Designing a Tool to Reduce Operator-Dependent Variation of the Skin Prick Test
(Technical Topic)

Allergy, Class, and Pollution: An Analysis of the Structural Players in Allergy
(STS Topic)

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On my honor as a University 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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Allergy, Class, and Pollution: An Analysis of the Structural Players in Allergy

I. Overall Introduction

Food allergy incidence has increased worldwide over the past several decades, particularly in industrialized countries (Cosme-Blanco et al., 2020 p. 404). In the United States, at least 10% of the population suffers from a food allergy (Warren et al., 2020 p. 2). Thus, food allergy is a common condition with increasing relevance. Patients with more food allergies report a lower quality of life compared to those with fewer food allergies (Allen et al., 2015 p. 697), thus there is a large motivation for development of treatments to reduce or cure the symptoms.

The nine main allergens identified by the FDA are milk, eggs, fish, shellfish, tree nuts, peanuts, wheat, soybeans, and sesame (Program, 2024). Though food allergy is typically treated with food elimination, this avoidance can have unintended consequences. Food elimination can cause increased sensitivity to the allergen, nutritional deficiencies, and anxiety (Singh et al., 2022). In February 2024, the US Food and Drug Administration (FDA) approved the first medication for treatment of food allergies, Xolair (omalizumab). This medication, however, only reduces the risk of life-threatening allergic reactions, or anaphylaxis, and must be used in conjunction with food elimination, or the avoidance of the allergen food (Commissioner, 2024). Considering that Xolair is an extremely recent advancement and still requires diet restriction, much work still must be done to better understand and treat food allergies.

Considering the ever-rising prevalence of food allergy in the United States, I chose to explore the experience and diagnosis of food allergies for my Capstone project. My technical project focuses on the allergen skin prick test and aims to create a device to improve the reproducibility of the test results. My STS project explores the food allergy inequities faced in Appalachia, and its connection to inequalities in exposure to pollution across race, class, and geography in the United States.

II. Technical Topic

The current most popular method for allergy diagnosis is the skin prick test (Fatteh et al., 2014). In this test, allergen oil is dropped onto the skin, and the surface of the skin is pricked. Because the prick is shallow, blood is not drawn. Instead, the test administrator looks for a raised bump around the prick, referred to as a wheal. The size of the wheal is used to correspond to the severity of reaction (Chiriac et al., 2013). Benefits of the skin prick method is that the test is cheap, results can be seen within 15-30 minutes, and the test is representative of mast cell activation, a direct measure of allergic response (Fatteh et al., 2014). A major problem with this testing method, however, is that there is a large degree of variation in test results (Carr et al., 2005).

There are no consistent standards for the administration of allergy skin tests (Fatteh et al., 2014). Even the type of device used to prick the skin varies across nurses and clinics (Carr et al., 2005). Factors of the patient such as eczema, dark skin tone, and thick hair can also impact the interpretation of the test (Andersen et al., 2016).

The goal of my technical project is to create a medical device that reduces the variation in the skin prick test. The first specific aim of this project is to determine a method for testing the effectiveness of current devices. Prospectively, I will be synthesizing a gel with similar properties to the top layer of skin, or epidermis. Some properties I will be replicating include elasticity, pore size, and thickness. Using a highly-calibrated force machine called an Instron that will "hold" the device, I will test the effects of angle of insertion, force of prick, and device design on the amount of allergen oil delivered inside of the gel. The goal of this aim is to determine potential problems with current devices and to create a standard for which my fabricated device will be compared against.

The second specific aim of this project is to design a new device to improve the reproducibility of the skin prick test. I am currently considering the force, angle, and depth of insertion to be variables that should be controlled by the device. The results of my first aim will provide me with data to inform my priorities in device design. The effectiveness of the device will be tested using the same method as in my first specific aim.

III. STS Topic

Allergy disease has both genetic and environmental factors. Pollution is one such environmental factor that can increase the incidence of allergy (Wang et al., 2023). One potential explanation for the mechanism by which pollution increases the rate of food allergy is that pollutants inflame the outside layer, or epithelium, of organs. Studies in mice have shown that epithelial inflammation is associated with severity of food allergy. (Lee & Ramsey, 2024). My STS topic is the association of allergies with pollution, and the further interplay of race and class within this association. To explore this topic, I aim to use the lens of Environmental Justice, Social Determinants of Health, and Ecological Systems Theory.

Environmental Justice

The exposure to pollutants is not equal among social or geographic groups. In North Carolina, assuming that each county has an equal likelihood of having a large polluter, counties with over 80-percent non-white residents would be expected to have just under 6-percent of the state's large polluters. In reality, however, these counties have 10-percent of the state's large polluters (Banzhaf et al., 2019 p. 186), which is almost double the expected value. Similar differences can be found across the country; in California, black, Hispanic, and Asian residents are more exposed to automobile emissions than white residents (Reichmuth, 2019 p. 1); across the US, black residents are more likely than white residents to have long-term exposure to pollution. There is additionally a well-established relationship between poverty and pollution exposure (Pais et al., 2014 p. 1191). All of this evidence paints a picture of unequal distribution of pollution exposure in the United States based on race and class.

Though pollution exposure is often associated with urban environments in the United States, rural Appalachia suffers from a unique set of conditions. The high mountain elevation traps air pollutants, causing sulfur and nitrogen deposition rates that are among the highest in North America. The average annual pH of rain in the Great Smoky Mountains is 10 times more acidic than natural rain (*Air Quality Monitoring (U.S. National Park Service)*, n.d.). Additionally, coal mining in Appalachia has been documented to public health concerns such as maternal mortality, cancer, and cardiovascular disease (Pericak et al., 2018).

Why are there such differences in pollution exposure across race and class, even in the same states or even cities? As eloquently stated by Dwight Billings, “regions do not exploit regions; classes exploit classes” (Billings, 2016 pp. 57-58). My suspicion is that the unequal distribution of pollutants is not accidental but rather by design of a white wealthy class that deems both the convenience of dysregulation and the class insulation from pollution to be worth the detriment of poor people and people of color. I hope to explore this connection further in my STS paper and determine if the distribution of pollution is indeed dictated by wealthy elites.

Scholars on the effects of pollutants on Appalachian health include Leigh-Anne Krometis at Virginia Tech, who focuses on waterborne disease; Michael Hendryx at Indiana University, who focuses on coal mining; and Nancy Schoenberg at University of Kentucky, who focuses on public health interventions. The field, however, is relatively small, and is funded primarily by grants from the US government or the Appalachian Regional Commission (ARC). A question I would like to answer in my STS paper is why there is a lack of investment to understand the health inequities faced in Appalachia and its connection to the inequality in exposure to pollution across both race and class in the United States. Why is there limited data on the pollutants present in Appalachia? What are the ways in which Appalachians interact with their environment? How do politicians and industries view the issue of environmental pollution and its effects on health?

Social Determinants of Health

Despite the current gaps in knowledge about the pathogenesis of allergy, there are some potential risk factors for its development; two factors well-supported by research are environmental pollution and delayed introduction of allergens (Togias et al., 2017; Wang et al., 2023). These risk factors are ironically very different; on one hand, an environment that is too dirty and unrestricted can promote allergy development, but on the other hand, an environment that is too hygienic and controlled can do so as well. For families with the ability to control their infants' exposure to common allergens, the solution is simple: expose infants to allergens early on (Togias et al., 2017). For families living in polluted environments, however, the solution of moving to a cleaner environment is not as simple; for this reason, poorer people are exposed to higher rates of pollution than wealthier people (Pais et al., 2014 p. 1191).

I am curious in contrasting the effects of wealth and poverty on people with allergies. Social Determinants of Health tells us that income, education, and social status can impact our health outcomes. What are the similarities and differences between the experiences of people with allergies? What is their level of access to allergen-free foods? What is the perception of their allergies by their neighbors? What is their level of anxiety around food?

Ecological Systems Theory

Ecological Systems Theory explores the effects of various levels of systems – micro, macro, meso, and exo – on an individual. The two previous theories explore the effects of large systems such as class, race, and environmental injustice on the individuals' experience with food allergy. These systems would be considered mesosystems and exosystems because they extend to the individuals' neighborhood and beyond. However, how is food allergy perceived within families, or the macrosystem? What are some of the obligations and anxieties felt in the macrosystem? How does the macrosystem adapt, or not adapt, to the presence of allergy?

How does the microsystem and macrosystem interact with the systems above them? Are these smaller systems aware of the larger systems? To which extent? I believe these questions are of relevance in Appalachia, where large disparities in health education exist. What is the level of awareness of Appalachians on the pollution in their environment, and who do they believe is responsible for fixing it?

IV. Overall Conclusion

My STS and technical projects are united by their focus on allergy. My technical project aims to improve the quality of allergy skin prick tests, a cheap but currently unreliable method of diagnosing allergy. Improving the test can hopefully result in more accurate diagnoses. My STS project, on the other hand, aims to explore potential disparities in allergy prevalence and experience, particularly in Appalachia.

By the end of my Capstone, I hope that I would have accomplished enough work in the area so that someone is able to step on my shoulders to continue the work in reducing healthcare disparities in allergy and beyond.

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