

Design of Customized Mobile Application for Patient Adherence to Oral Anticancer Medications Utilizing User-Centered Design

Grace I-Hsuan Hsu, Stephanie Y. Crawford, Gennaro Paoella, Sandra Cuellar, Scott M. Wirth, Neeta K. Venepalli, Edward Wang, Donna Hughes, and Andrew D. Boyd

Adherence and compliance to oral anticancer medications (OAMs) can be challenging for patients due to their complex regimens. The goal of this research project was to design an effective and engaging user interface (UI), based on user-centered design (UCD) and incorporate animations, to reinforce and improve patient's understanding of the key aspects of taking OAMs. This current paper encompasses the development process and describes the initial phase of the project, which focused on the design and development of the tablet-based educational application (app). A UCD approach was implemented by consulting with oncology clinicians and patients at an early stage of development. Animations were developed and incorporated to convey complex medical concepts and information. An iterative design process will help ensure that the tool is customized for patient engagement.

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Introduction

Oral anticancer medications (OAMs) enable oncology patients to benefit from life-saving treatments at home. Though convenient, orally-administered (i.e., tablets and capsules) anticancer medications place greater responsibility on the patient and/or caregiver than infusion-based cancer therapies, traditionally administered by healthcare professionals in physician offices and clinics (Patel et al., 2013). It is sometimes assumed erroneously, that patients with cancer are unlikely to become non-adherent to their cancer medications. On the contrary, studies have found that medication adherence rates could be as low as 16% and as high as 100% (Patel et

al., 2013; Ruddy et al., 2009). Positive therapeutic outcomes are in direct correlation to adherence to OAMs (Hartigan 2003). Since OAMs are usually self-administered by patients in their residence or other non-institutional setting, there is less direct clinician-patient interaction. Adequate patient education is essential to increase patients' knowledge of their medication, as well as self-management skills. Both behavioral and system-of-care factors contribute to non-adherence to cancer medications and include low health literacy, problematic patient-provider miscommunications, insufficient patient knowledge of the regimen, patient beliefs related to taking medication, forgetfulness, lower socioeconomic status, side effects, and regimen complexity (Geynisman 2013). An interdisciplinary team at the University of Illinois at Chicago (UIC) is developing a personalized mobile application (app) to address some of those factors.

Mobile Application for Patient Education

Electronic health (eHealth) literacy is defined as, "the ability of people to use emerging information and communications technologies to improve or enable health and health care" (Neter 2012). Mobile devices, such as tablets and smart phones, are becoming universal and often more widely utilized than desktop or laptop computers (Mirkovic et al., 2014). Patients, as consumers, have a great need for mobile health (mHealth) applications that can help with their medication adherence, as suggested by the 106% increase of iOS mHealth apps available to the public from 2013 to 2015 (Aitken and Lyle 2015). mHealth apps grew from 43,689 in 2013 to 90,088 in 2015, and these counts do not include mHealth apps for Android or other mobile platforms (Aitken and Lyle 2015). Tailoring content to make mHealth/eHealth interventions more personally relevant promotes

patient engagement and post-intervention behavioral changes among patients, including minority populations and those with low levels of education and computer experience (Jacobs et al., 2014; Mohr et al., 2014). Use of digital technology to deliver behavioral intervention information to patients allows greater patient access to effectively self-manage their medication, while saving healthcare practitioner time (McDermott and While 2013). A study of low-literacy patients using an eHealth intervention showed a significant improvement in their knowledge of health information (Mackert 2009).

Visual Components in Patient Education

Communication between healthcare professionals and patients can be challenging. Clinicians tend to overuse medical jargon, and may often be unable to communicate equivalent terms in a lay language that is understandable to patients (Houts et al., 2006). In oncology clinics, patients are emotionally stressed, and often clinicians try to communicate more information than patients can manage. Even patients with a high literacy level can find it difficult to process the voluminous information provided to them, and spoken medical instruction averages recall rates of only 14% (Houts et al., 2006). Time constraints during in-clinic visits also present a problem for clinicians to effectively deliver information (McDermott 2013). From the instructional design field, it is known that pictorial information allows patients to form a mental model of the situation and may enhance the comprehension of text (Kools et al., 2006). Appropriate visual depictions can facilitate connections between written text and mental images when learners reconstruct the information through visual association. When words are presented alone, learners must form their own mental images and associate those with the words they are reading or hearing, which is especially difficult for those with low literacy (Choi 2010). Having visual depictions accompanying verbal and/or written instructions can be an effective, and culturally sensitive, way to address literacy issues.

Animation for Patient Education

As mHealth use grows, visual depictions can be used effectively to enhance communication. Mobile devices are uniquely suited to the inclusion of many visual medias, including animation. The use of a mobile device, in conjunction with animation, has been shown to significantly improve patient understanding and clinician-patient communication (Schooley et al., 2015; Schnellinger et al., 2010). This was demonstrated to be especially effective in use with low health literacy populations, as animations can help to overcome issues of literacy, and they are perceived as non-threatening when used to deliver medical information (George et al., 2013; Leiner et al., 2004). Animation has been found to be more effective than live-action video for conveying symbolic concepts, since the creators have greater control over the look, timing and characterization of an animation (Champous 2005; George et al., 2013). Often, lower health literacy populations are more receptive to information disseminated via visual multimedia (Brock 2007).

User Centered Design and Development

User centered design and development (UCDD) is a design philosophy in which users are placed at the center of the design process (Spector et al., 2014). Contact with target user populations is initiated early in the development process to identify possible functionality issues, need for new features, and design requirements; this is followed by an iterative design process (Ruland et al., 2003). The implementation of UCDD ensures that the application being designed is effective in fulfilling its function. There are many cancer apps currently available, and each represents an effort to promote behavioral change or act as a supportive intervention. Significantly more mobile apps designed for healthcare professionals have scientifically valid information as compared to those designed for patients, 96% versus 32%, respectively (Bender et al., 2013). This finding further supports the need for a cancer mobile application that is designed for patients and is evidence-based, grounded in theory, and utilizes UCDD.

Description of the Educational App

The tablet-based, personalized, mobile educational module, designed by our research team, will engage patients in active learning about their medication and behaviors. The app includes information on individually prescribed OAMs, patient scenarios representing common barriers to medication adherence, and take-home messages on what patients should communicate to the clinician. Content was written at a 6th grade level with audio voiceover to overcome possible literacy barriers and is also visually rich. A personalized treatment calendar, generated from the mobile application with reminders of when the patient is to take their medication, was designed to help with the complexity issue of this type of medication regimen. One feature of the app is the ability to send customized text messages to the patients, to reinforce salient points from the education modules. The text messaging feature is a permanent part of the app. The mobile app intervention was designed to be completed within 20 minutes, so that the patients can go through it in the clinic or oncology pharmacy waiting room or during counseling with clinicians.

Methods

Pre-production scope assessments were conducted with clinicians (i.e., oncologist with board certification in internal medicine and hematology and two board-certified oncology pharmacists) to gain an understanding of the most important information they want their patients to remember. Based on these clinician interviews, we prepared a site map that indicated the education modules to include in the application (Figure 1). The functionalities of the mobile application included: 1) Patient-centered educational tutorials on the specific OAM they are prescribed, including pictures of the OAM and his or her specific dose and schedule; 2) Patient scenario modules based on clinician-identified, common adherence barriers for patients; 3) A customized medication calendar; and 4) Specifically tailored text messages, sent via cell phone for reinforcement of take-home messages and follow-up appointments.

Barriers addressed in the patient scenario modules were:

- Confusion regarding changes in dosing
- The on-off schedule for some OAMs
- Side effects, which have been known to cause patients to stop taking their OAM because they could not tolerate them
- Forgetting to pick up refills in a timely manner.

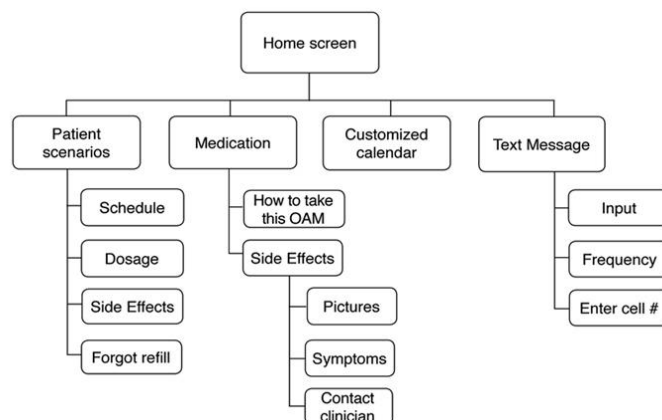


Figure 1. Site map of the mobile application.

Wireframes were produced based on the site map and shown to the clinicians for their approval of the planned contents for each page of the application.

Three different user interfaces (UI) were designed with a final selection of soft, desaturated hues with graphic elements that have contrast in saturation or hue in order to visually organize the information hierarchy. The first design was minimalist and used white as a background and blue-green hues for graphic elements. The second concept was inspired by the yellow daffodil symbols for cancer charities. The overall design followed a traditional linear book layout, using the website development guidelines from the United States Department of Health and Human Services. The third concept was more dynamic in appearance, with icons that resembled mobile app icons, and with more graphic elements, as compared to the first two designs (Figure 2). We avoided sharp edges in all three concepts, as it was not desirable to have harshness associated with this

application. Circles, curves, and rounded corners were used as design elements. Sans serif fonts, Arial or Helvetica, were chosen because they are crisp and easier to read on screen than serif fonts, and they have been shown to be more readable among elderly populations (Fromme et al., 2011).

important messages to the patients. Animations were created by the lead author (GI-HH) to explain four anticancer medication concepts that some patients may not comprehend: 1) taking medication on an empty stomach, 2) medication side-effects, 3) taking medication with food, and 4) on-off dosing schedule.

The concept of taking the medication on an empty stomach is related to the OAMs bioavailability when certain food is present, but research suggests that it is not appropriate, nor effective to provide these types of complex scientific explanations in patient education, thus, we did not explain the biological reason for something this complex to our patients. A time scale slider was developed to symbolize the passage of time between the meal and taking the OAM (Figure 3). The grey triangle slides across from the meal symbols to the 1 hour before (meals) mark or towards the 2 hours after (meals) mark or towards the 2 hours after. A capsule appears which indicates that medication can be taken at the time indicated.

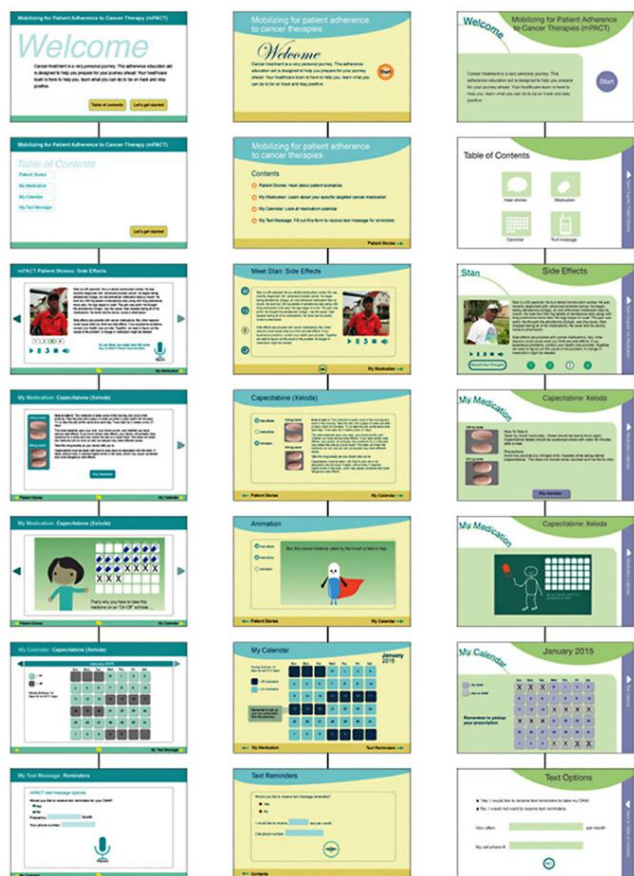


Figure 2. The three different User Interface designs.

For the patient scenario modules, stock photographs representing the diverse demographics of patients at University of Illinois Hospital (UIH) were used, courtesy of UIH Marketing Photo Library. For the medication module, the high-resolution photos of the oral anticancer medications were taken from National Library of Medicine’s Pillbox page (<http://pillbox.nlm.nih.gov/pillimage/search.php>).

Development of Animation

The animations were developed to reinforce the most

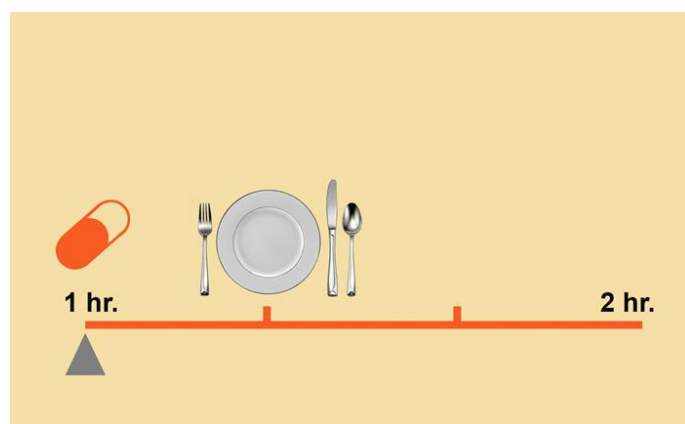


Figure 3. Motion graphic depicting the message to take medication on an empty stomach.

The goal of the side effects animation was to show that everyone may have different side effects, and patients should contact their clinicians if they have concerns. Thus, this animation ends with encouragement to the patients to contact their oncologist, pharmacist, or clinic staff member (Figure 4).

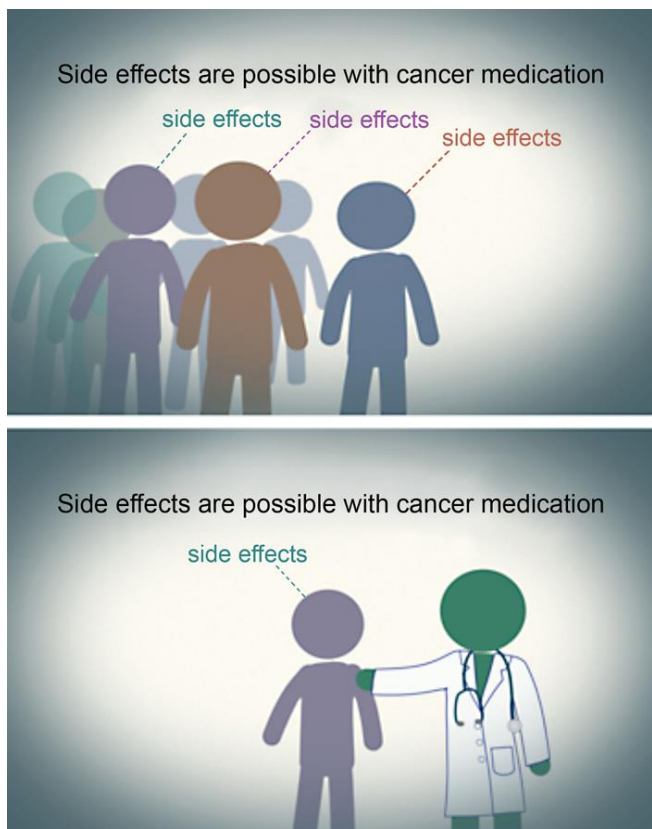


Figure 4. Animation for side effects.

As some OAMs need to be taken with food, the lead author created an animation that shows patients that they need to take their medication within 30 minutes of eating (Figure 5).

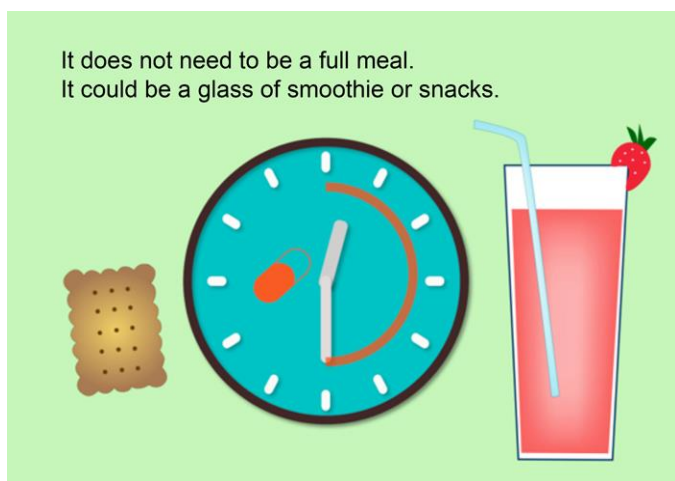


Figure 5. Animation depicting message to take medication with food.

The concept of an “on-off” medication schedule is challenging, since most medications require a daily administration regimen. We chose to represent the “off” days as rest days, which enable the patient to recover from the therapy.

The lead author explored the style of the animation visuals and decided on iconic styles (Figure 6). The idea was to enable the patients to put themselves in the situation depicted without being distracted by the look of the animation. Previous studies have shown that people with lower health literacy level tend to get distracted by details in visuals (Houts et al., 2006).

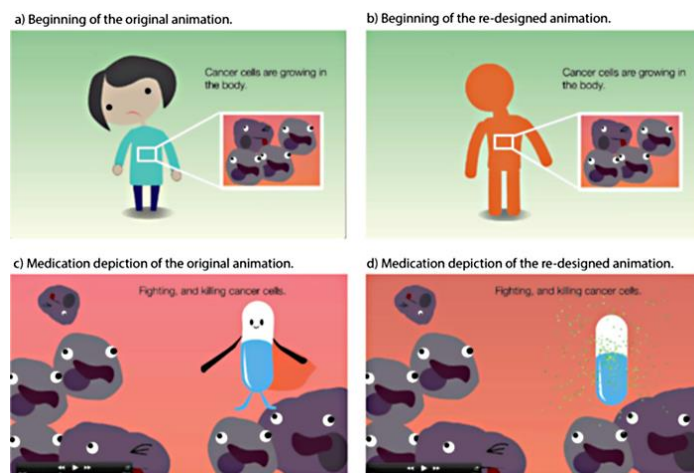


Figure 6. Comparison of the original and re-designed on-off cycle frame to frame.

Study processes were conducted in accordance with policies of the institutional review board at the study site, including compliance with the Health Insurance Portability and Accountability Act (HIPAA). The study was also approved by the Protocol Review Committee at the UIC Cancer Center.

Informal, semi-structured interviews were arranged, where patient advocates, who were cancer patients, evaluated the prototype of the three different UIs, as well as the four animations. The patient advocates evaluated the icons used, the colors, font type, font size, the layout, and graphic elements in each design, as well as the style of the animations. Two oncology patients were interviewed for feedback on the

preliminary design, each of whom had undergone anti-cancer therapy with OAMs. They are designated as Participant 1 (P1) and Participant 2 (P2).

Results

Responses to the Patient Stories Module

Adherence to an OAM regimen can be a challenge, as some patients may deviate from the prescribed medication regimen without consulting their clinicians. This issue was confirmed by two patient advocates during the interviews. P2 stated that patients, especially elderly patients, are very good at being "self-appointed physicians." The main criticism of the patient scenario module was that it contained too many words, although the participants perceived the four patient scenarios as being very helpful, as they had experienced some of these adherence barriers firsthand. This represented a form of "role modeling" as the basis for introducing the story, in order to promote patient identification between the actual patient and the fictional patients in the scenarios. This type of representation has been shown to be very effective in modifying behaviors (Leiner et al., 2004). The participants related to the patient scenarios very well and felt that they would be helpful in preparing the patients taking OAMs for some of the potential obstacles.

Responses to Animations

When asked if live footage should be used instead of animation, P1 said, "No, I don't want to see live actors. Animation might be a fun way to present and reinforce information about the medication. Doctors intimidate a lot of people. Animation could be seen as friendly and approachable. Not so much cold and hard facts." P1 did not like the more "cutesy" style of animation where the OAM pill has a cartoon-like face, and is wearing a cape to fight off cancer cells. The facial features of the patients were perceived as those of a child by P1.

Prior to viewing the animation, P1 stated, "Keep everything as basic as possible. Moreover, what does it mean by taking this medication on empty stomach? Does that mean before eating anything that morning? No breakfast? What timing is associated with it? Are a few bits sufficient? What is a meal? These things are not common knowledge for the general public." After seeing the animation, P1 felt that the, "Take medication on empty stomach," animation helped to clarify the messaging and addressed her questions.

User Interface Designs

Both participants preferred the UI design concept 2 with its warm hue and more straightforward linear navigation. Simple, easy-to-understand visuals that focus on what they need to know and what buttons to push to navigate were perceived as more welcoming. The design of the UI in concept 1, with its mostly white background and blue graphic elements, was seen as "cold and clinical" by the subjects. Another point noted by the patients was that they did not wish to see too many words in the modules. This is in agreement with previous findings that mobile devices should show limited content and with reduced word count (Mirkovic et al., 2014).

Discussion

Animation

We evaluated the appropriateness of the use of animation as a tool for communicating OAM information. We also determined if the educational modules resonated with the target audience. Feedback indicated that patients responded positively to animations, which were seen as being more fun and humorous than the more realistic portrayals, such as live-action. One of the participants felt that the short animation could help reinforce information, and that it may be helpful in delivering information in a way that is not intimidating or scary.

The size of the food and type of food portrayed in animations were initial points of contention. From the patient advocates, we learned that many oncology

patients drink a smoothie or have light snacks instead of a large meal (because some patients cannot tolerate a full meal). Thus, the depiction of the food in the animation should reflect what is more common for an oncology patient's diet.

The iconic character in the on-off cycle animation was preferred, especially when the patient character was changed to an androgynous figure without any facial features. This was seen as more relatable across different patient populations since gender, race, and age are not portrayed in the animation. In addition to the iconic animation, the lead author had produced and presented a realistic 3D animation to explain the mechanism of tyrosine kinase inhibitors. However, this animation was poorly received by one of the patients. She disliked the growing cancerous tumor; she looked away and said it made her feel nauseous. The realistic portrayal of a tumor in animation may not be the most desirable or sensitive portrayal for this target audience. This portion was eliminated in our module.

Content of Modules

As outlined in Figure 1, the content of the program is split into four areas, patient scenarios, medication, customized calendar, and text messaging. As seen from the engagement of users, the animation is an acceptable format for portraying complex topics to patients.

Conclusion

It is known that the need exists for the development of effective and efficient tools to help educate patients with chronic illnesses who have complex medication regimens, especially those with low literacy (Parmanto et al., 2013). Many people, including clinicians, already use mobile devices on a daily basis, including within their clinical practices (Mirkovic et al., 2014). This article reviews the development and use of animation as part of a mobile education tool to enhance the understanding of managing a complex medication regimen within a minority patient population. The use

of effective visual graphics renders drug information more understandable, when compared to lengthy written content.

Future Directions

The application will be coded into an actual app and hosted on HIPAA-compliant servers that will allow tablets to access the patient's electronic health record. When completed, the app will be deployed onto Android 10-inch tablets. Additional studies will include usability testing in the Oncology clinic, with participants in the intended outpatient clinic environment. A subsequent Phase 2 study will test whether the customized mobile application empowers low health literacy patients taking OAMs and increases adherence to, and satisfaction with clinical care. The research team will be conducting a feasibility study, and a randomized prospective pilot study at the UIC Oncology Center, to evaluate this mobile education tool and determine how it will contribute to patients' understanding and adherence to their OAM regimen. Additionally, we hope to better understand the function served by visual aids in facilitating communication between patients and their health care providers. It is our hope that the significance of this study and the proposed research in evaluating its usefulness will translate to improved patient care.

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