Technological Interventions to Detect, Communicate and Prevent Sexual Assault

by

Manisha Mohan


Submitted to the Program in Media Arts and Sciences in partial fulfillment of the requirements for the degree of Master of Science in Media Arts and Sciences at the MASSACHUSETTS INSTITUTE OF TECHNOLOGY June 2017

© Massachusetts Institute of Technology 2017. All rights reserved.

Signature redacted

Author .................................................................

Program in Media Arts and Sciences

May 16, 2017

Signature redacted

Certified by ...........................................

Chris Schmandt

Research Scientist

Program in Media Arts and Sciences

Thesis Supervisor

Signature redacted

Accepted by ......................

Pattie Maes

Academic Head

Program in Media Arts and Sciences
Technological Interventions to Detect, Communicate and Prevent Sexual Assault

by

Manisha Mohan

Submitted to the Program in Media Arts and Sciences
on May 16, 2017, in partial fulfillment of the requirements for the degree of
Master of Science in Media Arts and Sciences

Abstract

Every 98 seconds, a person in the United States is sexually abused. Every 16 hours, a woman in the United States is murdered by her romantic partner or ex-partner. Sexual abuse, assault, and harassment are regarded as some of the most common human rights violations in the world by the United Nations. Our work examines methods to prevent sexual assault, from pre-historic times to latest technologies, to inform contemporary designs. In this thesis, we investigate multiple methods to detect initial signs of assault and develop methods for communication and prevention of assault. We also explore olfactory stimuli as a potential means to prevent sexual assault in real-time.

We present three technological interventions which can seamlessly integrate with existing clothing to respond to initial signs of assault like forced disrobing. The proposed solutions aim to combat Child Sexual Abuse (CSA), College Campus assault and abuse of elderly and disabled.

The proposed solution operates in two modes, an active mode for instances when the victim is unconscious or cannot fight against the assaulter, for example in case infants, bed-ridden patients, elderly, disabled, intoxicated people and the passive mode where the victim can self-actuate the safety mechanism. Both modes release distress signals to prevent an assault in real-time, also alert the victim’s friends and family, and call emergency services for help.

Our clothing design is based on input from sexual assault survivors, 338 on-line participants, 67 volunteers and 20 users who helped us understand the real world feasibility of our system. Users evaluated the clothing appeal, functionality, cultural sensitivity and provided feedback on their general sense of security wearing the smart clothing. We demonstrate the practicality of our unobtrusive design with user studies that support our technological development and use of olfactory stimuli by showing the effect of smells on sexual arousal and partner selection. We believe our technosocial approach can help improve user safety and prevent sexual assault.
Thesis Supervisor: Chris Schmandt
Title: Research Scientist
Program in Media Arts and Sciences
Acknowledgments

First and foremost, I would like to express my sincere gratitude to my advisor Chris Schmandt, whose expertise, understanding, and patience, added greatly to my graduate experience. I sincerely thank him for all his guidance during the time of research and writing of this thesis.

I would like to thank Prof. Ethan Zukerman and Prof. Azra Aksamija for their guidance, support, insightful comments, and feedback throughout this whole process. It has been a wonderful experience to be a part of the Living Mobile group and a great opportunity to work with all my amazing friends and colleagues. A big thank you goes to all my friends at the MIT Media Lab for the stimulating discussions and for all the fun we have had together in the lab. Here is a list of my colleagues in random order: Misha Sra, Srishti Sethi, Dhruv Jain, Prashanth Vijayaraghavan, Luke Vink, Margaret Church, Joy Buolamwini, Sands Fish, Andres Calvo, Nikolas Vlavianos, Cindy Kao, Katia Vega, Mina Soltangheis, Carmelo Presicce, Neil Gaikwad, Ivan Sysoev, Emil Kuruvilla, Sunanda Sharma, and Eddy Awad.

Very special thanks to Lab Director- Joi Ito, Media Lab faculty, administrative staff (Keira for being the Superwoman) and facilities whose friendship and guidance have helped me push my boundaries in achieving my small yet fruitful professional goals. I would also like to thank Daniel J Fitzgerald and his family for encouraging and supporting me at every step in Boston, especially when I was sick.

Last, but certainly not least, I would like to thank my dad, mom, brother, grandparents, cousins and friends (Priya Kuber) for their continued emotional support and encouragement through my years at MIT.
Technological Interventions to Detect, Communicate and Prevent Sexual Assault.

by

Manisha Mohan

The following people served as readers for this thesis:

Signature redacted
Thesis Reader

/ Ethan Zuckerman
Ethan Zuckerman
Associate Professor
MIT Media Lab

Signature redacted
Thesis Reader ... Azra Aksamija
Azra Aksamija
Associate Professor
MIT Program in Art, Culture and Technology
Contents

1 Introduction ........................................... 17
   1.1 Motivation ........................................ 17
   1.2 Contributions ..................................... 19
   1.3 Outline of thesis ................................. 20

2 Background ........................................... 21
   2.1 Methods to prevent assault and rape (before the 1950s) .............................. 22
      2.1.1 Regulation for women .......................... 23
      2.1.2 Disfiguring body .............................. 23
      2.1.3 Pepper powder ................................ 24
      2.1.4 Self-immolation ............................... 24
   2.2 Practices post-abduction and sexual assault ............................................ 26
      2.2.1 Negotiations .................................. 26
      2.2.2 Extreme punishments ......................... 26
   2.3 Methods to prevent sexual assault after 1950 ......................................... 27

3 Related Work ......................................... 29
   3.1 Active devices .................................... 29
      3.1.1 Limitations of active systems ............... 31
   3.2 Passive on–body systems .......................... 32
      3.2.1 Limitations of passive on–body systems ... 32
   3.3 Self–actuation devices ............................. 32
      3.3.1 Limitations of on–body systems .............. 34
4 Design Considerations

4.1 Assumptions ........................................ 37
4.2 Cause of assault ...................................... 41
4.3 Why are existing solutions not satisfactory or accessible? .......... 43
  4.3.1 Misunderstand focus groups ....................... 43
  4.3.2 Suggested methods by NGOs ...................... 43
  4.3.3 Product design .................................. 44
  4.3.4 Human perception about vulnerability .............. 45
4.4 Design dimensions .................................... 46

5 System Overview and Design .................................. 49

5.1 Clip-on sensor ......................................... 49
  5.1.1 System design .................................... 49
  5.1.2 Sensor ............................................. 51
  5.1.3 Communication .................................... 56
  5.1.4 Prevention ........................................ 58
5.2 Infants and toddlers ...................................... 62
  5.2.1 System overview .................................... 63
  5.2.2 Sensors to detect bladder & bowel movements ........ 63
  5.2.3 Communication .................................... 64
5.3 Solution for elderly and disabled .......................... 65
  5.3.1 Sensor ............................................. 65
  5.3.2 Communication .................................... 66

6 Evaluation .................................................. 67

6.1 Technical evaluation ..................................... 67
  6.1.1 Software ............................................. 67
    6.1.1.1 Functionality (false positive) ................ 67
  6.1.2 Hardware ............................................. 68
6.2 Evaluation of olfactory stimuli ............................. 72
  6.2.1 Influence of olfactory stimuli on sexual arousal .......... 72
List of Figures

2-1 Evolution of Rape Culture ................................................. 22
2-2 Women in veil ....................................................................... 23
2-3 Women disfigured in tribal communities to prevent assault. ...... 24
2-4 Women performing *Juhar* .................................................. 25

3-1 Female condom (a) Schematic representation of first anti-rape condom[3] and (b) *Rape-aXe* ................................................. 30
3-2 (a) Anti-molestation jacket and (b)*Snare* .............................. 30
3-3 SHE-bra with sensors and can burn predators. ....................... 31
3-4 Passive On-body devices (a) anti-rape underwear and (b) hairy stockings ................................................................. 33
3-5 Smoke dress to prevent assault by Anouk Wipprecht and NiccolÃš Casas 34
3-6 Self-actuation devices .......................................................... 34

4-1 The table represents different scenarios of sexual assault and other dependents. ......................................................... 38
4-2 The graphical representation highlights different states of victim and assaulter. The horizontal axis represents the ability of the victim to consent and fight back. The vertical axis represents the assaulter’s physical, emotion and mental strength. .......................... 39
4-3 Popular flyer about sexual consent (Source:Canadian Federation of students) .............................................................. 40
4-4 Assault survivor hand book .................................................... 41
Motivation for rape, by men who reported ever raping any woman or
girl, including partners and not partners, by site.[28] 42
Suggested methods to prevent assault by NGO-RAINN 44
Suggested methods to prevent assault by NGO-RAINN 45

The chart shows possible methods of actuating, detection, communica-
tion and prevention of assault using the device. 50
(a) Clip-on sensor, (b) schematic representation of clip-on sensor, and
(c) mobile application and communication device 50
System Overview for clip-on sensor 50
Left to right- (A) Exploded diagram of multi-layer sensor patch (a-
hydrogel adhesive, b- copper connector, c- insulator, and d- conductive
fabric), (B) Communication module and sensor patch attached to a
garment (C) Communication module with a self-actuation button. 52
Resistance values for conductive fabric during actuation. 52
Resistance values for conductive fabric during actuation. 53
Different ways of actuating slip-on sensor. 53
Change is resistance with respect to different activities. 54
(a) e-textile by Project Jacquard [11], (b) Jabil's smart sport's bra and
(C) Clip-on sensor prototyped at Media Lab 55
Message is sent to the safety circle whenever user's position changes
during assault. 58
Wearable smell capsules in the form of a) Ear-ring b) Buttons c) Deco-
rations on Tie pin d) Ring and e) Trinket. The capsules can be activated
to release pungent odors when needed to deter sexual assault. 60
Gelatin Capsule (a) Layer-by-layer exploded schematics, (b) Capsule
encapsulating pungent smelling emulsion, and (c) Gelatin capsule being
tested for dexterity. Man weighing 140 lb steps on the capsule. 60
(a) Layers of aroma-film and (b) Aroma film embedded in wearable
ornament. 61
5-14 Schematic representation of CSA (Child Sexual Abuse) prevention, communication and notification system

5-15 (a) Communication module connected to the bio-film to monitor diaper wetting (b) Smart diaper.

5-16 Diaper with a bio-film sensor to detect wetting and unwanted removal.

5-17 Prototype device for detecting elderly abuse.

5-18 (a) Tracking and communication device, Wi-Fi enabled and (b) E-mail alert sent to a person (member of safety circle).

6-1 Participants using mobile application during user testing

6-2 A note in student’s bathroom showing lack of confidence in Campus Police.

6-3 Possible positions to place the communication module in different garments

6-4 Participants doing vigorous activities to test the robustness of the device.

6-5 Condition of clip-on sensor (a) before machine wash and (b) after wash

6-6 Time spent by participants (P1-P22) viewing images in condition A and condition B

6-7 Average EDA sensor data for Group 2 participants during unpleasant and pleasant conditions.

6-8 Average EDA sensor data for Group 1 participants during pleasant and unpleasant conditions.

6-9 The aggregate of self-reported sexual arousal rating of each participant in Group-1 (a) and Group-2 (b) while experiencing pleasant and unpleasant odor.
Chapter 1

Introduction

1.1 Motivation

Approximately 120 million girls worldwide have experienced forced intercourse or other form of sexual abuse at some point in their lives[6]. Across the globe sexual abuse has different forms, but violence against women, as a whole, is a massive issue in virtually every society and is likely to affect 1 in 3 women during their lifetime[19]. The US Department of Justice describes sexual assault as any sexual contact or behavior that occurs without the consent of the recipient. However, what legally constitutes sexual contact can vary across countries and states. For example, the United Kingdom does not consider penetration with a foreign object as rape whereas in the US, penetration, no matter how slight, without the consent of the victim, is considered rape [5].

Similarly, there is a debate about whether sexual assault is a crime of power and control or pleasure and false entitlement. A United Nations multi-country study on men and violence in Asia and the Pacific showed that a vast majority of men who raped felt entitled to it or did it for fun or out of boredom[27].

We recognize that sexual assault is a global menace, and in the recent years, social scientists, engineers, artists, NGOs and government organizations have tried to address the problem by making law amendments, strengthening and educating law enforcements, enhancing support systems for survivors by providing on-line and on-
site counseling. Interventions have included the use of speculative design, artistic interventions and technological solutions from mobile applications to on-body personal safety systems. However, studies on campus assault indicate a significant rise in the United States [12]. We surveyed 338 college campus students in an online study and found that only 2.6% students use any technological solution. Only 33.75% carry or use any assault prevention device.

A survey done in India of 364 women (ages 16-45) discussed alternative technical solutions and their application for evading sexual assault. Women rated built-in wearable solutions like clothing, lingerie or footwear more desirable than those integrated with accessories like handbags, bracelets, watches and mobile phones [32]. Not surprisingly, a wearable on-body system was considered more accessible than a gadget in a handbag, or a cell phone during an assault. Women are less enthusiastic about systems that require them to reach for a phone or other device for very good reason. Victims of violence experience high levels of subjective distress, autonomic arousal, and tonic-immobility (freezing of body) which constraints and impairs their cognitive and physical functioning. Hence, the victim is unable to provide consent or reach out for help [21, 23]. Nearly, 50% of victim suffer from this, and it is almost impossible for them to trigger an alarm or to reach out for a phone in the bag.

In our research, we address a subset of sexual assault scenarios which are motivated by entitlement, one-sided sexual attraction, fun or boredom where the assaulter is more likely to be a stranger or an acquaintance and the victim cannot fight against due to physical, mental or emotional dominance of the assaulter. Solutions to prevent domestic violence and marital rape by a romantic partner are beyond the scope of this research.

We propose smart clothing solutions that detect, communicate and prevent sexual assault. Our prototypes are designed to reduce the sexual interest of the attacker by producing offensive olfactory and auditory stimuli when triggered by the victim or activated automatically by sensors in their clothing. The proposed solutions also call for help which is critical in scenarios where the victim is unconscious or incapacitated, unable to either provide consent or call for help themselves.
We have designed 3 wearable solutions for different audiences - infants, adults, and elderly or disabled people - based on feedback from 338 on-line participants, 67 volunteers, 20 users and consultations with survivors of sexual assault, who overwhelmingly preferred on-body devices as opposed to those that can be carried in a bag or pocket. In our study we have found that many sexual assault scenarios involving women and girls progress through four discrete steps:

I. Step Zero - when the victim can anticipate unwanted sexual attention, and also includes verbal attacks.

II. Step One - when the assaulter has bodily contact with the victim.

III. Step Two - forceful disrobing and,

IV. Step Three - when the assaulter establishes direct contact with victim's private parts, with possible penetration.

In this research we aim to detect forceful removal of clothing or initial signs of abuse to prevent step three of a sexual assault.

1.2 Contributions

The major contributions of this work include:

- Discussing pre-historic strategies to prevent assault.

- Defining principles for identifying stages of assault and opportunities for intervention.

- Exploring low-cost wearable technologies to detect, communicate and prevent sexual assault.

- Develop prototype to combat Child Sexual Abuse (CSA), college campus assault, and elderly and disabled abuse.

- To study perception, reception, and response about technological systems among college campus students.

- Evaluation of proposed solution.
1.3 Outline of thesis

The current chapter is an introduction to the project and a brief overview of the motivation and contributions of the thesis. The remaining chapters are arranged as follows:

- Chapter 2 explains the historical methods of prevention assault, and post-assault negotiations.
- Chapter 3 discusses related work and technological solutions to prevent assault since 1950.
- Chapter 4 highlights design considerations for this work.
- Chapter 5 describes methods to detect, communicate and prevent Child Sexual Abuse (CSA), college campus assault and abuse of elderly and disabled.
- Chapter 6 talks about evaluation of the system design and user studies.
- Chapter 7 discusses limitations of the system, future work and conclusions.
Chapter 2

Background

The history of sexual assault and forced intercourse is one we must infer from prohibition rather than examine from historical accounts. We infer that sexual assault was a major problem in Greek and Roman times given language prohibiting and condemning the practice, treating it as a religious and social transgression. The infamous 'crime of Laius' in Greek mythology is believed to have not only destroyed him but his extended family too. Laius kidnapped and raped his student Chrysippus, a divine hero of Elis in the Peloponnesus[39].

However, there is little documentation of actual instances of sexual abuse, forceful intercourse, etc. before the 1950s, which makes it difficult to gauge how these crimes occurred or how they were handled in everyday life. In most societies, we see two social accommodations to sexual assault. First, the vulnerable group is forced to live a constrained life to prevent assault. Second, if victimized, they are compelled to marry the assailter or are killed. However, these trends have changed with the growing feminist movements and advancement of technology as shown in Figure 2-1.

We define customs and norms before 1950 as first phase of rape culture and post 1950 as the 'modern phase of rape culture.' We select 1950 as the origin of modern rape culture as it defines the time between first phase and second phase of feminism. Most women at the time were forced to quit their jobs and return to household chores after the second World War[17]. Also, the colonial powers were weakening in South–east Asia. On the other hand, United States was about to declare Civil
Disobedience Movement and minorities played a significant role in it, giving space to women representation.

2.1 Methods to prevent assault and rape (before the 1950s)

As today, rape in history resulted from feelings of hatred, anger and lust by the assailant. In addition, in many battle grounds, rape was used as a weapon of war, a practice that has not been eliminated today. As invasions and conflicts between countries and tribes become more recurrent, the threat to the personal safety of vulnerable groups like women, young children increased. Hence, kingdoms introduced different kinds of preventative measures.
2.1.1 Regulation for women

Before 1950, it was common to constrain women’s movement to protect them from assault. Women, girls and other potential victims were asked to stay indoors; elders of the family monitored their activities. Women were considered their father’s property before marriage and after the wedding, their husband’s property. The veil was another practice to hide women and their charm as shown in Figure 2-2 [29, 35, 26].

![Figure 2-2: Women in veil](image)

2.1.2 Disfiguring body

In some tribal communities in Africa and the Amazon, purposeful disfigurement of women has been practiced since 500 B.C. By piercing their lips and inserting disc-shaped ornaments and wooden structures, women were made to look unattractive. This was practiced as a preventive measure against abduction, rape, and slavery. Men in those communities believe that by mutilating their daughters and women, they can be saved from other tribes and potential risks. Lip Plate or Lip Disc is a practice which continues until today in Ethiopia, now as a form of tradition(see Figure2-3)[8, 33].
2.1.3 Pepper powder

Women in India and China used chilly and pepper powder to incapacitate sexual predators. The powder was readily available in the communities as a household product, and no investment was required to procure it[10]. This traditional, passive defense mechanism is now commercially available as pepper spray.

2.1.4 Self-immolation

Johar or Juhar, was the Hindu custom of mass self-immolation (see Figure 2-4) by women in parts of the Indian subcontinent, to avoid capture, enslavement, and rape by invaders, when facing certain defeat during a Hindu-Muslim war, but not Hindu-Hindu war [22]. Johar, the most extreme measure to avoid capture and assault was common in the 13th-14th century. The fort of Jaisalmer, in India witnessed self-immolation of 24,000 women when Alauddin Khilji, a Mughal ruler besieged the fort. Today, the practice of mass self-immolation is not common but we do hear about cases of self-immolation after assault [16].
Figure 2-4: Women performing Juhar
2.2 Practices post-abduction and sexual assault

2.2.1 Negotiations

Since chastity of a girl or woman before marriage was considered sacred, in most communities if an unmarried girl/woman were sexually abused, the father would receive compensation in the form of money or land as he is responsible for the household economy. In most cases the system was biased and conditional. For example according to the Sumerian Code, if the victim of the rape is a slave, a fine of 1.66 ounces of silver will be charged but if a citizen were to rape another citizen, that’s punishable by death.

Another unusual law in the 1650–1500 BC, Code of the Nesilim in Mesopotamia, was the punishment for hitting a free woman so hard that it causes her to miscarry. If she’s at the end of her pregnancy, a fine of 10 half-shekels was announced[1].

The negotiations took an ugly turn when victims were forced to marry the predators to avoid seclusion of the family and extended relatives from the society.

2.2.2 Extreme punishments

In states where sex before marriage is criminalized and abortion is illegal, women who are abused face an impossible choice. They may seek abortion through non-medical procedures like consuming ergot, opium, gun powder or push a leech up their vagina or eat pulverized Spanish fly[2]. Some chose to end their lives rather than face criminal sanction. Women as early as the 16th century had observed that cows that consumed ergot miscarried their calves. In spite of disastrous side effects of the fungus, called ergotism, women poisoned themselves to seizures, itching, psychosis, vomiting, contractions, diarrhea and death.

The newspapers in mid-1800s advertised pills and powders that claimed to cause miscarriage. 'French Periodical Pills: Warranted to Have the Desired Effect in All Cases' was one such ad that appeared in The Boston Daily Times in 1845[25].
2.3 Methods to prevent sexual assault after 1950

The definition of sexual assault has evolved since pre-historic times. As described in this chapter, the earlier focus was on preventative measures and post-assault negotiations. In most cases, the victim was deprived of justice and was excluded from the society. In many parts of the world, these practices still continue. Vulnerable groups are forced to abide by the preventative measures, and as a victim, they are revictimized at the hands of law, society, and tradition. However, since the 1950s, in modern societies we see a shift in the way, women are treated. As women started getting access to education; equal pay with men; the right to initiate divorce proceedings; the right of women to make individual decisions regarding pregnancy (including access to contraceptives and abortion); and the right to own property; it also led to increasing awareness about sexual assault. Due to growing feminist movements and awareness, social scientists and engineers have started looking for real-time interventions for sexual assault which includes active and passive on-body system (discussed in Chapter-3). These interventions certainly put some responsibility on the victim but are less detrimental than other practices described above. On the other hand, we also come across forms of assault which were rare or unrecognized earlier. New manifestations of abuse like date rape, street violence, brutal forms of child sexual abuse have become prominent, and some like the marital rape, abuse in romantic relationships have been recently recognized in some parts of the world and criminalized.

We recognize this paradigm shift and call it *Evolution of Modern Rape Culture*, where rape is no longer likely to condemn a woman to ostracism, but where we still have attitudes that trivialize abuse. As seen in Figure 2-1, after 1950 victims are now able to use innovative methods and technology to ask for help and post-assault victims can reach out to police and organization for support and rehabilitation. Since 2007, 70 countries have introduced domestic violence legislations to address women’s issues. This shift in norms ensures that rape is no longer inevitably leading to ostracism, instead increase the likelihood of prosecution and lower likelihood that a woman will face criminal charges for being victimized. However, these technological innovations
remain unpopular among people due to their design constraints and perception of individuals about sexual abuse, assault, and harassment.
Chapter 3

Related Work

In this chapter, we take a deeper dive to understand innovative designs and technologies designed to combat assault. In the last 70 years, feminist movements and awareness of feminist issues have changed the way women are treated in society. With the first wave of feminism focusing on legal matters like the right to vote in the 19th and 20th century in the US, the movements have more recently been concerned with sexual assault and gender biases. Meanwhile, along with this social movement, scientists have been inventing technological mechanisms to prevent individual cases of sexual abuse. They are classified as active, passive and on-body systems.

3.1 Active devices

Technological interventions which do not need any instruction from the wearer to detect, communicate and prevent assault are called active devices. These devices get input from the environment instead of the wearer and automatically trigger deterrents. Devices against sexual assault and harassment have been available for a few decades now, but a female condom with a hypodermic syringe that injects tranquilizer fluid was developed in 1979 [18]. There were others that followed like Rape-aXe (see Figure 3-1(b)), the Trap, and the killer tampon [3].

With technological advancement and growing awareness against sexual assault, innovative products surfaced in the early 2000s. Students at a fashion design school in
India developed an anti-molestation jacket with a battery powered taser (see Figure 3-2). The taser would give electric shocks to people who tried touching the jacket.
Snare (2002) had tubular motion sensors and spring-loaded lasso to capture and impale intruders as shown in Figure 3-2 [38]. The device was criticized for its design as it had striking similarities to the Chastity belt. These were mostly design exercises and art pieces. They were not generally designed to be practical, usable interventions. After the heinous Delhi, gang rape in 2012 [34] technologically advanced on-body devices like SHE (Society Harnessing Equipment) were developed that used flexible force sensors embedded in the brassiere to detect touch and micro-heaters to cause electrical burns to the assailant[31]. Other methods which victims resort to prevent abduction, slavery and forced sex include suicide and self-immolation.

![Figure 3-3: SHE-bra with sensors and can burn predators.](image)

### 3.1.1 Limitations of active systems

The disadvantage of the active systems like vaginal insertions and *Snare* is that they are difficult to wear on a daily basis and can cause infection as they are unhygienic. Also, most of these technologies are expensive and not in the reach of victims. Devices like SHE and Anti-Molestation jackets can provoke the perpetrator, and in the case
of gang-raping with many assailants or incidents involving the use of weapons, the
victim’s life can be endangered. Some of these technologies were speculative designs
which led to discussions and awareness campaign.

3.2 Passive on–body systems

Systems which discourage assaulter and prevent assault at stage zero by turning
off the attacker without ubiquitous computing methods is called a passive on–body
system. Anti–Pervert Hairy stockings are used to discourage potential perpetrators.
Another anti-rape undergarment gained public attention in 2016. The design of the
garment is such that only the wearer can remove the garment. Special buttons and
tight fitting garment promise to evade assault (see Figure 3-4).

3.2.1 Limitations of passive on–body systems

On–body systems like hairy stockings are similar to methods used in the past to
disfigure women (discussed in Chapter 2), compel the victim to change their dressing
sense and they are targeted to women only.

3.3 Self–actuation devices

Devices which require input from the assaulter are called self-actuation device. These
devices act on wearer’s command, assuming that the wearer/user is in a condition to
operate the device. Hand–held pepper spray bottles, and mobile applications have
also been introduced in the recent years. Mobile device add-ons like Flare claim to
generate a flare when the device is physically de-attached from the mobile device. (As
of this writing, the device is yet not released.) This technology is conceptually similar
to Smoke Dress (see Figure 3-5) which interacts with the immediate environment of
the wearer—if someone gets too close, the proximity sensors in the dress react, and
a veil of smoke is created around the wearer. However, some of the self-actuation
Figure 3-4: Passive On-body devices (a) anti-rape underwear and (b) hairy stockings.

devices are provocative art installations to spread awareness and don’t aim to be practical, commercial products.

Some systems like Angle Wing and Roar (see Figure 3-6) use loud sounds to alarm the predator and alert others nearby [4]. This technology is inspired by the anti-rape whistle which was commonly used by college campus students in late 20th century, the use of whistles has reduced significantly. In our survey we found 0.29% of students using it. On the other hand, accessories like Nimb and Ripple feature concealed buttons that can send alert messages with the wearer’s location to friends and family and emergency services. Another approach like ONEE manifest as mobile apps, and primarily focus on college campus assault and try to address it using the buddy system. The bracelet connects friends and helps track them by tapping on it.
3.3.1 Limitations of on-body systems

However, these solutions have been unable to provide any real assistance because people fail to calculate the potential risk of being a victim.

What makes the problem challenging is the victim’s inability to make quick decisions and take action due to impaired cognitive and physical ability during assault[21]. Thus, using safety products that require input from the user or have a multi-step
activation process may not be as useful as intended. Devices like the pepper spray are dangerous as they can be used against the victim.
Chapter 4

Design Considerations

4.1 Assumptions

Thus far, we have discussed sexual assault primarily as a problem for women. However, the nature of assault varies drastically and is a function of gender, age, location, number of assailters involved, the physical, the mental and emotional state of the victim, the relationship between the victim and the assaulter, etc. Hence, while designing technology, we must consider multiple target audiences, different probable scenarios of assault and other design aspects. We discuss the different scenarios of assault and the causes in depth using Figure 4-1 below.

The off the shelf technologies try to position themselves as a personal safety device ignoring the broad spectrum problem and are governed by some assumptions. They assume that the assaulter does not immediately overpower the victim by their physical, emotional and mental strength. We define this in the graphical form Figure 4-2, where the victim’s physical and cognitive ability to fight against the assaulter is represented on the horizontal axis. The physical ability is dependent on the conscious and unconscious state of the victim, hence represent the extreme ends. The vertical axis represents the assaulter’s physical, emotional and mental strength which the assaulter exercises during the abuse.

CASE 1. The first quadrant (I) highlights scenarios when the victim is conscious but is emotionally, physically or mentally suppressed by the assaulter. These scenarios
include gang rape, child sexual abuse, marital rape, abuse at workplace and street assault. Communities which are most affected by this kind of assault include sex workers, and LGBTQ communities, especially in societies where there is no widespread acceptance of those sexual identities.

CASE 2. The second quadrant includes cases of assault where the victim is unconscious or unable to fight against the assaulter, and the assaulter is overpowering the victim like date rape, abuse of elderly, bed-ridden patients, and disabled. In these scenarios, it is impossible for the victim to give consent when the victim is intoxicated but the assaulter is not.

CASE 3. The third quadrant represents situations when the victim is unconscious, but the assaulter is not dominating the victim. It can include cases when both victim and perpetrator are under the influence of alcohol or drugs or consent is misunder-
Figure 4-2: The graphical representation highlights different states of victim and assaulter. The horizontal axis represents the ability of the victim to consent and fight back. The vertical axis represents the assaulter’s physical, emotion and mental strength.

CASE 4. The fourth quadrant highlights situations of street assault, an unknown person is the predator. Since the victim is conscious, they can trigger alarms and call for help. Most technological innovations and mobile applications target this sweet spot.

Among scenarios discussed here, 2 out of every 3 cases of sexual assault, predators use physical means e.g. teeth, hands, legs to immobilize the victim. In 11% scenarios we find the victim threatened by the weapons (6% guns, 4% knife and 1% other kinds of lethal weapons) for example during domestic violence, Child Sexual Abuse, marital rape, emotional and mental coercion dominate[36]. Through our work we propose
solutions which can address issues in first, second and third quadrant as well.

In cases of date rape, where victims are intoxicated, drugged, or in situations when the victim is physically challenged or disabled (children, elderly and bed-ridden patient), we recognize that victims are unable to provide obdurate consent. Hence, any forceful sexual intercourse should be considered assault. Debates around 'NO Means NO' (see Figure 4-3) have been highlighted by feminist groups and mainstream media, but cases where a victim cannot voice themselves continue to suffer. Such situations fall in the II and III quadrants of the safety net where it is tough to address the victim’s and assailter’s concerns. However, the proposed technology ensures that if a victim is unable to consent, the act should be considered an assault and /or their safety circle should be informed.

Figure 4-3: Popular flyer about sexual consent (Source: Canadian Federation of students)

In cases of date rape, Police officers often find it difficult to assess the situation without bias to either party. 'We struggle with complaints where the boy and girl are in a relationship, but later when the (girl) victim accuses the partner of not asking for consent, it becomes a serious issue. As officers, we try to do justice, but it is hard.' says, MIT Police Officer.
x Misconception

All men want to commit sexual assault.

✓ Truth

This misconception results from a simplistic and ultimately inaccurate understanding of gender. At the root of this argument is the belief that men are biologically predisposed to sexual violence because of their hormones, sex drive, etc. But sexual assault isn’t about sexual desire; it is about power and control. While it is true that the majority of perpetrators are men, this has more to do with how men are socialized, and how our society has constructed gender and masculinity, than biology. Rooting the issue of rape in biology is counterproductive because the actual issue is behavior and culture—things that are well within our power to change.

x Misconception

Sexual assault happens because people need sex. People get carried away by their sexual desires and/or hormones and lose control.

✓ Truth

Sexual assault is a form of sexualized violence, that is, violence enacted in a sexual way. Like many other crimes, sexual assault is about power and control. Sexual assault happens because perpetrators put their desires over the survivor’s agency to consent. The survivor is never to blame.

Figure 4-4: Assault survivor hand book

4.2 Cause of assault

Across the globe, it is believed that sexual assault is about power and control, popularly used as a weapon of war to terrify and coerce (see Figure 4-4). Even the Survivors of Sexual Assault Handbook considers sexual assault within this frame.

On the other hand, quantitative findings from the United Nations Multi-Country (Asia and Pacific) Study shows that men rape women mostly due to sexual entitlement, fun and boredom (see Figure 4-5)[28]. The reason may vary for sexual abuse in the same sex, CSA (Child Sexual Abuse), and other cases.
Figure 4-5: Motivation for rape, by men who reported ever raping any woman or girl, including partners and not partners, by site.[28]
4.3 Why are existing solutions not satisfactory or accessible?

4.3.1 Misunderstand focus groups

Most technologies target and market to adult women and don’t pay attention to the broader victim base of sexual abuse [15]. Hence, sexual assault is considered as a women’s issue, and companies position their products for them. Transgender communities, LGTQ, socially excluded groups like prostitutes, prisoners, children and elderly, are overlooked, despite being highly vulnerable.

In the recent years, organizations like Members in Violence Prevention (MVP) have shed some light on the inclusiveness of the matter of sexual abuse and share the burden of reducing violence prevention in the United States. Jackson Katz rephrases sexual assault in his TEDx talk 'violence against women is not a women’s issue, it is men’s issue’[7].

4.3.2 Suggested methods by NGOs

There is a huge disconnect between front-line respondents to sexual abuse, like workers at helplines and relief centers, and the social engineers who are designing technology to combat sexual abuse. Most sexual assault hotlines, post-trauma centers, etc. operate as with feminists expectations of their constituents and believe in uprooting the cause of the problem by education. Education may be the ultimate solution, but the current system seems to forget a major critical step between prevention of assault and post-assault help: intervention. Organizations like RAINN (Rape, Abuse, and Incest National Network), United State’s national anti-sexual violence organization focus on prevention of crime, using methods suggested below, and set the onus on the victim, assuming the victim is conscious (not drunk or drugged), or they focus on post-assault recovery and criminal justice system(see Figure 4-6 and 2-1). There is no mention of any technology or any other help which a potential victim can call for during the assault. Sexual abuse facilitated by possession of weapons, like guns,
knives, and other threatening objects, is not discussed. No method for prevention or intervention is presented to educate the victims/ vulnerable groups.

**Steps You Can Take to Prevent Sexual Assault**

Everyone has a role to play in preventing sexual assault. There are many different ways that you can step in or make a difference if you see someone at risk. This approach to preventing sexual assault is referred to as “bystander intervention.”

**How can I play a role in preventing sexual assault?**

The key to keeping your friends safe is learning how to intervene in a way that fits the situation and your comfort level. Having this knowledge on hand can give you the confidence to step in when something isn’t right. Stepping in can make all the difference, but it should never put your own safety at risk.

![Four steps to protect your friends](image)

Figure 4-6: Suggested methods to prevent assault by NGO-RAINN

### 4.3.3 Product design

Most wearable technologies function at stage zero and the intersection of the first and fourth quadrant. However, these devices are gaining popularity in the commercial space due to increasing awareness and feminist movements. Price points make these devices less accessible to vulnerable but low-income groups. Some solutions like pepper spray can be used against the victim (see Figure 4-7)[20].

On the other hand, products like RapeX position themselves as STAGE 4 interventions when the predator is about to penetrate the victim[3]. The solution does not help in situations where same-sex abuse happens or is limited to fondling, molestation, and other sexual acts (including the use of a foreign object for penetration). Also, some victims have raised their concern about hygiene and side effects. Social
scientists argue that the rubber device designed to catch a rapist's penis in its Velcro-like network of hooks can aggravate the intentions of the assaulter and make him more violent which in turn may cause more damage to the victim.

4.3.4 Human perception about vulnerability

To understand how vulnerable students feel on MIT and Wellesley University campus, an online survey was circulated among student groups. 338 students participated in the study. We asked a question about their vulnerability of being abused in comparison to other students on campus and divided the group into three categories:

- GROUP 1-Participants who are more concerned about their safety more than the community.
- GROUP 2-Participants who consider themselves equally vulnerable to others on campus.
- GROUP 3-Participants who are less concerned about their safety in comparison
to others. We were also interested in understanding what the most popular and commonly used technologies/methods among students to prevent the assault.

Only 23.37% students reported any use of active (2.36% use of technology e.g. ROAR, disfiguring hairy stocking), passive (20.41% use pepper spray, pocket knives, and other lethal gadgets) and self-defense methods. One participant mentioned 'devices not necessary for me, but maybe for someone else.'

Surprisingly only 5.32% fall in Group 1, 35.2% are equally concerned about their safety, leaving the rest to Group 3, who underestimate their vulnerability.

Assuming that these population groups are well educated and aware of their surroundings, we were curious to see what kind of preventive measures they use. Notably, on an average only 23.52% people in each group used any mechanism of self-protection. Surprisingly, use of technology was unpopular among this group. Traditional passive devices like pepper spray and pocket knives were sought after.

4.4 Design dimensions

When designing a technological solution, it is most important to carefully consider assumptions and not fall into the trap of using the limited set of assumptions previous solutions have addressed. Our other design considerations include following parameters:

1. Device that can be used actuated irrespective of wearer's physical and conscious state.

2. Should be preferably on-body.

3. Should give the user the ability to prevent assault and make them self-sufficient.

4. The wearer should be able to ask for help whenever they anticipate threat.

5. The product should be gender neutral.

6. It should be easy to use and affordable.
7. Exhibit re-usability, aesthetics, and robustness.

8. Should have a multi-layer safety net.

The next chapter discusses the system design which is based on the parameters mentioned above.
Chapter 5

System Overview and Design

In this chapter, we discuss different methods to detect, communicate and prevent assault. We propose three solutions to curb Child Sexual Abuse (CSA), college campus assault, and elderly and disabled abuse. The proposed solutions create a communication bridge between victim, their clothing, action of the assaulter, family, friends, & the police (see Figure 5-1). The proposed methods are based on the design parameters discussed in the previous chapters.

5.1 Clip-on sensor

We have designed fabric based clip-on sensor which can adhere to any fabric and can be used across age groups. In our study we focus on college campus assault.

5.1.1 System design

We designed a multi-layer sensor patch (see Figure 5-2) which consists of a conductive fabric with a known value of resistance. We use a 1cm * 5cm conductive patch for this experiment. The resistance of the sensor is directly proportional to the length of the patch. The fabric sensor is attached to a communication module (see Figure 5-2(c)) which relays signal whenever forceful removal of clothing is detected. The device can be activated in two ways:
Figure 5-1: The chart show possible methods of actuating, detection, communication and prevention of assault using the device.

Figure 5-2: (a) Clip-on sensor, (b) schematic representation of clip-on sensor, and (c) mobile application and communication device

- Active mode- when the clip-on sensor reads 'unusual' activity like forceful removal of clothing, it activates the active mode of sensing. This is generally triggered during forceful removal of garments by the assaulter. It is applicable to scenarios when the victim is unable to fight against the assaulter or is not in a state to provide consent. Incidences include stage-1 and stage-2 of assault, for example abuse of patients in hospitals, elderly abuse in nursing homes or by care-givers, date rape etc.

- Passive mode- the self-actuation button on the device gives ability to the wearer
to trigger the sensor whenever in danger. The passive actuation aims to prevent assault at stage zero.

It also consists of deterrents like deafening sound and pungent odor to prevent assault in real-time. The overview of the system is shown in Figure 5-17.

![System Overview for clip-on sensor](image)

Figure 5-3: System Overview for clip-on sensor

5.1.2 Sensor

The sensor consists of (a) fabric based stretch sensor and (b) accelerometer. They together help detect following:

- Forceful removal of clothing.
- Activity sensing, monitoring and classification.

Sensor design

The multi-layer sensor patch (see Figure 5-17) consists of a conductive fabric with a known value of conductive resistance. Below the conductive fabric, is an insulating layer of silicon. This layer prevents a short circuit between the conductive fabric and copper (conductive) patch. It also eliminates the need for wires. The silicon layer has physical slots (0.5*0.5 cm) in between it.

According to the model developed by Popper [30], the sinker loop length and change
in resistance for a plain knitted structure can be given by the following relationship (equation in Figure 5-6). The resistance of the sensor is directly proportional to the length of the patch. We use a 1cm * 5cm conductive patch for the experiments.

Figure 5-4: Left to right- (A) Exploded diagram of multi-layer sensor patch (a- hydrogel adhesive, b- copper connector, c- insulator, and d- conductive fabric), (B) Communication module and sensor patch attached to a garment (C) Communication module with a self-actuation button.

Figure 5-5: Resistance values for conductive fabric during actuation.

**Functionality of sensor**

The sensor can detect forceful stretching and pulling of the garment, also activities like fondling and squeezing. The slots in the silicon film can detect forces acting in the perpendicular direction (see Figure5-7). Since we are using plain knitted conductive fabric with locks in wale and course direction, the electrical current flows through the
Sinker loop length per stitch

\[ L_{\text{sinker}} = \frac{L_{\text{stitch}}}{4} + \frac{\pi r}{2} \]

Sinker loop length for fabric width \( w \)

\[ L_{s,p.w} = \frac{w \pi}{25.4} \left( \frac{L_{\text{sinker}}}{4} + \frac{\pi r}{2} \right) \]

Hence, change in resistance is given by,

\[ R_{s,p.w} = \frac{\rho \left( \frac{L_{s,p.w}}{w} \right) L_{s,p.w}}{A} \]

- \( R_{s,p.w} \) - resistance of the Sinker loop.
- \( L_{\text{stitch}} \) - length of the stitch.
- \( L_{s,p.w} \) - Sinker loop length along width.

Figure 5-6: Resistance values for conductive fabric during actuation.

Feet of the stitches in the sinker loop. The conductive patch has nominal resistance of 600 ohms but the resistance of the 1*5 cm conductive patch drops on stretching and increases when compressed (see Figure 5-5). Different activities cause change in resistance and using a microprocessor this change can be classified as 'usual' and 'unusual' activity.

![Figure 5-7](image)

Figure 5-7: Different ways of actuating slip-on sensor.
Activity monitoring

Activity mapping can be done via conductive fabric sensors. In our primarily tests we found that activities like walking, running, and bending cause the sinker knots in the conductive fabric to compress and activities like hugging and forceful removal of clothing to stretch. The activities which lead to sinker knots' compression are classified as 'usual'/'safe' activities.

We performed an experiment to classify the activities. A user was asked to perform 6 different activities for 5-12 minutes wearing a sensor patch on their shirt (dimensions: 1*5 cm). The data was then plotted on the same scale. We found that hugging and forceful removal of clothing caused the sinker knots to stretch, i.e. the values were observed below the nominal range of 600 ohms (see Figure 5-5). The act of forceful removal shows the least resistance before release (see Figure 5-8) the release of the garment. The values are highlighted in red. The resistance values in the range of 250-100 ohms are classified as 'unusual activity'. When such activities are detected by the on-body sensor, it sends an alarm asking for help.

![Figure 5-8: Change in resistance with respect to different activities.](image-url)
A 9-axis accelerometer to increase reliability and precision as it amplifies increase measurement resolution and improve signal-to-noise ratio. Hence, we can estimate the type of activities better.

*Other possible ways of integrating sensor*

Integration of conductive materials in fabric and miniaturization of electronic components has led to the development of e-textiles and on-body sensors[11]. During scenarios of sexual abuse when the victim is unconscious or dominated by the physical or emotional power of the assaulter, we consider using the above mentioned method to detect initial acts of assault as it calls for help automatically, can be clipped to any garment, is easy to use and users do not have to spend money on buy specific kinds of clothes, compromising their style statement, Figure 5-9 (C). However, if in the future all garment manufacturing industries adapt this technology, we hope that users will be willing to use the embedded sensor clothing for personal safety. Seamless integration of such sensors is possible by following methods:

- Embedding them in the clothing,

- Designing the clothing with conductive yarn.

- Attaching conductive patches on existing clothing.

The first two options have been explored by Google Jacquard and Lewis (see Figure 5-9(A)and (B)).

![Figure 5-9: (a) e-textile by Project Jacquard [11], (b) Jabil's smart sport's bra and (C) Clip-on sensor prototyped at Media Lab](image)

Figure 5-9: (a) e-textile by Project Jacquard [11], (b) Jabil’s smart sport’s bra and (C) Clip-on sensor prototyped at Media Lab
5.1.3 Communication

The sensor data is sent to the on-body processing unit. The prototype is developed using a BLE (Bluetooth Low Energy) device, powered by 3.7V coin cell battery. The communication module is integrated with a Android mobile application. This application communicates with the wearer, clothing of the wearer, and the mobile phone. It broadcasts information to friends and family in case of emergency. The mobile application needs to be installed on the wearer’s phone only.

Features of the mobile application

The user can define their safety circle (five people), people with whom they are comfortable sharing the information of assault. The phone numbers are registered on the phone by the user. They can use double tap to delete a number and single tap to designate a number for calling. The application does not need to be open on the phone during an assault simulation condition and the phone can be anywhere in 800 feet range. When the assault is detected the application triggers notification, asking if the act was done with consent. The user gets 30 seconds to confirm. If no response is registered within 30 seconds, the deterrent (sound and / or smell) is automatically activated. The phone produces an alarm like sound which alerts the remote user. To deactivate the system a passcode (known only to the user) can be used within additional 20 seconds (this after the deterrents are released). If the user does not deactivate this alarm, then the geolocation of the user is sent to the pre-defined safety circle.

Safety circle

Five people who receive message about the user’s well-being and the geolocation during emergency are defined as the ‘safety circle’. They are predefined by the user and can be friends, family members, police or NGOs. One of the five is designated as the most trusted member. This person is called during an emergency. If the call is unanswered, background audio information is stored in voice mail for future legal proceedings.

Working
The processing unit processes sensor data (from the stretch sensor and accelerometer) and defines the activities as 'usual' and 'unusual'. When 'unusual' activity is detected, the on-body processing unit sends a message to the wearer’s phone asking if the act was done with their consent.

During 'active' actuation of the system, wearer gets 30 seconds to respond to the phone. If the wearer says 'yes', the device does not take any further actions. But if 'no' is registered as a response or no response is received in 30 seconds, it releases deterrents (discussed in following section) to prevent on-going assault. The user gets additional an 20 seconds to act on it and deactivate them using a passcode. If not deactivated within 20 seconds, the device sends a message to the safety circle about the wearer’s geolocation and calls one of them.

*Passive actuation*

Intuitive actuation can help prevent assaults at 'Stage Zero', when the victim can anticipate a potential threat but is conditional if the wearer has enough time to actuate the alarm. The self-actuation switch on the device can be triggered by the victim to inform the safety circle about the wearer’s well-being and coordinates on a map. The wearer will not have to pull out their phone int this case and the information will be sent directly. This system has become popular for geo-tracking and signaling recently. Most personal safety devices use the same methodology.

The coordinates are sent every 5 minutes or whenever a change in location is observed, keeping the friends informed about the victim’s latest location (see Figure 5-10). The frequency of sending and receiving data is dependent on how often the user’s coordinates change over time i.e. if the victim is in a moving car, the location will be sent regularly to the safety circle.

This can be useful in situations when the wearer is feeling unsafe, as in a dark alley, in an unsafe neighborhood, traveling during odd hours at night, abduction, when the victim is intoxicated, cannot fight against the assailter and in insecure workplaces.

*Post incident*

The system also allows the user to report the incidence to a local helpline, police or to share it anonymously on the online platform 'Fear the Fear.' People can sign up
as potential users of the product, take our on-line surveys. We hope this platform will provide a place to vent and secure online support to users.

5.1.4 Prevention

Studies show that senses like touch, smell and visuals can enhance sexual arousal [24, 37]. However, research indicates that some odorous compounds contain chemosignals that can decrease sexual arousal [40]. Since touch and sight cannot be altered during a sexual assault, we focus on altering olfactory stimuli by using pungent smells and auditory stimuli to deter assault in real-time.
Deafening sound

We use sound as an intervention. Loud deafening sound can cause distraction and a sense of threat to the assaulter. This is actuated after 30 seconds when no response is received during active actuation and immediately on pressing the self-actuation button[13].

Olfactory stimuli

Research in neuroscience shows that human sexual arousal can be altered by introducing olfactory stimuli. Some smells are found to activate receptors in the olfactory bulb which are directly linked to the sexual arousal. Tears, for example, have chemosignals that can reduce sexual arousal in some men [40]. We propose a unique method to curb sexual assault which can prevent scenarios of abuse, especially those which are caused by one-sided sexual attraction and the victim is not in a condition to consent like date rape. When the act of forceful disrobing is sensed, a pungent, repulsive smell is released to reduce the attacker’s sexual arousal and motivation. It creates immediate aversion in assaulter.

The solution proposed here is intended to interrupt assault at Stage Zero and prevent its progress to later stages. Smell capsules attached to the clip-on stretch sensor are designed for on-body wear and can be actuated passively by spitting and pressing the smell capsule. The active method is discussed later in this chapter. The capsules are otherwise durable and can withstand up to 140lbs distributed load without any fracture. This makes their use in garments as buttons or as parts of jewelry practical.

Properties of capsule

The water-based biodegradable capsules are coated with silicon on the outermost surface. This surface shields the emulsions and chemicals from moisture, rain and ambient relative humidity. Since gelatin is extremely sensitive to temperature (>45°C) and humidity, an extra shield of the hydrophobic film was coated on top of it. Picking emulsions and emulsions of pungent smelling chemicals like (E)-2-butene-1-thiol, mercaptan, and Putrescine or tetramethylene diamine (1,4-diamino butane or butane diamine) weighing 7500 mg were made keeping in mind the no-observed-adverse-effect level limits [5, 41]. Figure 5-12 (a) shows the exploded layer-by-layer formation of a
capsule. The wearer can actuate the capsule by applying a normal force to the surface of the capsule. Figure 5-12 (c) shows the robustness of the capsule as the gelatin and silicone films laterally distribute the forces and prevent it from rupture. The rigidity of the capsule was tested in an Open-house exhibition by 25 people. The capsules have been designed to integrate into any wearable object and surface. Figure 5-11 (a), (b), (c) and (d) show a few on-body wearable applications.

![Figure 5-11: Wearable smell capsules in the form of a) Ear-ring b) Buttons c) Decoration on Tie pin d) Ring and e) Trinket. The capsules can be activated to release pungent odors when needed to deter sexual assault.](image)

![Figure 5-12: Gelatin Capsule (a) Layer-by-layer exploded schematics, (b) Capsule encapsulating pungent smelling emulsion, and (c) Gelatin capsule being tested for dexterity. Man weighing 140 lb steps on the capsule.](image)

*Development of gelatin based bio-aroma films for active pads*

Gelatin based aroma films do not contain any emulsions. Instead, the bio-films carry the pungent odor in the solid state. The gelatin is dried to form a thin film of 0.25mm thick 'smell pads.' Since the aroma is encapsulated in a shell, the smell does not leak out. The film pads are placed on heating elements which are made up of copper etched Polyimide (Kapton) film. Kapton film is highly insulative, with a thermal conductivity of 0.12 W/(mK) [9] and thus, can be used in wearable clothing without
causing burns to the wearer. In Figure 5-13(a), the flexible smell and heating pad together form a 0.76mm of thick film, which can be attached to textile and jewelry (Figure 5-13(b)).

![Figure 5-13: (a) Layers of aroma-film and (b) Aroma film embedded in wearable ornament.](image)

The thickness can be reduced by using sophisticated fabrication tools including 3D printing gelatin. Gelatin pads were tested with four different concentration ratios -1:4, 1:8, 1:16 and 1:32 (gelatin: water, w/w ratio) and each concentration were then poured into a vessel of 3g capacity. Four different thickness were poured into the vessels. The solution with pungent smells was then dried off at ambient room temperature conditions (24°C and 32% Relative humidity) for 14 hours. After the dehydration stage, the thickness of the solution decreased variable depending on the concentration levels and structural rigidity increased enormously in samples with high gelatin concentration. Since the smell pads are to be worn on the body, the smell pads are designed with 1:16 (w/w) ratio of water to gelatin solution at 38°C. Humidity actuates dried thin gelatin smell pads, i.e. direct contact with water or heat (temperature >45°C). In the threatening situation, we expect the user to spit on the smell pad. The pads further activate the odor, when exposed to pH 3-8 (acidity range of human saliva). If the user is unconscious, it takes input from the user’s clothing and then heats, the pad copper etched Kapton film. The film heats up to 85°C to produce pungent odor. The bio-engineered active film can function on a 1.2V nickel-cadmium rechargeable button cell.
5.2 Infants and toddlers

In the United States, one in every nine girls and one in every fifty-three boys is sexually abused under the age of 18 years. In 93% of the cases of CSA (Child Sexual Abuse), the perpetrator is known to the victim, and the assault takes place at home in 48% of the incidences [14]. These traumatic events have a long-lasting impact on the child’s brain and linger for the rest of their life. Victims of CSA (Child Sexual Abuse) are four times more likely to develop symptoms of drug abuse and to experience PTSD (Post-traumatic Stress Disorder) as adults. We have proposed solutions to intervene in early stages of Child Sexual Abuse, addressing the communication gap between the infant and the parent. The block diagram (Figure 5-14) below is a schematic representation of the system’s functionality.

![Block Diagram](image)

Figure 5-14: Schematic representation of CSA (Child Sexual Abuse) prevention, communication and notification system
5.2.1 System overview

For infants and toddlers, we propose a thin-film insert inside the diaper for children who are using diapers. The diaper may or may not be disposable (see Figure 5-16). The inserts are biodegradable and 0.2 mm thick. They are used to track the chronological order of events. Through conversations with 10 young mothers and 3 survivors of child sexual abuse, we found that their concern is mostly related to the child's health. Wearing soaked diapers for long hours can lead to UTI, rashes, etc. and is especially problematic in the case of working parents who cannot constantly monitor their children. Survivors, on the other hand insisted on sharing the initial signs of assault with Police. One of the survivor's parent was involved in their assault and forced them to believe that it was to please God, when they were young. Survivors believe that early help can prevent child from permanent damage.

Working
The designed solution notifies (1) the immediate caregiver (parent, guardian, or other designated persons) about a required diaper change, and (2) if the diaper is removed from the child's body, another notification is sent to the parent notifying them of the removal. If the diaper is replaced, it is also reported. If the act (2) occurs without (1), then the parent can call for emergency help.

5.2.2 Sensors to detect bladder & bowel movements

Diaper wetting is common among infants, toddlers, elderly and bed-ridden people. We have developed a thin biofilm insert which can detect diaper wetting and inform the distant caregiver if the diaper is removed from the body without wetting. It also measures the frequency of change and for how long the diaper was not on the body (see Figure 5-15). The thin film sensor alerts the change in pH via the communication module, and detects moisture levels and 10 components of the urine to monitor the health of the child. The diaper change log and urine analysis data are stored and notified to the parent and distant caregiver.
Figure 5-15: (a) Communication module connected to the bio-film to monitor diaper wetting (b) Smart diaper.

Figure 5-16: Diaper with a bio-film sensor to detect wetting and unwanted removal.

5.2.3 Communication

The prototype was developed using Particle electron[9]. The device uses IFTTT, a free web-based service to create chains of simple conditional statements, called applets. An applet is triggered by changes that occur within other web services such as Gmail, Facebook, Instagram, or Pinterest and BLE beacon. It runs the applets via Internet. The communication module in the diaper connects to the home and day care center’s Wi-Fi, where infants spend most of their time. Immediate caregiver or
5.3 Solution for elderly and disabled

A wearable accessory is designed to analyze the body movements of elderly, bed-ridden and disabled people. Since this population group has very limited bodily movements, it is easy to detect activities which are more vigorous and potentially harmful or indicative of dangerous situations. High-frequency movement can be classified as a medical emergency or an act of assault. In both the cases, the distant relative and designated caregiver are informed. Hence, activity monitoring is an important input to monitor groups like these, who are unable to communicate their abuse/discomfort because of physical disability or mental inability. Since they are more vulnerable to sexual assault it is essential to device solutions for them. Research indicates that physical disability and failure to communicate assault can cause depression and prolonged trauma[36].

Figure 5-17: Prototype device for detecting elderly abuse.

5.3.1 Sensor

Due to their fragile condition, one does not expect the elderly to perform strenuous activities like running, etc. Hence, low-cost, moderate precision sensors like a 9-axis
accelerometer can be used to detect 'unusual' vigorous body movements. These movements can be the result of medical emergency or physical assault.

Figure 5-18: (a) Tracking and communication device, Wi-Fi enabled and (b) E-mail alert sent to a person (member of safety circle).

Sexual harassment can also be detected using bio-film sensor inserts (discussed earlier). They can be added to the diapers to monitor bladder and bowel movements of bed-ridden patients, elderly and disabled people. If unwanted removal of undergarments or unusual activity is detected, it can alert the care-givers.

5.3.2 Communication

Since the victim is confined to a specific geographic location, WiFi can be used for communication. The information can be relayed using the IFTTT applet and a pre-recorded message can be sent via a voice call. The stand-alone device is connected to Wi-Fi and has the ability to send e-mails, messages and call distant relatives of the user (see Figure 5-18), if the device is removed from the wearer’s body. We hope that the proposed solutions can help detect, communicate and prevent assault in real-time and address problems in all four quadrants and stages of assault. In the next chapter we will evaluate the clip-on sensor via user studies.
Chapter 6

Evaluation

In this chapter we evaluate technical, social and aesthetics aspects of the designed solutions. In the first half we discuss the clip-on-sensor and in the second half we evaluate the smell capsules.

6.1 Technical evaluation

6.1.1 Software

6.1.1.1 Functionality (false positive)

This test was conducted with 67 participants (Female, Age-18-55 years) to study basic features of the clip-on sensor. We investigated mobile application and communication module. A post-experiment questionnaire followed the 20-minute user-study. Features include:

1. Successfully uploading the Android application on the participants’ phones. The application was developed using Android Studio.

2. Defining five people as their most trusted caregivers. This group of five is called the Safety Circle. Participants add their phone numbers; they can add police to this contact list but are not asked to.
3. Selecting one caregiver as their primary contact. This contact is called during an emergency.

*Experiment design and procedure*

During this experiment, a manikin was dressed with the clip-on sensor on her bra. Participants used the Android application to register five contact numbers in the application and designated one phone number for calling during the artificially created assault condition. When the manikin was touched inappropriately (acts include fondling, squeezing), or her bra was removed. The message was sent to the participant’s phone asking if the act was done with consent. It is up to the participants to say "yes" or "no." Calling and messaging to safety circle were disabled as this was a pilot, and we did not want to bother people. Instead, message and emergency call was enabled to call the participant.

*Findings*

All participants were able to successfully register their safety circle and the calling feature. When the artificially created assault simulation situation was triggered, 52 participants decided 'NOT' to consent, and others consented. Those who did not consent experienced a loud deafening sound. Some participants felt uncomfortable and shocked as they were not expecting such a high decibel annoying sound. Two participants suggested increasing the volume gradually instead of doing it all of a sudden. Five participants were hesitant to use the product fearing false alarms.

6.1.2 Hardware

To address the concern related to false positives we performed another experiment at MIT Media Lab with 20 participants (female, age- 18 -30 years, M- 24.4).

*Experiment design and procedure*

Participants were asked to wear a shirt with the sensor patch for 45 minutes. They were invited to choose a position on their garment to place the communication module. They performed daily activities like lying on a mattress, running, walking, sitting and strenuous exercises like jumping, squatting. Post experiment participants were asked
to fill a questionnaire. Robustness of the device, false actuation, and ease to wear was evaluated during this study. The available options to place the communication module in different locations of the garment as shown in the figure 6-3. In the questionnaire, we asked if participants faced any discomfort and if they were to wear the device, how often would they wear it and on which kind of garment would they want the sensor to be placed.

Figure 6-1: Participants using mobile application during user testing

Findings

1. Evaluating Robustness, Comfort and ease to wear

During all activities, participants found the device very comfortable. A participant mentions her experience as follows: 'The piece did not impede my movement in any way; I was only afraid it was going to fall out, but even without restricting my movement it was not noticeable and didn’t fall out.' A participant who chose to place the communication module behind the neck of the shirt expressed discomfort- 'There are some minor discomforts when lying on the back since it presses against your spine.' In the study, most participants chose to position the communication module near the shoulder and in the front of the bra. They found the device lightweight, concealed and invisible.

19 out of 20 participants also chose panties (undergarments) as the most preferred location. However, we found that most participants use bathroom 3 times
a day. In order to prevent false alarms we will have to machine learn each participant’s daily activity and map is as ‘usual’ activity. However, the participant also has the ability to disable a false alarm within 50 seconds using a passcode. When asked if they would like to use the device on a daily basis or occasionally, 15 participants said they wanted to use the device as a clip-on as they can have freedom to choose the location for the sensor and they will not be forced to a particular dress. Some mentioned that if the device were integrated into all clothes, they would like to use it every day.

While defining the safety circle, most people were hesitant to include police in their safety circle. 17 participants felt comfortable to share the information of assault with their mothers, followed by friends, sister, father, roommate, boyfriend, cousin, and aunt. One participant mentioned that she is afraid reporting such incidences to police, as people will judge her and not offer her prestigious positions. This may affect her career and reputation in society as well. Another participant said that she could not trust the campus police as they favor perpetrators. A sticky note in the women’s bathroom on Title IX pamphlet confirms that students don’t trust campus police and are uncomfortable sharing their experience with them (see Figure 6-2).

2. Re-usability, Aesthetics, Comfort, and Robustness of sensor patch

To evaluate the re-usability, robustness and adhesive properties of the clip-on sensor, we asked 8 participants (R1-R8, 4 men, and 4 women participants, age - 18 to 36 years, M=24.8) to wear the 3 different kinds of clip-on sensors for 24 hours or more. The sensors had three separate kinds of adhesive layers attached to the sensor- (a) adhesive tape, (b) cello tape and (c) hydrogel. The sensors were tested on 8 various kinds of fabric (net, wool, cotton, linen, etc).

Fabric glue and adhesive fabric were not used because they leave adhesive residues behind and require equipment (ironing) to create a strong bond. Findings After 24 hours, some participants chose to wash the sensors in regular washing machines. No-prior instructions related to washing was given to par-
Figure 6-2: A note in student’s bathroom showing lack of confidence in Campus Police.

Figure 6-3: Possible positions to place the communication module in different garments.

Post experiment results show that the clip-on sensor with hydrogel adhesive layer was able to create a strong bond with all kinds of clothing. It was able to sustain the test period without detaching and interfering in any activity.
Figure 6-4: Participants doing vigorous activities to test the robustness of the device.

It also sustained the heavy-duty machine wash and could be reused for future applications. R4 wore the sensor underneath semi-transparent clothing and felt comfortable since the gel is translucent. After washing the sensor in normal wash conditions we found the sensor intact (see Figure 6-5). The stickiness and thickness of the hydrogel increased for sometime but as the conductive fabric dried, the gel dried to its normal form as well.

Figure 6-5: Condition of clip-on sensor (a) before machine wash and (b) after wash

6.2 Evaluation of olfactory stimuli

Since it is impossible to recreate the scenario of sexual assault, we tried evaluating the components of our design through experiments.

6.2.1 Influence of olfactory stimuli on sexual arousal

Study design
A mixed, within and between subjects, experiment aimed to study the influence of odors on sexual arousal was conducted in laboratory. 22 heterosexual males (ages 18-50) were recruited, split into two groups of 11 each, and asked to self-report their sexual arousal state on the scale of 1-10 (1 denotes arousing and ten non-arousing) while watching 20 different explicit (adult heterosexual pornographic) images. Each participant was asked to watch 20 images in the presence of condition A - unpleasant (0.3 ppm ammonium sulfide- below TEEL-1) odor and Condition B -pleasant (Bulgarian natural Lavender oil) odor. Participants in Group 1 experienced condition A followed by condition B and those in Group 2 experienced them in the reverse order. Images were shown on a laptop owned by the researcher and data collected was stored anonymously.

An E4 Empatica wristband was used to collect physiological data from electrodermal activity (EDA) on each wrist. A digital clock kept track of time spent on every image. Participants in Group 1 experienced condition A followed by condition B and those in Group 2 experienced them in the reverse order. Images were shown on a laptop owned by the researcher and data collected was stored anonymously.

Procedure

Before the study, participants were briefed about the nature and purpose of the study and asked to sign consent forms. Two E4-wristband sensors were then fitted with both hands. Sensors were turned on 15 minutes before the start and remained functional until the end of the study. 11 participants experienced condition A before condition B and were part of Group 2. Group 1 had the rest of the participants who experienced condition B followed by condition A. All participants experienced both conditions A and B. Subjects used the 'spacebar' on keyboard to move through images. The images were presented in a random order, and the same set of images was used for both conditions. At the end of 20 images, the subjects were instructed to call the researcher to stop the session. After both, the conditions were tested the wristband sensors were removed, and participants were asked to fill out a post-experiment questionnaire with
open-ended questions to gather feedback.

Results
Each participant, on average, took 17-18 minutes to complete both sessions A and B excluding the time spent on reading the consent form and filling out the post-experiment questionnaire. We found that participants spent less time on viewing images when exposed to the unpleasant odor. The only exception was participant P17 which had nasal congestion and had informed us of that before the experiment.

Figure 6-6: Time spent by participants (P1-P22) viewing images in condition A and condition B

Figure 6-6 shows the time spent by each participant on viewing images for condition A (unpleasant) and B (pleasant). Group 1, which experienced the pleasant odor followed by the unpleasant odor showed remarkable variation in cumulative scores, i.e.; subjects rated images as more arousing in condition B as compared to condition A.

Figure 6-9(a) shows ratings by Group 1 subjects during Condition B followed
by Condition A. Figure 6-9(b) shows Group 2 subjects rating the images almost the same in both Conditions A and B. We also identified that the participants in Group 2 had lingering effects due to the pleasant odor. It is clear from Figure 5a that subjects who were exposed to Condition B first found images more arousing than subjects who experienced Condition A first. The maximum score for non-arousing images was 139 in Group 1 and 185 in Group 2. The scores for arousing images as rated by Group 1 during condition A and condition B showed more variation as compared to Group 2. This suggests that introducing the unpleasant odor decreased arousal throughout.

The Empatica E4-Wristband sensor was used to collect electrodermal activity (EDA) from both the dominant and the non-dominant hand of each user. The normalized data for 11 participants in Group 2 showed low EDA values during Condition A and continued to be low in Condition B (Figure 6-7). Normalized EDA values of participants in Group 1 were found to be higher during Condition B, and they gradually decreased in Condition A (Figure 6-8).

![EDA vs. Time](image)

Figure 6-7: Average EDA sensor data for Group 2 participants during unpleasant and pleasant conditions.

**Discussion**

Self-reported arousal data indicates that the unpleasant odor negatively influenced sexual arousal. However, due to the small number of participants, it is
Figure 6-8: Average EDA sensor data for Group 1 participants during pleasant and unpleasant conditions.

Figure 6-9: The aggregate of self-reported sexual arousal rating of each participant in Group-1 (a) and Group-2 (b) while experiencing pleasant and unpleasant odor.

hard to assess the extent of the impact of unpleasant odor, or how effective these odors are in deterring sexual assault in practice. Some flaws in the experiment design were identified while reviewing the post-experiment questionnaire. Two subjects expressed uneasiness; Subject P19 said, "It is very difficult to remain calm during an experiment." P4 expressed discomfort due to the presence of a female instructor, "It was strange to perform an arousal study in the presence of female instructor." A prolonged effect of the unpleasant odor was observed in Group 2 participants, which provokes the question of how long can pungent
odors influence sexual arousal? The study was designed with the hypothesis that if people are exposed to pungent odors for extended periods, they may get acclimated to the offensive smell. However, no such habituation was observed. One can argue that a span of 18 minutes is not enough time to get adapted. After reviewing and analyzing the results of the experimental study, we believe pungent odors are correlated to sexual arousal and can be explored as a potential deterrent against sexual assault.
Chapter 7

Limitations, Future Work and Conclusion

In this chapter we discuss the limitations of our proposed solution. We also include other possible scenarios of use case and discuss plausible means to take the solutions to market.

7.1 Limitations

7.1.1 Technical

The current technology is dependent on a power source. Hence, the communication module would stop working if the device or the Li-ion battery dies out. In some security check posts, the device can be misunderstood as a lethal weapon and cause embarrassment to the wearer. The other biggest limitation of the proposed solution is that the GPS coordinates do not include the altitude elevation which limits help to reach in time, if the victim is in a high rise building.

7.1.2 Non-technical

In countries, where victims are marginalized and accorded inferior status, and if their family and society are shaped by strong cultural and historical roots of gender
discrimination; there is a very high possibility that proposed technological solutions can be used against the victim for stalking and limiting their freedom. Also, these systems are of no good in scenarios of martial rape or abusive relationship, if the victim is not willing to stand for themselves.

A significant technological threat is also posed to the victim if they are going through an abusive relationship. The other most challenging situation is in the case of child sexual abuse, elderly and disabled, where the victim is dependent on others for their basic needs and the caregiver is the perpetrator. In these situations, the system will not be able to help the victim.

7.2 Future work

We hope to extend this work in our everyday textiles to monitor day-to-day activities and monitor other forms of the street, domestic violence. Applications can extend to prisons, military as well.

We hope to startup a company which devices technology to prevent assault and enhance personal safety. This can be realized by collaborating with existing garment and textile manufacturers or companies who focus on personal safety products. Since, the issue is very close to personal safety and security, we think crowd-funding could be another way to bring it to life. We have received interests from e-textile, e-commerce companies and NGOs recently to manufacture our products. We would also propose to coin a global definition for rape, assault, and molestation to treat all victims of assault at par. As this is deeply rooted to the societal norms; these definitions can be tweaked by the local customs and norms of the land.

7.3 Conclusion

With this work, we present technological interventions to detect, communicate and prevent sexual assault in real-time for infants, grown-ups, elderly and disabled. The seamless integration of the technologies in our current wearables like shirts, diapers,
and undergarments was prototyped using embedded electronics and conductive materials. To complement the design other deterrents like pungent odors were developed and tested for ease of use, comfort, durability, false actuation and reflex responses for actuation.

These stand-alone interfaces can be snapped to any of the three prototypes. They can future be explored as passcode protected clothing and as a human-computer-clothing interaction system. The developed prototypes bring functionality to our existing clothing and add another layer of self-protection. Design decisions were made cautiously to ensure wearer’s safety in both conscious and unconscious state. We believe that the designed system can help improve personal safety and reduce the incidences of sexual assault in the discussed scenarios.
Bibliography


[9] Particle Store.


[12] Reports of Sexual Assault Rising Sharply on College Campuses - WSJ.


[14] Scope of the Problem: Statistics | RAINN.


[36] RAINN. Statistics | RAINN.

[38] Ira Sherman. IMPENETRABLE DEVICES, 2002.

