Mobile Pressure Mapping Application Development for Wheelchair Users with Spinal Cord Injuries: User Experience-based Design

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Disclosures

Presenters have the following interest to disclose:

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• Ms. Vos-Draper owns equity in and serves as an executive officer of Sensabil, LLC, which seeks to commercialize the IP developed in this project. This interest has been reviewed and managed by the University of Minnesota in accordance with its Conflict of Interest policy

• Mayo Clinic and Dr. Morrow have a financial interest related to this research. This research has been reviewed by the Mayo Clinic Conflict of Interest Review Board and is being conducted in compliance with Mayo Clinic Conflict of Interest policies.

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Study Team
Project Overview
Learning Objectives
Study Team and Affiliates

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Project Overview

Primary goal
• Reduce pressure injury incidence

Specific goal
• Advance the design of a mobile application for pressure mapping

Overview of our approach
• Improve an initial mobile app prototype
• Design: experience-based methodology
Learning Outcomes

At the conclusion of this presentation, the participant will be able to:

• Identify the process of Experience-Based Design as it relates to mobile application development for a specific population.

• Differentiate features of the mobile pressure mapping system as they relate to pressure injury prevention.

• Explain concepts of how a mobile pressure mapping system may improve a wheelchair user’s confidence and effectiveness in managing their seated pressure distribution.
Background

Pressure Injury Defined
Pressure Injury Risk Factors
Prevention Strategies Identified
Barriers to Sustained Prevention Strategies
Pressure Injury Definition

• Pressure injury: terminology adopted by the National Pressure Ulcer Advisory Panel (NPUAP) in 2016.
  
  • Localized skin or underlying tissue damage
  • Related to intense or prolonged pressure
  • Shear
  • Typical: bony prominence + interface with a surface
  • Skin’s tolerance varies

Pressure Ulcer = Pressure Injury
Prevalence and Incidence of Pressure Injuries in SCI

- Pressure injuries are the **only** secondary condition that has not declined in the past 40 years.
- Rehospitalization: 2\textsuperscript{nd} leading cause
- Mortality: 2\textsuperscript{nd} (infections, sepsis)
- Prevalence: 35% for those 40 years post injury
- 80% will have a pressure injury in their lifetime
- 30% will have recurrence of pressure injury.

**UNRELIEVED PRESSURE IS THE MOST COMMON CAUSE FOR PRESSURE INJURIES IN SCI.**
Risk Factors for Development of Pressure Injuries in Individuals with SCI

• Sensation: Inability to feel pain or discomfort
• Movement: Reduced or absent strength
• Adherence to skin protection strategies
• Mobility: Sitting/lying vs. standing
• Lifestyle factors
Pressure Injury Prevention

• **Pressure redistribution**
  • Individualized
  • Regular seating/positioning assessment
  • Leaning, power tilt and/or recline, pushups
  • All movement

Because levitation doesn’t exist

• Provide patient and family with **education**
  • Inpatient rehabilitation
  • Annual rechecks
  • Hospital stays
Problem #1

Translating prevention strategies into daily routines and habits.

• Retention of education

• Adherence to movement recommendations
Problem #2

Prevention strategies are not reducing incidence or prevalence in the SCI population.

• Lacking effective strategies?
  • What works for people who are successful?
  • Sensation?

• Are we measuring the right things?
  • User competence, comfort, confidence, self-efficacy?
  • Movement (what, when, where, how?)
Problem #3

Technologies have good intentions but...

• Technology abandonment
  • End-user opinion not considered
  • Poor device performance
  • Change in user needs or priorities

• Purpose of technology
  • Reminders, alerts, alarms
  • Awareness of pressure
  • Track behavior
Proposed Solution

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Risk factors addressed

Pressure mapping as a compensatory strategy

Mobile pressure mapping
Targeted Risk Factors

• Redistribution of pressure
• Compensation for loss of sensory cues
• Identification of problems with equipment or positioning

Is there a device or system that can address these three key factors?
Pressure Mapping as a Prevention Strategy

• Pressure mapping is common in the clinical setting and is used for:
  • Assessing for equipment (chair and cushion)
  • Patient education for positioning or weight shifts
  • Identification of problems
Can Pressure Mapping Work Outside of the Clinical Setting?

• Initial prototype: Mayo Clinic
  • Mobile phone + Pressure Mapping
    • Informal focus group of wheelchair users with SCI (n=10) and SCI clinicians (n=4).
    • Assessed feasibility through 3-hour sessions sitting on mat
    • Trial of mat for 1 week at home
    • No skin issues
    • Improvements needed in connectivity

• Concurrently, researchers at the Minneapolis VA had similar questions about use of a mobile app to influence care in wheelchair users with SCI.
  • Wheelchair users “Wish” list for mobile app: ability to SEE their pressure distribution!

• Mayo + Minneapolis VA = Current Project
It Takes a Village!

Researchers and clinicians, along with wheelchair users who have an SCI joined forces to further develop:

Comprehensive Mobile Assessment of Pressure (CMAP)
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Experience-Based Design
Mixed Methods: Qualitative and Quantitative
Experience-Based Design (EBD)

- **Challenges** the tired notion of patient centrisim: an old idea which “medicalizes” people and objectifies them as a clinical object in a system.
- Rather, EBD goes beyond simple compliment-or-complaint feedback (like satisfaction surveys), to set up a *process* of co-creation.

![Diagram of experience-based design process]

- When we talk about patient, clinician or inventor *experience* with something, we mean...
  - How (and how well) you understand it;
  - How you feel while using it;
  - How well it does the job;
  - How well it fits your life.
Quantitative & Qualitative

- Explanation through numbers
- Objective or Subjective
- Deductive reasoning
- Predefined variables and measurement
- Data collection before analysis
- Cause and effect relationships

- Explanation through words
- Subjective
- Inductive reasoning
- Creativity, extraneous variables
- Data collection and analysis intertwined
- Description, meaning

Ron Wardell, EVDS 617 course notes
Find different source.
Olney, Christine M., 6/8/2018
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Hardware: The CMAP System
Study Flow
Focus Groups and Interviews
• Influences on App Prototype and Iterations
Hardware: The CMAP System

Bluetooth-enabled pressure mat

Raspberry Pi

Battery

Smart phone with app
Study Flow

Year 1 - Phase 1a
(n=12)
Formative Focus Group

Year 2 - Phase 1b
(n=12)
Tutorial Interviews plus follow-up Focus Groups

Year 3 - Phase 2
(n=6)
Field Testing-Interviews and Surveys
Year 1 - Phase 1a
(n=12)
Formative Focus Group
## Participants

<table>
<thead>
<tr>
<th>Demographic Element</th>
<th>Screened</th>
<th>Enrolled (and Completed)</th>
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<tbody>
<tr>
<td>Sex- Male</td>
<td>36</td>
<td>12/12</td>
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<tr>
<td>Age (average)</td>
<td>60.14 years</td>
<td>61.5 years</td>
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<tr>
<td>Injury Level</td>
<td></td>
<td></td>
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<tr>
<td>- Paraplegia</td>
<td>16 (.44)</td>
<td>5 (.42)</td>
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<tr>
<td>- Tetraplegia</td>
<td>20 (.55)</td>
<td>7 (.58)</td>
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<tr>
<td>Chair type</td>
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<td></td>
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<tr>
<td>- Manual</td>
<td>15 (.42)</td>
<td>4 (.33)</td>
</tr>
<tr>
<td>- Power</td>
<td>17 (.47)</td>
<td>5 (.42)</td>
</tr>
<tr>
<td>- both</td>
<td>4 (.11)</td>
<td>3 (.25)</td>
</tr>
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</table>
Software: Prototype App

Map of Seated Area

Data about pressure dispersion
Primary Feedback Phase 1a

- Worry about ulcers is a large burden on patients
- Would get a smartphone to be able to monitor pressure
- Phone is lifeline, battery life is important
- Mobile App
  - Simplicity
  - See the live map on home page
  - Adjustable reminders/alerts
  - Want to control who sees data
- Mat
  - Cleanliness
  - Slipping, sliding, folding, wrinkles
Participant Feedback (Phase 1a)

• Phase 1a, year 1 (Formative Focus Groups)
  • “[Phone] is sort of my lifeline. I use it to remind me [of things].” (FG1)
  • “For preventing pressure sores. I think that’s dynamite.” (FG1)
  • “If it’s available tomorrow, I just download it and use it.” (FG1)
  • “The simpler it is the better it is, for me anyway.” (FG1)
  • “If you need to get trained, all you do is make a plan with OT or PT.” (FG1)
  • “The main concern I have is battery drain.” (FG1)
  • “For something to fall on between the seat...the mat will be able to pick up [those] things[?]” (FG2)
  • “For a visit, you can show [providers] the position...you can bring it up. I see it as something I would just use for myself.” (FG2)
  • “I’d like reminders to [do] pressure reliefs.” (FG2)
  • “[I’d] only have to hit one button in the morning.” (FG2)
Year 2 - Phase 1b
(n=12)
Tutorial Interviews plus follow-up Focus Groups
Changes made to app for Phase 1b Usability

- Color coded Icons
- Five function categories
- Data added
- Data added
- Data added
- Data added
Usability Study Summary (1b)

• Can be confusing/intimidating to learn, especially for people who do not typically use smartphones. Can be an overwhelming amount of information
• A zoom feature on the global map may be useful. Some numbers and features are difficult to see
• Some confusion on what colors represent
• Pressure-relief countdown didn’t always come up
• Slider buttons can be tricky on smaller devices
• PPT may just shut off reminders—annoying or unnecessary
Usability Study Summary (1b continued)

- App (and its countdowns) must run in the background when doing other things on phone
- Can’t eat battery life
- Ability to snooze reminders
- Ability to open and command with voice
- Need time to learn on own (and this may be irritating)
- Ability to work consistently between seat types
- Ability to use with a cuff/stylus
- Confusion between different alert/reminder messages and what they should do
- Diff options to get ppt attention in loud environs: vibration, light, sound
Participant Feedback (Phase 1b)

• *Phase 1b, year 2 (Post-Tutorial Discovery Interviews and Confirmation Focus Groups)*
  • “I don’t learn in 15 minutes, but if you play around long enough, I suppose you figure something out.” (DI1)
  • “Me, design this? C’mon. No, I mean if I knew half, one tenth of what this does...It’s neat to look at.” (DI1)
  • “What do the colors signify that you’re seeing?” (DI9)
  • “I have a Jay gel cushion, is that going to make any difference?” (DI9)
  • “Should there have been some sort of tone or buzz [to shift]?” (DI9)
  • “Could I tap that [seat image] and get a value?” (DI9)
Year 3 - Phase 2

(n=6)

Field Testing-Interviews and Surveys
Final Redesign: The App for Field testing version

App Icon

Opening Page

Four Functions:
- Map
- History
- Graphs
- Set Up
The App for Field testing version (cont.)
Mobile Pressure Mapping System Components

- Pressure Sensing Mat
- USB Cable A: Connects from Battery/Power Component to Mini PC
- Battery/Power Component
- USB Cable connected to the Sensing Mat connects to the Mini PC
- Mobile Device (iPhone)
- Mini PC Component

Opening the Map (Live Feed) Screen:

1. At the top of this screen you will notice a grey highlighted instruction. In this example, the highlighted area informs you when the next weight shift will be in 12:47 minutes. We will specifically discuss how you will be notified later in the instructions.

2. In the center of the opening screen a picture of your seated area is shown. The colors indicate varying amounts of pressure on your seated area. For example, blue indicates a lower pressure, green is a little higher pressure. As the colors move towards orange and red the pressure is higher. Deep red color is highest pressure. More information about how you will be alerted if your pressure becomes too high is in the Set-up section.

3. Below the seated pressure image on this screen you will notice a “Record” button. You will tap on this button if you want to record an image. More on this in the next section.

4. At the bottom of the screen are icons that will allow you access to other functions of this App including headings of Map, History, Graphs, and Set Up. More on this later.
Feasibility Study Design

Week 1: Baseline trunk activity measurement

Week 2-5: Full access to CMAP System, interview, surveys trunk activity measurement

Week 6: Post trunk activity measurement
## Participants Phase 2

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Sex</th>
<th>LOI</th>
<th>PI Hx</th>
<th>Flap Hx</th>
<th>Wheelchair type</th>
<th>Caregiver</th>
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</thead>
<tbody>
<tr>
<td>PM-1</td>
<td>64</td>
<td>M</td>
<td>Tetraplegia</td>
<td>No</td>
<td>No</td>
<td>Power</td>
<td>AM/PM aides and significant other</td>
</tr>
<tr>
<td>PM-2</td>
<td>69</td>
<td>M</td>
<td>Tetraplegia</td>
<td>No</td>
<td>No</td>
<td>Power</td>
<td>AM/PM aides who have been with him for 17 years</td>
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<tr>
<td>PM-3</td>
<td>68</td>
<td>M</td>
<td>Paraplegia</td>
<td>Yes</td>
<td>No</td>
<td>Manual</td>
<td>Wife</td>
</tr>
<tr>
<td>PM-4</td>
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<td>M</td>
<td>Paraplegia</td>
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<td>Yes</td>
<td>Manual</td>
<td>No</td>
</tr>
<tr>
<td>PM-5</td>
<td>67</td>
<td>M</td>
<td>Paraplegia</td>
<td>Yes</td>
<td>No</td>
<td>Manual</td>
<td>Wife</td>
</tr>
<tr>
<td>PM-6</td>
<td>57</td>
<td>F</td>
<td>Tetraplegia</td>
<td>Yes</td>
<td>No</td>
<td>Power</td>
<td>Husband</td>
</tr>
</tbody>
</table>
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User Experience: What did they think?
Differences Between Power and Manual Wheelchair Users
Phase 2: Feasibility and usability in-home interview results

1) Any tool that can assist in prevention and monitoring is important;

2) The desired key features are present in the app;

3) The main barrier to CMAP use was inconsistent functionality;

4) When functioning as expected, the live pressure map was the central feature, with reminders to weight shift also of high importance.
• “The hardest part for me was mat placement after transfers. The edges of the mat rubbed on the wheels and was a little bigger than the cushion but not big enough to tuck under the cushion or put in the cover. I noticed I was doing more skin checks when I was using the map because I was more aware of my skin in general.”

• “You can see the pressure, so you're moving more. It reminded me to move. Breathability is my biggest concern with the mat. My skin did ok, but I noticed on the two warmer days we had this week that I was more sweaty after sitting on the mat.”

• “I found the ability to see my pressure very helpful. I've been hoping for something like this for years. A way to see how my pressure is distributed. I learned that I could lean back slightly and get pressure off my tailbone and that when I lean forward, I completely offload my ITs.”
User Experience of CMAP

• Last home visit: Usability assessments
  • System Usability Scale
  • User Experience Questionnaire

• Purpose of surveys
  • Did we meet expectations?
  • How do these results compare with comments from interviews?
  • Patterns among users?

https://www.ueq-online.org/
System Usability Scale

Purpose: Quick, reliable measurement tool for usability; industry standard.
Items: 10
Score of 68 is average.
System Usability Scale
CMAP System

Score

Participants

P1  P2  M3  M4  M5  P6
System Usability Scale: Individual Responses

1. I think that I would like to use this system frequently
   - Strongly disagree
   - Strongly agree

2. I found the system unnecessarily complex
   - Strongly disagree
   - Strongly agree

3. I thought the system was easy to use
   - Strongly disagree
   - Strongly agree

4. I think that I would need the support of a technical person to be able to use this system
   - Strongly disagree
   - Strongly agree

5. I found the various functions in this system were well integrated
   - Strongly disagree
   - Strongly agree

6. I thought there was too much inconsistency in this system
   - Strongly disagree
   - Strongly agree

7. I would imagine that most people would learn to use this system very quickly
   - Strongly disagree
   - Strongly agree

8. I found the system very cumbersome to use
   - Strongly disagree
   - Strongly agree

9. I felt very confident using the system
   - Strongly disagree
   - Strongly agree

10. I needed to learn a lot of things before I could get going with this system
    - Strongly disagree
    - Strongly agree
User Experience Questionnaire (UEQ)

- **Purpose:** Test a product for adequate user experience

- 26 items, 6 scales:
  - Attractiveness
  - Pragmatic qualities
  - Perspicuity
  - Efficiency
  - Dependability
  - Hedonic Qualities
Figure: Mean scores for each of the 6 scales. Scores > 0.8 are positive experiences and those < -0.8 are negative experiences. Range is -3.0 to 3.0. P= Power wheelchair users; M=Manual wheelchair users.
Power Wheelchair vs Manual Wheelchair
User Responses on UEQ

Manual wheelchair users

Power wheelchair users

Attractiv... Perspicui... Efficiency Dependab... Stimulat... Novelty

P3 P4 P5

Attractiv... Perspicui... Efficiency Dependab... Stimulat... Novelty

P1 P2 P6
Summary/Conclusions from Usability Surveys

Manual Wheelchair Users (n=3)
• More moderate responses
• Found system cumbersome
  • Mat movement
  • Parts of system to manage during transfers
• Thought they might use it for spot checks

Power Wheelchair Users (n=3)
• Tendency toward stronger responses
• Found system easy to use
• Thought they would use it frequently
• Rated system as efficient

Vs.
Summary/Conclusions from Usability Surveys: All Participants

• CMAP is novel and stimulating
• Confidence using the system
• Parts of the system were well integrated
• Dependability as a scale overall ranked lower
Directions for Future Work

• Continue with development
  • Hardiness/durability of connections and parts
  • Software platforms
  • Pressure sensing mat + cover

• Assess effectiveness with variety of seat cushions

• Explore further the differences in power and manual wheelchair users’ use of the system

• Begin to assess relationship between use of the system and reduction in pressure injuries (in clinic, inpatient rehabilitation, outpatient, and at home.)

• Continue to engage end-users in the design process!
References


Thank you
CE/CME Credit

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https://pva.cds.pesgce.com