Technological Interventions to Detect, Communicate and Deter Sexual Assault

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ABSTRACT
Every 98 seconds an American is sexually assaulted. Our work explores the use of on-body sensors to detect, communicate and prevent sexual assault. We present a stick-on clothing sensor which responds to initial signs of sexual assault such as disrobing to deter sexual abuse. The smart clothing operates in two modes: an active mode for instances when the victim is unconscious, and a passive mode where the victim can self-actuate the safety mechanism. Both modes alert the victim's friends and family, actuate an auditory alarm, activate odor-emitting capsules to create an immediate repulsion effect, and call emergency services. Our design is based on input from sexual assault survivors and college students who evaluated the clothing for aesthetic appeal, functionality, cultural sensitivity and their sense of personal safety. We show the practicality of our unobtrusive design with two user studies to demonstrate that our techno-social approach can help improve user safety and prevent sexual assault.

Author Keywords
Wearables; Self-Defense; Sexual Assault; Unpleasant Odor; Olfaction; Personal Safety Devices; High Decibel Sound

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION
The US Department of Justice describes sexual assault as any type of sexual contact or behavior that occurs without the consent of the recipient. There is debate about whether sexual assault is a crime of power and control or of pleasure [6]. A survey done in India discussed morphological analysis of function structures and alternate technological solutions and their application for evading sexual assault. Women rated wearable solutions like clothing, lingerie and footwear (on-body systems) as more desirable than those integrated with accessories like handbags, bracelets, watches and mobile phones [8]. Not surprisingly, a wearable system was considered more accessible than a gadget in a handbag or a mobile phone given that, during assault, victims experience high levels of subjective distress, autonomic arousal, and plasma catecholamine secretion which constrains and impairs cognitive and physical functioning [3, 4]. Sexual assault and solutions that aim to prevent it are part of a broader context of related social and ethical issues that warrant deeper exploration for informing the design of the technology, its use, and its impact.

In this work we aim to address a small part of this multifaceted issue. We propose smart clothing with stick-on sensors that can detect the initial signs of forced disrobing integrated with self-actuation buttons which the victim can activate when they feel threatened. Our device is designed to reduce sexual interest of the attacker by producing offensive auditory and olfactory stimuli. When triggered by forceful removal of clothing, the device sends a message to the wearer's phone asking if the trigger was intentional and with consent. If no response is received from the user within 30 seconds, the system calls for help, which is useful in scenarios where the victim is unconscious, incapacitated, or otherwise unable to provide consent or call for help themselves. If the victim is able to anticipate an assault, they can self-actuate the device to burst the smell capsule, produce a deafening sound, and send out alerts to those in their pre-defined safety circle. We designed our stick-on sensor based on input from 12 sexual assault survivors and 67 volunteers, who overwhelmingly preferred an on-body technological solution as opposed to devices that must be carried in a bag or pocket.

RELATED WORK
Technological interventions against sexual assault and harassment have been available for a few decades. A female condom with a hypodermic syringe that injected tranquilizer fluid was developed in 1979 [10]. There were others that followed like Rape-aXe, the Trap, Snare, and the killer tampon [1].

After the Delhi gang rape of 2012 [9] 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 electric burns [7]. Most solutions rely on the victim's ability to actuate an alarm and assume that the perpetrator is not dominating the victim - emotionally, mentally or physically - and would prevent the victim from activating the device. What makes the problem more challenging is the victim's inability to make quick decisions and take action due to impaired cognitive and physical ability during assault [3]. Thus

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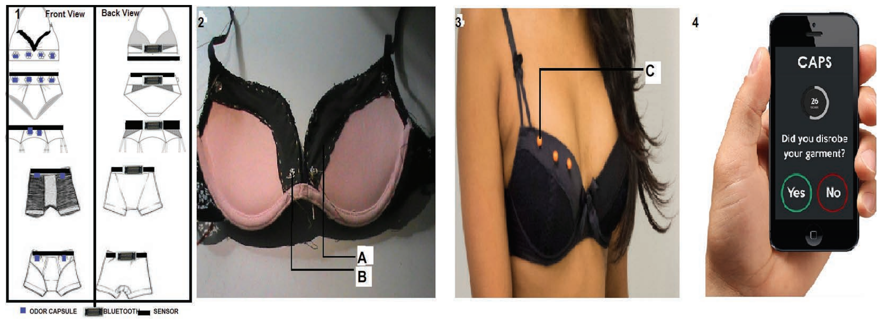

Figure 1. From left to right: a) Graphic shows how our sensor is attached to clothing. b) The stick-on sensor is made of stretch-sensing fabric A, in black, and clipped on to existing underwear B.c) User wearing our smart clothing. The design is comfortable and unobtrusive. The three dots visible on the bra labeled C are the odor capsules. d) The companion mobile application that connects to our sensor through a communication module and calls for help as needed.

using safety products that require input from the user or have a multi-step activation process maybe not be as useful as intended. Devices like the pepper spray can be used against the victim [2]. Studies show tactile, olfactory, and visual sensory data can enhance libido [5, 11] though some odorous compounds contain chemo-signals that can create immediate and powerful aversion [12]. Since touch and sight cannot be effectively used to deter sexual assault, we focus on altering olfactory stimuli by using pungent smells, and introducing deafening sounds to deter the assaulter and potentially stop an on-going assault.

SYSTEM OVERVIEW

Our personal safety smart clothing is designed to prevent sexual assault with a stick-on sensor and a communication module (self-actuation button). We divide the sexual assault event into four stages. These stages are based on data from registered reports at a women's helpline center over a six month period in a large metropolitan city of south-east Asia. Stage Zero is when the victim can anticipate unwanted sexual attention including verbal attacks. Stage One is when the assaulter has bodily contact with the victim. Stage Two is forceful disrobing and Stage Three is when the assaulter establishes direct contact with the victim's private parts, with possible penetration. Based on the stage of the assault, our smart clothing provides two types of responses against an assailant:

- Active - This response is automatically triggered when the victim is unable to fight back or escape an assailant due to loss of consciousness or diminished physical ability. The target users include elderly, infants, disabled victims and incidences where the victim cannot provide consent for e.g., if they are under the influence of alcohol and/or drugs.
- Passive - This response is triggered by the victim when they can predict threat prior to assault i.e., at stage zero.

Active Response

System Design and Actuation

The active response system consists of a sensor, an actuator, and an alert system (Fig. 1). The wearer pre-defines a safety circle with 5 people who are notified of the wearer's GPS location when the wearer is in danger. One of the five also receives a phone call that is recorded for potential legal proceedings. The stick-on sensor is used to detect any kind of fondling and disrobing. It consists of four layers: (i) a conductive top layer detects horizontal forces like stretching, (ii) a second insulating layer with 0.5x0.5cm slots, (iii) a conductive patch forms the third layer, and (iv) a fourth adhesive layer that helps attach the sensor to clothing (Fig.4b). The slotted second layer prevents short circuits and the slots help to detect vertical forces that happen when it comes in contact with the third conductive patch layer because of fondling, pinching and squeezing.

Stretching of garments, indicated by changes in electrical resistance due to the activity of the wearer, is classified usual or unusual activity. When disrobing (unusual activity) is detected, a verification message is sent to the wearer asking if they knowingly stretched or removed their garment. If no response is received within 30 seconds (based on survey data from 57 volunteers and 12 users and can be changed as needed), the device sends a message to the wearer's safety circle with their GPS coordinates and a call for help (Fig. 1d). Simultaneously, actuators emit a pungent odor (Fig. 1c) and a loud alarm is sounded that overrides existing sound settings. The actuator system consists of smell capsules and heating pads made by selectively etching Kapton tape. The capsules are small and discrete, and can be embedded in buttons, or jewelry (Fig. 1c). Upon activation, the heating pads melt the capsule shells, rapidly releasing the pungent odor inside.

Design consideration

Our sensor is made of stretch-sensitive fabric and can be clipped on to any kind of existing clothing (Fig. 1b). Any sudden changes in resistance due to stretching can trigger the system, with either an *active* or a *passive* response. The sensor has been designed such that it does not interfere with the user's outer clothing nor does it require the user to wear something that may be visible, awkward or intrusive. It is designed to look like it is part of the user's undergarments.

Intervention through smells

Neuroscience research shows that human libido can be altered by olfactory stimuli. Some odors are found to activate receptors in the olfactory bulb e.g., tears, which can cause immediate aversion [12]. When forceful disrobing is sensed, a pungent obnoxious smell is released to reduce the attacker's sexual motivation by triggering reflexive chemotaxis.

Passive Response

The solution proposed in this paper is intended to interrupt assault at Stage Zero and prevent its progress to later stages. The self-actuation tactile button (Fig. 1c) attached to the stick-on stretch sensor can be actuated by pressing down on it. This triggers the smell capsule and alarm immediately, followed by messaging and calling designated people for help.

EVALUATION

Since it is unethical to recreate actual sexual assault in a laboratory setting and beyond the scope of this work, we evaluate the components of our system through two experiments.

Impact of olfactory stimuli and high decibel sound

Study design

An IRB (Institutional Review Board) approved mixed, within and between subjects study was designed to understand the influence of odors on response to sexual stimuli. 22 heterosexual males (ages 18-50) were recruited. They were split into two groups of 11 each and asked to rate 20 diverse explicit (adult heterosexual pornographic) images. Each participant was asked to view 20 images sequentially 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 B followed by condition A and those in Group 2 experienced them in the reverse order. A high decibel sound was played at a random time during the experiment to distract and startle the subjects. High decibel sound was introduced as an additional deterrent. Images were shown on a laptop owned by the researcher and data collected was encrypted and stored anonymously. A digital clock kept track of time spent on every image. Participants rated their feelings for each image on a scale of 1 (arousing) -10 (non-arousing) in test conditions A and B.

Procedure

Participants were briefed about the nature and purpose of the study and asked to sign a consent form before starting. Subjects progressed through the randomized images using the space bar. At the end of 20 images they were asked to call the experimenter to end the session. After both the conditions were tested, 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 who had nasal congestion and had informed us of that prior to the experiment. Figure 2 shows the time spent by each participant on viewing images for condition A (unpleasant) and B (pleasant).

Group 1, which experienced the pleasant odor (B) followed by the unpleasant odor (A) showed remarkable variation in cumulative scores i.e., subjects rated images as more arousing in condition B as compared to condition A (Fig. 3a).

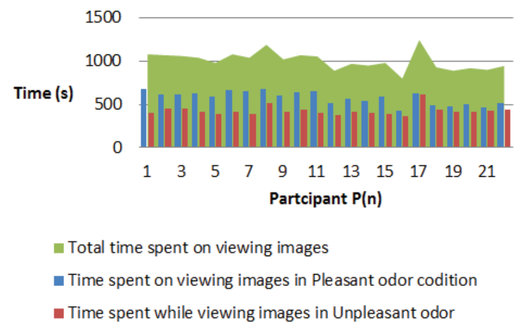

Figure 2. Time spent by participants (P1-P22) viewing images in condition A and condition B

Figure 3b shows Group 2 subjects rating the images almost the same in both Conditions A and B. We identified that participants in Group 2 had lingering effects due to the pleasant odor. Figure 3a shows 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. Overall participants in Group 1 rate every image 2 units more arousing in pleasant condition than unpleasant and participants in Group 2 rate the images almost the same. One can argue that the repetition of the same image in conditions A and B can cause boredom and hence Group 1 participants rate the images in unpleasant conditions less arousing. But this assumption does not hold when comparing with Group 2 results where participants rated the images less arousing in both conditions and the pleasant odor ratings remained lower when comparing between subjects in both groups. We can thus conclude that the unpleasant smell may have had a lingering effect on the participants in Group 2.

Discussion

Self reported data indicates that sexual feeling was negatively influenced by the unpleasant odor and the repetitive 10 seconds high decibel sound intervention. However, due to the small number of participants, it is difficult to assess the extent of the impact of the unpleasant odor or how effective the combination of odors and sounds is in deterring sexual assault in practice. We will modify the design for future experiments as two subjects expressed uneasiness and discomfort. P19 said, *"It is very difficult to remain calm during an experiment as the sound was suddenly very loud and unbearable."* P4 expressed discomfort saying, *"It was strange to perform a libido study in the presence of a female instructor."*

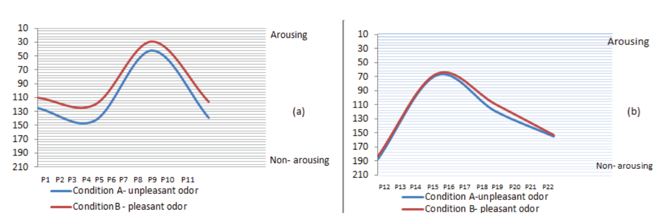

Figure 3. Aggregate of self-reported libido rating of each participant in (a) Group 1, and (b) Group 2 while experiencing pleasant and unpleasant odors.

Design evaluation

We asked 67 volunteers and 12 victims (all self identified as females, ages 18 - 48, mean 21.8) to evaluate the system's :(i) robustness (ii) comfort (iii) aesthetics (iv) ease of use, and (v) functionality. The experiment was conducted with a diverse set of multicultural and multinational participants on a university campus in the US.

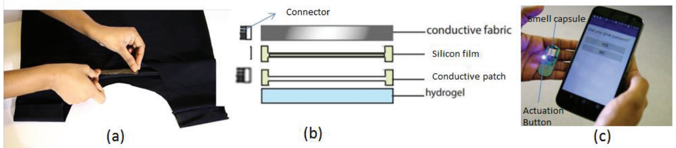

Figure 4. (a) stick-on sensor with hydrogel adhesive patch , (b) schematic diagram of the stick-on sensor, (c) communication module and the companion mobile application that connects to the sensor and calls for help as needed.

Functionality and ease of use

67 volunteers (D1-D67) were asked to define their safety circle in the mobile application and pull the garment off a manikin's body to test the prototype's functionality. We asked them if they were willing to buy/use the proposed solution as a personal safety device. 88.4% of the participants said they would purchase the device as a stick-on sensor because it gave them the ability to wear a protective technology with any kind of garment.12 victims (V1-V12) were asked to wear the sensor (Fig. 4) and perform daily normal activities like sleeping, running, working etc. 10/12 participants chose to attach the sensor to their undergarments (options were shirts, pants, or undergarments) and placed the communication module over their shoulder or near their underwear.

60/67 volunteers and 10/12 victims reported they were comfortable wearing the stick-on sensor on their undergarments and using the mobile application. 72 participants were unwilling to alert the police or immediate family members but chose to alert siblings and friends when activated. V7 said she was afraid it may lead to people judging her, affecting her career and reputation in society. V5 said she could not trust the campus police as they favored perpetrators.

Re-usability, Aesthetics, Comfort, and Robustness

To learn about re-usability, robustness and adhesive properties of the stick-on sensor we asked 8 participants (R1-R8, 4F, ages 18 - 36, mean 24.8) to wear 3 sensors, with different kinds of adhesives, continuously for at least a 24 hour period. The adhesives used were: (a) adhesive tape, (b) cello tape, and (c) hydrogel and sensors were attached to 8 different kinds of fabrics (net, wool, cotton, linen, etc.), without changing the rest of the sensing module. Fabric glue and adhesive fabric were not used because they leave residues behind and require equipment (ironing) to create a strong bond.

After 24 hours, 5 participants chose to wash the sensors in regular washing machines. No-prior instructions related to washing were given to participants. Results show that the stick-on sensor with a hydrogel adhesive layer was able to create a strong bond with all the clothing materials tested without getting detached or interfering with any user activity. It also sustained the heavy-duty machine wash and could be reused 300 times based on our lab testing. By adding a few drops on water on the adhesive layer the original adhesion properties can be restored for future applications. R4 wore the sensor underneath semi-transparent clothing and felt comfortable about how it looked since the gel is translucent. Other adhesives did not stay on longer than 30 minutes and some barely lasted 2 minutes e.g., cello-tape on a woolen sweater.

LIMITATIONS AND FUTURE WORK

Our system relies on mobile devices for communication but will fail in situations where the device is out of battery or in a low signal area. These are important concerns that we plan to explore in our future work along with a larger user study, deployed in the wild. There are social and ethical issues that need to be explored which would impact the design and usage of our sensor for e.g., in some communities it could be used to spy on the wearer while in others, not wearing such a device may be misinterpreted as inviting attention.

CONCLUSION

In this paper, we presented a new method to detect, communicate, and deter sexual assault and harassment with an on-body wearable safety system. Integrating our designed technology into existing clothing via a stick-on attachment we tested for ease of use, comfort, durability, false actuation, and reflex responses for actuation.

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