Design Thinking Pain Management: Tools to Improve Human-Centered Communication Between Patients and Providers

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Abstract This research explores the role of design thinking to improve pain management for patients and providers. Specifically, using a design thinking approach, we aimed to transform pain management from a unidimensional construct measured on traditional pain scales to a social transaction between patients and caregivers, through recognizing the behavioral, psychosocial, and environmental aspects of pain. To do so, we conducted a two-phase study which involved first developing a pain assessment intervention in the form of a novel Android-based pain management application. The novel application was prototyped and developed with a multidisciplinary team. This application was then tested with 10 post-operative patients and 10 registered nurses at Stanford Health Care. Our initial findings demonstrate that patients and nurses were able to communicate pain needs through the use of the novel application. Future studies will assess the concomitant changes in care delivery.

The proposed work impacts design thinking research through studying the use of technology to (1) solve a multi-dimensional problem involving complex thoughts and sensory features in individual patients; (2) improve communication and

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healthcare team performance; and (3) influence behavior change in situations requiring shared medical decision-making between patients and providers.

1 Introduction

1.1 The Problem

The subjective experience of pain has long been recognized as multidimensional (Melzack and Torgerson 1971; Clark et al. 2002; Ottestad and Angst 2013) comprising complex thoughts and feelings as well as sensory features. In adults, self-reported pain is most frequently assessed by using unidimensional scales that produce a numerical value ranging from 0 for "no pain" to 10 for "worst pain," either by asking a patient directly for a numerical rating (numerical rating scale) or by having a patient set a mark on a 10 cm line anchored by the terms "no pain" and "worst pain" (visual analogue scale; Fig. 1) (Jensen and Karoly 2001).

Pain scales quantify the subjective experience of the person on a unidimensional scale. When properly used, they can provide valid and reliable information; however, relying on unidimensional assessment tools and self-report is fraught with limitations. **We believe that applying a design thinking approach can significantly improve the human experience of pain management for both patients and providers.**

It is recognized that the richness and complexity of the pain experience is inadequately reduced and oversimplified when rated on a unidimensional scale (Williams et al. 2000; Knotkova et al. 2004). Although methodologically convenient, self-reporting pain on unidimensional scales requires the patient to integrate qualities of the experience in unknown ways, leaving important distinctions, such as "differences between sensory-discriminative qualities, intensities, and affective discomfort confounding" (Goodenough et al. 1999).

A glaring problem with self-report is that it excludes a large number of patients because of the cognitive and communicative burden it requires (Hadjistavropoulos

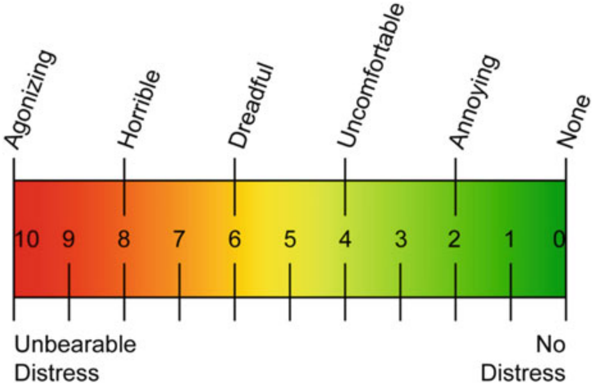


Fig. 1 Visual Analog Scale (VAS) for pain assessment

et al. 2007). Self-report requires the linguistic comprehension and social skills necessary to provide a coherent expression of pain; therefore, the strategy is problematic with some of our most vulnerable populations, the cognitively impaired (Abbey et al. 2004), the critically ill, infants, and young children (Walker and Howard 2002).

Even for people who are communicatively and cognitively competent, self-reporting pain leaves a large potential for bias and error. An inherent assumption in pain assessment is that the patient wants to minimize their pain and that the clinician wants to treat it or alleviate it. This is referred to as the "assumption of mutuality (AoM)" and unfortunately, is far from reality. Patients are often reluctant to self-report pain, and typically assume that clinicians will know they are in pain; yet, clinicians assume that patients will report pain as necessary despite this reluctance (Watt-Watson et al. 2001).

1.2 Communication Problems Between Patients and Providers

Patients provide many reasons for suppressing or masking their report of pain, including a fear of negative consequences. Patients often express concern about inconveniencing clinicians, seeming to be complaining, or having fears of tolerance or addiction to medications; and a belief that pain cannot be relieved (Ameringer et al. 2006; Cleeland et al. 1994). At the other extreme, patients might exaggerate, purposely or unwittingly, their report of pain. Reasons for exaggeration may include efforts to obtain opioids, the so-called drug seeking behaviors (Vukmir 2004), and avoiding responsibilities, or seeking compensation (Mendelson and Mendelson 2004; Mittenberg et al. 2002). A myriad of personal factors have been shown to influence or bias a clinician's response to self-reported pain. These include patients' demographics, such as age, sex, and ethnicity, as well as factors such as ***level of empathy, past exposure to pain, and personal beliefs about pain*** (Dalton et al. 1998).

1.3 Need for a Conceptual Shift

The American Pain Society introduced "**pain as the 5th vital sign"** and numerical or visual pain scales currently represent the gold-standard for assessing pain (Claassen 2005). However, to conceptualize pain as "a vital sign" implicitly assumes that it is comparable to the traditional four vital signs pulse, temperature, respiration, and blood pressure. These signs are objectively assessed, physiologically based, and easily obtained in the clinical environment. While the conceptualization of pain as a fifth vital sign highlights its importance, it is also misleading because pain is not easily measurable, nor is it an objective parameter. Pain is a subjective, multidimensional, and interactive experience that evolves over time. As such it is ***best described as a dynamic process, a transaction***.

1.4 Pain Assessment as a Social Transaction

There are compelling conceptual models that capture the complexities of the pain experience beyond its sensory dimension. An important example is the neuro-matrix model by Melzack stipulating that a wide-spread neuronal network integrates input from the body so that “experiences of one’s own body have a quality of self and are imbued with affective tone and cognitive meaning” (Melzack 1989). The model stresses the importance of integrating social, environmental, and behavioral modifiers of pain (Melzack and Katz 2004). Sullivan (2008) specifically advanced the biopsychomotor model of pain, which integrates communication patterns, protective bodily behaviors, and social response behaviors. The work by Frantsve and Kerns (Frantsve and Kerns 2007) further **highlights the importance of communication in pain management in the context of shared medical decision-making**, a process that is collaborative and dynamic in nature, and is affected by demographic and situational factors from both the patient and clinician.

A theme that emerges from these models is the complexity of pain and its assessment. In viewing pain assessment as a social transaction, **pain assessment is a process, an ongoing and dynamic exchange between the patient and clinician, subject to external influences.** This relationship is one that is purposeful and goal oriented in nature, with the exchange of meaning (i.e., pain) from the patient to clinician (and back) as the essence of the transaction. However, in many clinical settings pain is still assessed as a unidimensional sensory experience, which may explain why a significant portion of patients are dissatisfied with current pain management approaches. For example, at least a third of patients undergoing surgery still report severe pain after surgery (Brennan et al. 2007).

1.5 Standard of Practice

Californian law mandates the safe practice ratio of four patients to one nurse. Nurses assess a patient’s pain level routinely during ‘comfort rounds.’ Each hour nurses ask patients whether pain is present, and if so, the pain intensity. They address any personal hygiene issues, body comfort, and any other physical or psychological requirements. If pain is present, the nurse may provide medication or attempt non-pharmacological relief, such as distraction, repositioning, massage, or heat or cold packs. This routine is repeated over the patient’s hospitalization; however, it is complicated when a patient is experiencing active pain requiring significant intervention, as the nurse’s time is constrained. Currently there are no readily available communication systems available to the patient, other than a call-bell. Yet, the bell is non-specific and does not allow for remote two-way communication.

1.6 Previous Work

1.6.1 Initial Need Finding and Conceptual Prototype Development

To better understand the pain experience of patients undergoing surgery and to consider potential ways to communicate and alleviate pain more effectively, we conducted exploratory interviews with patient volunteers from Stanford's Patient and Family Advisory Council (PFAC), and shadowed nurses at Stanford Health Care (SHC) who specialize in pain management (from December 2015 to March 2016). Patients cared for by these nurses included women in labor and delivery, and patients having undergone heart transplantation.

We also conducted a literature review of non-pharmacological techniques for pain assessment and management, such as electronic gaming (Jameson et al. 2011; Kohl et al. 2013; Leanne 2012). A study showed that patients had more enjoyment, less anxiety and a greater reduction in pain with the use of active distraction (electronic gaming), than with passive distraction (television viewing) (Jameson et al. 2011). Based on the literature and our conversations with patients and providers, Table 1 provides a summary of our preliminary findings, and Fig. 2 illustrates early conceptual prototypes of interactive pain communication tools we developed. In the prototypes shown, patients are intended to squeeze the device or press a button as a way to share their pain experiences with other patients in the hospital, and to report pain to their providers.

Table 1 Features in an improved pain communication system (from patients and providers)

Must-have features	Nice-to-have features
• Improve communication between patient and provider (real time communication alerts). • Assist clinicians in making decisions about pharmacological pain relief. • Provide an easy and intuitive to use system for all patients, regardless of mobility limitations. • Recognize the complex, socio-behavioral aspects of pain.	• Provide distraction from pain (through social interaction, gaming, higher level cognitive function, etc.) • Facilitate data sharing, gathering and retrieval for patients and providers. • Provide non-pharmacological therapeutic relief through a pleasant touch and feel for patients, or way to reduce anxiety and restlessness.

Fig. 2 Early conceptual prototypes of interactive patient-to-provider and patient-to-patient communication tools

1.6.2 Pilot Study: Physical Interaction (Squeeze) as an Alternative to the Standard Pain Scale

From sharing the early conceptual prototypes with providers, we learned (as earlier work has shown), that in order for a new technology, process or intervention to be widely adopted in a health care setting, it must benefit not only the patient, but also the hospital and provider (Shluzas and Leifer 2014). As such, a human-centric, non-pharmacological pain communication system with features aimed at enhancing a patient's experience and wellbeing must likewise provide data that enables hospitals to quantitatively track pain levels and to make proper medication dosing decisions.

Since expressing pain by grip strength (cross-modality matching) is a more intuitive task than the cognitive process of assigning a numerical value (Gracely 1988), we conducted a pilot study with eight healthy subjects in the Stanford Human Pain Experimental Laboratory to determine if the magnitude of pain reported by a hand-squeezing action correlates with numerical pain reports using the standard pain rating scales. The TSA-II NeuroSensory Analyzer (Medoc Inc.) provided graded heat stimuli (up to 52 °C) to each subject's forearm. In each session, subjects quantified experienced pain on a numerical pain rating scale (Likert 1932) or by hand squeeze (dynamometer connected to a wireless data link (Vernier Systems) (Table 2). The data (unreported) showed a significant correlation between these two inputs for pain reporting.

2 Development of a Pain Management Application

A proxy measure for the performance of nursing staff is provided by the *Hospital Consumer Assessment of Healthcare Providers & Systems (HCAPHS)* questionnaire. This is provided to patients after they have been discharged from the hospital. As it relates to pain, patients are asked the following three questions:

Table 2 Summary of needs from a patient's perspective

Must have	Nice to have
Speedy method for pain assessment/reassessment	Non-pharmacological treatment recommendations: music, guided imagery, images/mindfulness
Provides human confirmation ("closes the loop")	Controls environment: dimming lights
Simplicity	Voice control options
Provides a clear plan (Expectation setting)	Personalize/tailor care options
Nurse response <2 min	Big data, learning health network
	Digital companion
	Record your story
	Comforting
	Communicate with support team (loved ones)
	Minimizes noise
	Education/informative

a. Did you need medicine for pain?
b. How often was your pain well controlled?
c. How often did the hospital staff do everything they can to help with pain?

Our prior work on pain management focused on the development of a pain *notification* device. This addressed the need for the patient to alert the provider about the presence of pain. However, it was flawed in that it did not address the providers' needs or address nurses' routine care delivery. The focus on the perception of the pain experience was important, and with the knowledge gained from the previous studies, subsequent work focused on a pain management *system* addressing both patient and provider needs.

2.1 User Insights

2.1.1 Patients

Similar to prior activities, we conducted a workshop with the PFAC ($n = 7$). First attendees were asked to think of a time when they experienced physical pain (preferably related to hospitalization). Based on this experience attendees were asked to describe how the pain experience made them feel. Emotions such as anxiety, powerlessness, vulnerability, and anger emerged. Based on these, attendees were asked what strategies they used to overcome these feelings. Remedies such as medications, loved ones, distractions, music, deep breathing, touch, and prayer were described. Once these were documented, attendees were asked to write or draw their ideal hospital-based pain experience. Two of the artifacts are shown in Fig. 3. Once an ideal state was designed, attendees described the important aspects of their

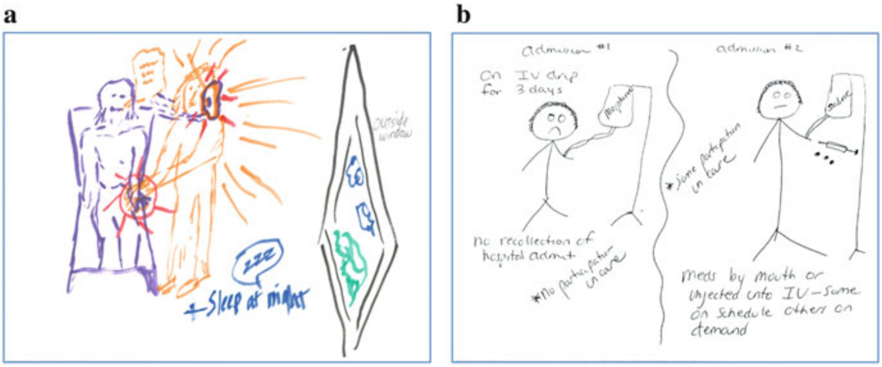


Fig. 3 (**a**–**b**) Drawings from PFAC members. (**a**) Depicts a PFAC participant laying in his hospital bed with loved ones at bedside holding his hand. An outside window is also visible letting in natural light as well as providing a view. In blue text, the PFAC member has written, "+ sleep at night" and verbalized a desire to increase the amount of sleep by reducing night time noise and interruptions from procedures such as blood draws. (**b**) Depicts a different PFAC participant at two separate admissions. Admission one depicts a sad-faced patient attached to a morphine bag. In text it sates, "One IV drip for 3 days", "No recollection of hospital admit", and "*no participation in care." Admission two depicts a patient with a natural face attached to a saline bag with pain pills and injections next to him or her. The text states, "* Some participation in care" and "meds by mouth or injected into IV—some on schedule others on demand." The PFAC participant verbalized that scheduling her medications and having "as needed medications" available provided better pain management. They also endorsed a strong correlation between their ability to participate in their care plan development and treatment and their overall care experience

experience. Such things as natural light, quietness, nurse listening, being in control, 'real' human interactions, and hands-on care were stated. To close the workshop attendees were asked to identify areas within their ideal situation that could be enhanced by technology. Attendees identified such things as pain assessment, human communication (closing the loop), screen with sounds and imagery, and individualized care.

A key insight gained from this workshop was the notion of—"Grace with technology." Patients were adamant about wanting to use technology to record their pain, and wanting more time and care from their nurses (i.e. technology that allows nurses to be more present with patients). The workshop further revealed the following must-have and nice-to-have features of a pain management application from a patient's perspective.

2.1.2 HPDTRP Focus Group

As pain is a universal phenomenon, we conducted a similar workshop to the one conducted with the PFAC, at the HPDTRP biannual workshop at Stanford University in 2017. In addition to the previous question format, we asked attendees to describe what was most important to them during their pain experience. Important to

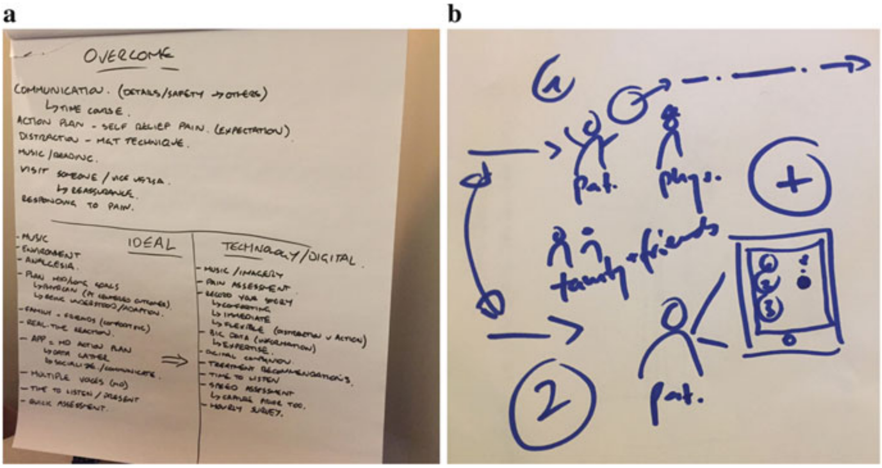


Fig. 4 Drawings from the HPDTRP community workshop. Participants were asked to think of what an ideal pain management system would offer and then describe what could be accomplished with the integration of technology. (**a**) Depicts the verbal discussion conducted during the workshop and highlights topics participants felt were important. Selections from the "Ideal" section include comments such as music, environment, pain medications, family and friends, time to listen, and quick assessment. Several of the things described under the technology and digital section are music/imagery, pain assessment, big data, time to listen, speedy assessment, and hourly survey. Participants were also asked to draw their ideal pain experience. (**b**) Depicts one participant's ideal experience. Depicted is a patient and physician interacting. Together they decide on the patients care plan. Family and friends are a key aspect of this participant's ideal experience and are depicted in the center of the image. Finally, the participant interacting with a device that allows providers and patients to communicate about their pain in real time is depicted in the lower left corner

attendees, among others, was the return of function, reduction of pain, getting empowered to fight the cause, developing contextual understanding, and establishing hope. The HPDTRP attendees provided new technical insights regarding the integration of technology into patient experience, suggesting its utility in developing individualized care through big data, ease of use with hourly pain assessment, ability to record 'my story' to improve care, and non-pharmacological support such as guided imagery and music (Fig. 4a, b).

2.2 *Providers*

2.2.1 Nursing Interviews

The lack of direct stakeholder input can limit technology transfer into the clinical setting. Because of this we wanted to ensure that nurses (one of the two main stakeholders) contribute to any future prototype. A visual non-functioning analog prototype of the proposed interface was developed and shared with nurses. The team

Table 3 Summary of needs from a nurse's perspective

Must have	Nice to have
Speedy (at a glance)	Provide remote intervention
Immediately informative	
Simple interface	
Preprogrammed response	
Accurately assess situation (pain)	

surveyed nurses at Stanford Health Care regarding their opinions on the system's overall proposed function, the display of features, and aesthetic preferences. The findings revealed that the initial prototype was in need of further development to provide the following must-have and nice-to have features (Table 3; Fig. 5).

2.2.2 Shadowing

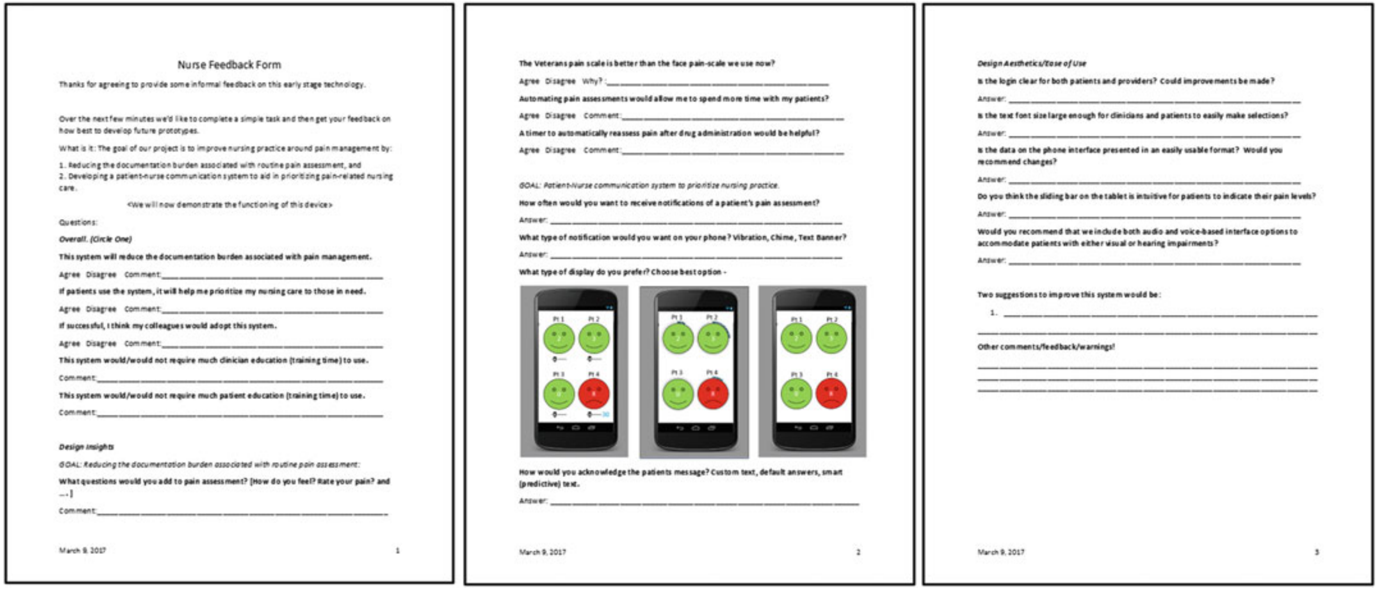
Understanding the current clinical practices was a key constraint the study team wanted to understand. This insight would help shape how the system was operationalized and drive some of the key functions. The team conducted two days of shadowing following the pain team and in a pre-operative surgical spine clinic. The pain team shadowing experience was unique in that it targeted patients with exceptionally difficult pain to manage, assess, and treat. These patients demonstrated a wide array of needs associated with pain assessment and treatment. For example, many patients seen by the pain team required high doses of opioid medications to treat their pain, other patients were known drug abusers and required more psychosocial interventions. These outliers in pain assessment highlight the need for high quality pain assessments that target each individual's unique circumstances, medical/social history, and background needs.

In a pre-operative clinic environment, patients were scheduled for elective surgery. We observed how patients were provided education on expectation setting for post-surgical pain. One key insight from these observations was that patients receive a cornucopia of information prior to surgery on a wide range of topics—questioning the retention of much this information. Hence knowledge of what to expect regarding pain and the overall experience may be dampened.

2.3 Environment

2.3.1 Direct Observations

Hospital environments are complex systems that can be broken down into subunits—typically wards or nursing units. Understanding the nursing unit's microsystem is paramount, as the rituals of the unit may differ from the established



Nurse Feedback Form

Thanks for agreeing to provide some informal feedback on this early stage technology.

Over the next few minutes we'd like to complete a simple task and then get your feedback on how best to develop future prototypes.

What is it: The goal of our project is to improve nursing practice around pain management by:

1. Reducing the documentation burden associated with routine pain assessment, and
2. Developing a patient-nurse communication system to aid in prioritizing pain-related nursing care.

<We will now demonstrate the functioning of this device>

Questions:

Overall. (Circle One)

This system will reduce the documentation burden associated with pain management.

Agree Disagree Comment:________________

If patients use the system, it will help me prioritize my nursing care to those in need.

Agree Disagree Comment:________________

If successful, I think my colleagues would adopt this system.

Agree Disagree Comment:________________

This system would/would not require much clinician education (training time) to use.

Comment:________________

This system would/would not require much patient education (training time) to use.

Comment:________________

Design Insights

GOAL: Reducing the documentation burden associated with routine pain assessment:

What questions would you add to pain assessment? [How do you feel? Rate your pain? and …]

Comment:________________

March 9, 2017 1

The Veterans pain scale is better than the face pain-scale we use now?

Agree Disagree Why? :________________

Automating pain assessments would allow me to spend more time with my patients?

Agree Disagree Comment:________________

A timer to automatically reassess pain after drug administration would be helpful?

Agree Disagree Comment:________________

GOAL: Patient-Nurse communication system to prioritize nursing practice.

How often would you want to receive notifications of a patient's pain assessment?

Answer: ________________

What type of notification would you want on your phone? Vibration, Chime, Text Banner?

Answer: ________________

What type of display do you prefer? Choose best option -

How would you acknowledge the patients message? Custom text, default answers, smart (predictive) text.

Answer: ________________

March 9, 2017 2

Design Aesthetics/Ease of Use

Is the login clear for both patients and providers? Could improvements be made?

Answer: ________________

Is the text font size large enough for clinicians and patients to easily make selections?

Answer: ________________

Is the data on the phone interface presented in an easily usable format? Would you recommend changes?

Answer: ________________

Do you think the sliding bar on the tablet is intuitive for patients to indicate their pain levels?

Answer: ________________

Would you recommend that we include both audio and voice-based interface options to accommodate patients with either visual or hearing impairments?

Answer: ________________

Two suggestions to improve this system would be:

1. ________________

____

Other comments/feedback/warnings!

____
____
____

March 9, 2017 3

Fig. 5 Nurse feedback survey. This figure depicts the 20 question survey provided to nurses to assess there overall experience with early prototypes. Questions regarding their overall experience, technical design insights, the *Defense & Veterans Pain Scale* used, practice questions, design aesthetics, ease of use, suggestions to improve the system, and general comments/feedback were assessed. Each question also allowed the nurse to provide any comments or free text to elaborate on their response. These comments proved to be invaluable in the future iterations of the application. One key insight gathered and implemented was from a comment to the question, *A timer to automatically reassess pain after drug administration would be helpful?* stating, "needs to trigger in less than actual time and resend if that patient has not responded. Also, the system should alert the RN if the patient has not done the reassessment." The nursing display and system notifications were designed based off these responses policy or procedure manual. The team conducted fourteen pain management observations over a 7-week period. Each observation summary included a description of the clinical scenario, key insights from both verbal and non-verbal aspects of pain communication, as well as environmental factors associated with the assessment of pain. Factors such as noise levels, light, physical space, and overall cleanliness of the environment were all found to be factors that could affect patient's perception of pain. Figure 6 is an example of data collected at each session.

2.3.2 Review of Existing Technical Systems

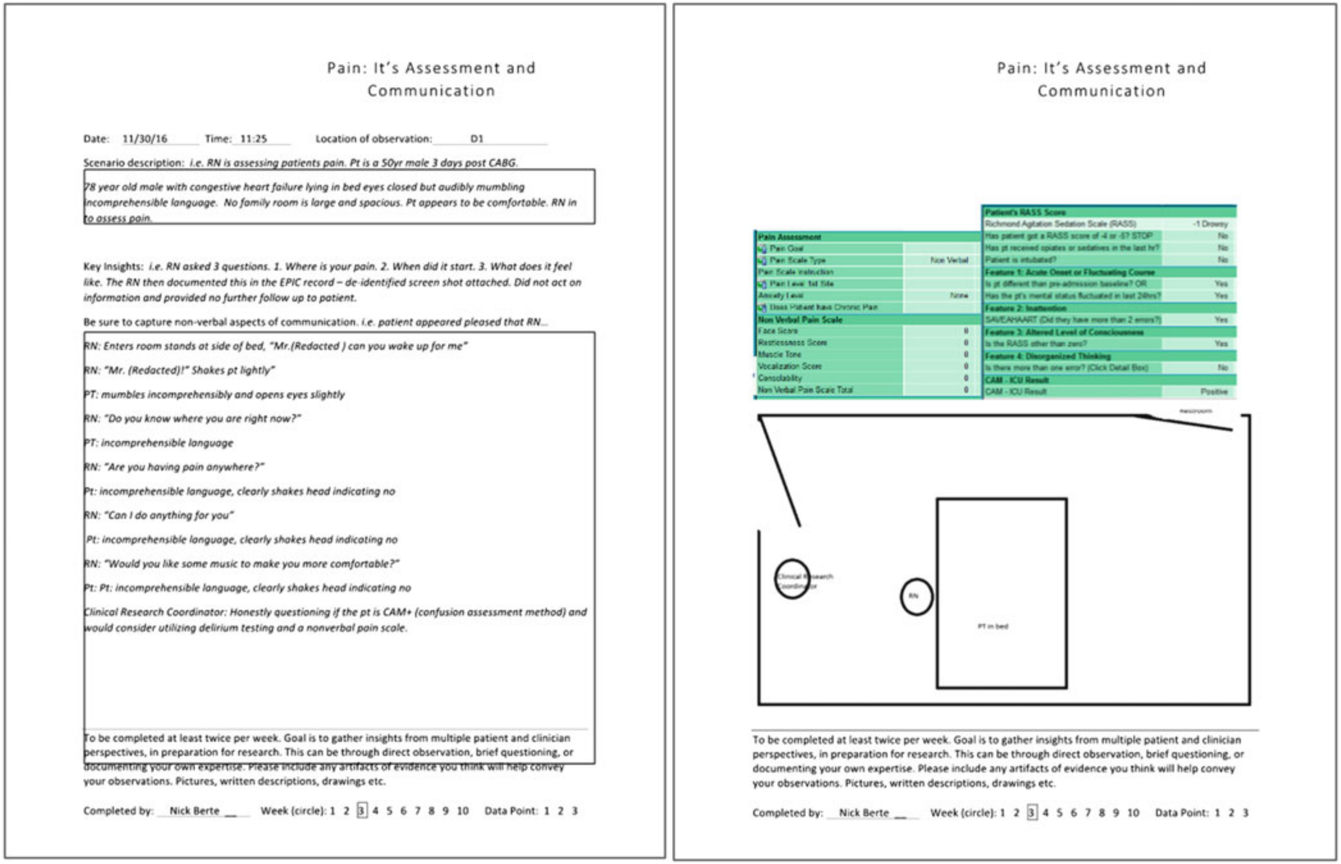
In preparation for functional prototyping, the team conducted an in-depth review of the pros and cons of nineteen commercially available personal digital assistant systems. An Android-based tablet platform was selected for patients (Samsung Galazy 9.7" Tablet), and a smart phone for nurses (Motorola G4 Play smart phone) (Fig. 7).

2.3.3 Prototype

Prototyping of the application started early to allow frequent and rapid design changes. We started with paper mock-ups of the user interface (UI) and explained the features to staff and patients. Through this hands-on prototyping we gained valuable insight into what would work and what was most valuable to each individual stakeholder. This also allowed the team to swiftly evaluate and improve multiple design iterations before coding the final application.

Once initial UI design was determined, the nursing and patient interfaces were concurrently developed. Together these two interfaces allowed the patient to communicate his or her pain needs with their respective provider. The patient interface provided a system that allowed the patient to communicate pain information, request assistance, and indicate if pain was improving.

Key feedback we received from nurses was that any solution could not 'add' to their existing documentation burden. The application offloads routine pain management documentation, providing nurses more time for direct human (patient-to-provider) interaction. Care delivery is modified as routine hourly assessments are no longer necessary. With this prototype, nurses visually identify patients experiencing pain above their preset threshold and can then prioritize his/her time to each patient. Below are screen shots from the system for both the tablet (used by patients) and the smart phone (used by nurses) (Figs. 8 and 9).



Pain: It's Assessment and Communication

Date: 11/30/16 Time: 11:25 Location of observation: D1

Scenario description: *i.e. RN is assessing patients pain. Pt is a 50yr male 3 days post CABG.*

78 year old male with congestive heart failure lying in bed eyes closed but audibly mumbling incomprehensible language. No family room is large and spacious. Pt appears to be comfortable. RN in to assess pain.

Key Insights: *i.e. RN asked 3 questions. 1. Where is your pain. 2. When did it start. 3. What does it feel like. The RN then documented this in the EPIC record – de-identified screen shot attached. Did not act on information and provided no further follow up to patient.*

Be sure to capture non-verbal aspects of communication. *i.e. patient appeared pleased that RN…*

RN: Enters room stands at side of bed, "Mr.(Redacted) can you wake up for me"

RN: "Mr. (Redacted)!" Shakes pt lightly"

PT: mumbles incomprehensibly and opens eyes slightly

RN: "Do you know where you are right now?"

PT: incomprehensible language

RN: "Are you having pain anywhere?"

Pt: incomprehensible language, clearly shakes head indicating no

RN: "Can I do anything for you"

Pt: incomprehensible language, clearly shakes head indicating no

RN: "Would you like some music to make you more comfortable?"

Pt: Pt: incomprehensible language, clearly shakes head indicating no

Clinical Research Coordinator: Honestly questioning if the pt is CAM+ (confusion assessment method) and would consider utilizing delirium testing and a nonverbal pain scale.

To be completed at least twice per week. Goal is to gather insights from multiple patient and clinician perspectives, in preparation for research. This can be through direct observation, brief questioning, or documenting your own expertise. Please include any artifacts of evidence you think will help convey your observations. Pictures, written descriptions, drawings etc.

Completed by: Nick Berte Week (circle): 1 2 [✓ 3] 4 5 6 7 8 9 10 Data Point: 1 2 3

Pain: It's Assessment and Communication

Pain Assessment	
Pain Goal	
Pain Scale Type	Non Verbal
Pain Scale Instruction	
Pain Level 1st Site	
Anxiety Level	None
Does Patient have Chronic Pain	
Non Verbal Pain Scale	
Face Score	0
Restlessness Score	0
Muscle Tone	0
Vocalization Score	0
Consolability	0
Non Verbal Pain Scale Total	0

Patient's RASS Score	
Richmond Agitation Sedation Scale (RASS)	-1 Drowsy
Has patient got a RASS score of -4 or -5? STOP	No
Has pt received opiates or sedatives in the last hr?	No
Patient is intubated?	No
Feature 1: Acute Onset or Fluctuating Course	
Is pt different than pre-admission baseline? OR	Yes
Has the pt's mental status fluctuated in last 24hrs?	Yes
Feature 2: Inattention	
SAVEAHAART (Did they have more than 2 errors?)	Yes
Feature 3: Altered Level of Consciousness	
Is the RASS other than zero?	Yes
Feature 4: Disorganized Thinking	
Is there more than one error? (Click Detail Box)	No
CAM - ICU Result	
CAM - ICU Result	Positive

To be completed at least twice per week. Goal is to gather insights from multiple patient and clinician perspectives, in preparation for research. This can be through direct observation, brief questioning, or documenting your own expertise. Please include any artifacts of evidence you think will help convey your observations. Pictures, written descriptions, drawings etc.

Completed by: Nick Berte Week (circle): 1 2 [✓ 3] 4 5 6 7 8 9 10 Data Point: 1 2 3

Fig. 6 Documentation of one example of direct pain assessment observation. This two-page document was created by observing real-world pain assessments in various inpatient units. The observer would document and capture as many factors as possible including the scenario or a description of the patient, their history,

3 Summary of Study

After initial testing was completed, the application was ready for inpatient clinical testing. The study team devised a research method that would focus on (1) usability and (2) proof of concept. The study team obtained approval from the Institutional Review Board (IRB) at Stanford University. Ten post-operative patients who were cognitively intact and who could interact with the tablet interface were selected as well as the nurse caring for them. Nurses and patients received a brief training on the use of the device and then allowed time to assess its function in a real-world setting. After each patient's and nurse's interaction with the application and device, the participants were then asked to complete a digital survey evaluating their experience.

The purpose of the study was to assess the usability and perceived feasibility of an Android application for communicating a patient's post-operative pain data to nursing staff. The application was assessed from both a patient and nurse's perspective. Patients were asked to evaluate the use of the app for inputting pain information into a tablet and the nurses were asked to evaluate the ability to receive this information on a smartphone. The information collected helped identify the opportunities and barriers to using the developed application in a hospital setting and aided the research team in refining the design of an effective patient-nurse communication technology in hospitals. The use and evaluation of the application did NOT influence the delivery of medical care in any way.

Initial findings demonstrate that patients and nurses were able to effectively communicate pain needs through the use of a novel application. The study also indicated that the application could be implemented into clinical practice. Both patients and nurses indicated that this device could help to improve pain management and that it would be feasible to use.

4 Future Work

Future research aims to explore ways to integrate technology into health care to assess complex and multifaceted topics such as pain assessment. The impact that such applications may have on patient and staff satisfaction indicators is also of interest. Research may also explore ways to utilize technology, such as the pain management application, in a way that would reduce overall nursing time needed to

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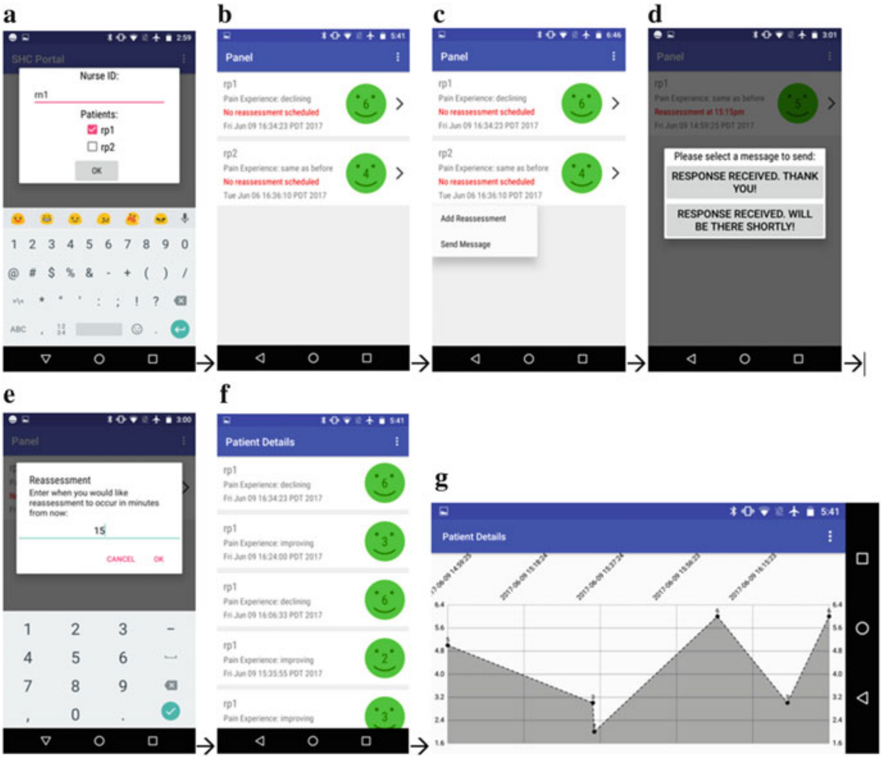
Fig. 6 (continued) and their general disposition at the time of the assessment. The observer also documented environmental factors such as loud or cramped rooms. Key insights were also captured including a script of the nurse-patient conversation. Nonverbal aspects such as tone of voice, facial expression, interruptions, and head shaking were all recorded. The observer would then capture the way the nurse documented the pain assessment in the electronic health record as well as a diagram of the layout of the room

Fig. 7 Study team actively reviewing early iterations of the pain management application. Every week the multidisciplinary study team would gather in person to review progress and assess the prototypes. This enabled early, rapid prototyping and multiple iterations to be reviewed. During this time, many technical bugs were identified as well as development of the ideal function and flow

document and assess pain. Future generations of the application could be expanded to integrate with the electronic health record in a way that could improve workflows and drive staff and nurse satisfaction. This application could also be expanded to offer a wide range of services including interventions such as music, guided imagery, meditation, or a wide array of non-pharmaceutical interventions. Incorporation of other existing systems may also greatly expand the functionality and uses of these types of application.



Nurse ID:
rn1
Patients:
☑ rp1
☐ rp2

rp1
Pain Experience: declining
No reassessment scheduled
Fri Jun 09 16:34:23 PDT 2017

rp2
Pain Experience: same as before
No reassessment scheduled
Tue Jun 06 16:36:10 PDT 2017

rp1
Pain Experience: same as before
Reassessment at 15:15pm
Fri Jun 09 14:59:25 PDT 2017

Please select a message to send:

Reassessment
Enter when you would like reassessment to occur in minutes from now:
15

rp1
Pain Experience: declining
Fri Jun 09 16:34:23 PDT 2017

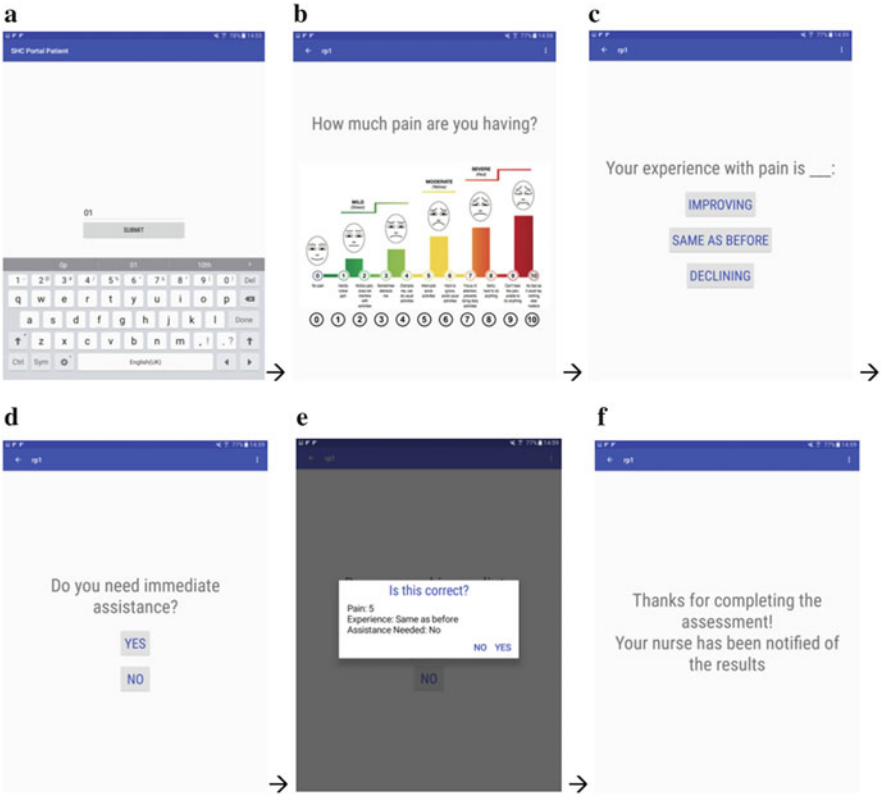
rp1
Pain Experience: improving
Fri Jun 09 16:24:00 PDT 2017

rp1
Pain Experience: declining
Fri Jun 09 16:06:33 PDT 2017

rp1
Pain Experience: improving
Fri Jun 09 15:35:55 PDT 2017

rp1
Pain Experience: improving

Fig. 8 Nursing user interface. Screen shots of the nursing interface are provided here sequentially *a* though *g* starting at the upper left flowing right across and then to the lower left and across. (**a**) Depicts the provider log in screen, here the provider is able to log in with their unique user ID (here shown as *rn1*). Next the provider is able to select the patients they are assigned by clicking the check box next to their patients de-identified name (here shown as *rp1 & rp2*). After making their selection the provider then clicks the ok box and is taken to the main display (**b**). In this main display the provider is able to see the patient name, how their pain experiences is doing (improving, same as before, or declining), if there is a reassessment scheduled when their last pain assessment was, and their numerical pain number. The color of the face indicates *green* for the patient not requesting immediate assistance and *red* if the patient is requesting immediate assistance. The "nose" of the face also displays the pain number for quick reference. If the provider would like to add a reassessment or send the patient a message they can hold down on the patient tab and the two respective options will appear as seen in (**c**). If the nurse wishes to send a message, two default options depicted in (**d**) appear for the nurse to select. If the provider would like to set a reassessment, they enter it in minutes and click ok as displayed in (**e**). When the provider wishes to see the sequential assessments of a patient they can do so by single clicking on the main patient tab taking them to the individual patient documentation displayed in (**f**). Here the provider can see the trend of patient pain over time and review all of the pain assessments for that patient. In this screen the provider can also turn the device sideways to view the patient's pain data graphed over time as displayed in (**g**)



How much pain are you having?

Your experience with pain is ___:

Do you need immediate assistance?

Is this correct?

Pain: 5
Experience: Same as before
Assistance Needed: No

Thanks for completing the assessment!
Your nurse has been notified of the results

Fig. 9 Patient interface. Screen shots of the patient interface are provided here sequentially *a* though *f* starting at the upper left flowing right across and then to the lower left and across. (**a**) Depicts the patient log in screen. Here the patient will log into the application with a unique identifying name or number (for the purpose of the clinical trial, the patient was logged in using a deidentified name depicted here as 01). Patients and providers alike are only required to log in once. After log in the patient is immediately prompted to do a baseline assessment. The first screen the patient will see when doing the assessment is depicted in (**b**). Here the patient is shown the *Defense and Veterans Pain Rating Scale.* This scale displays pain levels with associated (mild, moderate, & severe) faces, bars, colors, numbers and descriptors of each number. After making a selection by touching the corresponding number to their perceived pain, the patient is then taken to question two depicted in (**c**). In this screen patients determine if their pain is improving, the same, or declining by clicking the corresponding option. Next, the patient is asked if they need immediate assistance. This can be seen in (**d**). The patient is able to select their response by touching the corresponding options. After making the selection the patient is presented with a summary of their assessment for verification as depicted in (**e**). If the patient needs to make a modification they can do so by selecting *No* and completing the assessment again. If they agree with their selections, they select *Yes* and the assessment is sent to the nurse assigned to that patient. Finally, the patient receives a confirmation screen informing them that their results were sent to the provider caring for them. When a new assessment is due the device with light up, chime, and restart the assessment. Patients can also submit an assessment at any time they need. When the nurse sends the patient a message it displays as a banners at the top of the device. The device also chimes and lights up

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