CPS: Beyond Usability:
Applying Value Sensitive Design Based Methods to Investigate Domain Characteristics for Security for Implantable Cardiac Devices

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Implantable Cardiac Devices

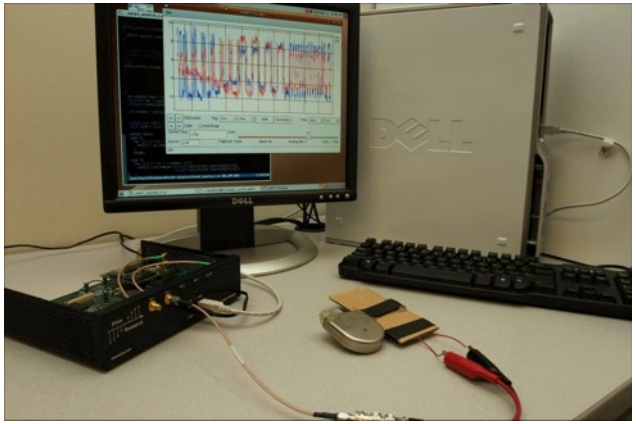
- Pacemakers
  - Correct for slow heart rhythms
  - Correct for *no* heart rhythm

- Implantable Cardioverter-Defibrillators
  - “Reset” potentially fatal heart rhythms

Wireless ICD Security & Impacts

[Halperin 2008] [Gollakota 2011]

- Private information
  - Obtain serial number, patient name, diagnosis
- Health impacts
  - Turn off therapies (defibrillation)
  - Induce cardiac fibrillation



Wireless ICD Security

- **Need more security**
  1. **No individualized security**
  2. **Demonstrated security vulnerabilities**

Securing Implantable Cardiac Devices

More security is needed

Securing Implantable Cardiac Devices

More security is needed

- **Proposal:** Password on file

Securing Implantable Cardiac Devices

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Cost: Inaccessibility
- In emergencies
- Travel
- Switching providers

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The Science and Art of Tradeoffs

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Security Solution "Costs"

Value of Human "Assets"

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Implantable Cardiac Devices: Broader Context

- Defense designs require interaction with domain experts
- Exploratory studies surface issues

Quantitative Research

How much?

Qualitative Research

How much **of what?**

Qualitative Research

How much **of what?**

Why?

Human-Centric Investigation: Implantable Cardiac Devices

- **Question:** What are relevant costs (to avoid) with respect to security systems for implantable cardiac devices?

Patient Study

- Semi-structured interviews with patients with IMDs
- Investigated patient values and concerns
- Elicited reactions to security system concepts






[Denning 2010]

The Medical Ecosystem: Many Roles, Complex Interactions

Primary Care Physician

Hospital Billing

FDA

Medical Technicians

Electrophysiologist

Insurance Companies

Nurse Practitioner

Nurse

Cardiologist

Emergency Room Staff

Implanting Surgeon

Anesthesiologist

Device Manufacturer Representative

Informing Security Research via Studying the Application Domain

- Richness of underlying issues

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- Richness of underlying issues
  - Stakeholder priorities

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Design better security solutions

Framework: Value Sensitive Design

[Friedman 2006]

Account for people's **values**

Framework: Value Sensitive Design

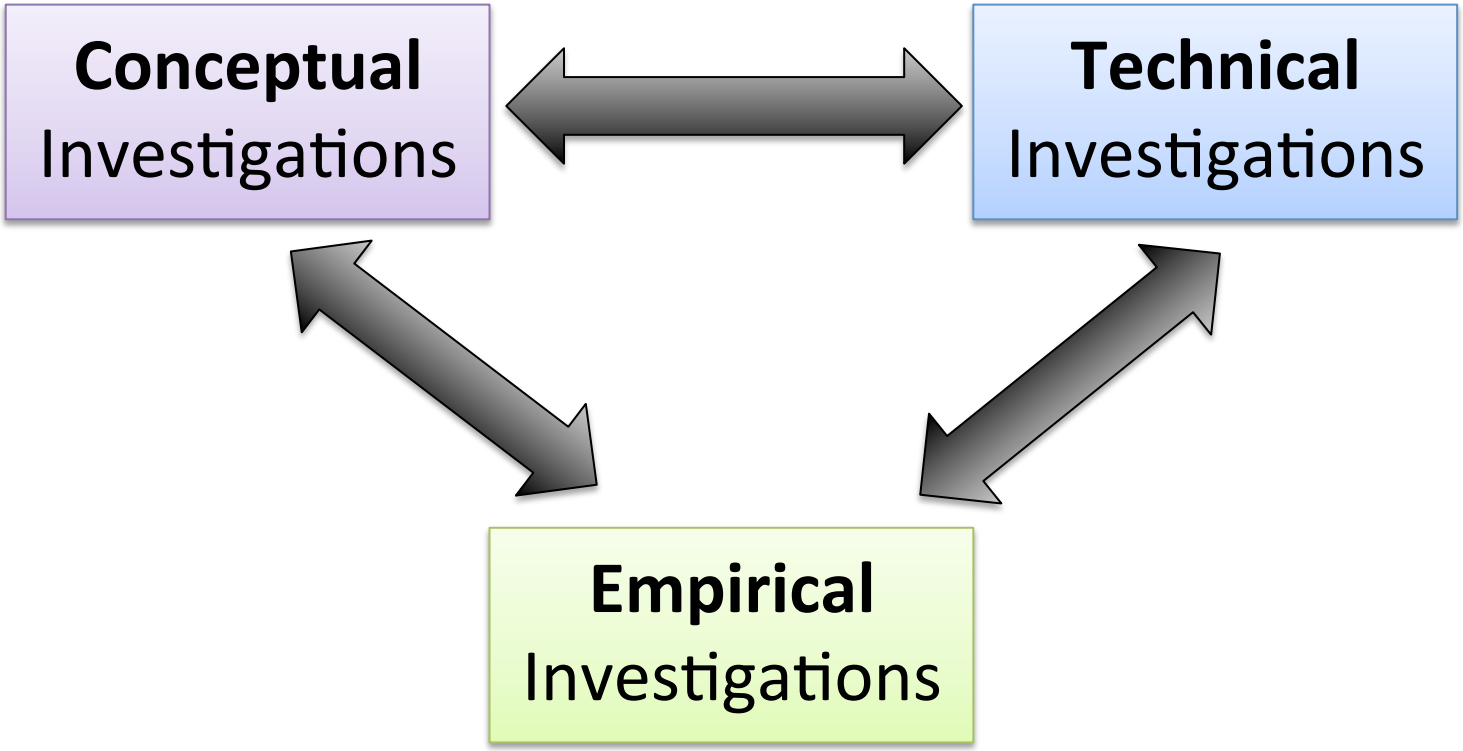
[Friedman 2006]

Account for people's **values**

Account for **direct** *and* **indirect** stakeholders

Framework: Value Sensitive Design

[Friedman 2006]



Qualitative Study Design

- 3 Workshops:
  - 24 providers
  - Cardiologists, nurses, anesthesiologists, etc.
- Workshop format facilitates:
  - Interactive discourse
  - Surfacing consensus, tensions
- Group Activities & Paper Instruments

Workshop Format

- Stakeholder Perspectives
- Metaphor Generation
- Critiques and Concerns

[Kensing 1991]
[Yoo 2013]

- Evaluation of Security System Concepts
- Open-ended Discussion

Workshop Format

- **Stakeholder Perspectives**
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Stakeholder Perspective Data Analysis

- Open-ended answers used to develop topic categories
- Independent researcher used categories to code participant responses
- Kappa = 0.745
  - >0.75 is excellent agreement
  - 0.40-0.75 is intermediate to good [Fleiss 2003]
  - 0.61-0.80 is substantial agreement [Landis 1977]

Stakeholder Perspective Results Inform Security Design

- Access & Sharing
- **Compatibility**
- Correct Usage
- **Device Battery Life**
- Device Compactness / Inertness
- Device Ecosystem
- Device Functionality
- Patient / Patient Health
- Programming
- Quality of Data
- Remote Monitoring
- Security & Privacy
- **Surgery & Healing**

Stakeholder Perspective Results Inform Security Design

- A
- C
- C
- D
- D
  In
- D

1. Assets we want to protect from attacks
2. Costs we want to avoid

?
Human Assets

?
Security Costs

th

- Surgery & Healing

Workshop Format

- Stakeholder Perspectives
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[Kensing 1991]
[Yoo 2013]

- **Evaluation of Security System Concepts**
- Open-ended Discussion

Security System Concepts

- Surveyed literature for proposed security solutions
- Chose representative concepts with varied properties
- Participants:
  - Provided overall evaluations
  - Commented on properties

Disliked System Concepts: Uncovering Security System Costs

?

Security Costs

Medical Alert Bracelet
with Password

Disliked System Concepts: Uncovering Security System Costs

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Security Costs

Medical Alert Bracelet with Password

UV-Visible Tattoo

[Denning 2010]
[Schechter 2010]

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Security Costs

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Criticality-Aware IMD

[Gupta 2006]

Disliked System Concepts: Uncovering Security System Costs

?
Security Costs

Positive Properties (of Disliked Systems)

- ↑ Facilitates emergency access
- ↑ Reassures patient
- ↑ Not visible
- ↑ Cheap
- ↑ No patient effort
- ↑ Always present

Disliked System Concepts: Uncovering Security System Costs

?

Security Costs

Negative Properties

- ↓ Access is not guaranteed
- ↓ Cultural, social, or personal objections
- ↓ Broadcasts patient condition to others
- ↓ Potential impact on battery life

Liked System Concept: Uncovering Security System Costs

Fail-Open Wristband with Safety Features

[Denning 2008]
[Gollakota 2011]
[Xu 2011]

- Presence blocks unauthorized access
- In its absence, system fails into an open state—accepts all communications

Liked System Concept: Uncovering Security System Costs

Fail-Open Wristband with Safety Features

[Denning 2008]
[Gollakota 2011]
[Xu 2011]

- ↑ Fail-open
- ↑ Safety features
- ↑ Security
- ↑ Empowers patient
- ↑ Visual cue

- ↓ Security
- ↓ Maintenance
- ↓ 911 false positives
- ↓ Visual indicator
- ↓ Training
- ↓ Expense

Human-Centric Investigation Indicates Security Costs to Avoid

Security Solution Costs

Inaccessibility	Battery life
Money (→ denied claims)	Patient privacy
Patient comfort + mental health	Infection
Implant size	Incompatibility

Human-Centric Investigation: Implantable Cardiac Devices

- Study indicates security costs to avoid when designing security solutions

- Additional features (e.g., safety) may entice buy-in

- Tensions exist (e.g., visual indicators)

Beyond Implantable Cardiac Devices

Connectivity

Sensors

Actuators

Usage Scenario

Human-Centric Investigation: Implantable Cardiac Devices

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- Tensions exist (e.g., visual indicators)
- **Defense designs require interaction with domain experts**
- **Exploratory studies surface issues**