How Framing Engineering Ethics Changes our Conception of the Engineer

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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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Introduction

In the United States, men and women alike rely heavily on automobiles as their primary mode of transportation, but women are at far greater risk of injury and even death, due to inequitable safety design. Currently, the National Highway Traffic Safety Administration (NHTSA) uses almost exclusively 50th percentile male crash test dummies in their automobile safety tests, and these tests profoundly impact automobile design. The NHTSA is the bureaucratic agency responsible for devising car safety standards, and in a report by Stucki, who is an NHTSA engineer, Stucki states that "the current frontal impact protection standard assesses vehicle performance with a single size, 50th percentile, male dummy" (Stucki, 1998, p. 9). This raises the question of whether or not women are safe in automobiles, and a thorough look at the data suggests they are not, with one report from the NHTSA stating that "the fatality risk of women drivers and RF (right front) passengers [is] 17.0 percent higher than it is for male drivers" (Kahane, 2013, p. 12).

The safety standards an industry tests against will directly influence the design constraints placed on engineers operating within that industry. The goal to make airplane ejections safer for pilots revealed a need for models of multiple anthropometries, or proportionalities of human measurement, which are absent in most safety designs. Current models and safety designs are centered around what is deemed a standard anthropometry, which refers to a very specific 50th percentile male. The issue of allowing generalized models to dictate safety standards is that "[because] automotive design is directly influenced by the results of safety testing, any bias in the way cars are crash-tested translates into the way cars are manufactured." (Barry, 2019). If safety standards are such that we only test to ensure devices are safe for 50th percentile males, we do so at the peril of the rest of the population.

Engineers responsible for developing safety standards, injury criteria, and safety models have a bias for centering all these safety standards around males, leaving the rest of the population vulnerable.

The NHTSA has focused very heavily on male drivers, but with a bit of digging it becomes clear that this is not just some overt bias. According to data from two governmental agencies compiled by Bose a senior transport specialist, men are nearly three times as likely to be involved in a fatal car crash than women are (Hux, 2021). However, when this raw data was further processed by data scientists and controlled for factors like miles driven and differences in vehicle choice between men and women, it was found that “The odds for a belt-restrained female driver to sustain severe injuries were 47% higher than those for a belt-restrained male driver involved in a comparable crash.” (Bose et al., 2011). The STS research in this paper analyzes how framing the engineer as a system can alter how we go about inculcating virtues, leading to a generation of engineers that emphasizes equity in design.

<u>Neck Brace Designed to Augment Spinal Safety During Pilot Ejection</u>

My introduction to the safety design problem came when Dr. Robert Salzar, who is my capstone team’s research advisor, showed us the work he performed on characterizing ejection bio-kinematics across multiple anthropometries. This work simulated vertical loads on mannequins and then tested those values on cadavers to determine the manakin’s biofidelity, which simply refers to the ability of something like a manakin to accurately represent a human. The work performed by Dr. Salzar showed that flawed models hide the mistakes of flawed designs. When Dr. Salzar modeled the ejection forces on manakins everything seemed to be fine across the various anthropometries, but when he moved on to confirm those findings with cadaver tests, he found that the 5th percentile female was likely to have her thoracic spine snapped in two. Current neck injury criterion models for pilots use a 50th percentile male in their models, with Bass stating that their values were “scaled to a 50th percentile adult male” (Bass et al., 2006, p. 2). Dr. Salzar’s work puts the limitations of current safety criterion on full display, and since engineers have to work within the parameters they are given, the development of safety criterion that better represents the population will lead to more inclusive engineering.

The problem with using a 50th percentile male as a model for the average population, is that there is an assumption that these models scale accurately. According to the Department of Transportation, a 50th percentile male is defined as “a person weighing 164 pounds and possessing the following dimensions: erect sitting height: 35.7 inches; hip breadth (sitting): 14.7 inches; hip circumference (sitting): 42 inches; waist circumference (sitting): 32 inches; chest depth: 9.3 inches; and chest circumference: 37.4 inches” (Department of Transportation, 1999, 123). Although there are many fields where inequitable safety considerations leads to portions of the population being less safe, this research will focus primarily on the automobile industry since it is one the most pervasive examples of this.

The NHTSA is Biased Towards High Exposure Populations

Stucki states in a report that “The 95th percentile group, although the least populous, experiences substantially more fatalities and MAIS 3 injuries than the 5th percentile group and has the highest injury and fatality risks…” (Stucki, 1998, p. 11). In this quote Stucki identifies a risk to a population, but ends his assessment as quickly as it begins by emphasizing how unpopulous this group is, insinuating that it is less important as a result. The inclination to focus on males is likely

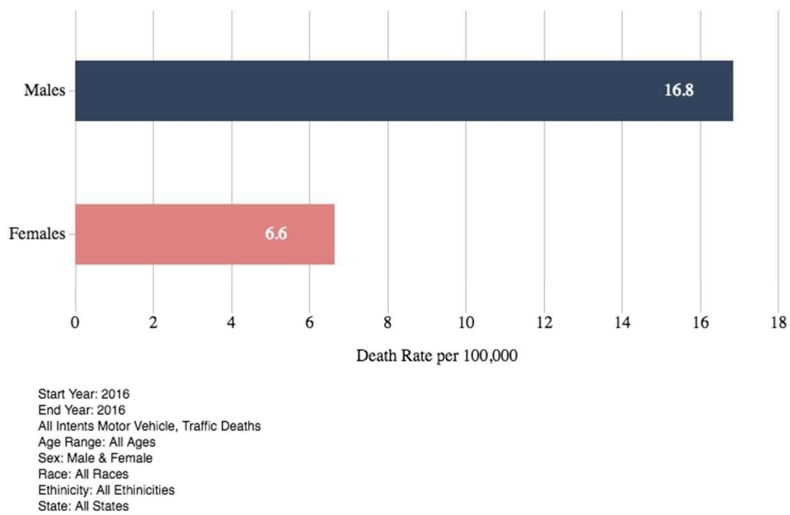

Figure 1: Graph by the American Council on Science and Health showing the death rate caused by automobile per 100,000

justified in the minds of engineers by data like that shown below in Figure 1, which illustrates that men are more than two and a half times as likely to die in an automobile accident than women are.

The report written by the NHTSA that validates current testing standards indicates clear limitations as you move farther away from the 50th percentile. The report by Stucki contains a table comparing injury severity and driver size, shown below in Table 1; this table shows the absolute values of injuries across populations, further illustrating the fact that these outliers in the population are at significant risk compared to those who are closer in stature to the 50th percentile male.

Estimated Annual Driver Injury/Fatalities in Left Offset Impacts With Air Bags

		DRIVER SIZE GROUP		
INJURY LEVEL	Total	5th Percent	50th Percent	95th Percent
MAIS 2	45,924	11,796	19,819	14,309
MAIS 3	11,520	1,261	7,307	2,953
Fatalities	4,243	224	3,004	1,015

Table 1: NHTSA's report on estimated driver injury/fatalities in left offset impacts with air bags, showing both injury severity as well as number of fatalities per population. (Stucki, 1998, p. 11)

This table shows the increased exposure when you stop to look at the ratios and consider a standard distribution; in a standard distribution one should expect 68% of all injuries and fatalities to fall within one standard deviation of the average, but this curve is significantly flattened. According to Ferreira who wrote a review on maximum abbreviated injury scale (MAIS) ratings, a 3 on the scale is defined as a "serious traffic crash injury" (Ferreira et al., 2016). One of the major conclusions drawn from the Stucki report is that both smaller and larger individuals are at much higher risk of injury, but this fact is again accompanied with a statement about "decreased crash exposure" (Stucki, 1998, p. 2).

According to another NHTSA report, this one written by Kahane, women are far more vulnerable than men in car crashes that exhibit similar circumstances (Kahane, 2013, p. 9). In Kahane's report, which is a data analysis on the effects of age and gender on population vulnerability, he writes that women are far more likely to sustain injuries to the neck, abdomen, and legs. Despite reporting on a lot of facts Kahane never attempts to diagnose the issue, nor is there a call to action, instead Kahane opts to simply state facts and suggest what the largest potential influences that give rise to the disparity between men and women may be. These reports show a clear bias for efficiency and populations with higher risk exposure, so current safety standards reflect this bias. Gaps in safety design are the result of using almost exclusively male crash test dummies and working on the assumption that these models scale accurately for females.

Safety Design Must Aim for Equity

Authors of academic journals and news articles alike bring up strong accusations against the NHTSA of being derelict in their duty of protecting the American people. In the paper written by Bose, crash vulnerability between genders is again the question of interest but the problem is dealt with much more directly than it was in the paper written by Kahane. After analyzing data on automobile crash victims, Bose found that females are 47% more likely to sustain severe injuries than males under similar crash conditions, and from this result Bose drew the conclusion that "health policies and vehicle regulations must focus on effective safety designs specifically tailored toward the female population for equity in injury reduction" (Bose, 2011). Kuhn, an author for Fast Company magazine, writes that the NHTSA is contributing to social inequality and that this problem is "swiftly solvable" (Kuhn, 2021). A writer for The Guardian newspaper stated that "The gender data gap is both a cause and a consequence of the type of unthinking that conceives of humanity as almost exclusively male" (Criado-Perez, 2019). And Sarah Holder, a Bloomberg author, writes at much further length on the issue and strikes a much better balance in her definition of the problem, calling on a variety of specialists in order to best encompass the scope of the problem. It is clear from these papers and news articles that many scholars and reporters are concerned about the lack of female representation in the automotive industry's safety test criteria, which raises the question of why there is such a vast chasm between what engineers are designing and what the population needs.

Pacey's Approach to Ethics in Engineering (SA2)

The focus of Pacey's work that laid the foundation for my STS research, was the problem that engineering ethics does not get near enough attention in either engineering training or the engineering design process. Much of the writing that Pacey produces about engineering ethics emphasizes rich dialogue between engineers and the members of society most greatly impacted by the engineer's technology. The goal of this dialogue is to prevent a disjunction between what Pacey terms the "virtuosity-oriented imperatives" of experts and the "need-oriented views" of lay people. This is to say that experts easily lose sight of their original goal of improving public wellbeing and start focusing on challenging their abilities, and pressing the limits of their practice, whereas non experts are directly concerned with improving public wellbeing because they are directly impacted by it. Pacey outlines two ways in which this disjunction can be mitigated. The first approach is through the fostering of a strong ethical framework in engineers that will help them to keep the needs of society at the forefront of their minds so that these needs are addressed in their work. The second of the two approaches is to open up dialogue so that those affected by technology have some input that may allow them to influence the design process. Pacey's application of engineering ethics can either be achieved through changing individuals, institutions, or some combination of the two.

On the NHTSA's website, they state their mission is "to save lives, prevent injuries, and reduce economic costs due to road traffic crashes, through education, research, safety standards, and enforcement." After reading through the literature and articles available on female representation in automobile safety tests it is clear that there is a disconnect between NHTSA engineers, who uphold current automobile safety standards, and journalists and academics, who challenge the completeness of current automobile safety standards. This disconnect is reminiscent of the Massachusetts hospital case described by Pacey where a group of surgeons planned to perform five heart transplants that would have been demanding of both the skills of the surgeons and the resources of the hospital, but this plan was swiftly denied by the hospital's board who opted to instead focus the expertise of their surgeons and resources at their disposal to more routine procedures that could save many more lives. The situations of the NHTSA and the Massachusetts hospital are different in that the NHTSA's disconnect is likely caused by bad modeling assumptions and a desire to uphold the status quo while pursuing other aims, where the surgeons were likely blinded by prestige. However, these situations are very similar in that they both illustrate the disconnect that often arises between the virtuosity-oriented imperatives of experts and the need-oriented views of lay people. These two situations also illustrate the importance of rich dialogue; in the case of the Massachusetts hospital a requirement for dialogue and arbitration of expert desires resulted in the general population being taken care of more effectively, and similarly the lack of dialogue between the NHTSA and the public has resulted in a lack of equitable protection, clearly evidenced in the earlier section "Safety Design Must Aim for Equity".

Without rich and continuous dialogue engineers are not likely to produce technology that has an all-encompassing view of the end user in mind, making the establishment of some sort of structure that necessitates dialogue of experts and lay people necessary. There is often a disconnect between what engineers produce and what the public needs, as mentioned by Pacey when he says that engineers in high tech feel more like they are "playing with toys" than working towards the betterment of humanity. Despite the calls of academics like Bose and journalists like Criado-Perez for more equitable safety design and validation protocols, the NHTSA continues to base safety ratings almost exclusively off of performance on male crash test dummies. There is a disconnect between the public desire for more equitable safety design and the NHTSA's insistence on focusing on males despite the fact that females are 47% more likely to sustain injuries compared to males under the safety guidelines.

In addition to outlining a path for reconciling the disconnect between virtuosity values and user or need values through the implementation of institutions that foster dialogue, Pacey also outlines how this end could be achieved through individual discipline. The aim of this individual discipline is illustrated through a quote by Bacon where he states that "men should seek knowledge and practical skill not for pleasure of mind, superiority to others, or for profit… but for the benefit and use of life." Pacey describes the changes necessary to achieve this aim in an almost spiritual sense and says that the ability to "strike a balance between virtuosity values and user or need values… requires a discipline and a process of personal ethical development". While it is unclear how this personal ethical development should take shape, what is clear is that the current state of engineering ethics is lacking.

According to Pacey, one key ingredient that is missing from engineering ethics is charity. Lawyers can take on cases pro bono to help those who cannot afford their services, doctors provide basic health screenings to communities, local or otherwise, who cannot afford medical care, but engineers have no such way of providing their services to those who need them. Bacon and the Sarvodaya movement both describe charity as "practical action to relieve suffering", but unlike Bacon the Sarvodaya movement emphasizes the deep spiritual connection such work can bring (Pacey). Pacey, Bacon, and the Sarvodaya movement have one distinct trait in common; they all believe in the importance of charity. These three thinkers argue that one of the root causes of such a disconnect between engineering work and ethics is that engineering work in high technology is so far removed from its societal impact that it is more akin to "playing with toys" than improving the well-being in society. Without something clear to connect an engineer's work with the profound societal impacts their work will have, the engineering discipline will continue to produce engineers who fail to prioritize public needs.

The NHTSA serves as just one example where engineers have failed to strike a balance between virtuosity values and user values. Engineers at the NHTSA like Stucki are more interested in using the models already in place than producing better, more representative models. The proclivity of engineers like Stucki is to maintain the status quo, rather than focusing on adjusting methods to better suit the needs of the end user. There is a clear disconnect in the case of automotive safety that pits engineers against scholars and journalists. Stucki, an engineer for the NHTSA, wrote a technical paper that validated the current models, and made no mention of a need for crash test dummies that better represent females, despite the outcry from scholars like Bose who wrote that the NHTSA has to focus on female specific safety design if there is to be a change towards “equity in injury reduction” (Bose, 2011). Engineers have the ability to shape and alter society with the technologies they produce, so it should be a high priority to setup institutions that keep engineers in constant dialogue with those people most affected by their technologies, hopefully resulting in design for human needs and safety being at the forefront of concerns in the design process.

<u>Experiences and Training can Alter a Person’s Moral Framework (SA3)</u>

If we can appropriately frame the problem of engineering virtues and where they diverge from engineering practice, then we can better diagnose the root cause of the problem and provide a more appropriate remedy. To better understand the goals and obstacles facing engineering ethics it is useful to borrow a framework from computer programming. In the world of computer programming a function is a module that takes in data, like integers or strings, processes it, and then returns a result. Using this method of framing engineers as funcitons, we can think of the conditions requiring ethical action to be like the arguments to a function, seen below in Figure 2; these conditions are the inputs, and changes to these inputs will affect the outputs in a direct causal manner. These arguments can be thought of as containing the raw data that will be processed by the function. The function body is the internal workings of the function, where the data is processed and altered, in our analogy this would be the engineer themselves. And finally, we have the output of the function, this is the final product of the function and is akin to the actions taken by an engineer in this analogy. In the analogy constructed in this paragraph it can be seen how a function which takes inputs and provides outputs can be a system which is analogous to the system of an engineer as a moral agent.

The issue with the model described in the paragraph above is that we cannot change the inside of it, but by also thinking of training and experiences as inputs we can make changes to the engineer, the function body, that will result in a different outcome. In programming the way to alter a function's behavior given the same data is to also provide a function as an argument; by layering functions on top of each other you can add functionality to the existing system. Keeping with our engineer function analogy, which is illustrated above in Figure 2, anything which alters the way an engineer thinks, whether that be experiences or training, can be thought of as an input which alters or extends the functionality of the original function. This can get a bit confusing, but another way of visualizing it, which I am borrowing from Jonathon Haidt's *The Righteous Mind,* is to think of people and the moral intuitions they are born with like the first draft of a paper, the original

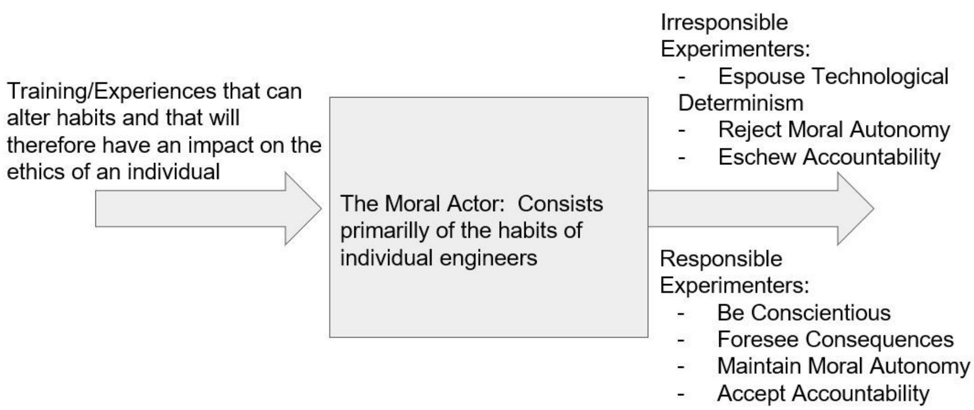

Figure 2: Moral actors, which includes engineers, can be conceptualized as a function where training/experience are the arguments, or inputs, and moral action, good or bad, is the output.

system; this first draft provides the original moral intuitions a person will exhibit, but a person's life experience has the ability to either rewrite or strengthen this first draft. The reason I have so forcefully drawn up this analogy of functions is that it points clearly to the fact that if we want to alter the actions taken by moral agents, what we need to focus on is not the actions these agents take, but the building up of a moral or ethical framework which yields the actions we desire.

Comparing engineers to functions makes it clear that training and experience are what have the capacity to change a person's moral compass, so these are the inputs we should be most interested in modifying if we want to change the behavior of engineers. Pacey emphasizes the power of charity and how this experience, or input, can alter and extend the way that a person's moral framework processes incoming data. While Pacey may have been convinced that charity is the best way to produce more ethical engineers, modeling engineers as functions points to the idea that this may only be one of many ways to drive engineers towards more ethical actions. What can be gleaned from framing this issue as a need for extended functionality is that the missing ingredient in engineering ethics is not necessarily charity as Pacey suggests, but any experience that can enter into the argument side of the function that would lessen the divide between an engineer's work and the effects of that work on society.

The analogy of engineers as functions provides a framework for analyzing engineers and other moral actors that places the emphasis on the inputs; what goes into altering a moral actor's intuitions, or habits, will affect their actions, and therefore it should be the focus of many of our conversations on engineering ethics. If this framework were to be adopted, and we were to begin thinking of experiences as inputs that have the ability to alter a function, we can start to identify which inputs have profound impacts, and then further identify which of those factors are most readily within our ability to control. Identifying which inputs have the most profound impact on nurturing the development of competent moral actors will require that we first identify which virtues lead to favorable actions, and then identifying what experiences lead to the development of those virtues. This novel framework will require further inquiry in the fields of sociology and psychology, and will need to be the subject of much debate since we cannot begin to identify what virtues are desirable if we cannot come to any sort of consensus on what a favorable outcome ought to look like. Although most of our work is still ahead of us, the goal of this model which poses moral agents as functions is to get us looking at moral agents in a way that is more formulaic, providing a framework for inquiries into what makes for a good moral agent, and eventually resulting in the development of training that produces more effective moral agents.

Conclusion

There is often times a disconnect between the work engineers do and the needs of society, with one example of such a disconnect being the automobile safety standards developed by the NHTSA. Although my capstone project's technical work was focused on protecting pilots, it led me to a glaring issue that exists in the automobile industry; that all safety models are designed with the assumption that a 50th percentile male can adequately model the entire population. This issue led me to Pacey's work on engineering ethics which emphasized the importance of charity in connecting engineers to the impact their work has on society, which led me to design my own framework for producing moral agents. The model I created used computer programming as a scaffold, where we can think of moral agents as a function where inputs affect their thinking, which in turn affects their outputs, or actions. The purpose of this framework is to move our discussions regarding ethics towards what is most important, which is identifying what experiences and education actually leads to the production of effective moral actors.

Although this framework does not fix the problem outlined, it does help to get us asking the right questions. This framework may be useful in shifting our gaze, emphasizing the importance of experience in developing moral agents. However, this framework cannot tell us what a moral actor should look like, nor can it tell us what experiences are of greatest importance. Despite these shortcomings, if we can do the heavy lifting and identify what experiences create what we define to be an effective moral actor, the disparity between what engineers design and what the population needs should be significantly lessened. Through the development of more capable moral agents, we can achieve a society where the engineers emphasize human care and compassion.

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