosema* infection. Honeybees that contract it have decreased levels of ATP and a reduction in digestive enzymes. Their midgut cells also fail, and this results in them becoming energetically stressed. Moreover, *Nosema*-infected honeybees have increased juvenile hormone titer, decreased vitellogenin expression, degenerated hypopharyngeal glands, and decreased royal jelly protein secretions, leading to severe implications in honeybee caste determination. Adaptations of *Nosema*-tolerant honeybees include the ability to maintain energy stores, acquiring a mechanism that mediates an anti-apoptotic gene, and the upregulation of genes in the *Toll* signaling pathway. The understanding of such concepts can enable queen bee breeding programs to prevent honeybee populations from declining as a result of the *Nosema* infection.

Introduction

Honeybees (*Apis millifera*) are crucial pollinators of the ecosystem as they have the highest floral visitation frequency (Hung et al., 2018). To initiate new plant generations, many crops depend on them for pollen transfer. Honeybees are eusocial insects that have a highly organized reproductive caste system. A hive consists of a single queen, and countless female workers and male drones. Since female workers are sterile, only queen honeybees possess the ability to produce fertilized eggs when inseminated by male drones (Wharton et al., 2007). Thus, without a queen honeybee, reproduction will cease and along with it, the colony's existence. Worker bees are also very important as their role is to secrete royal jelly (RJ) and feed it to newly hatched (i.e., eclosed) larvae (Buttstedt et al., 2018). RJ is a secretion that consists of several components such as fatty acids and proteins. The primary protein is called "major royal jelly protein 1" (MRJP1) and it is synthesized by the hypopharyngeal gland of worker bees (Buttstedt et al., 2018). MRJP1 in its monomeric form is

called “royalactin” and royalactin has been reported as the key factor that dictates caste determination (i.e., the development of a queen or worker bee) by impinging on the epidermal growth factor receptor (*Egfr*) signaling pathway (Formesyn et al., 2014; Kamakura, 2011).

One stressor that honeybees have faced for over a century are microsporidian fungi called “*Nosema* parasites”. Although there are numerous *Nosema* species, honeybees appear to only be infected by *Nosema ceranae* (*N. ceranae*) and *Nosema apis* (*N. apis*) (Borges et al., 2020). When honeybees ingest their spores, they contract the *Nosema* infection, and the spores will begin to proliferate extensively in their midgut. Since *Nosema* parasites rely on their host for energy, this infection alters the metabolic pathways of honeybees and steals their ATP, thereby energetically stressing them (Holt et al., 2013; Mayack & Naug, 2009; Roberts, 1968). In addition to inducing energetic stress, the *Nosema* infection causes hormonal consequences such as increasing juvenile hormone (JH) titer in honeybees (Ares et al., 2012; Goblirsch et al., 2013). JH refers to a class of hormones involved in several roles such as nutritional status (Holt et al., 2013) and stress resistance (Ares et al., 2012). JH is also associated with the hypopharyngeal gland and high levels of JH lead to the degeneration of the gland (Liu, 1989; Rutz et al., 1976). This in turn decreases the synthesis of RJ proteins, such as MRJP1 (Deseyn & Billen, 2005; Hu et al., 2019), which interrupts queen caste determination (i.e., the development of a queen bee). Another consequence of the *Nosema* infection is that by increasing JH titer, vitellogenin (Vg) levels will decrease through a negative feedback loop. Vg is a yolk-forming protein that has antioxidant properties, and high levels of it promote honeybee longevity (Corona et al., 2007; Seehuus et al., 2005). Therefore, not only does the *Nosema* infection disrupt honeybees at the level of their colony (i.e., caste determination) but also at the level of individual bees (i.e., energy and longevity reduction).

This paper aims to recapitulate existing studies that explore the consequences of the *Nosema* infection in honeybees and emphasizes the role and physiological mechanism of RJ in caste determination. This paper will also review several adaptations that *Nosema*-tolerant honeybees have developed against *N. apis* and *N. ceranae*.

The *Nosema* Infection Induces Energetic Stress in Honeybees

When honeybees contract the *Nosema* infection, they are energetically stressed as *Nosema* parasites induce changes in their metabolic pathways (Holt et al., 2013; Mayack & Naug, 2009; Roberts, 1968). For example, *Nosema* pathogens may associate with the mitochondria in the gut cells of honeybees and steal their ATP via ATP transporters (Holt et al., 2013). Moreover, Higes et al. (2007) and Liu (1984), as quoted by Mayack & Naug (2009), have observed that *Nosema* parasites consume carbohydrates, like trehalose, from the gut epithelial cells of honeybees. This drop in nutrient levels will increase the need for feeding in these bees. However, since *Nosema* parasites also reduce digestive enzyme secretions (Mayack & Naug, 2009) and cause midgut cells to fail (Roberts, 1968), the absorption of nutrients is vastly reduced, so honeybees are unable to consume enough food to compensate for the energy loss. In consequence of this energetic stress, *Nosema*-infected honeybees incur low fitness, and their ability to survive is reduced ($p < .0001$; Mayack & Naug, 2009). This has reproductive implications because if a queen bee is infected, she will not have sufficient energy to reproduce.

Adaptations for Tolerating the *Nosema* Infection

Since *Nosema* parasites have been a threat to honeybees for over a century, some lineages of honeybees have undergone adaptations to better tolerate the *Nosema* infection (Huang et al., 2012; Kurze et al., 2015; Kurze et al., 2016). Kurze et al. (2016) obtained bees that were sensitive to the *Nosema* infection and bees that were tolerant to the infection. *Nosema*-tolerant honeybees had significantly higher trehalose concentrations compared to the *Nosema*-sensitive bees ($p < .05$). Thus, the authors concluded that honeybees can adapt to the energetic stress induced by the *Nosema* infection by preserving certain energy stores (Figure 1 in the Appendix). In a separate study, Kurze et al. (2015) stated that for the *Nosema* infection to be successful, these parasites must inhibit apoptosis in the honeybee epithelial cells, a natural defense mechanism that occurs during infections. Therefore, when Kurze et al. (2015) examined why some honeybees were better able to tolerate the *Nosema* infection, they focused on genes that are involved in apoptosis. *Nosema*-tolerant

honeybees had a significantly lower expression of the iap-2 gene compared to *Nosema*-sensitive honeybees ($p < .001$). Since iap-2 is an anti-apoptotic gene, the authors speculated that *Nosema*-tolerant honeybees must have adapted a mechanism that downregulates its expression. (Figure 2 in the Appendix). A third adaptation was studied by Huang et al. (2012). The authors found that *Nosema* infected honeybees that have upregulated genes in the *Toll* pathway successfully tolerated the infection ($p < .05$), suggesting that the upregulated genes may enhance the immune response of honeybees and thus subdue the virulence of the infection.

The Physiology Behind Royal Jelly and Caste Determination

Honeybee colonies consist of two types of female castes: fertile queen bees and sterile worker bees (Wharton et al., 2007). What dictates which caste a larva belongs to (i.e., caste determination) depends not on its DNA but rather its diet (Buttstedt et al., 2018; Drapeau et al., 2006; Kamakura, 2011). For a queen to develop, the larva must be fed large amounts of RJ after the first three days of eclosion. In the absence of RJ, the larva will fail to develop into a queen and instead develop into a worker (Drapeau et al., 2006).

RJ is associated with body growth and ovary development and its main protein component, royalactin, has a major role in caste determination. The association between RJ and queen caste determination involves a very complex pathway. RJ first manipulates the epigenomic and hormonal response system of the larva before impinging on DNA modifications (e.g., methylation, histone modification) and gene regulation (Maleszka, 2018). Such processes will ultimately lead to queen tissue and organ differentiation (Figure 5 in the Appendix).

According to Kamakura (2011), the main physiological pathway behind queen caste determination is the epidermal growth factor receptor (*Egfr*) signaling pathway, and it involves royalactin impinging on several components. This includes activating phosphorylation enzymes p70 S6 kinase (S6K) and upregulating mitogen-activating protein kinase (MAPK). S6K is involved in increasing cell size, so when S6K is activated, it behaves as a morphogenic factor that increases the body size of queens.

When royalactin activates MAPK, MAPK shortens the rate of developmental processes and increases ovary size. To validate that royalactin is the ligand responsible for queen-caste determination and not another component of RJ, Kamakura (2011) fed honeybee larvae either RJ or royalactin. Both royalactin-fed and royal jelly-fed bees had comparable results. Both samples developed into queens and had a significant decrease in developmental time ($p < .01$), a significant increase in ovary size ($p < .01$), and a significantly heavier weight at eclosion ($p < .01$) when compared to controls (Figure 3 in the Appendix). To confirm that the *Egfr* signaling pathway was involved, Kamakura (2011) performed a loss of function experiment where he suppressed *Egfr* in honeybees using RNAi. In the absence of *Egfr* expression, bees were unable to develop into queens, and there was an increase in developmental time and decrease in ovary size and weight at adult eclosion. See Figure 4 in the Appendix.

One thing to consider is that while researchers are supportive of the involvement of *Egfr* signaling in honeybee caste determination (Formesyn et al., 2013; Maleszka, 2018), there is debate on whether RJ/royalactin is the sole ligand that underlies caste determination (Buttstedt et al., 2016; Maleszka, 2018). For example, Buttstedt et al. (2016) failed to replicate the findings of Kamakura (2011) and challenged the notion that royalactin independently dictates caste determination. Moreover, Maleszka (2018) argues that from an evolutionary perspective, it is illogical for caste determination to rely on just one protein when the fertility of queen bees is such a vital component for the persistence of honeybee colonies. These criticisms suggest that more research is needed before a reliable theory on honeybee caste determination can be universally accepted. However, regardless of whether royalactin is the sole ligand or not, it is evident that it has a crucial role in queen caste determination. Thus, it is important for honeybees to either avoid or adapt to the *Nosema* infection, so the hypopharyngeal gland remains intact to continue secreting RJ for the formation of new fertile queen bees.

The Relationship Between Juvenile Hormone, Vitellogenin, and Honeybee Longevity

Increased levels of JH titer result in a decrease in Vg expression

as JH and Vg interact in a negative feedback loop (Corona et al., 2007; Seehuus et al., 2005; Wang et al., 2012). Wang et al. (2012) observed that when the Vg gene was inhibited in honeybees, their JH titer was significantly higher than the control ($p < .05$). Having high Vg expression is important as its antioxidant properties promote honeybee longevity (Corona et al., 2007, Seehuus et al., 2005). In a study by Seehuus et al. (2005), honeybees that were injected with Vg had higher survivorship when exposed to oxidative stress compared to the control ($p < .0001$). Corona et al. (2007) conducted a similar experiment where they compared the survivorship of queen bees with worker bees when exposed to oxidative stress (i.e., paraquat). Since queen bees naturally have higher Vg levels than worker bees, this allowed the queen bees to have higher survivorship ($p < .0001$). See Figure 6 in the Appendix. A higher Vg level found in queens may be an adaptation to increase the survivorship of honeybee populations because queen bees are the sole reproducers in a colony.

Conclusion

Nosema ceranae and *Nosema apis* are significant stressors of honeybees. Once honeybees ingest their spores, their ATP is stolen, their midgut cells begin to fail, and they become energetically stressed. The *Nosema* infection significantly increases juvenile hormone titer in honeybees which leads to the degeneration of their hypopharyngeal gland and a reduction in royal jelly protein secretions. As a result, caste determination is disrupted because the epidermal growth factor receptor signaling pathway requires royalactin to ensue. Furthermore, the longevity of *Nosema*-infected honeybees is significantly reduced as high juvenile hormone titer decreases vitellogenin. In order to move forward in this field, the physiology behind caste determination must be further investigated. As of now, it is uncertain what processes are involved in caste determination, and there are ongoing debates on whether royalactin is the key driver behind the development of a queen. When a better understanding of caste determination is established, researchers can incorporate such data with the known adaptations of *Nosema*-tolerant honeybees (e.g., upregulation of *Toll* genes, lower expression of iap-2) to breed new queens. These queens

can be used to start new colonies or be integrated into existing queenless ones with the goal of re-populating honeybees. By introducing more of these vital pollinators in the ecosystem, the numerous crops that depend on them for fertilization will thrive, and new plant generations will be initiated.

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Appendix

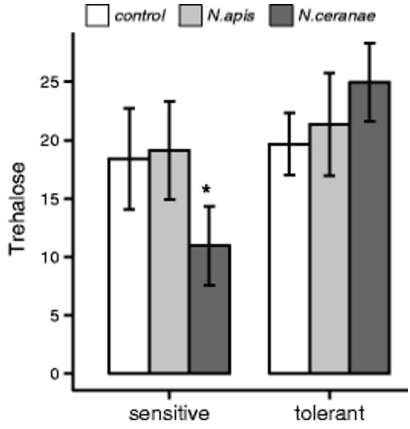


Figure 1. Comparison of *Nosema*-tolerant and *Nosema*-sensitive bees in trehalose concentration.

Note. Control and infected *Nosema*-tolerant bees (n = 63, right) had a higher trehalose concentration compared to *Nosema*-sensitive bees (n = 75, left). Asterisks represent a significance of $p < .05$. Error bars represent standard deviation from the mean (Kurze et al., 2016; Figure 1c).

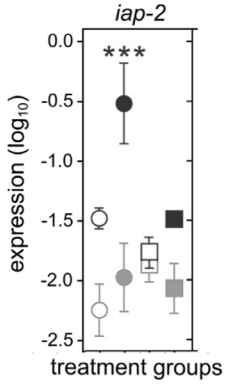


Figure 2. Comparison between *Nosema*-tolerant bees and *Nosema*-sensitive bees in iap-2 gene expression.

Note. Nosema-tolerant bees (TN, n = 63, solid squares) had a significantly lower expression of the iap-2 gene compared to *Nosema*-sensitive honeybees (SN, n = 3, solid circles). TC and TN are controls.

Asterisks represent a significance of $p < .001$. Error bars represent standard deviation from the mean (Kurze et al., 2016; Figure 2).

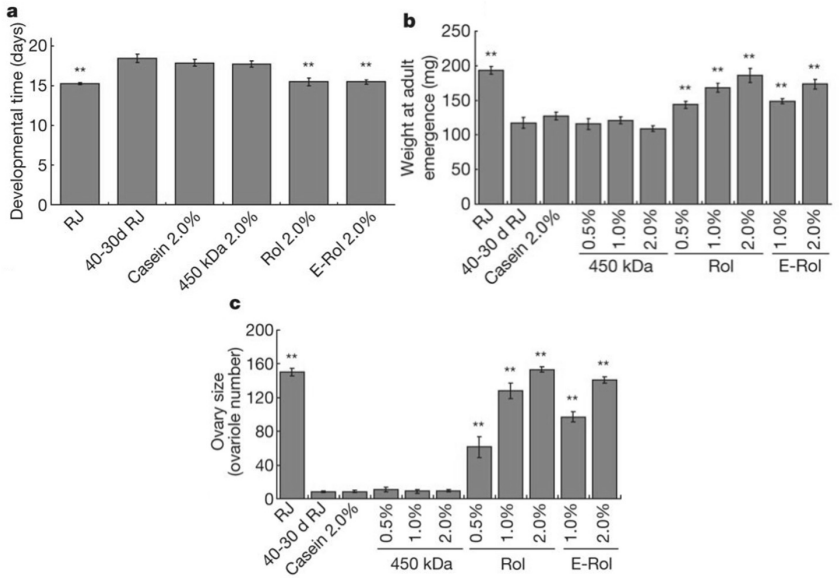
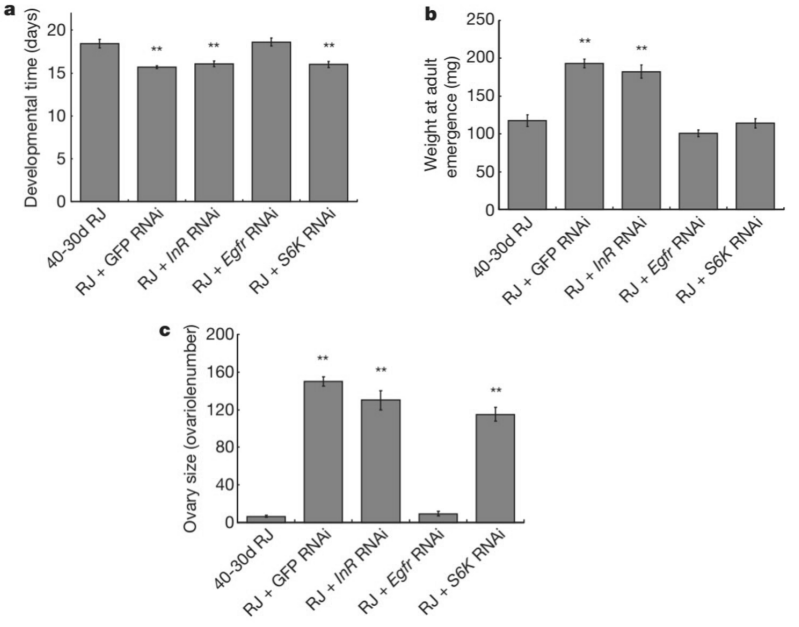


Figure 3. Comparison between royalactin-fed and royal-jelly fed bees in developmental time, weight at adult eclosion, and ovary size.

Note. Royalactin-fed bees (Rol, n = 10-28) and royal-jelly fed bees (RJ, n = 10-28) had comparable results. (*A*) Rol and RJ had a significant decrease in developmental time when compared to the control (450-kDa and casein) bees. (*B*) Rol and RJ had a significantly heavier weight at eclosion when compared to the control (450-kDa and casein) bees. (*C*) Rol and RJ had a significant increase in ovary size compared to the control (450-kDa and casein) bees. Asterisks represent a significance of $p < .01$. Error bars represent standard deviation from the mean (Kamakura et al., 2011; Figure 1).


a
Developmental time (days)
20
15
10
5
0
**
**
**
40-30d RJ
RJ + GFP RNAi
RJ + InR RNAi
RJ + Egfr RNAi
RJ + S6K RNAi
b
Weight at adult emergence (mg)
250
200
150
100
50
0
**
**
40-30d RJ
RJ + GFP RNAi
RJ + InR RNAi
RJ + Egfr RNAi
RJ + S6K RNAi
c
Ovary size (ovariolenumber)
200
160
120
80
40
0
**
**
**
40-30d RJ
RJ + GFP RNAi
RJ + InR RNAi
RJ + Egfr RNAi
RJ + S6K RNAi

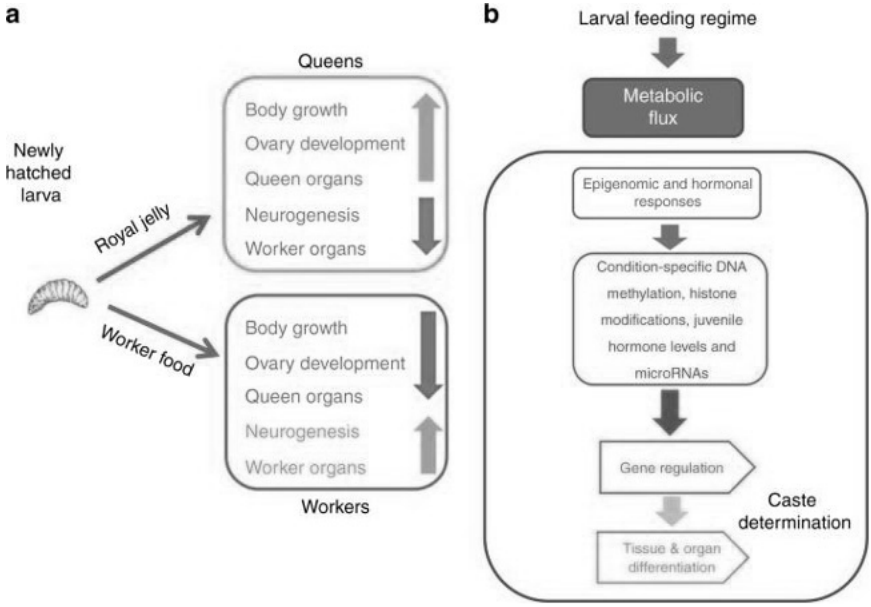

a
Queens
Body growth
Ovary development
Queen organs
Neurogenesis
Worker organs
Newly hatched larva
Royal jelly
Worker food
Body growth
Ovary development
Queen organs
Neurogenesis
Worker organs
Workers
b
Larval feeding regime
Metabolic flux
Epigenomic and hormonal responses
Condition-specific DNA methylation, histone modifications, juvenile hormone levels and microRNAs
Gene regulation
Caste determination
Tissue & organ differentiation

Figure 4 (Top Left). The effects of RNAi in suppressing *Egfr* in honeybees on developmental time, ovary size, and weight at adult eclosion.

Note. (*A*) Honeybees without *Egfr* expression (RJ + *Egfr* RNAi) had an increase in developmental time. (*B*) Honeybees without *Egfr* expression (RJ + *Egfr* RNAi) weighed less at adult eclosion. (*C*) Honeybees without *Egfr* expression (RJ + *Egfr* RNAi) had a decrease in ovary size. Asterisks represent a significance of $p < .01$. Error bars represent standard deviation from the mean (Kamakura et al., 2011; Figure 4).

Figure 5 (Bottom Left). Schematic of the association between RJ and caste determination.

Note. RJ first manipulates the epigenomic and hormonal response system of the larvae before impinging on DNA modifications (e.g., methylation, histone modification) and gene regulation. Such processes will ultimately lead to queen tissue and organ differentiation (Maleszka, 2019; Figure 1).

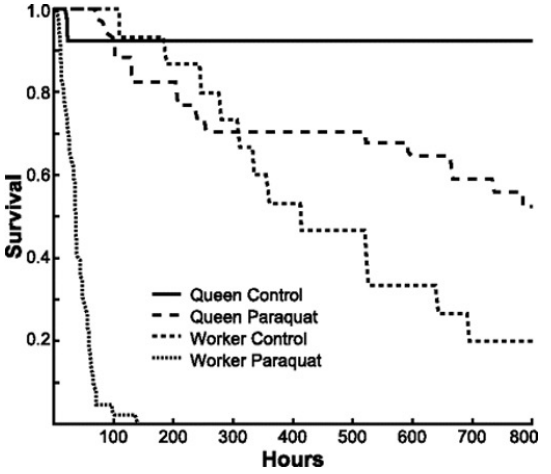


Figure 6. Comparison of the survivorship between queen and worker bees exposed to oxidative stress.

Note. Queen honeybees (long-dotted line) exposed to paraquat have a significantly higher survivorship ($p < .0001$) in comparison to worker bees (short-dotted line; Corona et al., 2007; Figure 6).

Exercise and Neuroplasticity in Brain Injury

Bryan Handoyo Kartono is a fourth-year Neuroscience and Immunology student.

Abstract: Neuroplasticity typically refers to the nervous system's ability to alter, reshape, and reorganize its structure, function, and connections in response to an intrinsic or extrinsic stimulus in order to adapt better to novel situations. Neural networks, depending on experiences, are not fixed, but dynamically occur and disappear throughout the lifetime. Intensive training in motor and cognitive skills and imagination of brain injury movements is thought to contribute to the reorganization of brain activity patterns, which in turn normalizes brain function. Numerous scientific articles discussed the significance of neuroplasticity on recovery following brain injury. The study conducted by Griesbach et al. observed that exercise induces neuroplasticity through the BDNF-related pathway. Studies conducted by Szulc-Lerch et al., Juenger et al., and Chin et al., show that in human subjects, exercise induces neuroplasticity in brain damage caused by radiation in patients with brain tumors, congenital hemiparesis, and traumatic brain injury. With substantial data that shows cellular and cognitive effects caused by exercise in animal models and results to support the impact of exercise in patients with different types of brain injury, strong evidence is available to support the role of exercise in inducing neuroplasticity in patients with brain injury.

Key words: neuroplasticity, exercise, brain damage, brain tumor, congenital hemiparesis, traumatic brain injury, brain-derived neurotrophic factor

Introduction

Neuroplasticity is the incredible ability of the brain to change and adapt. It generally refers to the nervous system's ability to change, remodel, and reorganize its structure, function, and connections in response to an intrinsic or extrinsic stimulus for the purpose of better ability to adapt to new situations[1]. Even though the idea of neuroplasticity just came out recently, it is one of the

most remarkable discoveries in the field of neuroscience. The fact is that neural networks, depending on experiences, are not fixed, but dynamically occurring and disappearing throughout the lifetime[2]. While we repeatedly practice one activity, neuronal circuits are being developed, leading to a better ability to perform the practiced task with less energy[2]. In contrast, once we cease to practice one activity, the brain will reroute these neuronal circuits by a 'use it or lose it' principle[2]. Research showed that various aspects of the brain could be reconstructed even through adulthood[3]. However, the developing brain exhibits a higher degree of plasticity than the adult brain[3]. Neuroplasticity ranges from microscopic changes in individual neurons to larger-scale changes such as cortical reorganization in response to brain injury[4].

The concept of neuroplasticity allows one to explain various phenomena, such as habituation, sensitization to a specific position, medication tolerance, and even recovery following brain injury[2]. As a matter of fact, it is known to be the basis for many of the cognitive and physical rehabilitation treatments following brain injury[1]. It is believed that intense training of motor and cognitive tasks and imagination of movements following brain injury leads to the reorganization of brain activity patterns, which in turn normalizes brain function[5]. The purpose of this review paper is to discuss the efficacy of exercise in inducing neuroplasticity in subjects with brain injury.

Numerous scientific articles have discussed the significance of neuroplasticity on recovery following brain injury in animal models. For instance, by evaluating the effects of exercise following experimental TBI, Griesbach et al. concluded that, in the rats' traumatic brain injury (TBI) model, voluntary exercise could endogenously upregulate brain-derived neurotrophic factor (BDNF) and improve recovery when applied at the appropriate post-injury time window, as they found that exercise dramatically increases the levels of hippocampal phosphorylated synapsin I and phosphorylated cyclic AMP response element-binding-protein (CREB), as well as phosphorylated synapsin I and BDNF[6]. A study conducted by Yamamoto et al. focused on the re-development of neural pathway following brain injury. They found that following a motor exercise for

three months, adult primate brains with motor lesions can rearrange an extensive network to allow motor recovery by enhancing the coupling of sensorimotor and motor commands through rewired fronto-cerebellar connections[8].

Numerous studies also support the role of exercise on neuroplasticity in human subjects. Szulc-Lerch et al., after examining the anatomical T1 magnetic resonance imaging (MRI) data and multiple behavioral outcomes, concluded that exercise in radiation-treated pediatric brain tumor patients has a benefit on the brain as it is associated with increase pre- and postcentral gyri, left temporal pole, left superior temporal gyrus, and left parahippocampal gyrus cortical thickness[9]. Exercise also improves the cognitive function of the brain following brain injury. Chin et al., examined the effect of aerobic exercise on TBI patients and found that aerobic exercise improves various aspects of cognitive function[10]. Juenger et al., the experimenters examined ten patients with congenital hemiparesis which was caused by unilateral cortico-subcortical infarctions in the middle cerebral artery territory that received a 12-day intervention of constraint-induced movement therapy (CIMT)[11]. Following an observation by functional MRI (fMRI), the experimenters concluded that exercise could promote changes of cortical activation in congenital hemiparesis, as they discovered increases in cortical activation during paretic hand movements in the primary sensorimotor cortex of the affected hemisphere as well as improved task performance[11].

Major Results

Exercise Increases BDNF in Animal Models

The study conducted by Griesbach et al. observed that exercise leads to the increment in BDNF (Figure 1), as well as its downstream effectors, CREB, and synapsin I[6]. However, the experimenters also noted that if the exercise is administered immediately after TBI, it will not yield the same result as the molecular response to exercise is disrupted, leading to a delayed recovery time[6]. It will instead lead to a lower level of CREB and phosphorylated synapsin I, as well as the failure to upregulate BDNF[6]. The experimenters also noted that the changes in the amount of BDNF and enhanced synaptic plasticity caused by exercise might improve cognitive performance[6]. This

finding came from the fact that mice from the delayed-exercise group perform better in the Morris water maze test than the early-exercise group[6].

*Figure 1 – SEQ Figure * ARABIC 1 - BDNF immunostaining on day 21 of the post-injury. BDNF was primarily distributed in the hippocampus region of the dentate gyrus and CA3. Exercise resulted in an increase in the number of BDNF[6].*

Exercise in Long-Term Pediatric Brain Tumor Survivors

Szulc-Lerch et al. main research focus is to examine the effectiveness of exercise practice in 28 radiation-treated long-term pediatric brain tumor survivors for neural and behavioral rehabilitation[9]. By using unbiased automated vertex-wise analyses, as seen in Figure 2A, the experimenters found out that exercise leads to an increase in cortical thickness for the right precentral and postcentral gyri[8]. They also recorded an increase in cortical thickness in the left temporal pole, left superior temporal gyrus, and left parahippocampal gyrus[8]. As seen in Figure 2B, Szulc-Lerch et al. also found out that, based on the Deformation Based Morphometry (DBM) results, exercise resulted in increased white matter (WM) volume underlying the right motor and somatosensory cortices, as well as in the parietal lobe[8]. Szulc-Lerch et al. noted that the areas where they found an increase in WM volume, in motor and premotor cortices, also showed an increase in cortical thickness in response to exercise[8].

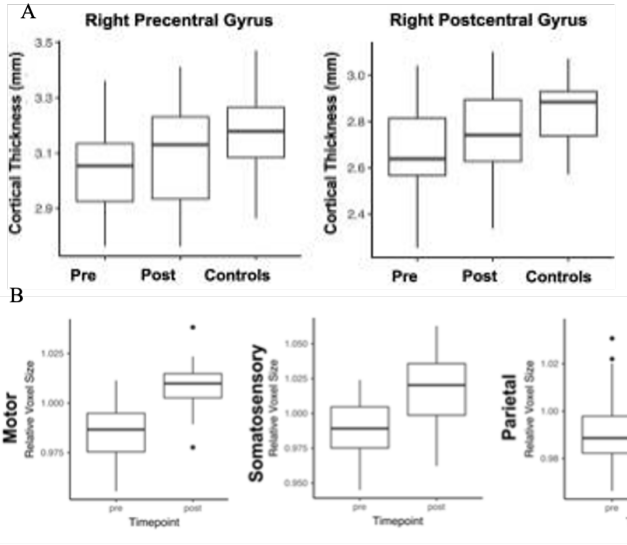


Figure 2 – (A) Comparison of the thickness in the right precentral and postcentral gyrus cortex before (Pre) and after (Post) exercise visualized by boxplots. (B) Increased white matter (WM) volume underlying the motor cortex, somatosensory cortex, and parietal lobe visualized by boxplots[8].

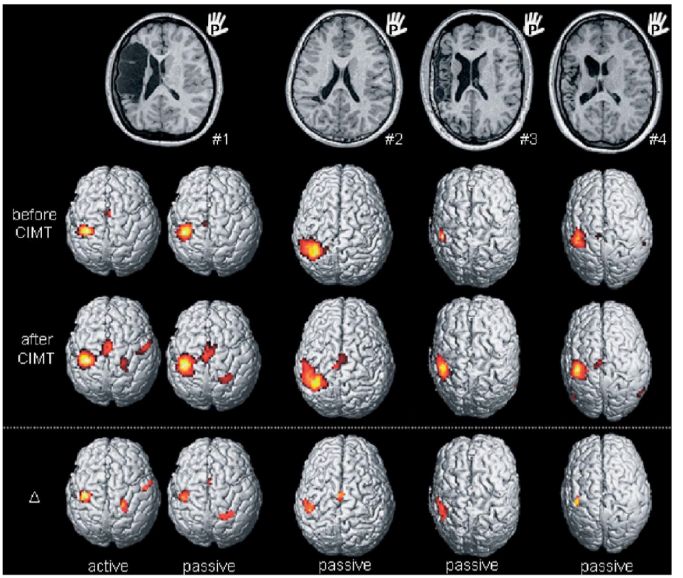


Figure 3 – fMRI activation before and after CIMT during active and passive movements of the paretic hand. Δ indicates significant increases in activation. The brain surfaces were flipped, such that the left side of the picture is the left side of the patients[11].

Exercise in Congenital Hemiparesis Patients

Assessing the impact of CMIT on ten patients with congenital hemiparesis caused by unilateral cortico-subcortical infarctions in the middle cerebral artery is the collective focus of Juenger et al. study[11]. As seen in Figure 3, FMRI during paretic hand movement revealed an increment in activation of primary sensorimotor cortex of the affected hemisphere, in this case, the left hemisphere. In addition, the researcher also found an increase in activation in the interhemispheric fissure, in the primary sensorimotor cortex of the contralesional hemisphere and in the cerebellum.

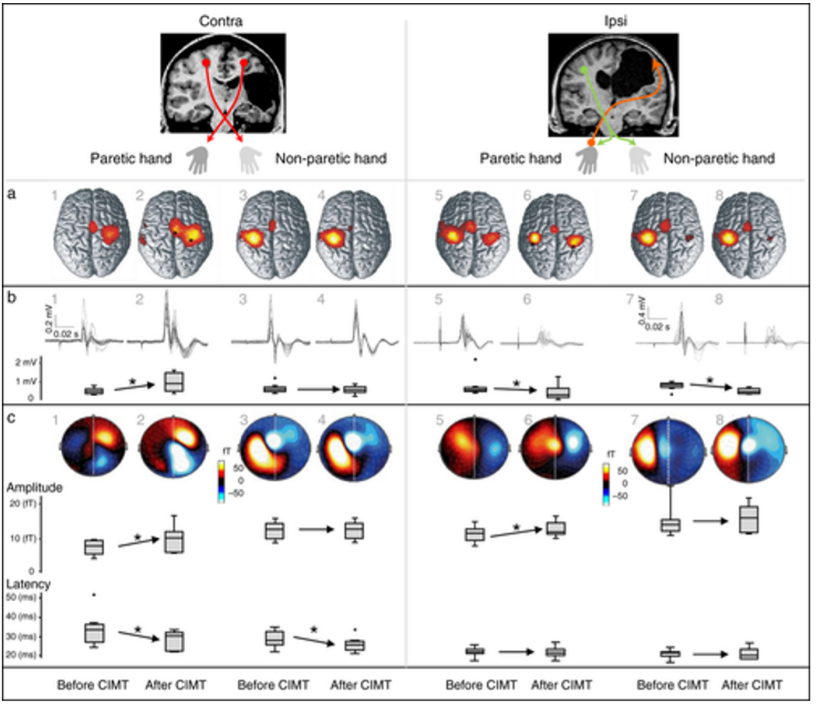


Figure 4 – Changes in the brain after 12 days of CIMT visualized by (a) fMRI, (b) transcranial magnetic stimulation (TMS), (c) magnetoencephalography (MEG). These data shows that the type of corticospinal reorganization in congenital hemiparesis affects the CIMT-induced diverging cortical changes[16].

A later study by Juenger et al. discovered that the type of corticospinal reorganization in congenital hemiparesis affects the CIMT-induced diverging cortical changes[16], such that, as seen in Figure 4, patients with ipsilateral corticospinal projections showed

a reduced transsynaptic primary motor cortex (M1) excitability and reduced synaptic activity during paretic hand active movements after 12 days of CIMT, whereas patients with crossed contralateral corticospinal projections showed an increment in those parameters[16].

Exercise in Traumatic Brain Injury Patients

Chin et al. main research focus is to examine the effect of exercise, specifically aerobic exercise, on cognitive function of TBI patients[10]. Following a supervised intensive aerobic exercise program, TBI patients showed significant improvements in cognitive function[10]. These cognitive functions include the domains of processing speed, executive functioning, and overall cognitive function. The experimenters also noted that the magnitude of the improvements observed may be influenced by the adaptability of the patient's cardiorespiratory system to the aerobic exercise[10]. The positive effect of aerobic exercise on cognitive function was also reported on various study. Voss et al. found a strong association between the improvements in cardiorespiratory fitness and cognitive function in older adults[13], while Kluding et al. concluded that exercise is associated with an improvement in cognitive function in stroke patients[17].

Discussion

Based on the available data showing effects that were induced by exercise in animal models, together with findings to support the effect of exercise in patients with various forms of brain injury, there is significant evidence to support the role of exercise in inducing neuroplasticity in patients with brain injury. The study conducted by Griesbach et al. concluded that, in animal models, voluntary exercise could endogenously upregulate brain-derived neurotrophic factor (BDNF) and improve recovery when applied at the appropriate post-injury time window[6]. This study specifically highlights the importance of exercise on BDNF, as exercise leads to the increase of BDNF, as well as its downstream effectors CREB and synapsin I, excercise will promote brain recovery[6]. However, it is known that the effect is time-dependent as they observed a delayed recovery when exercise is administered too soon after injury. They suggested that it might be caused by metabolic alterations that occur during the post-injury

period[6]. A study conducted by Lee et al. suggested that there is a lower concentration of ATP, which is the primary source of cellular energy, following TBI, and Lifshitz et al. indicated that there is a structural alteration of the mitochondria following TBI[18,19]. Therefore, it is suspected that if exercise is administered too soon, it may enhance ATP loss or redeploy it from functions that are vital for recovery, such as producing synaptic plasticity molecules by introducing an unnecessary additional amount of energy needed at a time when the brain is exhausted. The experimenters also noted that the changes in the amount of BDNF and enhanced synaptic plasticity caused by exercise might improve cognitive performance[6]. It is presumed that the lack of BDNF, synapsin I, and CREB increases reflect changes in selected molecular systems that influence cognitive performance[6]. It is unclear, however, if the same mechanism also applies to humans .

Szulc-Lerch et al. concluded that exercise in pediatric brain tumor patients has a benefit on the brain as it was associated with increase the pre and postcentral gyri, left temporal pole, left superior temporal gyrus, and left parahippocampal gyrus cortical thickness, as well as increased WM volume underlying the right motor and somatosensory cortices, as well as in the parietal lobe[9]. This finding is supported by a study conducted by Chaddock-Heyman et al., in which they discovered that fitness level is directly proportional to cortical thickness in children and adults[12]. The exercise-induced cortical thickness increment may represent brain recovery processes in the context of injury, although it does not follow the development pattern that is normally observed in healthy children[12]. Szulc-Lerch et al. observation on the WM volume is also supported by Voss et al., in which, they observed training-related changes in white-matter structure in human adults[13], as well as a study by Scholz et al., in which they found out that the increase in WM volume is typical following motor-skill learning. Szulc-Lerch et al also suggest that the increase in WM volume in motor and premotor cortices may be caused by the increased neural activity during exercise, which in turn may induce activity-dependent myelination or axonal sprouting and branching, which may lead to increased WM volume that was seen in this study[2].

While Juenger et al. did not specifically look at brain tumor

patients, they also concluded that exercise could induce changes in the brain cortex. In this case, it induces changes in cortical activation in patients with congenital hemiparesis[11]. They suggest that an increment in activation of the primary sensorimotor cortex of the affected hemisphere indicates that even severe lesions acquired early during brain development do not hinder the development of neural circuits that is critical to neuroplasticity in this part of the brain[11]. This study is the first study to observe neuroplasticity activity predominantly in the affected hemisphere, as the contralesional hemisphere is known to be the major player during the reorganization of hand functions[15]. Therefore, this study brought up the possibility that neuroplasticity activity of motor recovery would also occur in the contralesional hemisphere[11]. In contrast, Chin et al. concluded that exercise improves the cognitive function of TBI patients[10]. It is suspected that cardiorespiratory fitness gains may be a determinant of the observed improvement in cognitive function[10].

All in all, the current existing human studies, including studies from Szulc-Lerch et al., Juenger et al., and Chin et al., showing enhanced neurocognitive outcomes for patients with various kinds of brain injury who participated in exercise supports the need for a supervised prospective study looking at the effect of exercise on cognitive recovery. While the exact mechanism underlying the neuroplasticity in the human brain following brain injury is unclear, it is possible that, as proposed by Griesbach et al. and Chytrova et al., the BDNF, synapsin I and CREB play a significant role in promoting brain recovery[6,7]. These studies have some limitations. Most of these studies have small sample sizes. A small sample size leads to several problems, such as a higher probability that the results obtained from the study are due to chance, as well as the study does not represent the general population, which can render the study useless. Another limitation is that most of these studies did not look at long term effects, which means that we did not know whether the changes observed in this study ceased or maintained after completion of the training.

Critical Analysis

Several types of research indicated that neurogenesis

following brain injury in rodents was correlated with the upregulation of the BDNF, an omnipresent growth factor of the central nervous system (CNS), in the rodent hippocampus and that this process was associated with enhanced performance in temporospatial memory tasks[6,7]. The link found between cellular regeneration and enhanced neuroplasticity makes the signaling pathways by which exercise promotes hippocampal cell growth and in the potential for newly-born neurons to perform in the context of traumatic cell loss interesting. This also raised the possibility of the role of exercise in enhancing neuroplasticity to promote recovery following brain injury as a therapeutic intervention. Many kinds of research have helped to explain the molecular and cellular changes that occur following exercise in the hippocampus. Current work indicates that exercise promotes neuroplasticity by affecting the cellular regeneration mechanism that occurs through BDNF upregulation through a pathway that includes a CREB and synapsin I[6]. More research also indicates that the environment of exercise upregulates several proteins that play a role in energy metabolism and synaptic plasticity if administered at the right time[6].

An increasing number of retrospective population-based research also supports the role of exercise on neuroplasticity in human studies. Nevertheless, as convincing as these studies are, they only demonstrate correlation, not causation. Research on exercise and neuroplasticity following brain injury in humans provide important insights into the potential positive effects of exercise on neuroplasticity for several important reasons. Despite the variation of exercise, time after injury, and study parameters, the current literature implies that patients with a brain injury can participate safely in exercise. Several studies on human subjects also investigated the effect of exercise on various kinds of brain injury. It has been proven that exercise work on brain damage caused by radiation in brain tumor patients, congenital hemiparesis patients, and traumatic brain injury patients[9,10,11]. However, given the lack of research examining the role of exercise in promoting brain recovery, there is limited evidence to define the extent to which exercise will improve recovery mechanisms such as plasticity, regeneration, etc.

Future Directions

Current studies on exercise and neuroplasticity accentuate our narrow knowledge of the mechanism through which neuroplasticity takes place and suggest that further investigation in this area is critical. Researchers should resort more to testing the effect of exercise on a specific brain mechanism that is known to promote brain recovery. For instance, the researcher can opt to investigate BDNF in humans with brain injury, as according to animal models, the upregulation of BDNF and its related downstream effectors plays a role in promoting neuroplasticity, which in turn helps brain recovery. Results from this experiment might provide us an insight into how exactly exercise might induce neuroplasticity in patients with brain injury. While we expect to see an increase in the amount of BDNF in the brain, a negative result does not necessarily mean the study is a failure; it just simply eliminates the possibility that exercise induces neuroplasticity through the BDNF-related pathway. It is essential to specify which kind of brain injury the researcher's are investigating as, from the previous sections, we know that exercise induces a different type of effect depending on the type of brain injury. Thus, different kinds of brain injury might have its own specific recovery mechanism that is unique from one another.

We can also do an experiment in BDNF-knockout mice. As mentioned earlier, the upregulation of BDNF and its related downstream effectors is essential in promoting brain recovery through neuroplasticity. While we expect to see little-to-none improvement on BDNF-knockout mice following brain injury, a different result does not mean that the study is controversial; it means that there might be another pathway that promotes brain recovery, and this leads to more thorough research on identifying that particular pathway.

We can also test this at a different time period of when the exercise was administered as based on Griesbach et al., exercise will upregulate the expression of BDNF and its related downstream effectors only if administered at the right time[6]. It is suspected that we will not see an increase in BDNF and its related downstream effectors if exercise is administered too soon after the brain injury occurs . However, a negative result might mean either time is not important

in human subjects or exercise does not affect neuroplasticity through the BDNF-related pathway. It is therefore essential to remove the possibility of exercise acting on the BDNF-related pathway by doing this study after a considerable amount of time, considering the result of the study by Griesbach et al[6]. It is also important to observe long-term effects that might be present following the exercise training.

It is also interesting to test the effect of a different kind of exercise on brain plasticity following brain injury. The studies mentioned in this paper have different types of exercise, such as aerobics, cardio, and even a therapy that has a specific set of different kinds of exercises. Different kinds of exercise might exert a different kind of effect, and even if they did exert the same kind of effect, it might affect the brain through a different kind of pathway.

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Techniques and Literature Investigating NAP, NAP Target Genes and NAP Regulators On General Senescence of Plants

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Abstract: Plant senescence is a process characterized by biomacromolecules degradation, excessive water-loss leading to desiccation, and nutrients remobilization. This process is an important part of the plant life cycle and is often the final stage; thus, controlling plant senescence can have a myriad of potentially beneficial effects, not just in science. For example, if senescence is delayed, plant lifespan can substantially increase. NAP is a transcription factor that is primarily responsible for leaf senescence and fruit senescence in *Arabidopsis* while having similar functions in other plant species. In the efforts of studying NAP, many i*n vivo* and *in vitro* techniques were used, such as generating loss-of-function and gain-of-function NAP mutants, pull-down assay, and gene expression profiles. Of these techniques used, the ideal *in vivo* techniques to further investigate NAP is NAP mutants and Y1H analysis while the ideal *in vitro* techniques are qPCR, pull-down assay, and EMSA. These techniques are effective since they can often incorporate temporal components in the analysis. However, the *in vitro* techniques have limitations because they do not preserve the complex natural environment in which NAP functions, which could potentially skew the results and the interpretations.

Abbreviations: Gibberellin (GA); Abscisic Acid (ABA); Quantitative Real-Time Polymerase Chain Reaction (qPCR); Yeast 1 Hybrid (Y1H); Electrophoretic Mobility Shift Assay (EMSA)

Introduction

Plants have conserved mechanisms for many fundamental biological processes like senescence. Understanding the mechanisms of various tissues' senescence can have a great impact on how plants can be better fertilized, grown, stored, and developed. This understanding would contribute to model organism development and better experimental control of existing model organisms' senescence.

The real-world applications on agriculture could greatly benefit the society because controlling the senescence process can affect how many fruits and vegetables are being modified, farmed, and stored. There had been many studies that used a plethora of different techniques and experiments to investigate NAP in different processes in different plants (Chen, 2011; Fan, 2015; Kou, 2012). The main goal of the review is to understand the role of NAP, specifically the downstream effectors of NAP, regulators of NAP as well as the techniques used to study NAP. This review will investigate the role of NAP in plant senescence of leaf, fruit, and flower tissues across different species with a focus on *Arabidopsis thaliana (Arabidopsis)* as well as the strengths and limitations of various experimental techniques and protocols performed to investigate NAP.

Senescence

Senescence is an important and often required part of plant growth, development, and aging that occurs in different tissues. It is age-dependent and inducible with stress such as dark treatment, often involving phytohormones like GA or ABA that regulate certain cellular processes like chlorophyll degradation, ion leakage, etc (Lei, 2019; Yang, 2014). These processes can be regulated by various specific transcription factors such as NAP, a transcriptional factor from the NAC family, are involved in different processes contributing to senescence (Kim, 2013).

NAP & Senescence In *Arabidopsis*

In *Arabidopsis*, GA's role in senescence and NAP is shown by GA3 (bioactive form of GA) treatment versus water treatment that showed the levels of NAP and senescence increased in GA3 treated leaves compared to water treated leaves through qPCR (Lei, 2019). The role of NAP in GA signaling is further tested using a pull-down assay that showed that NAP physically interacts with and is inhibited by RGA and GAI, two DELLAs proteins that are degraded by GA (Lei, 2019). This suggests that NAP is normally inhibited by DELLAs, when a GA is released in response to stress or age. The DELLAs are then degraded and NAP is free to bind to AAO3 and SAG113 promoters to activate their transcription, leading

to chlorophyll degradation promoting leaf senescence (Yang, 2014; Zhang, 2012).

NAP binding with the AAO3 and SAG113 promoters was confirmed by EMSA, showing that NAP binds to a segment 162 to 196 bp before the AAO3 start codon and 9 bp core sequence inside the SAG113 promoter, respectively (Yang, 2014; Zhang, 2012). After NAP is bound and AAO3 is expressed, the stay-green phenotype in extended darkness is suppressed. Endogenous ABA determination showed that ABA levels have increased which corresponds to increased senescence (Zhang, 2012). Overall, the data showed that AAO3 expression leads to the biosynthesis of ABA, a senescence-inducing hormone that causes chlorophyll degradation leading to senescence, especially in the leaves and sepal (Yang, 2014). The SAG113 gene encodes for a PP2C family protein that is involved in water-loss control, therefore once expressed, a regulatory chain of ABA-NAP-SAG113 PP2C is formed (Zhang, 2014). This is how the SAG113 PP2C gene along with NAP and ABA prevents stomata of senescing leaves from closing, accelerating water loss, and desiccation leading to greater senescence (Zhang, 2014; Fan, 2015). Using RNA gel-blot analysis, it is also shown that the actions of NAP and SAG113 are sensitive to the ABA level, in that more ABA leads to greater activity of the ABA-NAP-SAG113 PP2C chain (Zhang, 2014).

Besides GA and DELLAs interactions, NAP is also regulated by an H3K27me3 demethylase REF6 (Wang, 2019). Using gene expression profile and EMSA, it is demonstrated that REF6 functions by epigenetically upregulating NAP and other senescence promoting genes, leading to greater chlorophyll degradation and overall senescence (Wang, 2019).

NAP is also involved in silique (fruit) senescence by stimulating ethylene biosynthesis, perception, and signaling, as well as ethylene-stimulated respiration (Kou, 2012). Similar to SAG113, NAP works with ABA to control fruit senescence by promoting stomata opening (Fan-2015; Kou-2012).

NAP In Other Plants & Other Non-Senescence Functions

Functions of the NAP gene are conserved among many plants, often serving similar functions in leaf and fruit senescence (Kou, 2012; Chen, 2011). For example, it is shown through expression profile analysis that NAP in *Gossypium* functions similarly to NAP in *Arabidopsis* (Fan, 2015). In peaches, there are seven peach NAPs, and through qPCR it was found that the NAPs, in different combinations, are involved in reproductive organ growth, flower, leaf, fruit senescence, and fruit ripening (Li, 2016).

Besides promoting senescence, NAP has also been found to function in embryogenesis, root morphogenesis, seed development, salt, drought, and H_2O_2 stress (Fan, 2015; Kim, 2013).

NAP Techniques

Throughout the literature on NAP and its role in plant senescence, one commonly used technique is generating NAP mutants to observe phenotypic changes like delayed or premature senescence, response to ABA, and ethylene (Kim, 2013; Zhang, 2014; Kou, 2012). This *in vivo* way of observing the changes brought on by specific gene mutations and treatments is effective in showing the overall effect as well as preserving the complex natural environments of cells (Lei, 2019). Another *in vivo* technique that can be used is Y1H analysis that uses a reporter LacZ gene to confirm promoter binding in transformed yeasts (Zhang, 2012). This *in vivo* technique allows researchers to observe promoter binding and gene activation. However, its limitation is that it must be performed in yeasts and that do not possess the same environment found in *Arabidopsis* cells (Kim, 2013; Zhang, 2012; Yang, 2014).

NAP mutants can be further analyzed through qPCR for relative expression of genes of interest, a technique that is very effective and provides a temporal component that accurately shows when each of the genes is activated or repressed (Chen, 2011; Kim, 2013; Kou, 2012; Lei, 2019; Wang, 2019; Zhang, 2014). In transformed strains of E. *coli* and yeasts, pull-down assays can be performed to determine if specific proteins physically interact while EMSA can also be performed to determine if specific proteins bind

with target promoters (Lei, 2019; Yang, 2014). Both techniques are effective and have low ease of manipulation. However, they are also *in vitro* assays and thereby limited in its inability to preserve the complex environment of normal cells.

Conclusion

Based on the existing literature, the NAP transcription factor in *Arabidopsis* is controlled by GA and REF6 (Lei, 2019; Wang, 2019). NAP functions to increase senescence in leaves and fruits by expressing genes promoting ABA synthesis, ethylene-stimulated respiration, and stomata opening control (Fan, 2013; Yang, 2014). As NAP is conserved in many plant species, it functions in a similar fashion in many other plants, like its role in *Gossypium* leaf senescence, peach fruit senescence, etc (Chen, 2011; Fan, 2013; Li, 2016). There are also additional functions of NAP such as a stress-responding transcription repressor in *Arabidopsis* (Kim, 2013; Lei, 2019; Zhang, 2012). This review demonstrated an important role ABA has in senescence and the functions of NAP transcription factor as well as the ideal techniques for studying NAP involving NAP mutants, Y1H analysis, qPCR, EMSA, and pull-down assays, allowing for both *in vivo* and *in vitro* level of analysis.

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Mental Model: A Failure to Formalize and Mechanize Reasoning

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Abstract: Revolution has taken place in the debate of human reasoning. Mental model theory is now a widely acceptable theory that captures the nature of human reasoning. It is able to explain the way humans perform reasoning tasks in daily life as it proposes that people construct mental models to make decisions. Although this theory attempts to analyze the reasoning process, it fails to formalize and mechanize reasoning. Thus, no computer programs or algorithms have been developed to actually simulate human reasoning. This paper investigates abduction, one of the three core reasoning concepts (deduction, induction and abduction), and discusses how it is unlikely that abduction can be performed with a mental model in a machine. Specifically, a mental model does not explain how to zero in on the relevant knowledge for abduction. No hypothesis construction or selection criterion is established, nor has a non-supervised machine been invented to recognize causal relations. In conclusion, it is unlikely that machines can reason with a mental model as the underlying supporting theory at the current state.

Mental Model: A Failure to Formalize and Mechanize Reasoning

The ability to reason and perceive are considered the two superior human cognitive capacities (Zhou, 2019). There has been a long-lasting debate on how humans reason. Thirty years ago, scientists agreed that human reason is based on mental logic, which consists of formal rules of inference similar to those in logical calculus (Johnson-Laird, 2010). However, later research on human reasoning revealed inconsistencies between mental logic and humans' reasoning in daily life. For example, mental logic proposes that there are two steps people follow when making a deductive inference. People first recover the logical forms of the premises. In this way, only the syntax of the premises matters because words that carry meanings are extracted, and only the syntax of the sentences stays. They then apply formal rules to obtain a conclusion (Johnson-Laird, 2010). Nonetheless, everyday

assertions may not necessarily follow the same syntax format. It will be extremely complicated if the speaker wants to convey more information. Besides, attempts to mechanize reasoning failed because no algorithms can recover everyday assertions to logical forms. However, a logician can work it out successfully. Since logical forms needed for mental logic also depend on knowledge (Johnson-Laird, 2010), humans are aware of the meaning of the words within the premises. So, they can determine the relationship between premises and make deduction inferences. Moreover, mental logic also suggests that formal logic is monotonic (Johnson-Laird et al., 2015). That is, a conclusion is never withdrawn if the inference is valid, not even when a newly added premise contradicts it. However, humans do not behave in this way. Defeasible reasoning happens when additional information that falsifies the unverified preconditions is present and that the default knowledge is retracted (Longo & Dondio, 2014). The conclusion is always withdrawn if they detect inconsistencies with the new premise.

Given that mental logic does not accurately depict human reasoning, an alternative theory – the mental model theory is proposed to remedy some aspects of human reasoning that mental logic fails to capture (Johnson-Laird, 2010). Although a consensus on a formal definition of a mental model has not been reached, there are two characteristics that scientists agree on: mental models are internally held and can affect individuals' behaviours (Rook, 2013). In this paper, a mental model refers to "a concentrated, personally constructed, internal conception, of external phenomena (historical, existing or projected), or experience, that affects how a person acts" (Rook, 2013). The mental model theory better captures the nature of human reasoning than mental logic does. For example, mental model theory suggests two separate systems—intuitive system and deliberative system in human reasoning (Johnson-Laird & Khemlani, 2013). Similar to the dual processing theory mechanism, the intuitive system can only represent one mental model for rapid conclusion since it has no access to working memory. On the contrary, the deliberative system can construct multiple mental models, search for alternative models and manipulate them. Hence, mental model theory is the most prevalent theory in analyzing humans' ability to reason.

Nonetheless, this paper will argue that the mental model theory, although good at analyzing reasoning, fails to formalize the abductive inference process and cannot mechanize reasoning on machines. Constructing a model for abductive reasoning requires a hypothesis construction and selection criteria and also the understanding of causal relations. However, the mental model theory does not provide such an account that can be applied to machines. This paper will first introduce two features of mental model theory to lay the foundation for further discussion. Then, it will discuss the insufficient account of abduction in mental model theory and how it is implausible to implement abduction in computers. Finally, this essay presents an example of the current attempts on machine reasoning and how those claimed implementations of machine reasoning still have deficits in their use of unsupervised learning.

Introduction to Mental Model Theory

Mental model as an internally held representation of the external world

Human beings are thought to construct their mental model uniquely (Jones et al., 2011). Depending on their personal experiences, perceptions and understanding of the world, each individual's mental model of external reality varies. Even looking at the same event may produce two different mental models for two individuals due to their diverse understanding of this event. Although individual differences widely exist, there are still principles that individualized mental models manifest (Holyoak & Morrison, 2012). The first principle – the principle of iconicity, indicates that a mental model people construct reflects the perceived premises. For example, if a problem consists of statements about the spatial relationship, the mental model one constructs is likely a reflection of the spatial relationship (Ragni & Knauff, 2013). The following problem from Ragni and Knauff's research provides a vivid example.

The Ferrari is parked to the left of the Porsche

The Beetle is parked to the right of the Porsche

The Beetle is parked to the left of the Hummer

The Hummer is parked to the left of the Dodge

Question: Is the Porsche (necessarily) parked to the left of the Dodge?

Participants in this study can easily construct a mental model that has the arrangement like the following:

Ferrari Porsche Beetle Hummer Dodge

With that model in mind, participants can make a decision and answer the corresponding question.

Mental Model Versus Schema: The Dynamic Nature of Mental Model

One function of the mental model is its ability to affect people's behaviours (Rook, 2013). Cognitive processes like judgment, reasoning, and problem solving that produce the behavioural responses depend on the result produced by manipulating the stimuli' complex mental representations. A substantial amount of the literature in cognitive psychology claims that a mental model is a mental organization of knowledge (Rook, 2013). People's understanding or comprehension of the world relies on the knowledge structure in the mental models. However, the external environment is constantly changing and therefore, the mental model is also dynamic (Rook, 2013). Another cognitive structure, schema, can be easily confused with the mental model (Ifenthaler & Seel, 2013). Schema is the pattern formed by capturing the common features across events and can guide people's decision making under new contexts (Pudhiyidath et al., 2020). In this empirical study done by Ifenthaler and Seel (2013), whether or not participants were doing model-based or schema-based reasoning was distinguished by measuring participants' possibility of change in their task performance at various measurement points. As mental models are dynamic and subject to change, participants were more likely to perform differently. In contrast, schemas are the subsequent stabilization of the probability of change reflected by a low probability of change. Hence, researchers concluded that cognitive structure transition from mental model to schema is characterized by the possibility of performance change from task to task. The flexibility and dynamical nature of mental models help human beings manipulate their mental models easily according to the changing external stimulus.

Abduction in Mental Model Theory

The main contribution of mental model theory is its attempts to remedy the flaws of previous theories that manage to analyze human reasoning (Johnson-Laird et al., 2015). Mental model theory is thus a better theory in analyzing human reasoning because of the improvements mentioned above. Although deduction, induction, abduction are the three systematized core concepts in C.S. Peirce's methodological philosophy, the studies on reasoning always emphasize the latter two (Åsvoll, 2014). Sometimes, abduction is categorized as a subtype of induction, and confusion could arise (Aliseda, 2017). However, there are clear distinctions between these two reasoning processes and equating them is neglecting a crucial part of human's ability to reason. Three major differences are identified in the article by Aliseda (2017). Abduction always starts from a single observation and ends with an explanation of the observation. Comparably, induction will extract general statements from a set of observations. Besides, the statement produced by induction can predict further observation, whereas abduction does not have a strong prediction power as induction. Lastly, induction does not require background theory to draw conclusions, but it depends on background theory to construct and test the constructed explanations.

Selection Criteria for the Best Hypothesis and Relevant Explanations

Human reasoners' capacity to formulate explanations surpasses any known algorithm (Johnson-Laird, 2010). When given a premise and a question, people can generate different explanations. For example, when provided with a premise of "If a pilot falls from a plane without a parachute, then the pilot dies," and a question of "The pilot did not die. Why not?", participants provided different explanations (Johnson-Laird et al., 2004). For instance, "The plane was on the ground and s(he) did not fall far," "The pilot fell into deep snow and so was not hurt," or "The pilot was already dead." This result also reflects how people could generate different mental models even when the premise is the same. Hence, mental models are highly subject to an individual's knowledge, personal experiences and even preference for each possible model, as is mentioned in the

previously stated characteristic of the mental model.

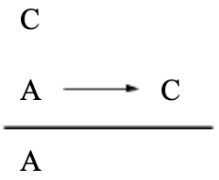
Nonetheless, the mental model theory does not address the process of abduction directly. This is not surprising as mental models start from a set of existing premises and use those given conditions to construct internal representations. As it is meaningless to repeat the premise and produce no novel or parsimonious information (Johnson-Laird, 2010), abductive reasoning does not create any mental model until a set of possible explanations toward the given observation is generated. Therefore, abductive reasoning consists of two distinct procedures: hypothesis construction and hypothesis selection (Aliseda, 2017). Although only the latter relies on the mental model, the former is a necessary step and without which the mental model of abduction is merely a repetition of the premise.

C.S. Peirce's formulation of abduction has been interpreted as the following argument-schema (see Figure 1) in AI circles (Aliseda, 2017). In this formulation, C is the observation or the given facts, A could be any hypothesis that explains C. The pilot example mentioned above can be an exemplification of this formula. From a given fact that "a pilot did not die from the fall from a plane without a parachute" (C), each participant could generate a hypothesis (A) to explain this fact. Although it is not stated explicitly in this formulation, an observation can be explained by multiple hypotheses (Aliseda, 2017). There could be hypotheses B, D, E, F, G, as shown in the pilot question, that can explain the observation. Abductive reasoning is characterized by its utilization of background theory (Aliseda, 2017). This theory consists of the possible causes of the observation event (Console et al., 1991), that is, not necessarily all possibilities. Human beings have such a knowledge base of what might cause a pilot to fall from a plane without a parachute and have that knowledge all sorted into a particular and unique theory. When asked to reason about the observation, they can extract one of the causes. During this hypothesis construction procedure, knowledge and the understanding of causal relation are two essential determinants. Knowledge provides a pool of factors in which people can judge whether every single factor has causal relation with the given premise (Johnson-Laird, 2010). However, the mechanization of hypothesis construction on computers or machines fail to address the two necessary conditions mentioned

above. If given a knowledge base that contains substantial facts that are able to answer the premise, there is no specified principle or rules that can command the computer to select the relevant facts. Not even to mention whether computer programs can identify causal relations without human supervision (Blanco et al., 2008).

Figure 1

C.S. Peirce's Formulation of Abduction



When the abduction process moves to the hypothesis selection stage, problems still exist. If it is assumed that with a pre-existing input of relevant facts that could all cause the premise, the computer program now has to "decide" which hypothesis is the best for the explanation, namely inference to the best explanation, IBE (Harman, 1965). It is the process of picking out the most likely factors to explain the premise and no other hypothesis can outcompete it. However, how to determine which hypothesis is better is also worth considering. A better hypothesis or inference could be simpler, more plausible, more explanatory or less ad hoc (Harman, 1965). It is difficult to decide which consideration is better if the selection criterion for the best inference is not specified. Human reasoners can easily make such decisions because they are aware of the context in which a particular hypothesis outcompetes the rest. Nonetheless, this chosen factor is not paired with the premise forever. On the contrary, the best explanation can change constantly depending on the context. That is, an individual generates hypotheses and selects the best inference with the knowledge of the context (Johnson-Laird, 2010). Moreover, For human reasoners, individual differences (knowledge, personal experiences) may lead to different mental models (Johnson-Laird, 2010). For instance, participant A suggested that the pilot fell into deep snow because s(he) may have seen news reporting a similar accident before. Nevertheless, participant B may have refuted this

possibility as (s)he may know how unlikely it is for the pilot to survive after falling from the plane without a parachute. Therefore, (s)he could have concluded that the pilot was dead before falling out of the plane. In this case, participants have a preference for the best explanation. In conclusion, the mental model theory fails to account for the formulation of hypothesis selection. It does not specify what is counted as a better inference, how a better inference is selected from all the hypotheses generated and how a machine considers the knowledge of context like a human would. The obstacles of recognizing context and selecting the best explanation lies between machine abduction and mental models.

Moreover, the mental model theory does not explain how humans perform non-monotonic reasoning either. Non-monotonic reasoning is crucial as people do not have a complete set of knowledge in mind in reality (Ragni et al., 2017). In reality, conclusions are withdrawn when people receive new information that contradicts the previously established one. If additional information is added to the premises, how will the dynamical mental model respond? Also, how does a reasoning program identify which premises are relevant to the newly added information? Again, if the rule of distinguishing relevancy is not established, it is difficult for a machine to perform reasoning tasks by constructing and manipulating models.

An Example of Mechanizing Mental Model on Computer Program

In this section, the discussion will be centred on the attempts to mechanize the mental model to achieve machine reasoning. Abduction has attracted some attention in artificial intelligence (AI) since abductive reasoning is a vital cognitive model (Dai et al., 2019). Although a well-developed mental model reasoning machine is scarce, there are some preliminary attempts to simulate reasoning via the mental model theory. The proposed computer programs that claimed to mechanize abduction fail to address the process of hypothesis construction and selection mentioned in the paper's arguments. Nonetheless, the presentation of those programs serves as a counterargument that further addresses the unlikelihood of formulating or mechanizing mental models.

Researchers developed the reasoning program – mSentential

and applied the principle of sentential reasoning to simulate how human reasoning constructs mental models (Khemlani et al., 2018). It is worth mentioning that the program consists of two systems: the same system 1 and 2 proposed in the dual-processing theory. System 1 bases its conclusion on a single mental model, whereas system 2 can construct many explicit models. Both systems are not the essential focus of this discussion because there is an important presupposition of this program to make it a simulation of human reasoning. A knowledge base is pre-imported inside the program as data input. The knowledge base modulates both system 1 and system 2, but at different stages. For the reasoning that happens in system 1, the program consults that knowledge base if the only constructed mental model generates a conclusion inconsistent with the premises. The pre-existing knowledge base provides relevant explanations to the program. Comparably, since system 2 can construct more than one mental model, it is also effective to avoid making meaningless models. Consider the following example: Pat visited Toronto, or she visited Canada. Rigorously, three possible models can be constructed.

Pat visited Toronto

Pat visited Canada

Pat visited Toronto but not Canada

However, human reasoners can tell that the third model is not likely. Toronto is a city in Canada, so if Pat visited Toronto, she must have also visited Canada. The blocking of particular mental models relies on the modulation of knowledge. Thus, cognitive resources are not wasted to generate models that have no meaning in reality. mSentential has explicitly stated that it looks up information from the knowledge base to either generate an explanation to resolve the inconsistency between the premise and conclusion or modulate the production of meaningful mental models. Nonetheless, there is no explanation of how the program zeroes in on the relevant information in the knowledge base. Even though it is a small knowledge base, a selection criterion or principle that restricts the searching process is necessary so that the program can simulate reasoning. If human intervention involves (supervised reasoning), this program fails to model the reasoning process and is also homunculus. It does not

indeed develop a program that can mechanize human reasoning. Instead, human researchers sit behind the scenes and pick the relevant knowledge out, not to mention that this knowledge base is already a simplified version that contains less knowledge. If, hypothetically, there is a theoretical knowledge base in which all knowledge is inside this knowledge bank, what is the formula that enables a program to look up the necessary and relevant knowledge? Programs that apply a similar algorithm as the mSentential fail to address this issue.

Conclusion

Mental model theory can remedy the flaws that previous theories on human reasoning fail to address. In this paper, abduction is the main focus among the three core reasoning concepts. Humans do not follow strict logical rules in daily life to reason or make decisions. Instead, they construct an internal representation of the premises using their knowledge to modulate the mental models. After that, they can select the hypothesis that best explains the premises. Although the mental model theory can analyze human reasoning's underlying process, it fails to formalize and mechanize it onto computer programs. The reason is that human beings can select the relevant information or knowledge in their knowledge base, but there is no conclusive formula that applies to machines. In the mSentential program, even though it is already a supervised reasoning machine and a small knowledge base that contains the required information is provided, no explanation on how the machine selects the relevant knowledge is addressed. Hence, a lack of the essential formula that can assist with relevant information selection is a devastative shortcoming of mechanizing the mental model theory onto computer programs or artificial intelligence.

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Distinguishing the Memory of Perceived and Imagined Items

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Abstract: Perception is the process of receiving and analyzing the incoming sensory stimuli, whereas imagination is the process of creating novel images based on previous knowledge. Despite their apparent difference, studies have found that they activate similar neural pathways. This study examined the participants' ability to recognize and make source attribution judgments for items they perceived or imagined. In this experiment, the participants saw a series of adjective-noun word pairs, some of which were followed by a corresponding image while others were followed by an empty frame, cueing the participants to imagine the item. Later, the participants were shown the words and they were asked to decide whether they had seen the word previously or if it was a new word. It was found that in general, the participants had better memory for the perceived items, and they were equally likely to make source-monitoring errors for the imagined and perceived items. A limitation of this study was that there was no measure for the vividness of mental images, hence, we couldn't determine whether the participants were able to imagine the items or not. Future research can remove this limitation using brain imaging techniques such as fMRI, to measure the activity of the brain regions involved in imagination.

Introduction

Human's mind is filled with knowledge and memories that stem from external or internal sources. A person experiencing an external stimulus can perceive it through analyzing the incoming sensory information, while other information results from internal sources such as the person's thought processes, reasoning, and even imagination (Johnson & Raye, 1981). However, memories are not labeled with their source. Memories originated from either source will have certain features that allow source inference. This is called source-monitoring.

Memories of perceived events contain sensory and contextual

details whereas imagined memories contain details that are based on the person's prior knowledge and cognitive processes (Garrison et al., 2017). Despite the apparent differences, neuroimaging studies have found that both processes activate similar neural networks in the brain (Kosslyn & Thompson, 2003; Zeidman & Maguire, 2016). This finding led the researchers to suggest that memories of perceived and imagined events might interfere with each other during retrieval, leading to source-monitoring errors (Mathews et al., 2013).

A study found that after a long retention interval, people report having seen a picture that they had only read its description. This false memory is likely a consequence of constructing a vivid mental image of the picture while reading its descriptions (Intraub & Hoffman, 1992), which tricks the mind into thinking that the person actually saw the imagined picture (Paivio et al., 1968). On the other hand, another study found that the participants' memory was more accurate for the perceived objects (Rosburg et al., 2011). They justified their finding through the picture superiority effect which states that the perceptual richness of the perceived images enhanced their accessibility and led to more accurate memories.

Another study conducted by Johansson, Stenberg, Lindgren, and Rosén (2002), also investigated the memory of perceived and imagined events. In this experiment, the participants were shown a series of words which were either followed by a corresponding image, or an empty frame which was a cue for the participants to try and imagine the object. The pictures used in this experiment were simple black and white line pictures, and the participants were instructed to create their mental images in the same format. Later, some of the participants took part in an old/new recognition and the rest performed a source-monitoring task. The results indicated that in both tasks, there was no difference in performance for the imagined and perceived items. This finding was not consistent with the aforementioned research. This inconsistency could be due to a few limitations of the experimental design. First, the experiment used black and white line images and instructed the participants to create mental images in the same format. However, when instructed to imagine an object, most people imagine the object in a way that they commonly see it in the real world (Mathews et al., 2013). Therefore,

it might have been harder for the participants to create mental images in this format, hence the external validity of the findings is low. Secondly, there was no retention period between the study and the test phase. Therefore, it is not clear whether after a longer retention period the memory for the imagined and perceived items would be different or not.

The purpose of the present study was to examine the memory for the imagined and perceived items in combination with reality monitoring. The design of the experiment was similar to the aforementioned study. However, to remove the mentioned limitations, this experiment included a two-minute retention period, and the stimuli of this study were coloured pictures of common objects that closely resembled their appearance in the real world. Moreover, the participants were asked to imagine the items in as much detail as they could, so that their mental images would closely resemble the actual object. Furthermore, the presented word labels were adjective-noun pairs such as a blue book, or a red ball. It was predicted that the presence of the adjectives would guide the mind into creating more vivid and specific mental images. Therefore, it was hypothesized that firstly, the participants would correctly recognize and identify the source of the items more often than not, and secondly, they would have a better memory of the imagined items due to the generation effect (Slamecka & Graf, 1978), hence, making fewer recognition errors. Lastly, they would be able to create vivid mental images, which would lead to falsely identifying the imagined items as perceived.

Methods

Participants

The participants consisted of 24 individuals (N = 24), 10 males and 14 females, in the age range of 18-60. The average age was 25. They were friends or family who were recruited by the experimenters. All the participants were fluent in English, had normal or corrected vision.

Ethics

There was a low risk of group vulnerability since the participants were adults and did not have a history of psychological

and neurological disorders or any other types of pre-existing vulnerabilities. Furthermore, the tasks used in this experiment were simple cognitive tasks which did not pose any type of physical or emotional harm and stress, so this experiment is considered to be low risk.

Material and Design

All participants saw a total of 60 words that were shown in a random order. Half of the words belonged to the imagined group while the other half belonged to the perceived group. Since all participants saw the words belonging to both perceived and imagined groups, this was a within-subjects design. Due to government isolation protocols, all subjects participated in the experiment from their homes and used their own computers. The independent variable was the words that were assigned to each condition (perceived vs. imagined), and the dependent variable was the accuracy of the participants in identifying the perceived, imagined, and new items.

Consent Form. The participants viewed the consent form, and they were given enough time to carefully read it. They provided verbal agreement to the experimenter via Zoom. If participants did not agree to participate in the experiment, the session was terminated immediately and no data was collected. A PDF of the consent form would be provided to the participants upon request.

Debriefing. After the experiment was concluded, all participants were debriefed on the purpose, hypothesis, the importance of the research question, and the rationale behind the experiment's design. The debriefing form can be found in Appendix A.

Stimulus. The stimulus was a series of concrete adjective-noun word pairs. A total of 90 concrete nouns were randomly chosen from a previous study that examined the concreteness of 260 words (Snodgrass & Vanderwart, 1980). A list of adjectives was created using a random word generator. The adjectives were selected if they were specific and concrete enough to evoke a mental image. The list of word-pairs can be found in Appendix B. The word pairs were randomly categorized into three conditions of imagined, perceived, and new. There were three counterbalancing groups to ensure that all words were presented in all conditions. Moreover, the participants

were randomly assigned to one of these counterbalancing groups.

Pictures. For the word pairs in the perceived condition, colored pictures that accurately represented each word-pair, were acquired using Google Images. Each of the images closely resembled the real-world appearance of each object.

Procedure

The experiment took place via Zoom, using screen-sharing to present a PowerPoint presentation. The experiment consisted of a study phase, a retention period, and a test phase. All stimuli were typed in black 24-point Times New Roman, and they were presented at the center of the screen. During the study phase, each trial began with a fixation cross which was displayed for 1000 ms, followed by a word-pair which was displayed for 1000 ms. There were a total of 60 adjective-noun pairs. Half of these were followed by a corresponding image which was enclosed by a 460 x 400 frame, and the participants were instructed to look at the picture (the perceived condition). The other half were followed by an empty frame, which cued the participants to imagine the described item. Both the picture and the frame were presented for 6000 ms (Figure 1). All participants saw both groups of stimuli, and they were presented in random order. Prior to the experiment, the participants were given the required instructions, and the meaning of the empty frame was explained.

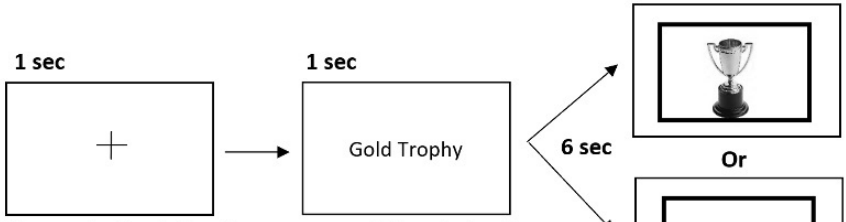

Figure 1. Depicting the process of the study phase

After the study phase, there was a two-minute retention period during which the participants were told to take a break. Following the retention interval, the participants received instructions, and took part in a test phase. Each trial began with a fixation cross which was displayed for 1000 ms. After that, a word-pair was presented for 1000

ms followed by a 15000 ms response interval, although the participants were instructed to respond as fast as possible. The participants were instructed to verbally identify the words as imagined, perceived, or new. (Figure 2) During the test phase, the participants saw a total of 90 word-pairs, which was composed of all 60 word-pairs that were previously studied (30 imagined items + 30 perceived items), in addition to 30 new word-pairs. Prior to each task, the participants were given thorough instructions, and they were given a test trial in order to assess their understanding of the instructions.

Figure 2. Depicting the process of the test phase

Results

In this experiment, there were two possible types of errors. The first type is the recognition error, wherein the participants did not recognize the items studied during the study phase, regardless of their source. To test for this type of error and to ensure that the participants were not randomly answering imagined or perceived for all words, the proportion of old responses was compared to the proportion of new responses across the three conditions of perceived, imagined, and new. In this case, the imagined and perceived responses for each of these conditions were combined, and they were considered as old responses.

Since this experiment followed a within-subjects design, a series of paired samples t-tests were used to analyze the results. It was found that the proportion of old responses was significantly lower for the new condition. However, both perceived and imagined conditions displayed a high proportion of old responses (Figure 3). A paired-sample t-test was performed to compare the proportion of old responses for the imagined ($M = 0.86$, $SD = 0.15$) and perceived ($M = 0.93$, $SD = 0.064$) conditions. It was found that the proportion of old responses was significantly higher for the perceived condition compared to the imagined condition $t(23) = -2.52$, $p < .05$; $d = .51$.

However, the effect size is lower than Cohen's (1988) baseline for a large effect size. This finding indicates that the participants recognized and identified the perceived items as old more often than the imagined items. This suggests that the participants generally had a better memory for the perceived items than the imagined items. Since it was expected that the participants would have a better memory for the imagined items due to the generation effect, this finding was not consistent with the hypothesis.

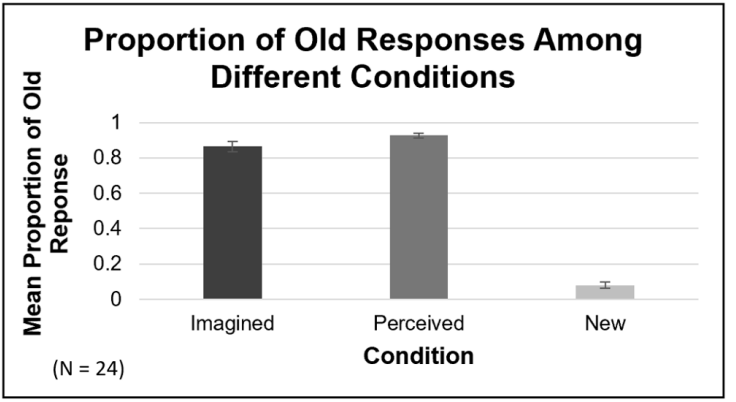

Figure 3. Proportion of old responses across three conditions of imagined, perceived, and new. Error bars represent standard error of the mean (SEM). (Imagined SEM = ±0.031, Perceived SEM = ±0.013, and New SEM = ±0.018)

The second type of error in this experiment was a source monitoring error, where the participants recognized an item as old, but could not make correct source-attribution judgments. Therefore, another paired sample t-test was performed to compare the proportion of correct responses between the imagined ($M = 0.83$, $SD = 0.19$) and perceived conditions ($M = 0.87$, $SD = 0.12$). It was found that there was no significant difference in the proportion of correct responses between these two conditions $t(23) = -1.44$, $p = .16$. This finding indicates that both the imagined and perceived items were equally likely to be correctly attributed to their sources, which is inconsistent with the hypothesis, which stated that the participants would be better at source monitoring for the perceived items.

Furthermore, another paired sample t-test was carried out to compare the proportion of wrong answers in perceived ($M = 0.13$,

SD = 0.12) and imagined (*M* = 0.17, *SD* = 0.19) conditions. The analysis revealed that there was no significant difference between the proportion of wrong answers between these two conditions $t(23) = 1.45$, $p = .16$. Therefore, the likelihood of making source-monitoring errors was similar for both the perceived and imagined items. This finding was also inconsistent with the hypothesis which had predicted that the participants would make more source-attribution errors for the imagined items.

Since there were two possible wrong answers for each condition, a paired sample t-test was carried out to find if there was a difference between the proportion of perceived responses (*M* = 0.33, *SD* = 0.052) compared to the proportion of new responses (*M* = 0.14, *SD* = 0.15) in the imagined condition. It was found that the proportion of new responses was significantly higher compared to the proportion of perceived responses in the imagined condition $t(23) = -4.16$, $p < .05$; $d = .85$ (Figure 4A). The effect size for this analysis was found to exceed Cohen's (1988) baseline for a large effect, indicating that the participants were more likely to misidentify the imagined items as new rather than perceived. Hence, they did not have a good memory for the imagined items, and upon encountering these items in the test phase, it was as if they had encountered them for the first time. This finding was not consistent with the hypothesis.

A paired sample t-test was carried out for the proportion of imagined responses (*M* = 0.55, *SD* = 0.083) compared to the proportion of new responses (*M* = 0.074, *SD* = 0.064) for the perceived items. (Figure 4B) It was found that there was no significant difference between these two types of wrong responses in the perceived condition $t(23) = -1.039$, $p = .31$ (Figure 2B). This finding implies that the participants were equally likely to make recognition or source monitoring errors for the perceived items.

Taken together, it can be concluded that the participants were more likely to recognize and correctly identify the sources of the items than to not recognize or misattribute their sources; which is consistent with the hypothesis. However, when they did make mistakes, they were equally likely to make source attribution errors for both the perceived and imagined items. Although, for the imagined items, the

participants were more likely to make recognition errors rather than source-monitoring eros. Suggesting that overall, in contrast to the hypothesis, the participants did not have a good memory for these items.

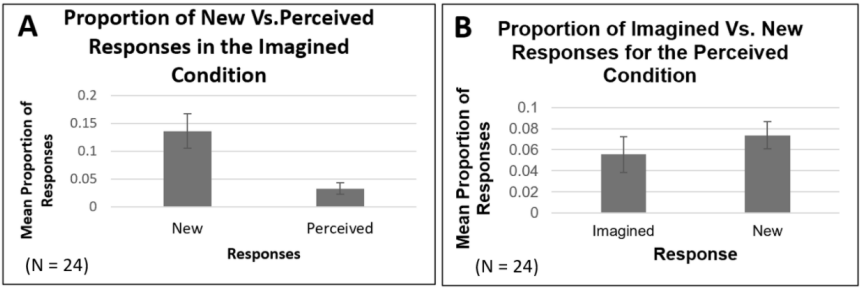

Figure 4. Proportion of wrong answers for the Imagined and perceived conditions. Error bars represent standard error of the mean (SEM). ***A)*** Proportion of new (SEM = ±0.04) versus perceived (SEM = ±0.013) responses for the imagined condition. ***B)*** Proportion of imagined (SEM = ±0.017) and new (SEM = ±0.013) responses for the perceived items.

Discussion:

Despite the apparent differences, studies have found that imagination and perception engage similar neural pathways within the brain (Kosslyn & Thompson, 2003). Therefore, during retrieval, especially if the mental images are vivid, it might be hard to distinguish between the two, which can lead to source monitoring errors (Paivio et al., 1968). The results of this experiment supported the hypothesis which stated that the participants would correctly recognize and identify the source of the items more often than not. However, the hypothesis, which predicted that the participants would make more source attribution errors rather than recognition errors for the imagined items compared to the perceived items, was not supported. In contrast, it was found that the participants were more likely to make recognition errors for the imagined items. Moreover, in contrast to expectation, the participants recognized the perceived items more often than the imagined items, indicating that they had a better memory for the perceived items. This finding was not consistent with the study conducted by Johansson, Stenberg, Lindgren, and Rosén (2002). It is noteworthy that due to the small sample size, the statistical power of this analysis was lower than 80%; therefore it is

possible that this statistically significant difference was in fact a false positive (Button et al., 2013).

The better memory of the participants for the perceived items can be justified by the picture superiority effect, which states that items presented as pictures are better remembered and recognized compared to items presented in words, even if the words were concrete and provoked creation of mental images (Defeyter et al., 2009). Furthermore, during the study phase, the participants had six seconds to either perceive the image or try to imagine the item. Creating a mental image requires attention and cognitive resources (Pelaprat & Cole, 2011), so it is possible that while trying to imagine the item, the participants were not able to rehearse the word itself. Hence, for those items that they weren't able to create vivid mental images, during the test phase, not only the word wouldn't cue them into remembering the mental image, the word itself wouldn't seem familiar to them either (Paivio et al., 1968). Therefore, they were more likely to identify these items as new. On the other hand, when the perceived items were presented during the study phase, the participants were not required to make an effort to create a novel image, so they could spend their time observing the images, processing them, and rehearsing the words. Consequently, during the test phase, they were more likely to recognize the perceived items because not only the word would remind them of the picture, but the word itself would also seem familiar.

After recognizing the items, the participants had to attribute them to their source. It was found that in general, the participants correctly attributed the items to their sources more often than not. However, in contrast to the expectations, they were equally likely to make source-attribution errors for both the perceived and imagined items. Seeing the word in the test phase would trigger a memory, and in order for the participants to make source-attribution judgments, they would have to evaluate the cognitive, perceptual, and contextual features of each of the memories. This evaluation process is slow and requires time and effort (Johnson, 1997). However, since the participants were instructed to respond as quickly as possible, it is possible that they did not perform an extensive evaluation. Furthermore, due to the small sample size, the power of this analysis

was significantly low, which significantly increased the chance of type II error. Therefore, it is highly possible that this was a false negative (Banerjee et al., 2009); and it is likely that a study with a larger sample size and higher statistical power, would find significance.

One of the main limitations of this experiment was the small sample size, which significantly reduced the statistical power. Therefore, it is possible that the observed results, regardless of being significant or not, were not in fact true effects. Furthermore, due to the restrictions due to the pandemic, the participants were not chosen randomly, therefore, the external validity of the findings are questionable (Mitchell, 2012). Another limitation of this experimental design was that the experiment consisted of a single long trial. Research has shown that the average attention span is 15 minutes, and after that the mind will begin to lose focus from the main task (Bradbury, 2016). Therefore, it is possible that the participants became tired towards the end of the experiment, which led to less accurate judgments during the test phase. Furthermore, since imagination requires effort and uses cognitive resources (Pelaprat & Cole, 2011), it is possible that during the study phase, the participants were fatigued after a while, and hence did not try to imagine the rest of the items or made less effort, leading to less vivid mental images. This limitation can be removed by having two trials and a break in between rather than one long trial. Lastly, in this experiment, it was not possible to check if the participants were actually imagining the items, so some of the participants may not have even tried to imagine the items. This limitation can be removed by including questionnaires or self-reports regarding the vividness of the mental images.

Future studies can remove the aforementioned limitations and take a step further by using brain imaging techniques such as fMRI to measure the activity of brain regions involved in imagination, such as the left supramarginal gyrus (Oberhuber et al., 2016), to confirm that the participants are in fact trying to imagine the items. If future studies also find that the memory is better for the perceived items compared to the imagined items, this can have implications for teaching strategies. Based on this result, it would be plausible to conclude that including pictures, diagrams, graphs, and other visual aids in slides and teaching materials can lead to better learning for the

students and increase material retention.

This study found that in general, people are able to recognize and correctly make source-attribution judgments for the items they have previously studied. However, it was found that they had better memories for the perceived items compared to the imagined items. Due to the small sample size, the statistical power of this analysis was very low, therefore, the findings may not be true effects. Future studies can remove the limitations of the current experiment and examine the memory for the perceived and imagined items at a much deeper level.

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Appendix A. Experimental Debriefing Sheet

You just completed a cognitive psychology experiment that is part of a class project. We are studying whether people are more biased towards the retrieval of perceived or imagined features in memory. We also wanted to study the effects of using life-like images and concepts on imagination and memory. We had participants first learn a set of perceived and imagined concepts. We then had participants complete a recognition test, answering "perceived", "imagined" or "new", to measure memory recall for each item. We manipulated across participants which concepts were imagined and which were perceived. We hypothesized that people would be able to recall the imagined items better as a result of having to self-generate the items. Our main dependent variable is the proportion of correct responses for the word pairs that were perceived, imagined and new in comparison to one another. Some of the zoom calls were recorded in order to verify participants' answers for data analysis.

If you are interested in reading more about this kind of research, check out this journal article: Johansson, M. (2002). Memory for perceived and imagined pictures—an event-related potential study. *Neuropsychologia, 40*(7), 986-1002. doi:10.1016/s0028-3932(01)00148-8

If you have any questions, please contact the researchers [Mehraein Roointan; *m.roointan@mail.utoronto.ca*, Madeline Antidormi; *m.antidormi@mail.utoronto.ca*, Christie Lai; *christiee.lai@mail.utoronto.ca*] or the course instructor (Dr. Meg Schlichting; *meg.schlichting@utoronto.ca*). Please let the researcher know at this time if you would like to withdraw your data, now that you know the specific purpose of this study.

Thanks again for participating in our experiment!

Appendix B. List of the adjective-noun word pairs used in the study.

Excited Baby
Fuzzy Bed
Fluffy Dog
Chocolate Cake
Smiling Tiger
Plain Snack
Chubby Chicken
Large Hospital
Whole Heart
Big Mouse
Skinny Dog
Icy Cup
Brown Jacket
Tiny Owl
Burning Candle
Spicy Pepper
Shiny Button
Straight Line
Blue Vase
Blue Butterfly
Old Book
Tight Belt
Empty Bottle
Pleated Skirt
Green Apple
Slim Fish
Orange Plate
Closed Refrigerator
Curly Hair
Thick Toast
Pricey Watch
Wide Entrance
Loose Tie
Gold Ring
Soft Pants
Bright Sun
Damaged Shoe
Steaming Kettle
Heavy Crown
Fluffy Blanket
Green Eye
Black Glasses
Wounded Soldier
Wet Gorilla
Soggy Fries
Pink Chair
Wild Horse
Dull Pencil
Small Tomato
Round Table
Yellow Bowl
Thick Forest
Pink Flower
Young Puppy
Red Ball
White Mitten
Blue Balloon
Purple Phone
Long Coat
Broken Toaster
Pale Skin
Green Box
Fresh Bread
Glossy Dress
Plastic Fork
Modern House
Royal Ring
Huge Finger
Illuminated Lamp
Wooden Window
Lazy Guy
Angry Mother
Pretty Breakfast
New Basket
Rusty Ship
Silver trumpet
Short Ladder
White Whale
Heavy Stool
Messy Room
Half Moon
Historical Door
Dark Cloud
Fluffy Caterpillar
Black Bear
Basic Clock
Leather Couch
Happy Clown
Fearful Duck
Fat Cat

Multipartite mutualisms in Medicago truncatula are affected by drought stress

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Abstract: Mutualisms are commonly viewed as bipartite systems between two symbionts, predominantly in isolation from other organisms. Multipartite mutualisms have strong ecological implications, though the dynamics of multiple mutualists are not well-understood. The legume-rhizobium symbiosis is a well-documented mutualistic system. Rhizobia fixes atmospheric N2 to supply the plant with nitrogen resources, while the plant provides the bacteria with organic carbon and shelter inside of root nodules. Legume plants are also known to associate with mycorrhizal fungi which aid plant uptake of low mobility nutrients and water. This association may be costly in situations with minimal nutrient or water stress. In this study, we examined the effects of multiple microbial partners in *Medicago truncatula* under drought conditions. We found that water limitation mediates earlier flowering in fungi-associated plants. However, we did not uncover significant performance benefits in other areas of plant growth and survival that could be attributed to the additional symbiont. Our study suggests the ability to uncover context-specific effects of multipartite mutualisms and demonstrates the need to investigate the dynamics of multiple mutualists in varying resource environments.

Introduction

Symbiosis describes when two or more species closely interact or continuously associate. These relationships are prevalent across all levels of biological organization. Mutualism arises when the interaction is positive; each species involved receives fitness benefits from the association and this acts to reinforce the mutualistic relationship (Currie et al., 2003; Fujita et al., 2014). These associations are commonly viewed as bipartite systems between two symbionts, predominantly in isolation from other organisms (Currie et al., 2003). Theoretical and experimental studies call for the examination of multiple mutualistic partners to evaluate altered fitness landscapes that stem from cooperative and competitive interactions between the

parties involved, which may not be ascertainable in bipartite studies. Examining multipartite mutualisms and the network of interactions between partners is key to understanding the evolutionary dynamics and stability of mutualisms (Currie et al., 2003; Poulsen & Currie, 2010).

Interspecific interactions brought about by mutualisms are essential to maintain the structure of ecological systems. Multipartite mutualisms have strong ecological implications due to the number of species involved and the potential for greater complexity in interaction networks. The rewards provided by each mutualistic partner can vary in strength, similarity, and in the context of the environment (Stachowicz, 2001). Multiple partners may also compete for shared resources provided by a focal mutualist (Johnson & Bronstein, 2019). Multispecies mutualisms can facilitate context-dependent responses through changes in the magnitude and direction of interactions for all partners. These interactions are most advantageous when all rewards provided are beneficial and unique, while redundant benefits are likely to incur negative costs (Stachowicz & Whitlatch, 2005; Afkhami et al., 2014). Benefits provided by mutualists are often costly to produce; changes to the local environment can change the degree to which the interaction is mutually beneficial. In some cases, the net outcome may even be negative (Bronstein, 1994).

One well-documented pairwise mutualism occurs between legumes and nitrogen-fixing bacteria, rhizobia. Plants provide rhizobia with organic carbon and shelter inside of root nodules, while rhizobia supply the plant with nitrogen resources synthesized (fixed) from atmospheric N_2 (Vance, 2002; Fujita et al., 2014). Recent work has suggested up to 90% of legumes participate in this type of interaction with rhizobia and other nitrogen-fixing bacteria (Afkhami et al., 2018). Furthermore, mutualistic associations between plants and mycorrhizal fungi are widespread in nature. Fungi colonize plant roots, are provided with organic carbon, and in return aid plant uptake of low mobility nutrients (such as phosphorus and nitrogen) and water (Smith et al., 2010; Singh & Prakash, 2012). Studies have observed that mycorrhizal plants grown under water stress conditions display increased drought tolerance and lower drought stress compared to non-mycorrhizal plants (Duan et al., 1996; Augé et al., 2001).

However, the association between plants and mycorrhizal fungi may be costly in situations where there is minimal nutrient or water stress (Stachowicz, 2001).

Microbial symbionts may confer complementary benefits to a host plant, and they may also positively influence one another. The effects of multiple mutualists in *Medicago truncatula* (barrelclover) were previously investigated by Afkhami and Stinchcombe (2016). The study found synergistic effects of rhizobia and mycorrhizal fungi on plant performance; plants grown with both mutualists had higher aboveground biomass, more leaves, and more branches compared to those with one or no mutualistic partner. These findings suggest additional benefits can be induced by coaction of partner mutualists on the focal mutualist. Previous studies have also found positive effects of the partner mutualists on each other; rhizobia increase fungi colonization and sporulation on plant roots while fungi increase rhizobia root nodule number and biomass (Bagyara et al., 1979; Champawat, 1990; Geneva et al., 2006).

Synergistic effects of these microbial symbionts may vary with resource environments. Under nutrient-rich and saturated soil conditions, there is minimal nutrient or water stress. In this context, the association with mycorrhizal fungi may be more costly than beneficial. The fungi would still consume carbon but would not provide palpable benefits (i.e. water or nutrients) to the plant. However, under environmental stress, the association with fungi may provide enough benefit to the plant, outweighing the cost by supplying water and nutrients that are otherwise limited or inaccessible.

In this study, we examined the effects of a multipartite association with mycorrhizal fungi in conjunction with rhizobial bacteria in *M. truncatula*. We sought to uncover the context-dependent effects of specific environmental conditions in the greenhouse on plant performance. We hypothesized the association with mycorrhizal fungi would buffer against the costs of drought stress on *M. truncatula*. If the association were to be advantageous, it could account for the maintenance of the interaction in the wild despite the apparent costs of an additional microbial symbiont.

Methods

Study system

We investigated the impact of drought stress on the tripartite mutualism between *Medicago truncatula* and two microbial symbionts. *M. truncatula* is widely considered to be a model system for legumes (Young and Udvardi, 2009). In accordance with Afkhami and Stinchombe (2016), we used microbial symbionts that are found with *M. truncatula* alone and together to simulate natural microbial interactions — rhizobia (*Ensifer meliloti*) and mycorrhizal fungi (*Rhizophagus irregularis*) (Zribi et al., 2004).

Experimental design

All techniques and materials were conducted in sterile conditions to avoid contamination. The original experiment was conceived by Pebesma and Stinchcombe (2019 EEB488 project proposal; unreferenced).

To prepare seeds for germination, we scarified *M. truncatula* seeds using a razor blade, followed by surface sterilization in ethanol, then bleach, rinsed off with distilled water, and left to soak in distilled water. Seeds were germinated on sterile 0.08% agar plates wrapped in tinfoil and placed in the fridge at 4°C for 10 days. After overwintering, the seeds were removed from the fridge and let sit at 21°C for 18 h, as per Afkhami and Stinchcombe (2016). We individually planted the germinated seeds into pots in the greenhouse. Pots were constructed using nested magenta boxes, with the lower box containing sterile distilled water and a cotton rope wick to transfer moisture to the upper box containing autoclaved sand, as per Heath et al. (2010). No additional nutrients were added to the pots. To ensure a sterile and closed system, we autoclaved all equipment at 121°C prior to use in the experiment.

We planted 208 seeds in a generalized randomized block design with a 2x2 factorial design of treatments: mycorrhizal fungi (M±) and drought (D±). All plants across all treatments were inoculated with rhizobia. We set up thirteen spatial square blocks of 16 plants each, with 20 cm between blocks and 4 cm between plants within each block. Treatments were equally represented within each block and between blocks — each treatment comprised a quarter of the plants in

each block (4 plants of each treatment). Plants were inoculated with rhizobia and fungi twice — once on the day of planting and again one week after planting.

Four treatment groups:

1. Inoculated with living fungi, exposed to drought (M+D+)
2. Inoculated with living fungi, no drought exposure (M+D-)
3. Inoculated with heat-killed fungi, exposed to drought (M-D+)
4. Inoculated with heat-killed fungi, no drought exposure (M-D-)

Prior to inoculation, we grew rhizobia in TY media for 24 hours and diluted to an optical density of 0.1 with sterile distilled water. Each plant received 1 mL of rhizobial inoculant during both inoculations. Each M+ plant was inoculated with sterile water containing 300 spores (Premier Tech, Riviere-du-Loup, Quebec, Canada; Antunes et al., 2008; Powell et al., 2009). The same fungal solution was autoclaved three times at 121°C for 45 minutes to ensure spore inviability before inoculation in M- plants. Two weeks after the second inoculation, at the start of week four, we simulated drought exposure by removing the water supply from the D+ plants for three days. Water was returned for the remaining four days of the week. This process was repeated weekly, for a total of 9 droughts. The water from the D+ plants was stored in sterile 150 mL cups for the duration of the drought; the same water was returned at the end of the drought to ensure any microbes in the water were returned.

Harvest and data collection

During the first two weeks after planting, we collected data on germination time, days to first leaf (cotyledon), and days to first true leaf (non-cotyledon, trifoliate adult leaf). We collected measurements of leaf count one week and two weeks after planting. After we started implementing droughts, we collected measurements of leaf count and branch count before and after each drought period. Plants were inspected daily to accurately record survival. Once the plants started to flower, we collected data on flowering time. The plants were divided into two harvest cohorts: early (harvested on day 38 of the experiment) and late (harvested at the end of the experiment). The early harvest cohort consisted of four blocks (roughly 30% of the experimental

population) which were harvested on day 38 of the experiment. Peak nitrogen fixation levels occur around flowering; root nodules will start to senesce shortly after (Serova and Tsyganov, 2014). By harvesting after 50% of the cohort had flowered, the early harvest allowed more accurate measurements of nodule count. The remaining nine blocks comprised the late harvest cohort, growing for the full 13 weeks of the experiment. At the time of harvest, we collected measurements of height aboveground, root length, nodule count, and fruit count (if produced). Aboveground and belowground tissue from all plants were collected and separated. The plants were dried at 60°C for three days. The separated plant tissue was weighed for biomass. Seed count was excluded due to the low proportion of plants that had produced mature fruit at the time of harvest.

Statistical analysis

All statistical tests were performed using RStudio v1.4. We tested the main effects of mycorrhizal fungi treatment (living/heat-killed) and drought treatment (presence/absence), their interaction, and accounted for block effects to generate ANOVA models of the following response variables: nodule count, height aboveground, root length, aboveground biomass, belowground biomass, and fruit number. Length and biomass variables were assessed for covariance and analyzed using MANOVA models. The results from each harvest cohort were analyzed separately. We used box plots comparing trait values between treatments to aid in visual comparisons of responses across treatments. We plotted the difference between before- and after-drought measurements of leaf count and branch count to visually assess trends in plant growth over time. Additionally, we converted flowering and survival data to binary response variables to allow survival analysis using the Kaplan-Meier method and the Cox regression model.

Results

Germination time and days to first true leaf

We converted the data on germination time and days to first true leaf to binary response variables (event occurred/event did not occur). The time taken to germinate was consistent across

treatments. The time to the production of the first trifoliate leaf was also consistent across treatments. At the time of data collection, the drought simulations had not yet begun.

Leaf count and branch number

We averaged the values of leaf count for each treatment before and after each drought to plot the change in the number of leaves after drought stress. The same process was applied to the data on branch number before and after each drought. There were no significant effects of drought or fungi. Additionally, we did not observe any significant trends in the change in leaf or branch number across treatments ($p > 0.5$).

Nodule Count

Root nodules were counted for each individual at the time of harvest. The data collected from the early and late harvest cohorts were analyzed separately. The data from the early harvest cohort (Fig. 1A) was a more accurate assessment as the data was collected around the time of flowering before most nodules had started to senesce. The nodule data from the late harvest cohort (Fig. 1B) was likely lower than what would have been at the time of peak nitrogen fixation. This data lacked nodules that senesced and could not be observed at the time of harvest. No significant effects of drought or fungi treatments were observed in either harvest cohort ($p > 0.5$).

Height aboveground

Plant height was measured at the time of harvesting. Height was defined as the distance between the base of the stem to the base of the highest fully expanded leaf. No significant effects of drought or fungi treatments were observed in either harvest cohort ($p > 0.5$).

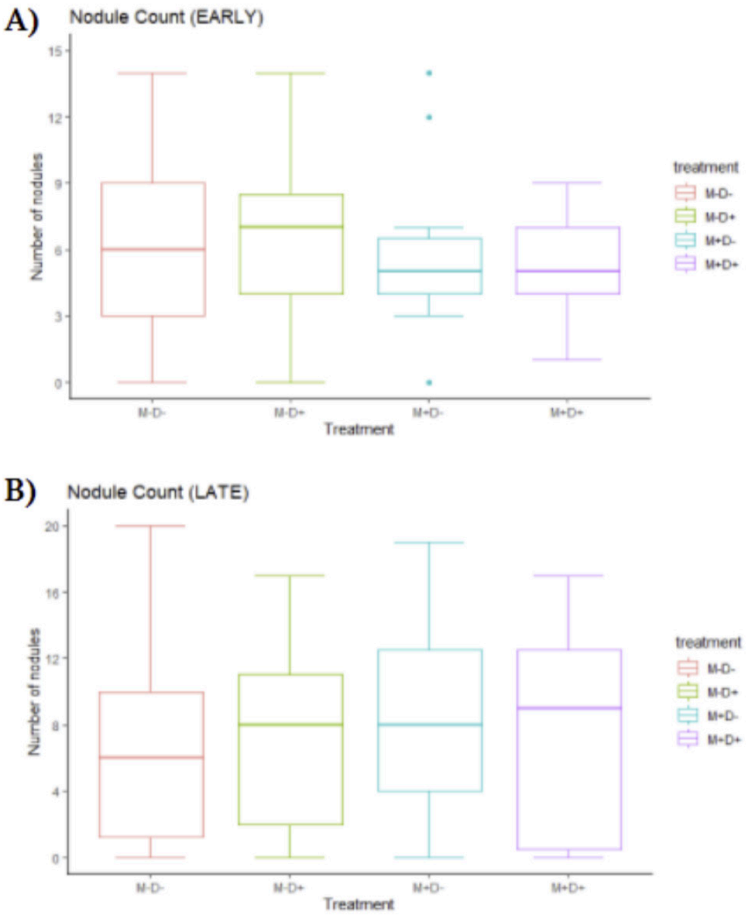

Figure 1: Nodule counts. Plot showing the distribution in the number of root nodules in individuals, separated by treatment (mycorrhizal fungi (M±), drought (D±)). Horizontal lines within each box denote median values. Error bars extend outside of each box. Outliers are shown as circles. Treatments are differentiated by colour. **(A)** Early harvest cohort. **(B)** Late harvest cohort.

Root length

Root length was measured at the time of harvesting. Root length was defined as the furthest distance from the base of the stem to either the primary root or the lateral roots. We found that drought

significantly increased root length in both the early ($p = 0.00119$; Fig. 2A) and late ($p = 0.0212$; Fig. 2B) harvest cohorts. This trend was not affected by the presence of fungi in either cohort.

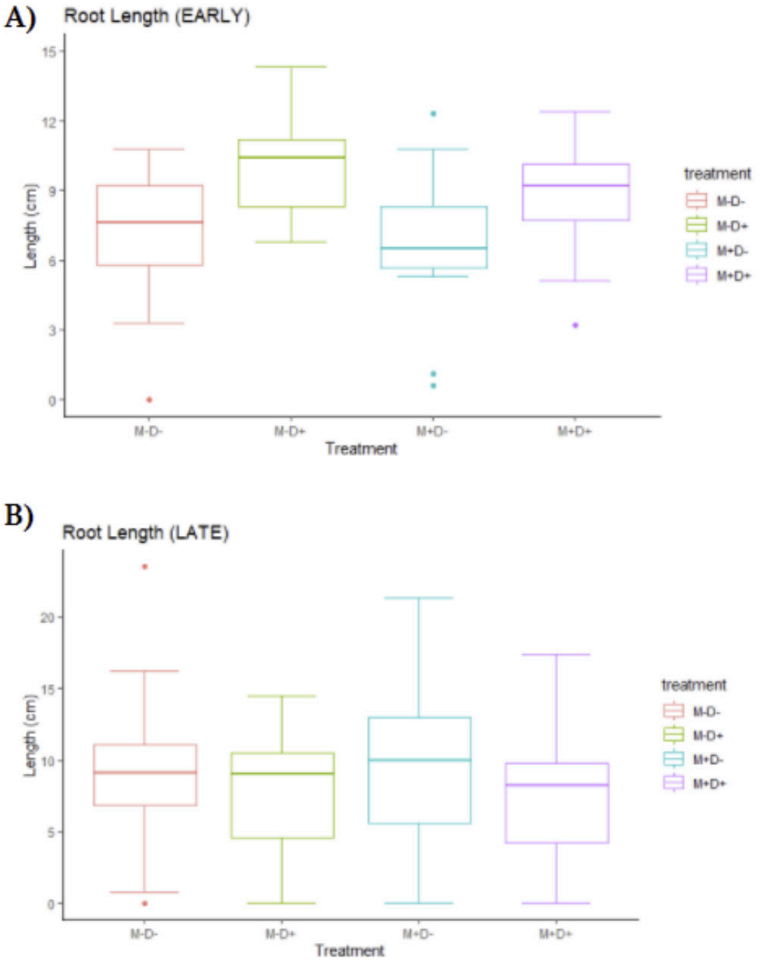

Figure 2: Root length in the early harvest cohort. Plot showing the distribution in root length, separated by treatment (mycorrhizal fungi (M±), drought (D±)). Horizontal lines within each box denote median values. Error bars extend outside of each box. Outliers are shown as circles. Treatments are differentiated by colour. **(A)** Early harvest cohort. **(B)** Late harvest cohort.

Height and root length were correlated in both harvest cohorts. We used MANOVA models to assess the effects of our independent variables on a composite variable composed of height and root length. In the early harvest cohort, we found significant effects of drought on the composite variable of height and root length ($p = 0.003136$). In the late harvest cohort, we found significant effects of both drought ($p = 0.01700$) and fungi ($p = 0.01653$) on the composite variable of height and root length.

Biomass

Prior to drying, plants were separated into aboveground and belowground portions. Once dried, aboveground tissue and belowground tissue were weighed and analyzed separately. Fruits (if produced) were included in the measurement for aboveground biomass. We did not observe any significant effects of drought or fungi on biomass ($p > 0.5$). However, we did find a significant block effect ($p = 0.00262$; Fig. 3A) on aboveground biomass in the late harvest cohort. This was not observed in the early harvest cohort (Fig. 3B).

Flowering

Data on flowering time was collected as the days taken to produce the first flower. We found that the presence of fungi had a significant effect on flowering time ($p = 0.00308$). There was a non-significant interaction effect between fungi and drought ($p = 0.06761$). Plants inoculated with living fungi flowered later than those that received heat-killed fungi, though the fungal-inoculated plants that experienced drought conditions flowered slightly earlier than those that did not. We converted the flowering data to a binary response variable (flowered/not flowered) to create a time-to-event plot using the Kaplan-Meier method (Fig. 4).

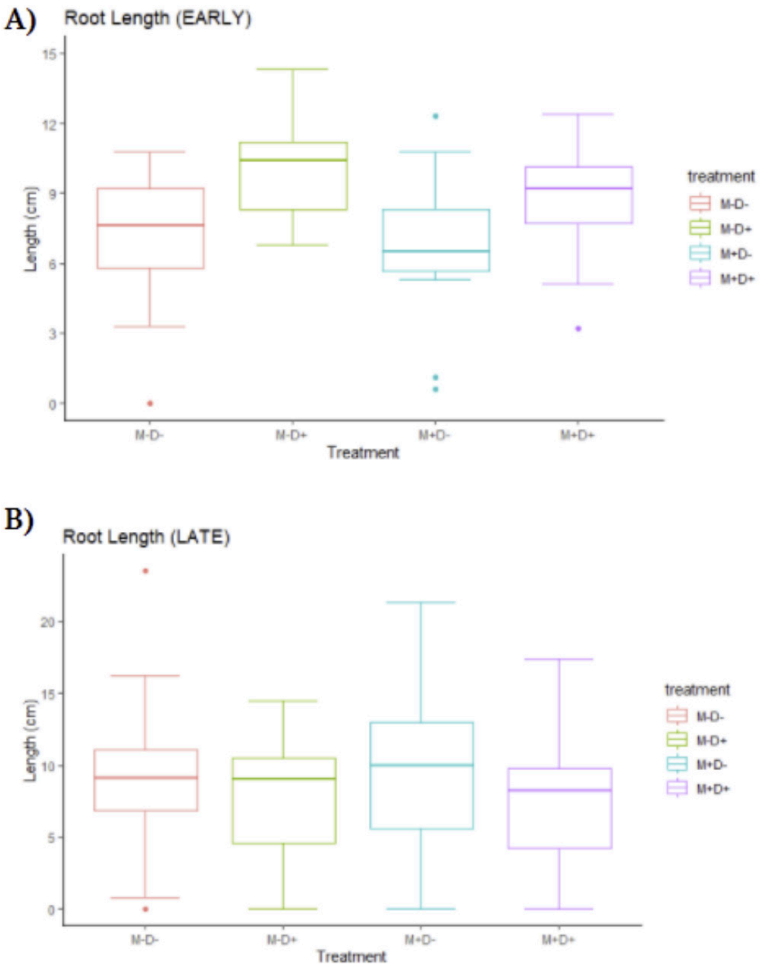

Figure 3: Aboveground biomass in the late harvest cohort. Plot showing the distribution in the biomass of aboveground plant tissue, separated by treatment (mycorrhizal fungi (M±), drought (D±)). Horizontal lines within each box denote median values. Error bars extend outside of each box. Outliers are shown as circles. Treatments are differentiated by colour. **(A)** Early harvest cohort. **(B)** Late harvest cohort. Three outliers are omitted from this plot for scaling purposes: 0.5268 (M+D-), 0.2136 (M+D+), 0.2148 (M+D+).

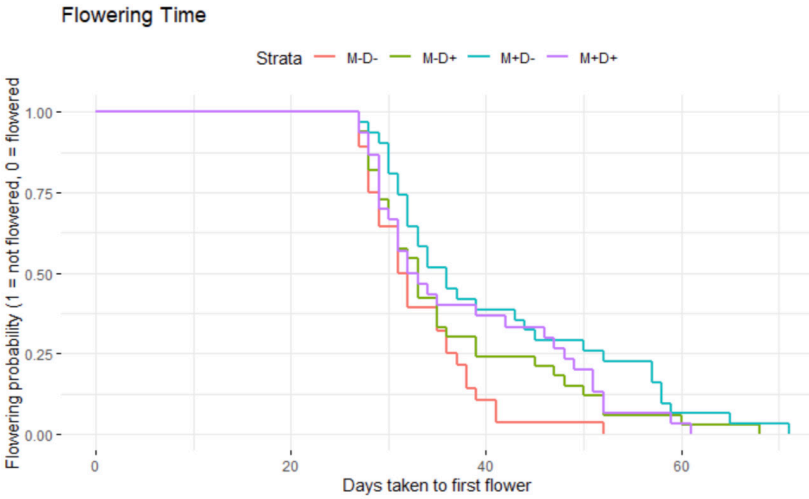

Figure 4: Flowering time. Kaplan-Meier curve depicting time-to-event data. A value of 1.00 indicates the individual has not yet flowered. A value of 0.00 indicates the individual has flowered. Treatments (mycorrhizal fungi (M±), drought (D±)) are differentiated by colour.

Fruit Production

Fruit number was analyzed exclusively from the data collected from the late harvest cohort (Fig. 5). At the time of harvest, only 50% of the early harvest cohort had flowered, much less gone on to produce fruit. The low percentage of plants in the late harvest cohort that successfully produced fruit (~40%) prevented the discovery of any significant effects of treatment on fruit production. An even smaller percentage of the late harvest cohort produced at least one fruit that had matured by the time of harvest (~14%).

Survival

Plants were inspected daily to accurately report survival times. We created a binary response variable of survivorship (died before the end of the experiment/survived to the end of the experiment). Survival analysis found that plants in the M-D- treatment group experienced the highest median survival time (Fig. 6). Using the Cox regression analysis of survivorship, we did not find any significant effects of drought or fungi on survivorship ($p > 0.5$).

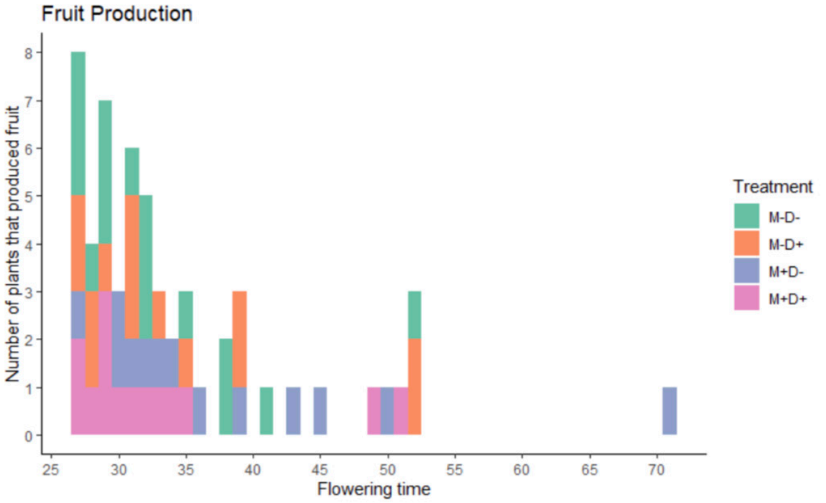

Figure 5: Distribution of fruit production across flowering time. Plot depicting the distribution of plants that produced at least one fruit, sorted by their flowering time. Treatments (mycorrhizal fungi (M±), drought (D±)) are differentiated by colour within each time point.

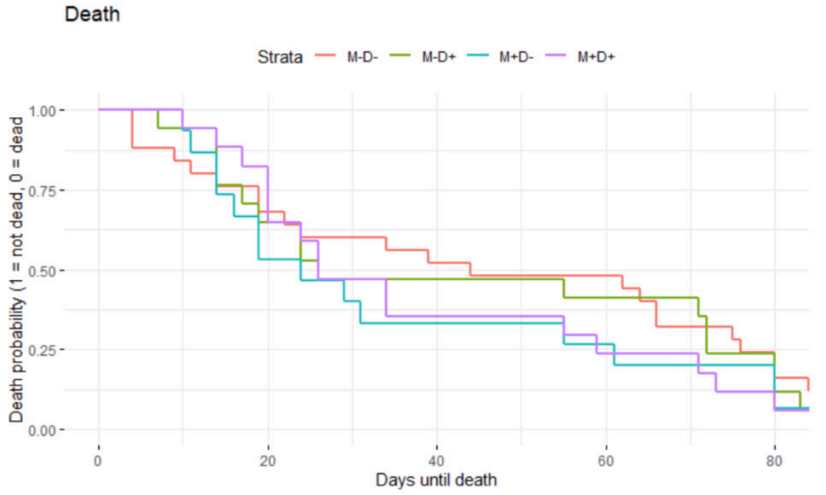

Figure 6: Plant survivorship across treatments. Kaplan-Meier survival curve depicting survivorship. Treatments (mycorrhizal fungi (M±), drought (D±)) are differentiated by colour.

Discussion

Our study revealed partial dynamics of multiple mutualists. We uncovered a context-specific benefit of multiple mutualists on flowering time. Though the presence of the fungal symbiont led to a later onset of flowering, drought stress mediated earlier flowering in plants inoculated with fungi. This suggests a benefit of multiple mutualists specific to water-limited conditions, though this benefit was weak. The strength of the drought treatment may have been inadequate to uncover other benefits in growth and performance. The lack of a clear trend in the changes in leaf count and branch number between droughts suggests the stress from the drought treatment was not sufficient to offset plant growth. Although the drought treatment led to longer roots, the fungal inoculant did not affect this trend. It is also possible that benefits that may be provided through symbiosis with mycorrhizal fungi in conditions of water limitation are more restricted to reproductive output as opposed to plant growth.

The absence of significant differences in nodule number suggests the mutualism between the plant and rhizobia was not compromised by the addition of the fungal symbiont. Mycorrhizal fungi did not enhance rhizobia nodulation and we did not observe synergistic effects on plant performance. The different mutualists may have drastically different impacts on plant performance in a nutrient-limited environment. We did not add any additional nutrients or fertilizers to the growth environment which could have minimized the potential benefits of mycorrhizal fungi in belowground nutrient uptake. Conversely, rhizobia can access nitrogen outside of the rhizosphere and have the potential to confer greater resource benefits to the plant. The lack of nutrient supplementation in fertilizers may have contributed to a growth environment that was not suitable for efficient plant growth and reproduction. The low percentage of plants that produced fruit barred accurate analysis of fitness. However, nutrient-rich environments may mask the potential benefits of mycorrhizal fungi and lead to a costly association.

Our results demonstrate the need for investigating multiple mutualists in varying resource environments. This could include stronger water limitation and nutrient supplementation and removal.

Other compounds produced by naturally occurring vegetation may play a role in shaping the environment upon which mutualisms transpire and are maintained. Aromatic plants produce monoterpenes that can enter the soil and affect the amount and availability of nitrogen in the soil (White, 1994; Pavolainen et al., 1998). Ehlers et al. (2012) found that plant and root symbiont fitness is strongly affected by such compounds in the soil. Multiple mutualists have also been shown to be beneficial in agricultural practices. Inoculation with both rhizobia and mycorrhizal fungi led to improved yield and nitrogen fixation efficiency in intercropping legumes with non-legumes (Meng et al., 2015).

Life history traits may also be important factors when considering the consequences of multiple mutualists. Differences in growth strategies lead to varying investment in microbial partners and dependency on these symbionts for success (Wilson & Hartnett, 1998; Middleton & Bever, 2012). The outcome of microbial interactions in long-lived plants may be more sensitive to environmental variation due to greater investment in belowground production. Larimer et al. (2014) found that the benefits of concurrent symbioses with rhizobia and fungi in the perennial legume *Amorpha canescens* depended on phosphorus level, but the tripartite mutualism was essential for the long-term fitness of the plant.

It is also important to consider the community context of interactions between species (Thompson, 2005; Agrawal et al., 2007), especially when appraising coevolved mutualistic interactions that may vary across environments. The effects of the local environment both in abiotic resources and co-occurring species may be principal factors in shaping the dynamics of these associations (Piculell et al. , 2008). Together, this study has provided promising encouragement for further investigations into the dynamics of multiple mutualists. Ultimately, the role of environmental conditions in the mutualistic landscape requires greater attention, to understand the greater network of interactions and its implications in the broader ecological and evolutionary landscapes.

Contributions

JRS conceptualized the study and obtained funding. JW, JAB, DP, and JRS designed the study. JW performed the experiment and analyzed data. JW, JAB, DP, and JRS interpreted data. JW wrote the original manuscript. JW and JRS revised and edited the manuscript.

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