Evaluating Social and Technological Influences on Patient Misuse in the Rise in Antibiotic Resistance

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On my honor as a student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Antibiotics stand as an exemplar of human innovation reapplying biological tools to revolutionize our way of life. However, data shows that bacteria are reclaiming these tools at an alarming rate. (Dodds, 2017) Antibiotic resistance has been rising with the increased use of antibiotics, in large part because of patients' decisions regarding the drugs' usage. (Abushaheen et al., 2020) Antibiotics are substances used to treat bacterial infection by interfering with cellular mechanisms and integrity, but many bacteria have defenses which guard against specific types of natural antibiotics, either because they themselves produce the antibiotic or because they've evolved to survive its usage. The resulting ability to survive in the presence of antibiotic is called antibiotic resistance. The following paper examines the influence of social and technological factors on the usage of antibiotics by patients that leads to a rise in resistance, employing the social construction of technology and technological determinism as frameworks.

Methods and Outline

The failure to adequately address the role of patients in AMR presents the need for a study evaluating their influence. To address this need, I will employ both the social construction of technology (SCOT) and technological determinism (TD) to give accounts of how social and technological factors influence the misuse of antibiotics by patients. Note that the scope is restricted to patients and regards only those actions which constitute misuse, leading to the rise in AMR. After having given the social and technical context of patient misuse, I will give an account using SCOT, first describing relevant work and then applying it to the topic, and follow it with an account using TD, again describing and applying relevant work. With both accounts in mind, I will present limitations, future work to be done, and possible applications. The research

supporting these arguments focuses primarily on the tools and methods described by proponents of each theory but special consideration is given to previous work done applying each theory to antibiotics and relevant medicine. Key words guiding this research include antibiotic, antimicrobial resistance, the social construction of technology, interpretive flexibility, and technological determinism.

Background

At the turn of the twentieth century, one third of all deaths were due to pneumonia, tuberculosis, diarrhea/enteritis (which would have normally been caused by a bacterial infection), and diphtheria. (Dodds, 2017) By contrast, in 2014, pneumonia accounted for less than 4.5% of deaths, and enteritis wasn't even in the top ten. (Dodds, 2017) Deaths due to enteritis and diphtheria, the former of which now seem to be increasing, amounted to less than a percent. (*CDC Online Newsroom - Deaths from Gastroenteritis Double, March 14, 2012*, n.d.; Clarke et al., 2019) While better hygiene and healthcare certainly play a role, few think the role of antibiotics is overemphasized. These developments are inestimably valuable for society. So, is the world cured of bacteriogenic diseases forever? Speaking broadly, no, or at least not without much continued effort.

This is because microbes evolve in response to antibiotics. A 2017 review of antibiotic resistance explains that “the end of the 20th century and beginning of the 21st saw the beginning and rapid rise of advanced microbial resistance to antibiotics.” (Dodds, 2017) Projecting future morbidity is a subject of some controversy, but one model predicts that by 2050 antimicrobial resistance (AMR) will raise the annual death toll from bacteriogenic illnesses to 10 million. (Sutherland & Barber, 2023) For reference, cancer was responsible for 9.56 million deaths in 2017 and, by the same model as above, is projected to be 8.2 million in 2050. While some argue

that this model is sensationalized and carries a lot of uncertainty (Kraker et al., 2016) none deny that AMR is a serious threat to public health.

The rise in AMR is due in considerable part— if not entirely— to the medicinal use of antibiotics, including the misuse of antibiotics by users. Alexander Fleming, who discovered penicillin, said at his Nobel prize address: "I would like to sound one note of warning… The time may come when penicillin can be bought by anyone in the shops. Then there is the danger that the ignorant man may easily underdose himself and by exposing his microbes to non-lethal quantities of the drug make them resistant." (*The Nobel Prize in Physiology or Medicine 1945*, n.d.) While taking too much of an antibiotic is bad for a patient, taking too little of an antibiotic presents an opportunity for the development of AMR, especially when the doses are administered by patients. Others will argue that resistance increases in proportion to the evolutionary pressure resulting simply from so many available antibiotics being in use, which few deny, but most do not consider this a comprehensive account of the rise in AMR. (Abushaheen et al., 2020) Generally physicians agree that the rise in AMR is due in large part to the "misuse of antimicrobials, inappropriate prescribing patterns, [and the] lack of new novel antibiotics." (Abushaheen et al., 2020) Out of these three, the misuse of antibiotics is particularly relevant when considering the role of patients in AMR. Inasmuch as patients are able to deviate from their prescribed regimen, "inappropriate prescribing patterns" is also relevant but would still fall under patient misuse.

While these factors which promote the rise of AMR involve a number of actors and relationships, this paper will consider patients and their families primarily and the other actors only secondarily. For this purpose, "patients" does not include animals, although much of what's said applied to farmers and their livestock. Patients are involved in the "misuse of

antimicrobials," but their involvement is limited. In general, over the counter oral antibiotics are not approved in the U.S. (*Can You Buy Antibiotics over the Counter?*, 2023) However, doctors do prescribe antibiotics to be self-administered, and "if the treatment regime is not completed, or the dose is too low, then the opportunity for developing antibiotic resistance will occur." (Dodds, 2017) This presents and opportunity for patients to misuse antibiotics by deviating from their prescribed regimen. In this way, the misuse of antibiotics which leads to AMR is partially a social problem, so an account of the social dynamic will be given first using the social construction of technology (SCOT) and then using technological determinism.

The Social Construction of Technology

In a study extending the SCOT framework originally developed by Pinch & Bijker, Humphreys explains that "the social constructionist argument… proposes that social factors and actors lead to technological innovation." (Humphreys, 2005) Acknowledging that the word used here is "innovation" and not "usage," I will extend these principles to argue that social factors influence the usage of antibiotics. SCOT analyzes conflicts, such as the misuse of antibiotics that leads to AMR, in the context of interpretive flexibility, closure, and stabilization. Interpretive flexibility emphasizes the capacity for technology to be understood differently by different social groups. (Pinch & Bijker, 1984) Closure refers to diminished need for an improved design resulting from a closure mechanism such as "rhetorical closure," which is when "relevant social groups see the problem as being solved," although it may only be a perceived resolution. (Pinch & Bijker, 1984) Finally, stabilization refers to the state of agreement between different social groups over the definition of a problem or design.

Previous scholars have applied these methods to AMR and similar problems, but with inadequate focus on patients. Clare Chandler writes on this issue by addressing the stabilization

AMR as a problem, arguing that its stabilization requires a sentinel approach, which provides models and projections of future AMR, rather than an actuarial approach, which consists in counts and trends in AMR up to the present. (Chandler, 2019) The paper argues that such stabilization is beginning to take form in policy, but does not adequately address the role of patients in AMR. Another study applied interpretive flexibility to the adoption of a new antituberculosis drug and found that interviewed patients' interpretations differed from other stakeholders by emphasizing recovery over risk. (Saidi, 2018) The authors point out that "the social groups defined the problems of [tuberculosis] differently and as a result the solutions that were brought by the drug were defined differently." (Saidi, 2018) Patients similar to these whose problem definition differs from physicians may decide to deviate from their prescription, impacting the use and effect of the treatment drug. Therefore this paper aims to characterize the role of patients in the misuse of antibiotics and the rise of AMR.

Technological Determinism

Proponents of technological determinism (TD), by contrast, might account for this conflict by identifying the effects of antibiotic design aspects, effects such as the ability of antibiotics to be shared or the inconveniences of the regimen, which influence a patient's usage. TD can refer to the "subtle but profound social and psychological influences at the microsocial level of the regular use of particular kinds of tools." (*Technological Determinism*, n.d.) This expression is a form of soft TD, as opposed to "hard TD," which "argues that technology is the main or the only significant driver" and "that social influences have little effect on the nature of technology." (Adler, 2006) Identifying aspects of design which enable or exclude certain usage, such as the ability of antibiotics to be saved and shared, aligns with hard TD, where identifying other aspects of design which influence but do not determine usage, such as the inconveniences

of an antibacterial regimen, aligns with soft TD. Proponents of TD in healthcare have applied the theory to antibiotics to explain their use and the technology's role in AMR. Edward Tenner emphasizes the causal role of antibiotics when illustrating how their use resulted in AMR. (Tenner, 1997) Cyrus Mody set out to apply TD to nanotechnology generally, rather than nanomedicine alone, and in doing so turned to antibiotics as an exemplar. He points out that "nature (or 'biology') has been doing nanotechnology for billions of years; every virus, bacterium, and cell is a nanomachine of enormous complexity." (*Mody*, 2004) This construes antibiotics as resulting from the inevitable course of evolution, from which some infer that AMR is also the inevitable product of nature. Observing that a view similar to this inference is held in practice, Jon Khan claims that "technological determinism is pervasive in healthcare." (Khan, 2021) Khan, an opponent of the theory, frames TD as the "idea that technology is the key force in society's evolution that independently determines its economic and societal impact" and argues, concerning the question of CRISPR therapeutics, that TD expects negative outcomes and that we fail to act due to this fear. The way that TD shapes a user's viewpoint and practices will be used below in application to AMR. Similarly, a review of STS in medicine, evidently opposing ideas of TD, argues that TD has been used to construe certain disruptive technologies as solely capable of reinforcing the dominance of select social groups, when from the author's view such technologies could really benefit the patient. (Timmermans & Berg, 2003) Therefore, since a TD-centered mindset can impact user practice, this paper will consider not only the tools of TD by which a scholar can understand a patient's misuse of antibiotics but also how ideas of TD present in healthcare may affect the interpretation of the patient and their consequent actions.

Results and Discussion Overview

Applying SCOT to answer the question of how social and technological factors influence patient misuse of antibiotics results in a description of how the interpretive flexibility of antibiotics allows for asynchrony between the closure of patients and doctors that results in patient misuse. Applying TD to the question yields three separate results, two belonging to hard TD and one to soft TD. Hard TD results in an identification of factors by which antibiotics seem to determine patient usage, but those who allow such factors to operate unchecked cause the concept of hard TD to be itself a driving force of patient misuse. In parallel to the first result of hard TD, soft TD results in the description of design elements which encourage patient misuse subtly but profoundly. By applying SCOT and TD to the research question, each of these four results, which follow closely from the work of previous scholars, will be demonstrated in turn.

Applying the Social Construction of Technology

The rise in AMR follows from the misuse of antimicrobials in as much as an incomplete treatment regimen or a lower than prescribed dosage presents the opportunity for developing antibiotic resistance. (Abushaheen et al., 2020) (Dodds, 2017) Under SCOT, misuse should be understood to originate from the way patients differ from doctors in defining the technology and perceiving the problem. Closure, which consists in a diminished need for intervention, drives the patient's choice to end a regimen early but depends on the perception of the patient. This dependence can be understood through the connected concepts of "interpretive flexibility" and "rhetorical closure." The first emphasizes the ability of social groups to define a technology in unique ways, (Pinch & Bijker, 1984) such as when patients may view antibiotic as a cure to symptoms rather than infection *per se*. The second, rhetorical closure, is when "relevant social groups see the problem as being solved" although it may only be a perceived resolution, (Pinch

& Bijker, 1984) such as when symptom-free patients become convinced the infection is over before it really is.

Whether it results from a different definition of the technology or a misperception of the problem's needs, closure may occur for patients before it occurs for the doctor, preventing stabilization. Stabilization is a state of agreement between different social groups over the definition of a problem or design. If patients and doctors reach stabilization with respect to the use of antibiotics to fight infections, then patients will be more likely to follow the directions of experts and experts more likely to value the priorities of patients. I will not consider here the possibility of provider's changing their interpretation of the technology, only because this paper is restricted to the patient's role in AMR. Currently it is likely that patients prioritize recovery over risk, as has been found in another study on a novel antituberculosis drug. (Saidi, 2018) Clare Chandler argues that the stabilization of AMR requires a sentinel approach, necessitating patients to understand and value AMR projections in their decision making. (Chandler, 2019)

As was said above, the interpretive flexibility of antibiotics between patients and doctors leads to different social groups defining the problem in different ways. If the patient prioritizes symptom remission, they will be encouraged to take an actuarial, short-term perspective rather than a sentinel approach to the problem. I make no claim here about which is right and wrong, but if doctors define antibiotic as a cure to infection and patients define it as a cure to symptoms, then closure, here consisting in a diminished need for treatment, may occur at different times for doctors and for patients. As long as the patient defines the problem this way, they will take an actuarial and symptom oriented approach, preventing stabilization. Therefore SCOT would expect that, in addition to the misperception of the problem that occurs in rhetorical closure, the

decision not to complete a regimen may result from the early closure encouraged by this symptom oriented approach.

Applying Technological Determinism

TD applied to the research question in both its "hard" and "soft" forms. Unlike soft TD, hard TD "argues that technology is the main or the only significant driver" and "that social influences have little effect on the nature of technology." (Adler, 2006) Hard TD would consider design elements as determining factors which necessitate, enable, or constrain a user's actions. Let it be known that the purely scientific questions connecting the presence of antibiotic and the rise of AMR will not be discussed here. I will take for granted that bacteria evolve in response to selection pressures by developing resistance and that the medicinal use of antibiotic has led to this. (Abushaheen et al., 2020) (Dodds, 2017) (Sutherland & Barber, 2023) Regarding the question of how technology may influence a patient's misuse of antibiotic, the concept of hard TD will be applied in two ways: first as a means of explaining the driving forces of a patient's decision and then as the driving force itself. After this, the question will be treated using soft TD.

As a means of explaining the sources of a patient's decision, hard TD would identify any *determining* factors, such as the antibiotic's ability to be self administered and its inability to kill resistant bacteria. The first enables patients to save or share antibiotic, ending the regimen early, and the second is a limitation of the technology, be it by nature or by design, that underlies the entire development of AMR. While these factors frame and enable the misuse of antibiotics, they do not seem to determine the patient's decision. However, hard TD still plays an important role in patients' misuse of antibiotics by acting as a driving force forming the user's understanding of the technology.

To take it as a driving force itself, hard TD must be considered as an influential idea. Jon Khan (2021) argues that TD instills a fear that if a certain technology is developed, certain negative outcomes are inevitable. In the case of CRISPR, on the one hand, Khan believes that this mindset prevents the technology's development. (Khan, 2021) In the case of antibiotic, on the other hand, the technology is already developed, so to say that the negative outcomes are inevitable would mean that patients have no influence on the rise of AMR. It is easy to see why bacteria's response to antibiotic is seen as inevitable considering the voice of scholars such as Cyrus Mody (2004) who describe the bacterium as "a nanomachine of enormous complexity" through which "nature (or 'biology') has been doing nanotechnology for billions of years." Machine's are by nature mechanistic, so if machines could evolve and if we applied evolutionary pressure, then they *would* evolve. Those patients holding this mindset may end a prescribed regimen early believing that they could not impact the rise of AMR even if they tried. In this way, TD as an idea, especially hard TD, influences patient behavior and promote the rise of AMR.

Soft TD on the other hand, which emphasizes the subtle but profound influence of tools over a longer span of time on the actions of its user, would utilize the aspects of design that encourage misuse without determining it. A patient may be discouraged from completing a regimen by the inconvenient side effects of antibiotics (Cunha, 2001) or their desire to enjoy the milk, alcohol, and citrus that patients are sometimes warned against mixing with antibiotics. (The Do's and Don'ts of Taking Antibiotics | St. Luke's Health, 2019) The technological factors identified by soft TD may be design choices, failures in the therapeutic's developement, or simply natural limitations, but inasmuch as they influence the patient's decision whether to

complete a prescribed regimen they should be considered both in the technology's redesign and in social initiatives aimed at promoting good use of antibiotics.

Limitations

The limitations of this paper include the assumptions about patient characteristics on which its conclusions depend and insufficient attention to the role of patient-doctor communication. The primary limitation of this paper is the conditional nature of its conclusion. It has been shown that *within* certain frameworks, namely SCOT and TD, and *given* certain characteristics in a patient, such as a symptom oriented approach or a TD-centered perspective, the patient may decide to misuse antibiotics. While each framework was shown to fit the situations to which it was applied, it is outside the scope of this paper to defend the principles and tools inherent to these STS theories and so I assume that they are valid. However, the conclusions of this paper cannot be applied to particular patients or even as trends within a population without the second condition, viz. the symptom oriented approach or TD-centered perspective of the patient population. Other limitations include the lack of attention given to patient-doctor interactions, which is beyond the scope of the paper but would be necessary to answer the research question fully.

Future Work

Given these limitations, future work should be done to investigate the patients' perceptions of the purpose of antibiotics, in order to determine if there is a trend towards symptom-oriented definitions of the technology that would prevent stabilization and encourage early termination of the regimen. Work should also be done to determine the prevalence of a TD-centered perspective among patients concerning the rise of AMR, since this may encourage antibiotic misuse as has been said. The research question would also benefit from the application

of different STS theories and the investigation of other inadequately addressed social groups, such as patients' families or those with and without health insurance. Applications of the study include (1) redesign of the therapeutic, including prescription practices, mode of administration, and shareability, and (2) design of social initiatives to explore and form patient perspectives on the therapeutic in order to reach stabilization between doctors and patients on the technology's definition.

Conclusion

In answer to the question of how social and technological factors influence the misuse of antibiotics by patients, SCOT expects patients' definition and perception to differ from doctors, leading to misuse and preventing stabilization. Hard and soft TD identifies various aspects of the technology which seem to determine and encourage misuse respectively, but TD's role as an influential concept may also encourage misuse of antibiotic if patients perceive the rise of AMR to be inevitable. While further work should be done to explore patient beliefs and different STS theories, the results of this study can be applied to redesign antibiotic treatments and to bolster initiatives which prevent misuse that promotes rising AMR.

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