How the Lack of a 50th Percentile Female Crash Dummy Affects Female Drivers

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

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Spring, 2020

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Paper Overview

If a man and a woman were to purchase the exact same car, should the vehicle be designed to protect them both equally from an accident? While shopping for a car, should the buyer be informed whether the safety rating of the car applies to them, or if that safety rating only considers another body type? The money spent is the same, their driving habits may even be the same, but cars are designed around the average male, and as a result are worse at protecting females.

As Americans rely on their cars to travel over 3.22 trillion miles a year, car design and safety is an ever present and important field (Schaper, 2017). With more licensed female drivers than males in the United States, females should be heavily considered in the safety design process for vehicles; however, this is not the case (Statista, 2017). The following analysis utilizes Actor-Network Theory to discuss the actors involved in car safety design (people, companies, governmental bodies), their relationships, and how this affects the population at large. In the following thesis paper, the ramifications of the lack of the use of an average female crash dummy in car impact testing is explored and analyzed.

Research Question and Methods

The central question of this STS research is: why is the 50th percentile female not considered in car safety and how does this affect the population at large? To pursue this question, documentary research and expert interviews have been conducted. Research papers and articles have given insight into the outlook of car companies and their willingness to investigate this issue. Keywords for these article reviews include, but are not limited to, “Anthropomorphic

Crash Dummy," "Hybrid III," "Gender difference in impact," "female car safety," and "gender difference in human biomechanics." In addition, these documents have shed light on the cultural impact the origin of the situation and the positions of power that females, governmental bodies, and manufacturers are currently in. Finally, an interview and discussion with Jason Kerrigan, PhD and University of Virginia's Center for Applied Biomechanics Deputy Director, clarified the role of governmental bodies on car impact testing, and possible causes of fatality differences in car impact due to sex. The Center for Applied Biomechanics (CAB) conducts research projects for private car companies, military, and other governmental bodies, and has published research on sex differences in a range of biomechanical applications, including car impact.

Background on Car Safety Evaluation

In the United States, cars are evaluated and approved for sale and road use through Federal Motor Vehicle Safety Standards (FMVSS) which are enforced by the National Highway Traffic Safety Administration (NHTSA). These FMVSS include safety standards like requirement of seat belts, mirrors, and a variety of impact testing measures. FMVSS use a pass or fail system to evaluate cars. If a car fails a test, NHTSA has the authority to force automotive manufacturers to conduct a recall of cars, or prohibit their sale until the manufacturer updates the car to pass the standard. NHTSA does not test every single vehicle from a manufacturer, but rather, "chooses vehicles and equipment to test for compliance" (NHTSA, 2020).

While every new version of a car is not tested for compliance to FMVSS, NHTSA instead runs a New Car Assessment Program (NCAP). The NCAP selects certain new models of cars from a variety of manufacturers to run through Frontal Crash, Side Barrier Crash, Side Pole Crash, and Rollover testing. The models are scored with a five-star ranking and these rankings

are then published on NHTSA's website, as well as displayed on car models to be sold to inform consumers.

Consumers are also informed about car safety by the Insurance Institute for Highway Safety, an independent nonprofit funded by insurance companies. The IIHS evaluates cars with six different Crashworthiness tests, three crash avoidance & mitigation tests, and also evaluates child seat anchors in the car. The cars run through these tests are given either a Good, Acceptable, Marginal, or Poor ranking, or in some cases a Superior, Advanced, or Basic ranking. The IIHS releases all of their crash testing data on the website including videos and crash dummy data points from the tests themselves.

NHTSA began testing with crash dummies in 1978 and has been using the 5-Star system since 1993 (NHTSA, 2020). Currently, three adult dummies are used for crash testing by NHTSA: the HYBRID III 5th Percentile Female, HYBRID III 50th Percentile Male, and HYBRID III 95th Percentile Male (NHTSA, 2019). The 50th percentile male is supposed to represent an average stature man in height, weight, and body proportions, and this logic is extended to the 95th Percentile Male and 5th Percentile Female. These dummies are supposed to represent a range of body types of the general population that they are being sold to, and, as stated, their test results are published by the NHTSA and car manufacturers to inform the public as well as used to evaluate the pass/fail criteria of FMVSS.

It is impossible, however, for these dummies to accurately represent the population at large due to the lack of a 50th percentile female dummy. In addition, "the characteristics of the 50th percentile male roughly correspond to a 90th to 95th percentile female and so only the extremes of the female population are accounted for by either the 50th percentile male dummy or the 5th percentile female dummy" (Welsh & Lenard, 2001).

In addition to not being accounted for in safety tests, the average woman is more susceptible to increased injury due to their increased physical fragility (Kahane, 2013). The fact that average female safety is not being considered or designed around in car specifications is compounded by the fact that females are more likely to be injured by similar forces (Evans, 2001). Testing has shown 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). These sex differences are not only seen in frontal impacts; "females had a 50% higher risk of reporting a whiplash injury in rear-end crashes and double the risk of whiplash injury with symptoms lasting longer than one month" (Kullgren, 2010).

Males also must be considered when evaluating sex differences in car crashes. In general, crashes involving male drivers are often more severe than those involving female drivers (Li et. Al, 1998). In addition, male drivers more frequently engage in high risk behaviors that result in fatal crashes such as speeding and driving under the influence (IIHS, 2017). Males also typically judge their driving skills as higher than women, and view dangerous activity as less likely to result in serious accidents (DeJoy, 2002). It follows, then, that males are an at-risk group that are involved in higher crash rates, so it does make sense to highly consider them in the design. All of these factors may be influencing how the U.S. Government and car manufacturers, two of the most powerful actors, are evaluating the urgency behind additional testing for the average female.

Application of Actor Network Theory

To analyze this problem with a Science, Technology and Society (STS) framework, Actor-Network Theory (ANT) is applied to consider the relationships and power dynamics all of

the players have regarding car manufacturing, safety, sales, and testing. ANT insists that relationships between 'actors' (people, places, things, organizations, etc.) are what is most important. These relationships are ever changing, and can be used to describe technological situations and social happenings. A large critique of ANT is in regards to the ability for nonhuman actors to participate in relationships. This will be combatted and used in the following analysis as cars themselves, seats, seatbelts and test dummies are intricately involved in this problem of better protecting car drivers and occupants. Another critique is in regards to researchers uninvolved from networks making calls regarding which actors are important or which are not. To address this, I have actively kept track of and mentioned that certain areas and actors will be focused on, and have conducted an expert interview to gain insight into which actors these should be.

The power that each actor in this network has significantly plays into how this situation came to be. As discussed, there are many actors at work and the relationship between them is not entirely understood. Car manufacturers have to design and build cars to meet with certain governmental regulations that are influenced by independent organizations as well as contracted out researches. These manufacturers, however, can also have their own research done to better represent their car safety as the government does not crash test every new model that goes to market. Consumers obviously hold a very large power as well, and "find safety to be very important car features" (GFK, 2019). This power must be taken into consideration as consumers evaluate their choices in car and should be fully informed on whether or not the safety ratings for the vehicle apply to that consumer, or only an average man.

Results and Discussion

Women and Men should be equally protected by car safety features, but the failure of crash dummies to represent women, the failure of governmental bodies to enforce equal protections, and the lack of motivation for car companies has caused female car occupants and drivers to be at higher risk for injury and fatality. The current family of ATD's in crash test use not only lacks an average stature female, but also do not consider biological and biomechanical differences between males and females. NHTSA and IIHS have access to the same research cited in this paper; however, they have failed to recognize and address the glaring discrepancies in car injury sex differences. Major car manufacturers have allowed profits to dominate their decisions on car safety, and have not taken appropriate steps inform or remedy this problem in their products. Overall, women are disenfranchised from equal safety in cars, and are misinformed by safety ratings that are not representative of their demographic.

NHTSA has been using a 50^{th} percentile male in car crash testing since the 1990s, but the 5^{th} percentile female ATD was only required in tests starting in 2011. The current family of dummies in use include updated versions of the 50^{th} percentile male, 95^{th} percentile male, 5^{th} percentile woman, and three child ATD's. The Hybrid III 50^{th} percentile male was created by General Motors and modeled after the average male in weight and stature in 1976 when the dummy was created. The Hybrid III 5^{th} percentile female ATD was developed in 1988 to represent a small female of weight 108.7 pounds and height 59 inches (Saul et. Al, 1998). This female ATD is not modeled after females' biomechanics or anatomy, instead, it is simply a "scaled-down versions of the standard, mid-sized male" (Stanford). As a result, this dummy fails to represent "1) female geometry, such as the shape and form of the torso; 2) female muscle and ligament strength; 3) female spinal alignment; 4) female dynamic responses to trauma; 5) mass distribution of different body parts" (Stanford)(Linder & Svedberg, 2019).

Not only is the female dummy in use non-representative of the female population, but in NHTSA and IIHS frontal impact tests, "this 5th percentile female dummy either rides as a passenger or doesn't participate in the test at all" (Barry, 2019). The 5th percentile female ATD does, however, ride and drive for an oblique impact test, using a different side impact ATD. When this test was introduced in 2007, the Alliance, a trade group consisting of the BMW Group, Fiat, Ford, GM, Jaguar, Mazda, Mercedes-Benz, Mitsubishi, Porsche, Toyota, Volkswagen, and Volvo, protested the inclusion of the 5th percentile female in this test (NHTSA FMVSS 214). NHTSA denied this request and has since phased in the side impact testing for both the 50th percentile male and 5th percentile female. So not only is an average female crash dummy not used, but the small female crash dummy doesn't represent a female, and car companies protested against the use of this small female in crash tests.

Another point of interest from the NHTSA FMVSS 214 is that the Alliance appealed to have the standard only include, "head protection criterion, and not criteria assessing injury to the thorax, abdomen, or pelvis," but this request was also denied by NHTSA (NHTSA FMVSS 214). It is known by NHTSA that "when regulators or testing organizations set a new bar for crash safety, most automakers quickly change their design so their cars ace the new test" (Barry, 2019). On first glance, this statement seems intuitive, but the underlying principle is that car companies only held accountable for passing the specific requirements held up by the test, and they will not go above and beyond to protect passengers, even if they know how.

Since NHTSA not only enforces regulations for safety, but also reports safety ratings to consumers, the relationship with car companies is incredibly complex. In 2006, NHTSA required that "window labels on new vehicles include 5-Star Safety Ratings information" (NHTSA, 2019). These labels are designed to "provide consumers with information about crash protection

and rollover safety of new vehicles" (NHTSA, 2020). While there is a description of which dummy is used in which test on the NHTSA website, information regarding the lack of these tests to represent certain demographics is not made readily available to consumers. To further compound the relationships between these actors, many of the car manufacturers are sponsors and developers of the ATD such as General Motors, who first invented the Hybrid III.

An important test missing from the NHTSA 5-Star program is the rear impact test. Unsurprisingly, in an evaluation of rear-end crashes, "females had a 50% higher risk of reporting a whiplash injury… and double the risk of whiplash injury symptoms lasting longer than one month" (Kullgren, 2010). While the IIHS has recently implemented a rear-impact dynamic test, it is performed with the BioRID II, a simulation of an ATD representative of a 50th percentile male. Initiatives by car manufactures and researchers have been taken on this topic to develop a simulation model for rear impact for the 50th percentile female. While is model has, "the potential of becoming a valuable tool," it still needs "updates of the joint stiffness… seated posture curvature of the spine, and head position of the 50th percentile female occupants" (Carlsson et. Al, 2014).

While the relationship between car manufacturers, governmental agencies, and research centers is complex, the end result of their relationship has the largest effect on consumers. When a female is looking to purchase a new car, and sees the legally required safety ratings displayed on the windshield, there is no disclaimer that these ratings may not represent the protection that she personally will receive in the car. When consumers are looking to purchase a car, safety is their highest concern of all car features (Statista, 2018). So, women when women are looking for cars, they are looking for safe cars, but are unable to access information regarding how safe these cars really are for them, and they may not even know it. In addition, important impact tests, like

rear crash that disproportionately affect women, are left out of crash testing results for women to consider.

The effects of this lack of safety considerations for females is apparent and a pressing issue. Testing has shown 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). In another study on risk for belted car occupants, "females exhibited a greater risk of lower extremity injury, even after adjusting for age, height, BMI, and delta-v" (Foreman et. Al). Not only are female dummies not represented in frontal car crash testing and ratings, but females may simply be more susceptible to injury (Foreman et. Al). Other biological sex differences also affect impact biomechanics such as female increased physical fragility (Kahane, 2013). Not only are women more likely to be injured, but since woman are shorter than men on average, they are more likely to drive closer to the wheel in an 'out-of-position' state further compounding this safety testing issue. In the IIHS side impact test, two 5^{th} percentile female dummies are used as, "woman are more likely than men to suffer serious head injuries in real-world side impact" (IIHS, 2020). This increased head injury vulnerability is due to the fact that women are shorter on average than men and, "shorter drivers have a greater chance of having their heads come into contact with the… striking vehicle," in this type of crash (IIHS, 2020).

It is known in the industry and among researchers that the lack of inclusion of female ATDs in frontal impact test is directly affecting the actual safety design of cars. Jason Kerrigan highlighted that typically, the driver's seat in a car has two pretensioners in the seatbelt. Pretensioners are small devices that go off in the milliseconds after an impact occurs to ensure that the seatbelt is pressed firmly against the occupant's body. While the driver's seat is equipped

with one in the waist and one in the shoulder, the passenger seat is only equipped with one. This is likely due to the fact that in frontal impact testing, the female dummy rides in the passenger seat, if at all, and the double pretensioner would be too forceful for the smaller occupant. This is another example of the power relationship between the governmental bodies and car manufacturers, and how this relationship makes cars less safe for women. If the tests simply included a female dummy in the driver's seat, these companies would be forced to adapt existing technology, or create new safety technology to be able to sell their cars on the market.

An easy fix to all of this seems to be: research and develop a set of female crash dummies that represent current population bodily characteristics, and then include them in the tests. This, however, is more difficult than it seems. In the discussion, Kerrigan noted that there is not enough research done including women to make a dummy that accurately reflects anatomical and biomechanical differences of females. In fact, in one literature study conducted by a PhD candidate at the CAB, it was found that only two average female cadavers have been used in car safety testing ever. Finally, Kerrigan noted that shoulder belt fit on females has never been studied, a basic safety consideration for any occupant of a vehicle.

In order to design these female ATD's massive works of scientific research and funding would be need to be invested, but it is a problem that affects every woman every time she gets into a vehicle. The consumer is left without information that females are not being largely considered in car safety testing, and without an alternative vehicle that is designed for females. Regulatory agencies like IIHS and NHTSA could take steps to include the best female dummies available in the entirety of their testing processes in order to force manufacturers to redesign for the safety of males and females. Even then, would these designs would be for smaller man and not consider sex differences, but every step helps.

While the effect of the lack of an average female crash dummy is clear, this paper has a few limitations on the complete application of ANT and discussion of the evidence. First, the time frame on this research paper was limited to 6 months. Secondly, ANT has large criticisms regarding how it is applied and the actors that focused on by the applier. This paper focuses on Governmental Agencies, Research Facilities, Car Impact Tests, Anthropomorphic Test Dummies, Car Manufacturers, Car Drivers and Car Occupants, but there are certainly other actors that have relation to some. Lastly, due to Coronavirus, additional planned discussions with Jason Kerrigan were cancelled. This interview includes snippets from the preliminary discussion and beginning of the interview with Kerrigan.

Looking forward, other researchers should continue this work to determine the extent to which the combination of ATD's not representing female biomechanics, females being more susceptible to injury, and tests not representing typical car positions held by females impact female car drivers and occupants. In addition, similar research could be done to consider other non-represented demographics in car crash testing such as the 5^{th} percentile male and the 95^{th} percentile male to determine if these populations too are not being protected to the same extent as the 50^{th} percentile male. Hopefully, this research can be used to better inform the public regarding how safety ratings are made by institutions like NHTSA and the IIHS. Finally, through further research and public awareness, possibly public opinion could sway these organizations to develop and use an average female ATD, and further down the line a more representative family of crash dummies at large.

The Future for Female Crash Dummies

The lack of a 50^{th} percentile female dummy has given car manufacturers the ability to ignore a large demographic of the US population when designing car safety features for the

general public. In addition, it has been found that while a 5th percentile female dummy is used in certain positions in specific tests, the dummy itself misrepresents female biomechanics leading to a further reduction in safety for women in cars. For female car occupants and drivers, this research indicates a necessity to look beyond safety ratings as they may misrepresent the safety for each consumer's specific demographic. Overall, this research should help push the industry to develop an average female crash dummy based on modern female anatomy and impact biomechanics, and to incorporate that crash dummy into a multitude of comprehensive crash tests.

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