SuperNurse: Nurses' Workarounds Informing the Design of Interactive Technologies for Home Wound Care

Dawood Al-Masslawi[1], Lori Block[2], Charlene Ronquillo[2], Shannon Handfield[3], Sidney Fels[1], Rodger Lea[1], Leanne M. Currie[2]

[1]Electrical and Computer Engineering
University of British Columbia
Vancouver, Canada
masslawi@mail.ubc.ca, {ssfels, rodgerl}@ece.ubc.ca

[2]School of Nursing
University of British Columbia
Vancouver, Canada
{cronquillo, lori.block}@alumni.ubc.ca, leanne.currie@nursing.ubc.ca

[3]Vancouver Coastal Health
Vancouver, Canada
shannon.handfield@vch.ca

ABSTRACT

The increasing aging population needing homecare is leading to additional clinical work for homecare nurses. Wound care and documentation are substantial components of this work required to monitor patients and make appropriate clinical decisions. However, due to barriers in the systems that nurses are expected to use, and context of their activities, they create and use workarounds to get their job done. In this study, the most common themes of workarounds were identified and used to inform design iterations of a wound documentation application: SuperNurse. The exploratory and experimental design iterations involved homecare nurses, who expressed: curiosity, leading to further reflection; frustration, leading to identifying problems; and surprise, leading to identifying useful and easy to use designs. We found that nurse-centred design, informed by workarounds, led to using mobile, wearable, and speech recognition technology and improving ease of use and usefulness in SuperNurse.

Author Keywords

User-centered design; home care; wearables; nursing; workarounds; speech recognition; community health, healthcare applications.

ACM Classification Keywords

• Human-centered computing~Ubiquitous and mobile computing • Applied computing~Health care information systems

INTRODUCTION

In recent decades the number of patient needing home wound care has increased [5]. Nearly 2% of the population suffer from chronic wounds in their lifetime, which can take from 3 weeks to 3 months to heal [14]. It is estimated that at least 20 million people in the world have chronic wounds, with a cost of care estimated to be at least $31 billion dollars [14]. Home Care Nurses (HCN) provide wound care in community health centres and at patients' homes [5]. We found that the nomadic nature of their work required them to create and use unconventional solutions, known as 'workarounds', when faced with barriers in their use of interactive technologies. As such, here we describe these workarounds and aim to highlight their systematic use as feedback in the design process. We measured and identified workarounds, analyzed their patterns, mapped the most common patterns to design principles, and evaluated the designs in user studies. In 3 phases of prototyping iterations and a total of 27 sessions, with 27 HCN participants, a low fidelity prototype for a wound care application was refined into a high fidelity application. The results of the data analysis and the user studies were validated using questionnaires. This is a step closer to homecare nurse-centred design that has not been carried out before. The approach to analyze and use that data in design and results presented in this study provide important material for pervasive health technology designers and researchers. Namely, the need for and processes through which to observe, understand, and predict user behaviour in healthcare settings that involve nomadic work. Ethics approval was obtained prior to all research activities.

BACKGROUND

To improve adoption, health information technology (HIT) design processes elicit requirements by engaging end-users [12]. In the homecare setting, some have used general information sessions and meetings with managers and clinicians [15], or used interviews and focus groups [1]. User-centred methods such as participatory design are more engaging, especially for users of pervasive health technologies in homecare [6]. These works often focus on users' needs and problems, and less on their problem-solving behaviours [16]. Over time users develop alternative paths to the same end goal when they perceive that the technology is less useful (e.g. inaccurate data), or is

PERVASIVEHEALTH 2017, May 23-26, Barcelona, Spain.

less easy to use (e.g. hard to remember functions) [8]. These alternative paths are referred to as *workarounds*: "intentionally using technology in ways the technology was not designed for, or relying on alternatives which conflict with the formal ideology of the used technology" [10], to accomplish the same end goal. Evidence suggests that workarounds are important user problem solving behaviours [8], however they have not been elicited in other user-centred approaches to HIT design in homecare [1,6,15]. There is a knowledge gap in the use of appropriate tools and methods to identify workarounds, and the conceptual links for mapping them to design principles [16]. In health informatics, tools and methods to identify workarounds are have been studied [8] as workarounds are seen only as inappropriate system use. Interactive system design research elicits behaviours similar to workarounds such as appropriation [3], mobility work [4], and deviations from Standard Operation Procedures [13], in the acute care and non-nomadic setting. Other work has acknowledged the complexities specific to nomadic work [18], highlighting that researchers and designers should expect to see workarounds in the adoption phase [16]. Especially since pervasive health technologies are prone to appropriation, adaptation, and other similar user behaviours [3,4,13]. The work presented here extends previous research by using the tools and methods developed for ethnographic studies and measurement of workarounds [8,11] in a new setting. Furthermore, the user-centred design approach in this work elicits not only the users' functional and data requirements [1,6,15], but also their problem solving behaviours (i.e. workarounds).

HOMECARE NURSES' WOUND CARE ACTIVITIES

In the ethnographic fieldwork that preceded this study [2], we observed HCNs in Vancouver, Canada (n=36) for 120 hours. The observations highlighted the complexity of a HCN's role. Especially related to wound care which included multiple types of wounds with varying stages of severity and healing. Wound treatment involved selecting from 120 medical products, and documenting 25 characteristics of wounds (e.g. wound etiology, wound measurements, exudate, wound bed, peri-wound skin). HCNs drove or walked to the homes of multiple patients each day, which required planning and coordinating appointments that may change unpredictably throughout the day. HCNs are expected to use a wound documentation system to chart patient data, and communicate asynchronously with other clinicians in their unit (figure 1). Usage varies across different health units, and on an individual level as well. The regional health authority provides nurses with laptops, digital cameras, and a USB dongle for internet connection on cell phone networks. In the intended implementation, nurses were expected to take this equipment with them to home visits, and to use the wound documentation system in patients' homes. However, this usage has not been well adopted. Nurses will take the camera with them on patient home visits, leaving their laptops at the office. Creation and use of workarounds are prevalent, which points to problems with nurses' satisfaction and their intention to use the technology they are provided with [16].

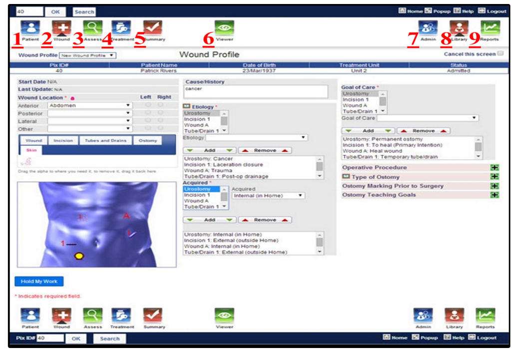

Figure 1. The wound profile in the system used by homecare nurses (1=patient profile, 2=wound profile, 3=assessment, 4=treatment, 5= summary, 6=patient viewer, 7=patient administration, 8=educational material, 9=reports) [21]**.**

BARRIERS TO WORK LEAD TO WORKAROUNDS

A common perspective suggests that barriers to work are the primary causes of workarounds [11]. Barriers include design flaws, component failures, and inability of the system to address the problem or task at hand, and design limits or constraints that block the path to the users' goals [11]. We found that workarounds occur when HCNs face barriers in finding a fit between what they need to accomplish and resources that vary in availability (e.g. time, people, technology, and equipment). This impacts their satisfaction with the technology and eventually their intention to use or work around that technology [12].

A study that developed and validated a measure of nursing workarounds identified underlying cognitive processes relating to nurses' perceived usefulness (of a task) and the associated perceived ease of use (of following the procedure) [11] – concepts consistent with the technology acceptance model (TAM) [12]. Given the empirical support for the consistent relationships between workarounds and TAM [12], and the validated tools that accompany TAM, this theoretical model was deemed a suitable fit for the purpose of this study. This study uses two constructs of TAM [12], perceived ease of use and perceived usefulness, to measure characteristics and identify workarounds that nurses are creating and using in homecare. These measures were developed and validated in a study in acute care settings [11]. Perceived usefulness is defined as *"the degree to which a person believes that using a particular system would enhance his or her job performance"*; and perceived ease of use is defined as *"the degree to which a person believes that using a particular system would be free of effort"* [11,12]. At the conclusion of the ethnographic fieldwork, we conducted a survey [11] with end-user HCNs and found that usefulness and ease of use from TAM [12] can be used to conceptualize a mapping from the identified workarounds to design principles for a wound documentation application.

HOW TO USE WORKAROUNDS IN DESIGN

Workarounds are valuable user feedback that are created and used by HCNs to solve problems. Articulation of workarounds as feedback in the design process can lead to solutions inspired by the problem solving strategies of the users. During the observations, event logs and field notes were recorded to identify the types of workarounds used by HCNs. The field notes were coded topically based on initial codes adapted from literature [8,11]. A code was assigned to each instance of workaround. Based on the identified instances of the codes, the frequencies of workarounds were calculated. In the next step, themes of workarounds were identified by analyzing the most frequent workarounds. The most common themes, extracted from 464 instances of workarounds, were organized into seven groups of workarounds (see table 1). Team consensus was used to agree upon the results.

HCNs often review their patients' records in the morning before they start their visits and they take notes of items that they need to do or remember during the visits. They might leave to-do lists or reminders for other HCNs who will visit the patient in the future. They are communicating this information to ensure that, despite potential barriers, the HCN visiting next would not have to use a workaround to access that information. HCNs are aware that the data residing in the electronic records might not be enough to convey the full "story" of the patient; hence they go to great lengths to ensure that the full story is known. Once the full story is known HCNs will have less need for workarounds.

If an HCN does not review the patient record before the visit, s/he might not anticipate some of the activities planned for that visit. Once the HCN realizes that they needed something else, a workaround was to write in retrospect on the patient's file, or in their electronic record to carry out the remaining activities in future visits. This prevents any risks due to the missed activity. In work settings where resources are scarce, the HCNs will have to appropriate the available resources to them in order to get their job done. This is a common occurrence in homecare practice. The proactive nature of nursing practice requires HCNs to ensure reliability of information regardless of barriers. The outcome of the work and the workaround are the same, the process used is different from what is intended for the system.

The categories identified in the ethnographic fieldwork were validated with 58 completed questionnaires by HCNs. Using a 5-point Likert scale (1= strongly disagree, 3 = neutral, and 5 = strongly agree), we confirmed that these themes are used by the HCNs and they are common in homecare (see table 2). HCNs were provided with the name and definition of each group of workarounds, as well a rationale and examples. The two questions for each group were: Q1: I have used <insert subcategory> when problems with technology, equipment, rules/policies, people and work processes prevent me from completing my activity; Q2: <insert subcategory> are common in homecare.

Pre-emptive information use (n=98, 21%)
Description: when a nurse provides cues (e.g. verbal, in writing, use of specific clinical supplies, data entry), informing the need to complete certain activities and preempt or reduce occurrence of future workarounds.
Example: A nurse says that based on the electronic records of a patient she creates a paper cheat sheet as reminder for when she visits the patient.

Preventive information use (n=31, 7%)
Description: when a nurse provides cues (e.g. verbal, in writing, use of specific care supplies, data entry) informing the occurrence of barriers to activities, their workarounds, and the need to prevent risks associated with those workarounds.
Example: changing the care plan and confirming with the wound clinician at later times.

Appropriative system use (n=35, 8%)
Description: when a nurse uses a system to complete activities in which the available system is not intended for completion of those activities.
Example: use of the wound photo component to document use of care supplies.

Appropriative resource use (n=38, 8%)
Description: when a nurse uses resources to complete activities that the resources are not intended for completion for those activities.
Example: a nurse uses her personal smart phone to take photos of wounds.

Adaptive system use (n=65, 14%)
Description: when a nurse uses a system for the intended activities but in unintended ways to complete those activities.
Example: a nurse says they might chart some information in multiple places so it cannot be missed.

Adaptive resource use (n=38, 8%)
Description: when a nurse uses resources for the intended activities but in unintended ways to complete those activities.
Examples: a nurse leaves extra supplies with the patient, or in her car.

Parallel system use (n=159, 34%)
Description: when a nurse uses more than one system for the same intended activities for those systems, and in the intended ways for those systems, to complete the same activities.
Example: a nurse looks at the sticky note on the cover of the patient's paper record with the summary care plan on it and packs care supplies (parallel paper system).

Table 1. Definitions and examples of the identified groups of workarounds.

Next, we used measures developed and validated for healthcare applications of the TAM [12] to identify which themes are more likely related to dimensions of usefulness and ease of use.

	Pre-emptive inf. use	Preventive inf. use	Parallel system use	Appropriative system use	Appropriative resource use	Adaptive system use	Adaptive resource use
Q1, Mean (sd)	4.40 (0.9)	3.48 (1.27)	4.21 (1.07)	3.65 (1.2)	3.48 (1.33)	3.77 (1.28)	4.23 (0.91)
Q2, Mean (sd)	4.53 (0.63)	3.66 (1.19)	4.37 (0.92)	3.82 (1.09)	3.45 (1.49)	3.82 (1.27)	4.26 (0.92)

Table 2. Descriptive statistics of the validation questionnaire for workaround subcategories (sd= Standard Deviation)

The usefulness measures were for effectiveness, accuracy, control over work, productivity, and the ease of use measure were for mental effort and physical effort. Then design principles within those dimensions were extracted from the literature for the mapping of workarounds to new and contextualized design principles. Some of the mapped design principles were focused on aspects related to usefulness such as: support for timeliness, chronological report of events, longitudinal format of data, completeness (assessments, tests, supplies, treatments, procedures, and sources of this information), comprehensiveness (according to different phases of the nursing process), correspondence between data and reality (prompts to reevaluate patient and treatments), as well more individualized and/or accurate care planning. Others were focused on ease of use such as: support visibility of system status (make changes visible so nurses would not have to document in multiple places), better control the current status of the document with a dashboard for summary, simplify data entry with pre-analyzed and prepared answers, and the system should easily view information structure without memorization. Using exploratory and experimental prototyping sessions [9], we evaluated these design features. Throughout exploratory prototyping, a low fidelity prototype was refined to get a set of features for a mid-fidelity prototype. During experimental prototyping, an operational mid-fidelity prototype was refined to get a set of features for a high fidelity prototype.

THE MAPPED AND THE EMERGENT DESIGN IN EXPLORATORY PROTOTYPING

User engagement and on-the-fly modifications of the designed features characterized the exploratory prototyping (phase 1) phase of this study. As the name suggests, this type of prototyping is best for exploring different design options rapidly and is informal by nature [9]. Individual 30-minute, semi-structured prototyping sessions were carried out with HCNs, to explore existing and desirable features, identify technology requirements, and evaluate the initial features of a mobile wound documentation application. The application was named SuperNurse, inspired by a common sentiment among HCNs that often they are asked to be "super nurses", just as the prototype design was informed by their creative solutions (workarounds).

Three key steps made up this phase: 1) functional selection, 2) construction, and 3) evaluation. During functional selection, the relevant work tasks that can serve as model cases for demonstration were identified, with the help of clinical experts. Construction involved the active creation and modification of the prototype and evaluation focused on assessing the usefulness and ease of use.

Material and Method for Phase 1

A total of 15 HCNs participated in this phase. The sessions were held in local Canadian community health units. During the sessions, a low-fidelity prototype (i.e. printout of a user interface) was presented to the HCN. A basic scenario (wound assessment for a homecare patient) was then presented, along with accompanying tasks that were to be completed with the help of the low fidelity prototype. HCNs were provided materials, such as pens, markers, and post-its to modify the prototype and make it more easy to use and useful, as they saw fit.

After the scenario ended, a semi-structured interview was conducted, where the researcher asked the HCNs to express their opinions about: 1) the type of hardware that would best capture wound documentation using speech recognition, 2) the location where documentation would be captured (e.g. in the patient's home, the nurses' car, etc.), 3) how the information would be displayed, and 4) what additional characteristics or features would contribute to perceived ease of use and usefulness in the prototype.

The Mapped Design

The main features discussed during the prototyping sessions were daily patients schedule and summary, patient contact information, wound photo capture using a wearable camera and speech recognition, patient data flow sheet, wound care plan, progress note, and a supply list. The wearable camera was an alternative to the existing system in use by HCNs that required them to carry a digital camera. HCNs stated that the current digital camera increased physical effort and decrease effectiveness. For example, an HCN described that in difficult wound bandaging and environmental situations they wear a headlamp for better lighting to provide wound care, and they preferred a wearable camera mounted on their head or on their arm.

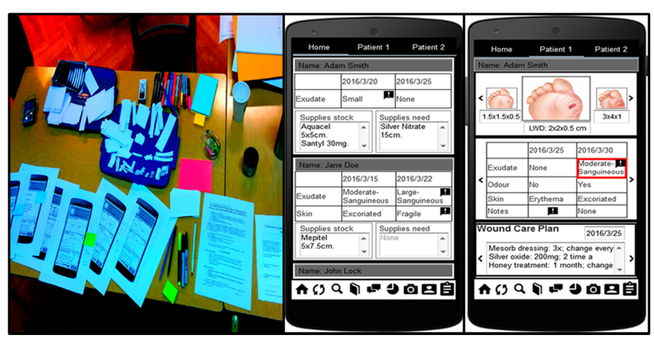

Figure 2. Exploratory prototyping session (left), patient assessments entries (middle), patient assessment page (right).

Speech recognition was discussed as a possible feature to be used to document wound care in some situations to capture wound dimensions and to take photos using a wearable camera. By the end of phase 1, 3 major refinement cycles were carried out, which involved the patient assessment page and entries, and the supply list. Figure 2 illustrates the setup and the material used for phase 1.

The Emergent Design

During the sessions, some features surfaced that were not in the initial design but organically evolved into new features, such as "sticky multimedia". Sticky multimedia was envisioned as disposable or temporary photos, text notes, or audio recordings that were not captured for the purpose of documentation, but instead used to collect information, in real time, to be used later, sometimes after reflection, in comprehensive clinical documentation. They are temporary in nature and used as non-legal reference facilitating the ability to review and complete the patients' records at later time. This concept was inspired by the paper system workaround which often involved use of disposable paper to collect information for later use. Further exploration of this concept with subsequent participants led to delineation of what this feature would look like. Namely, that it should support various multimedia options and have 'temporariness' as an important feature (i.e. not part of the legal charting, but used as a reminder to support accurate charting at a later time).

The nurses expressed that they use workarounds such as sticky notes to obtain or record information without worrying about the professional documentation required in the legal chart. During the ethnographic observations some HCNs noted that writing specific clinical terminology reflects their level of expertise and is in alignment with their professional image. The sticky multimedia enables recording audio or taking photos to quickly collect patient information similar to how nurses use sticky notes as workarounds. The temporary and disposable nature of this feature appeals to nurses who feel the existing system does not support information that changes frequently.

Low Fidelity Prototype Evaluation

The audio-recorded sessions were analyzed and coded with the aim of identifying when and which prototype features received more feedback, as well as noting nurses' reactions and responses to those features. After transcription, two researchers (CR, LB) coded instances of user feedback during the sessions and a third researcher reviewed the coding (DA). The most common topical codes were based on dimensions of usefulness, such as time needed to chart (timeliness) and corresponding data and reality (accuracy) [20], dimensions of ease of use such as ability to find and remember functions (view structure) [19], and dimensions of task-technology fit such as corresponding task characteristics and system usage (flexibility to fit workflow) [17]. The features mentioned in phase 1 were then ranked according to the amount of feedback received from nurses (see figure 3). The top ranked features made up a refined list to evaluate in the experimental prototyping (phases 2 and 3), and described in the next section.

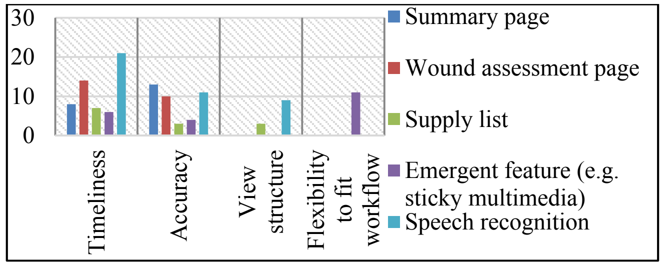

Figure 3. Exploratory prototyping user feedback.

THE INTERESTED, THE FRUSTRATED, AND THE SURPRISED IN EXPERIMENTAL PROTOTYPING

Experimental prototyping was used for enhancement of the target application's specification and to test a proposed solution for an identified problem [9]. Informed by phase 1, the top rated features were used to design an operational mid-fidelity wound documentation prototype for an Android device. These features included: 1) summary of previous charting, 2) wound measurements and photos, 3) wound assessment items (e.g. exudate, odour, and pain), 4) sticky multimedia, and 5) supply list. The prototype was an Android application using Android's speech recognition to recognize voice commands for the capture of wound measurements and wound photos (wearable wireless camera) when the homecare nurses' hands were occupied (i.e. when providing direct wound care). The experimental prototyping included 2 phases. During phase 2 a mid-fidelity prototype was refined into a high fidelity prototype that was evaluated in phase 3.

Material and Method for Phases 2 and 3

Phases 2 and 3 also included functional selection, construction, and evaluation; however, the sessions were structured to finish within 10 minutes for a patient wound care scenario and 30-40 minutes for an interview. The patient wound care scenario was set with the help of clinical experts. The sessions were carried out in local Canadian community health units with HCN participants (total n=12, phase 2=6, phase 3=6) different of those in phase 1. Prior to the start of the session, each HCN was given a short introduction to the prototype, and given a brief outline of the tasks they would be asked to complete.

The scenario included five main tasks: 1) preparation and review of patient history, 2) measuring and photographing the wound with SRT, 3) documenting the local wound assessment parameters, 4) using the sticky multimedia to take information related to the patient's medical status, and 5) finalizing the supply list based on the treatment plan.

Once the formal session began, the HCN was asked to complete a task at each step of the scenario and use the relevant prototype feature as they saw fit. Finally, we conducted an interview and asked HCNs to complete a questionnaire [12] related to perceptions of usefulness and ease of use, as well task-technology fit [17]. A total of 12 questionnaires were given to HCNs, of which 11 were completed and returned. The interviews lasted 30 to 40 minutes and were audio and video recorded. Three of the researchers later transcribed, coded topically, and analyzed thematically the audio and video recordings were. The coding was reviewed by the researchers and team consensus was achieved.

Reactions to the Mid-Fidelity Prototype

During phase 2, several themes of user reactions were apparent throughout. These reactions included interest towards the design features, frustration due to malfunctions, and surprise due to success. Participant responses highlight the impact the design had on the completion of tasks and the care provided for the patient. Figure 4 illustrates the setup and the material used for the phase 2 sessions.

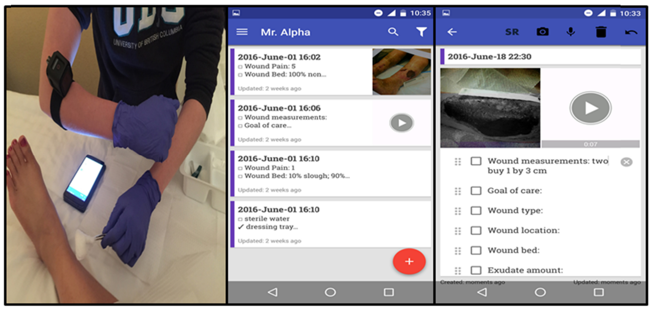

Figure 4. Mock-up of the experimental prototyping session (left), patient assessments entries (middle), patient assessment page (right).

The Interested

HCNs were hesitant, but interested in use of the mid-fidelity prototype. Specifically their interest was notable for features that were less conventional compared to what they use in their current medical records system. For example, one HCN started to lay out a scenario in which she would be interested to use the sticky multimedia feature. She said: *"During your conversations with patients you end up fumbling into…oh my gosh you have so many supplies at home, I don't have to pack, etc., and then from the audio sticky you will have a whole verbal diary of information that you can pick through and decide from what to keep and what to check."*

One of the HCNs added that she would use the prototype in its current state, and she thought it would replace paper for her, even if the prototype did not synchronize the collected information back to the electronic medical record system. The sticky multimedia and speech recognition seemed to trigger thoughts about the needs of the nurses while providing care for the patients. The sense of interest, curiosity, and anticipation about these features indicate that it resonated with the work and needs of the nurses. One HCN explained: *"Speech recognition is most useful for hand-free measurement, often in difficult positions in people's homes and hard to record without spreading germs or contaminating notebooks."*

Though it appeared that use of speech recognition and sticky multimedia features would not be appropriate in every homecare circumstance, the HCNs' reactions indicate that there is great potential to increase flexibility and fit the workflow, and decrease the time to chart. While searching in audio recordings might seem time consuming HCNs preferred to retain the option to record longer recordings, even though we offered an option to limit recordings to shorter time periods (e.g. 20 seconds). They noted that longer recording time can be used when they need more comprehensive wound assessments while they have gloves on and cannot type. They can use the recordings to chart later. Another positive aspect expressed by HCNs was that they felt the use of audio recordings as sticky multimedia encourages them to structure their thoughts better once they hear back what they recorded.

The Frustrated

The video, audio, and written comments contained moments of frustration, confusion, disappointment, and perseverance predominantly related to use of speech recognition for taking a photo with the wearable camera. While the speech recognition was reasonably accurate for simple voice commands and measurement numbers, it proved less practical for the phase 2 real-life simulation sessions. For example, one HCN attempted to take a wound photo and record a wound measurement five times each, and in all cases, was unsuccessful. Either due to easier-to-fix issues such as camera being off, or other issues such as recognition of "to" vs. "two". At the end of the session, she explained: *"I often have trouble with my own voice recognition."*

Her response suggests previous unsuccessful encounters with speech recognition were possibly reinforced during the phase 2 session. Expectations of what speech recognition can accomplish in the context of homecare nursing were tempered by previous negative or unsuccessful experiences with speech recognition. Ongoing unsuccessful encounters with this type of technology could be an important consideration for redesign in later stages. In particular, in the use of speech recognition to recognize voice commands for taking wound photos, as this feature seemed the most challenging.

It also should be noted that HCNs expressed that the wearable camera can be useful for cases where use of the phone camera is not possible, however in most cases they would opt to use the phone camera. That leads to a realization that future studies will have to focus on either redesigning these features, such as replacing the wearable camera with a phone camera, or studying these features for specific useful cases as noted by the nurses, for example, wounds located in hard to access body parts or cavities that need a wearable camera next to a headlamp to take photos.

The Surprised

While HCNs experienced frustration and interest, they were also positively surprised about prototype features that exceeded their expectations. For example, after successfully completing the documenting wound measurements using speech recognition, one HCN exclaimed, *"oh cool! totally worked."* Later on, when creating a sticky multimedia to serve as a reminder, she noted: *"mkay... (quiet laugher) um, I kind of forgot how to do this but we'll just try (laughing), um, 'remember to contact the vascular surgeon for Mr. A?' oh! It worked, cool."*

Surprise as a reaction can be viewed as an indicator of how well the features fit the original aims and intentions of the design. For instance, the latter quote suggests that the user is unsure of how to complete the assigned task. However, the surprised reaction at successfully completing the task suggests that the design functioned in the way it was meant to, especially in regards to ease of use. That is, the design allowed for the user to navigate and complete the task intuitively, even after forgetting the specific feature required. The HCNs expressed that the sticky multimedia and the use of speech recognition for capturing wound measurements, would especially decrease the time to chart and increase the accuracy, since the data are being collected at the bedside when they are assessing the wound and while their hands are busy.

By the end of phase 2 three major refinement cycles were carried out that involved the patient assessment page and the speech recognition. The final version included mostly functional features, however speech recognition functioning remained inconsistent.

Reactions to the High Fidelity Prototype

The feedback received during phase 2 was used to refine the mid-fidelity prototype into a high fidelity prototype. The high fidelity prototype did not use the wearable camera since the feedback received from phase 2 indicated that a wearable camera would be useful only for specific cases. The prototype has the same 5 primary components similar to phase 2. However, these features were modified according to the same experimental prototyping principles to reflect feedback received from phase 2. This included better functioning speech recognition, fully functioning wound photo capture, direct access to sticky multimedia from the main page, as well as completing the functions and interfaces of the supply list and the patient assessment page. The HCNs also were given a disposable plastic bag that was the same size of the phone. This was to address concerns expressed in phase 2 about spread of germs from one patient's home to another. Some of these features are shown in figure 5.

Predominantly similar to the previous phase in phase 3 we conducted further experimental prototyping sessions using the high fidelity prototype. A total of 6 HCNs participated in this phase. Each HCN participated in one session that was approximately 40 minutes in length. During the session the HCNs were asked to provide wound care for a fictitious patient in a home visit, while using SuperNurse. The same patient scenario from phase 2 was used in phase 3. The only difference was that a medical mannequin with a chronic wound on the buttocks area (figure 5) was used to better simulate the real-life situation of a home visit for the HCNs. The first portion of the session was dedicated to the patient scenario for 10 minutes, and the rest was for the interview. During the interview questions about usefulness and ease of use were asked to identify which features the HCNs found most easy to use or useful. A questionnaire also was given to HCNs which included items of TAM [12] and task-technology fit [17].

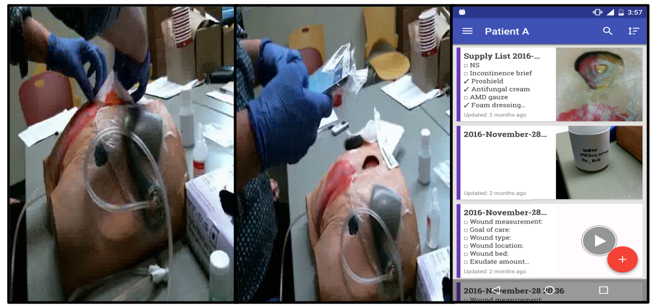

Figure 5. Wound cleaning (left), patient assessment (middle), patient assessment entries (right).

The interested

The high fidelity prototype further elicited interest from the HCNs to envision how they would use the prototype in their daily home visit routines. This lead to identifying other modes of interaction and workflows not discovered during phase 2. For instance, one HCN described how she thought the prototype would be used and said: *"I would take one glove off!"*

Then she put the phone between her stomach and her forearm of the gloved hand and started typing with the ungloved hand. She took a photo by holding the camera between the ungloved hand and her wrist on the other hand. She pressed to capture the photos by her ungloved thumb. This allows the nurses to multitask. They can use one gloved hand to carry out tasks that require sterile hands, and use the other hand in combination with other body parts (e.g. other forearm, stomach) to collect patient data. This can inform new designs that support this workflow. For example, one HCN noted: *"What I would like to probably do is to be able to touch goal of care and say "maintenance", and touch wound bed and say "70 percent blah and 30 percent blah", so I wouldn't have to say "goal of care"."*

This means HCNs can use one hand to point to their target data entry field and verbalize the value, which is easier than having to verbalize the data entry field name and then the value as well. This will save time and reduce the chances for incorrect data entry by speech recognition. As for the values, HCNs noted that minor mistakes can be negligible since they can review the data entry later and correct minor mistakes. For example, "to" instead of "two", or "buy" instead of "by". One HCN explained: *"When it (speech recognition) writes down the item if it's close enough it will trigger me to what it was."*

Overall, HCNs agreed that the prototype would save them time and make their job easier. One HCN even went as far as saying the following in regards to time saving: *"I think* *[it would save time] more than half, maybe initially not that, but once you get the hang of it and you get good at it, then it will be very fast."*

The Frustrated

The level of frustration observed during phase 3 decreased compared to phase 2. The primary concern of HCNs was how much time they might have to spend at the patient bedside when collecting patients' information. Especially in cases when the technology does not work properly. HCNs expressed concern that it is important that the prototype will function properly at the patients' bedside. One HCN noted: *"You don't want to spent too much time in there (patient's home) because a lot of wounds will be such that the patient is lying there, and they've got to lay there while you finish doing all this sort of stuff."*

As a solution, HCNs suggested that to reduce the amount of unnecessary time spent at the patients' bedside they can collect some basic data at the bedside and complete their data entries right after they leave the patients' homes, or in their car before they drive to the next patient. Another point of concern for nurses was keeping the sterile areas of their work clean and preventing spread of bacteria or viruses from one patient's home to another. During the patient scenario one HCN noted: *"I don't want to put it (the phone) down on anything, because you don't know what you're putting down on.*

Researcher: what if it was on the side of your sterile tray?

HCN: You could do that, but then you're contaminating the tray with your phone."

In addition to these reactions it is expected that some users will resist adoption and use of new technology, or as one HCN put it: *"I wouldn't be so keen on using a new piece of technology."* This was in response to a question about whether if she would use the prototype in her real-life wound care practice. Her perspective was that HCNs already use several healthcare information systems, and more technology means more work that is not providing care for the patients. This has been true according to literature [7], as well the ethnographic observations made during this research. Other HCNs felt differently and agreed that they would use the prototype during their real-life wound care practice if provided to them, even if it is not part of their mandated workflow. This is discussed in the next section.

The Surprised

The surprised reaction in phase 3 were much more common in reaction to the sticky multimedia feature. The overwhelming feeling of the HCNs was that the sticky multimedia can save them a substantial amount of time and it allows flexibility to collect patient data that they need even if those data are not supported by the current electronic medical record systems. At the end of one of the sessions a HCN explained: *"I would do everything with voice! I would just go to speech (sticky audio) and describe the wound, describe what I need to bring in next time, and everything will be there when I come back to the office."*

Another HCN noted the following: *"The sticky multimedia, I think that's the main thing, it does a little bit of everything!"*

The concept of "little bit of everything" refers to the flexibility that the HCNs perceive in the sticky multimedia feature. However, this also extended to the speech recognition feature. When asked what the prototype's most useful feature is, one HCNs answered: *"Uh, I think the voice recognition. To be able to use that is fantastic. Just the ease of using that rather than having to write it down…It's like a voice recognition notepad…that's a big selling feature for me."*

Mid and High Fidelity Prototype Evaluation

The audio and video recordings from phase 2 and 3 were topically coded by 3 researchers. The topical codes were adopted from the literature to identify usefulness and ease of use issues [12]. The coding was reviewed by the researchers to achieve team consensus. Figure 6 shows the results of the data analysis. Additional concepts compared to figure 3 are visibility of changes in patient information (status visibility) [19], and inclusion of all relevant and applicable information (completeness) [20].

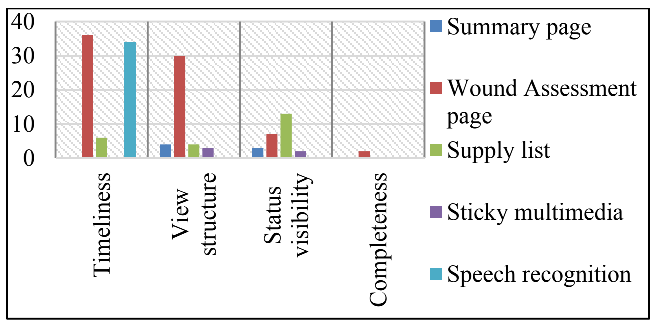

Figure 6. Experimental prototyping user feedback

The experimental prototyping user feedback shown in figure 6 indicates that compared to the exploratory prototyping phase accuracy and flexibility to fit workflow received much less feedback. This can be explained by the perception of the HCNs towards the sticky multimedia, as well the supply list and the wound assessment page. As noted in the previous section the nurses felt very strongly about how the sticky multimedia fits into their workflow. All three features also were identified by the nurses as having a very positive impact on the accuracy of their job. The nurses indicated that they are able to use the wound assessment page and the supply list to keep the patient's record up to date, while using the sticky multimedia to collect any complementary data that they need.

The larger number of instances coded in phases 2 and 3 is expected since the HCNs were using a functioning prototype. Furthermore, wound assessment required more time during the patient scenarios, which impacts issues related to the wound assessment page and the speech recognition active during wound patient assessment. Given this fact, compared to figure 3, the speech recognition received better user feedback. The wound assessment page elicited more feedback related to timeliness. The primary cause for this was that HCNs felt that other forms of input instead of typing can save them even more time. That can include dropdown menus, or radio buttons. However, a drawback is that HCNs will be limited to the options available in the application. The best solution can be a hybrid solution that affords free-text as well quick entry. The view structure issues discussed related to the wound assessment page were mostly focused at level of familiarity with the Android interface elements used in that page. Given higher complexity and the number of interface elements in the wound assessment page more user feedback is expected. Another comparison with figure 3 indicates that while the supply list issues related timeliness have been addressed, at times changes in the supply list items are not clear. This is caused by different interpretations of what supply items are already in stock and which ones are required. To further evaluate the usefulness, ease of use, and task-technology fit the questionnaires given to HCNs were analyzed using descriptive statistics. The questionnaires were in a 7 point Likert scale. Score 7 was assigned to, extremely likely, and score 1 to, extremely unlikely. The results are shown in table 3. i.e., smaller scores show higher satisfaction.

Usefulness	**Mean (sd)**
It saves time	4.91 (1.87)
It increases productivity.	4.73 (1.85)
It enhances effectiveness	4.82 (1.83)
It makes job easier	5.09 (1.64)
It is useful to job	5.36 (1.43)
Ease of use	
It is easy to learn	5.91 (0.94)
It is easy to complete tasks	5.55 (1.21)
It is clear and understandable	5.82 (0.75)
It is flexible to interact with.	5.45 (1.04)
It is easy to acquire skills	5.82 (1.17)
It is easy to use	5.73 (1.01)
Task-Technology Fit	
It is wise	5.09 (1.64)
It is beneficial	5.73 (1.56)
It is valuable	5.18 (1.83)
It makes me feel happy	5.27 (1.1)
It makes me feel positive	5.27 (1.01)
It makes me feel good	5.45 (1.21)
I intend to use it	5.55 (1.04)
I predict I would use it	5.73 (0.79)

Table 3. Results of the experimental prototyping survey

The questionnaire responses are aligned with the HCNs' reactions and the results of the data analysis from the prototyping sessions. The positive scores given to usefulness, ease of use, and task-technology fit items indicates higher intention to adopt the prototype [12,17]. The scores given to usefulness items are likely affected by timeliness issues, as discussed earlier in this section. The ease of use scores indicate that even though HCNs experienced issues related to view structure and status visibility during the prototyping sessions, they ultimately perceived the SuperNurse easy to use. Similarly, the task-technology fit scores indicate that HCNs perceive SuperNurse as a fit into their workflow.

DISCUSSION

The evidence presented here indicates that workarounds are common in HCNs' work, which may be true for similar nomadic work environments in healthcare. Furthermore, this study shows that pervasive technologies can be designed to support workarounds. As pervasive technologies become more prevalent in healthcare, interactive system designers should expect and account for creation and use of workarounds by end-users. However, they should be cautious to not treat workarounds as user errors or mistakes. In fact, during this study we found workarounds to be instrumental to the delivery of care. Workarounds revealed the needs of HCNs in regards to key aspects of usefulness and ease of use, such as timeliness and flexibility to fit workflow. The end result of the design informed by workarounds was a mobile wound documentation application that does not document all and every patient data that the electronic medical record might require, but it rather supports timely and flexible collection of patient data, and note-taking for nomadic workers.

CONCLUSION

HCNs are the primary care providers for patients with chronic wounds. However, their problem solving behaviours are understudied as a form of end-user feedback in the design of HIT. This study used identified themes of workarounds as a source of feedback in the design of SuperNurse. The designs were evaluated and refined in 3 phases, in which the reactions of interest and curiosity were essential in further refining the sticky multimedia and speech recognition. The nurses were interested and curious about designs aligned with their workarounds, such as sticky multimedia, which offered flexibility and fit to workflow, and speech recognition which supported accurate documentation. The nurses were frustrated when a feature, such as malfunction of speech recognition or wearable cameras, created a barrier to their work which indicated circumstances that challenge usefulness, ease of use, and task-technology fit. Positively surprised reactions in cases of success for speech recognition and sticky multimedia indicated improvements in usefulness and ease of use. Identification of workarounds and using them to inform design as a new approach resulted in innovative technology that fit the circumstances of HCNs' work, and the evaluation of it in experimental prototyping showed that the design informed by HCNs workarounds addresses key aspects of technology acceptance.

REFERENCES

1. Gabriel Aldaz, Lauren Aquino Shluzas, David Pickham, Ozgur Eris, Joel Sadler, Shantanu Joshi, and

Larry Leifer. 2015. Hands-Free Image Capture, Data Tagging and Transfer Using Google Glass: A Pilot Study for Improved Wound Care Management. *PLOS ONE* 10, 4: 3–21. https://doi.org/10.1371/journal.pone.0121179
2. Dawood Al-Masslawi, Sidney Fels, Rodger Lea, and Leanne M. Currie. 2017. Nurse-Centred Design: Homecare Nursing Workarounds to Fit Resources and Treat Wounds. In *21st International Conference on Engineering Design, 2017*, in press.
3. Junia Anacleto and Sidney Fels. 2013. Adoption and Appropriation: a design process from HCI research at a Brazilian neurological hospital. In *Human-Computer Interaction–INTERACT 2013*, 356–363. https://doi.org/10.1007/978-3-642-40480-1_22
4. Jakob E. Bardram, Steven Jeuris, and Steven Houben. 2015. Activity-based computing: computational management of activities reflecting human intention. *Ai Magazine* 36, 2: 63–72.
5. Canadian Home Care Association. 2015. *Home care in Canada: Advancing quality improvement and integrated care*. Canadian Home Care Association. Retrieved April 11, 2017 from http://www.cdnhomecare.ca/media.php?mid=4328
6. Jane Clemensen, Mette J Rothmann, Anthony C Smith, Liam J Caffery, and Dorthe B Danbjorg. 2016. Participatory design methods in telemedicine research. *Journal of Telemedicine and Telecare* 0, 0: 1–6. https://doi.org/10.1177/1357633X16686747
7. Neil Clynch and John Kellett. 2015. Medical documentation: Part of the solution, or part of the problem? A narrative review of the literature on the time spent on and value of medical documentation. *International Journal of Medical Informatics* 84, 4: 221–228. https://doi.org/10.1016/j.ijmedinf.2014.12.001
8. Deborah S. Debono, David Greenfield, Joanne F. Travaglia, Janet C. Long, Deborah Black, Julie Johnson, and Jeffrey Braithwaite. 2013. Nurses' workarounds in acute healthcare settings: a scoping review. *BMC health services research* 13, 1: 175. https://doi.org/10.1186/1472-6963-13-175
9. Jesus Favela, Monica Tentori, and Victor M. Gonzalez. 2010. Ecological Validity and Pervasiveness in the Evaluation of Ubiquitous Computing Technologies for Health Care. *International Journal of Human-Computer Interaction* 26, 5: 414–444. https://doi.org/10.1080/10447311003719896
10. Les Gasser. 1986. The integration of computing and routine work. *ACM Transactions on Information Systems (TOIS)* 4, 3: 205–225. https://doi.org/10.1145/214427.214429
11. Jonathon R.B. Halbesleben, Cheryl Rathert, and Sally F. Bennett. 2013. Measuring Nursing Workarounds: Tests of the Reliability and Validity of a Tool. *JONA: The Journal of Nursing Administration* 43, 1: 50–55. https://doi.org/10.1097/NNA.0b013e31827860ff
12. Richard J. Holden and Ben-Tzion Karsh. 2010. The Technology Acceptance Model: Its past and its future in health care. *Journal of Biomedical Informatics* 43, 1: 159–172. https://doi.org/10.1016/j.jbi.2009.07.002
13. Tobias Buschmann Iversen, Line Melby, Andreas Dypvik Landmark, and Pieter Toussaint. 2013. Managing variations from surgical care plans: Challenges for coordination. *International Journal of Medical Informatics* 82, 1: 47–57. https://doi.org/10.1016/j.ijmedinf.2012.08.009
14. Krister Järbrink, Gao Ni, Henrik Sönnergren, Artur Schmidtchen, Caroline Pang, Ram Bajpai, and Josip Car. 2016. Prevalence and incidence of chronic wounds and related complications: a protocol for a systematic review. *Systematic Reviews* 5, 1: 152. https://doi.org/10.1186/s13643-016-0329-y
15. Hanan Khalil, Marianne Cullen, Helen Chambers, Matthew Carroll, and Judi Walker. 2016. Reduction in wound healing times, cost of consumables and number of visits treated through the implementation of an electronic wound care system in rural Australia: Prospective study of wound healing times and cost in a rural population. *International Wound Journal* 13, 5: 945–950. https://doi.org/10.1111/iwj.12414
16. Marina Kobayashi, Susan R. Fussell, Yan Xiao, and F. Jacob Seagull. 2005. Work coordination, workflow, and workarounds in a medical context. In *CHI'05 Extended Abstracts on Human Factors in Computing Systems*, 1561–1564. https://doi.org/10.1145/1056808.1056966
17. Tung-Cheng Lin. 2014. Mobile Nursing Information System Utilization: The Task-Technology Fit Perspective. *CIN: Computers, Informatics, Nursing* 32, 3: 129–137. https://doi.org/10.1097/CIN.0000000000000039
18. Gloria Mark and Norman Makoto Su. 2010. Making infrastructure visible for nomadic work. *Pervasive and Mobile Computing* 6, 3: 312–323. https://doi.org/10.1016/j.pmcj.2009.12.004
19. Michelle L. Rogers, Paulina S. Sockolow, Kathryn H. Bowles, Kristin E. Hand, and Jessie George. 2013. Use of a human factors approach to uncover informatics needs of nurses in documentation of care. *International Journal of Medical Informatics* 82, 11: 1068–1074. https://doi.org/10.1016/j.ijmedinf.2013.08.007
20. Asta Thoroddsen, Guðrún Sigurjónsdóttir, Margareta Ehnfors, and Anna Ehrenberg. 2013. Accuracy, completeness and comprehensiveness of information on pressure ulcers recorded in the patient record: *Accuracy, completeness and comprehensiveness of information on pressure ulcers*. *Scandinavian Journal of Caring Sciences* 27, 1: 84–91. https://doi.org/10.1111/j.1471-6712.2012.01004.x
21. Pixalere Wound Care Management System. Retrieved April 11, 2017 from http://www.pixalere.com