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MOBILE & WIRELESS HEALTH

Design Considerations in the Development of App-Based Oral Anticancer Medication Management Systems: a Qualitative Evaluation of Pharmacists' and Patients' Perspectives

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Abstract

Smartphone apps can potentially help in enhancing oral anticancer medication (OAM) adherence. Patient adoption and efficacy of such apps depends on inclusion of user-centred and evidence-based features. The objective of this study was to identify important design considerations from the perspectives of patients taking OAMs, caregivers and oncology pharmacists. The study employed a qualitative study design. Data were collected using in-depth interviews with patients ($n = 15$), caregivers ($n = 3$) and pharmacists ($n = 16$). Interviews were audio-recorded, transcribed verbatim and inductive thematic analysis approach was used in data analysis. Monitoring medication-related problems, medication information, replacement of or integration with current systems and accessibility of app content on devices other than smartphones were the key themes identified in the analysis. Flexible input methods for monitored data, glanceability of monitored reports/information, near real-time adherence enhancing and symptom management interventions and customisable reminder options were design considerations identified under the monitoring medication-related problems theme. Participants suggested the provision of focused and easily understandable medication information with a potential for personalisation. Integration of app-based adherence systems with patients' electronic medical records with added mechanisms for alerts in the dispensing system was also suggested as a key design requirement to improve quality of patient care and facilitate adoption by clinicians. Finally, smartphones were the most favoured platform with optional accessibility of app content on other devices. In conclusion, important design considerations were identified through a user-centred design approach. The findings will help developers and clinicians in the design of new app-based systems and evaluation of existing ones.

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Introduction

Adherence to prescribed medications is an essential component of therapeutic success in the management of chronic diseases [1]. In recent years, the problem of medication non-adherence has become a persistent challenge in oncology practice, as more anticancer medications are being available for oral administration [2–4]. Studies generally report oral anticancer medications (OAMs) adherence levels ranging from 23% to almost 100% [4]. Suboptimal levels of adherence to OAMs significantly reduce patients' progression- and disease-free survival [5, 6]. Moreover, the estimated health care costs of non-adherence to OAMs range between 48,598 and 162,699 United States Dollars per patient per year [7, 8].

Complex factors including patients' socioeconomic status and health belief; factors related to the disease condition and health system-specific determinants influence OAM adherence [9–12]. These factors should be considered in the design and implementation of OAM adherence interventions [6, 13]. In this regard, a variety of educational, symptom management and reminder-based interventions, which involve delivery mechanisms such as face-to-face interactions, phone calls and SMS texting have been developed and tested [14–20]. However, the evidence on effectiveness of the interventions is not yet conclusive and those interventions, which show promises of effectiveness, are often considered expensive and difficult to implement in routine clinical practice [3, 16, 21].

Due to their capacity to deliver multiple adherence enhancing strategies and increasingly ubiquitous distribution in many parts of the world, smartphone technologies present a great opportunity for the development of effective interventions that can efficiently be introduced to address patients' needs [22–27]. Smartphones enable interventions that provide information, reminders, and ways for monitoring of adherence and medication-related side effects to be delivered in a single app-based system [26–29]. App-based systems also have a potential to provide personalised and context-specific interventions [22]. This is complemented by the wide spread popularity of health apps among patients and health care professionals [25, 30–35]. As a result, a plethora of apps, with claims of effectiveness for enhancing medication adherence, exist in the various app stores. However, most of these apps suffer from deficiencies that limit their usefulness for patients with medication adherence problems [36–38].

Part of the reason for the suboptimal quality of adherence apps is related to the minimal involvement of potential end users in their development process [39]. This lack of end user involvement is incongruous with the principles of user-centred design (UCD), which is generally defined as "an evidence-based approach informed by the needs and understanding of a specific end user group" [40]. The first step in UCD is concept generation, which involves a thorough assessment of user needs to identify the intended use and required features of an app [40, 41]. The second step is prototype design and system development. This requires continued engagement with users to elicit feedback that enables further refinement of the app. The use of prototype systems at this stage will help stimulate conversation and elicit more in-depth understanding of end users' opinions regarding design requirements [42]. The last stage in UCD is the evaluation of the app using walkthroughs and usability testing [40]. The most important aspect of the UCD approach is the involvement of potential end users throughout the app development process [40]. In the context of an adherence app, patients and caregivers have an irreplaceable role. Inputs from other stakeholders in the medication management process are also essential. In this regard, pharmacists will have crucial contributions due to their unique place in medication management [43].

Similar to other disease-specific and generic adherence apps, there is limited research on what constitutes an ideal OAM adherence app in terms of its features [25, 41, 44–46]. Previous attempts in this regard either focused on specific aspects of interventions, such as education and side effect management [44], or did not provide enough details beyond a listing of potentially relevant OAM adherence app features [25, 45]. While identification of OAM adherence app features is useful, details on the interface design requirements are equally important. In fact, studies suggest that the way health information is presented greatly impacts the usability and relevance of an app for patients [47, 48]. Therefore, this study aims to address the question: what are the functionality and user interface design requirements in the development of an OAM adherence app from the perspectives of patients, caregivers and oncology pharmacists? For this purpose, the study employed a preliminary prototype system, which was developed based on prior research by the authors [25, 36, 49]. The prototype system had interfaces for patients/caregivers and pharmacists and its use in this study corresponded to the second step in the UCD process.

Methods

Study participants

This study recruited participants from the National Cancer Centre Singapore (NCCS). Patients who were taking OAMs, 21 years of age or older, able to speak and understand English and had basic knowledge to use smartphones were eligible. Caregivers of eligible patients were also considered for

participation. Spouses or caregivers could join the patient if the patient requested or agreed to their presence during the interview sessions. Pharmacists had to be actively involved in the provision of pharmaceutical care to patients taking OAMs, willing and able to use smartphone- and/or computer-based software, willing to spend up to 90 min in the interviews. Potential participants who were unwilling or unable to take part in the study due to their medical conditions were excluded.

Data collection

Interviews and participant observation were used in data collection. Both pharmacist and patient/caregiver participants were recruited from the NCCS. The most convenient date and time of interview was arranged in consultation with the consenting participant. One of the authors (EA), a graduate student with training and experience in the conduct and analysis of qualitative studies conducted all interviews at NCCS. Another author, SC a final year pharmacy student at the time of the study accompanied EA during the interviews in order to facilitate note taking.

A prototype app-based system (called MedFC) developed by the authors was used to give participants an idea about potential functions of medication management systems. The prototype system was designed based on inputs from prior research by the authors [25, 36, 49] and included a smartphone app for patients and a web interface for pharmacists. The smartphone app included medication reminder, symptom reporting, medication information and adherence tracking functions. The web interface for pharmacists had functionalities that enabled creating patients' medication list and tracking their medication taking and side effect patterns (Fig. 1).

At the beginning of each interview, participants were allowed to perform various tasks related to medication management. Patients/caregivers were asked to use the app to record taken medication, access medication information, change reminder timing, report medication side effects and view adherence patterns and reported symptoms. Pharmacists performed similar tasks on the smartphone app. Moreover, they were asked to perform pharmacist-specific tasks on the web interface. These tasks included creating medication list and setting reminders for patients and viewing the list of medications, adherence behaviour and reported symptoms for a given patient. Both pharmacist and patient/caregiver participants were encouraged to talk about their thoughts and what they were trying to do while performing the tasks. The interviews lasted for 35–90 min and included questions on participants' overall impressions of the system and its usability, their most favoured features, features that they deemed unnecessary, and their suggestions for improvement (Appendix 1). As the MedFC system was a prototype that required improvements, participants were encouraged to suggest new features and improvements on existing features and interface considerations. Participants were also probed to suggest their ideal requirements to facilitate elicitation of information that could be applicable to other apps. Low fidelity mock-ups were drawn on paper and discussed in order to ensure understanding of participants' suggestions for improvements or additions to MedFC. At the end of the evaluation, participants were given a 30 Singapore Dollars shopping voucher for their time and participation.

Data analysis

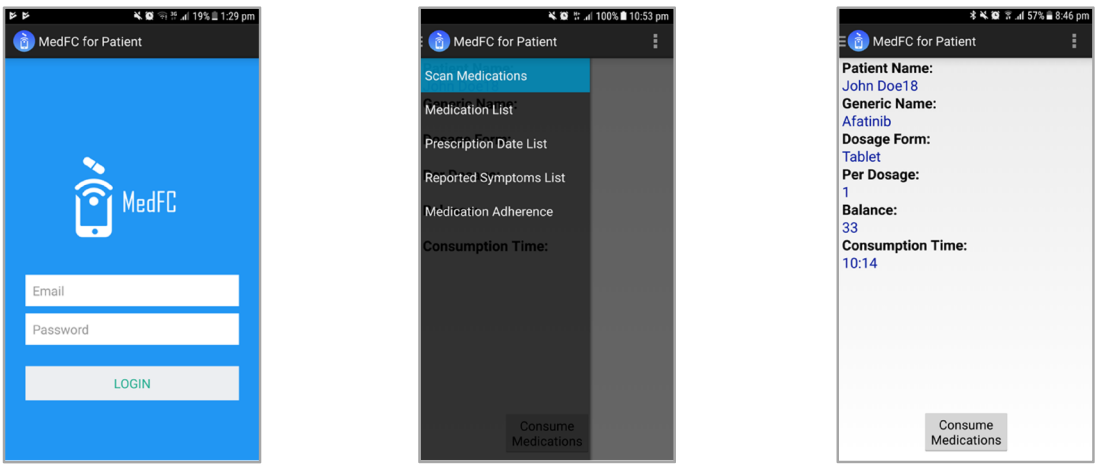
Analysis of the interview data followed the inductive thematic analysis approach outlined by Braun and Clarke [50]. All audio-recorded interviews were transcribed verbatim by one of the researchers. A second researcher checked interview transcripts against the audio-records to ensure accuracy. The inductive approach was employed to gain in-depth understanding of participants' opinions without having to subscribe to pre-defined theories or assumptions. In the cases where a patient and his/her caregiver attended an interview session together, their opinions were analysed separately in order to account for differences in their roles in medication management. Based on recommendations by Braun and Clarke [50], analysis in this study started with a repeated reading of the transcripts to ensure familiarisation with the data and credibility of data sources. This was followed by generation of initial codes. One of the authors (EA) generated initial codes based on interview transcripts. Identified codes were then sorted into themes by using thematic maps to depict potential relationships between themes and subthemes. The identified themes were then reviewed and refined to ensure coherence between the themes, coded extracts and the entire dataset. Constant meetings were held with the rest of the authors to ensure the accuracy of the interpretations by the coder and facilitate confirmability of the analysis. This helped in the definition and refinement of the themes and the final step of producing this manuscript. Detailed characteristics of participants are provided to facilitate transferability of the findings. The Qualitative Data Analysis software in family R (RQDA) was used in the process of data analysis [51].

Ethical considerations

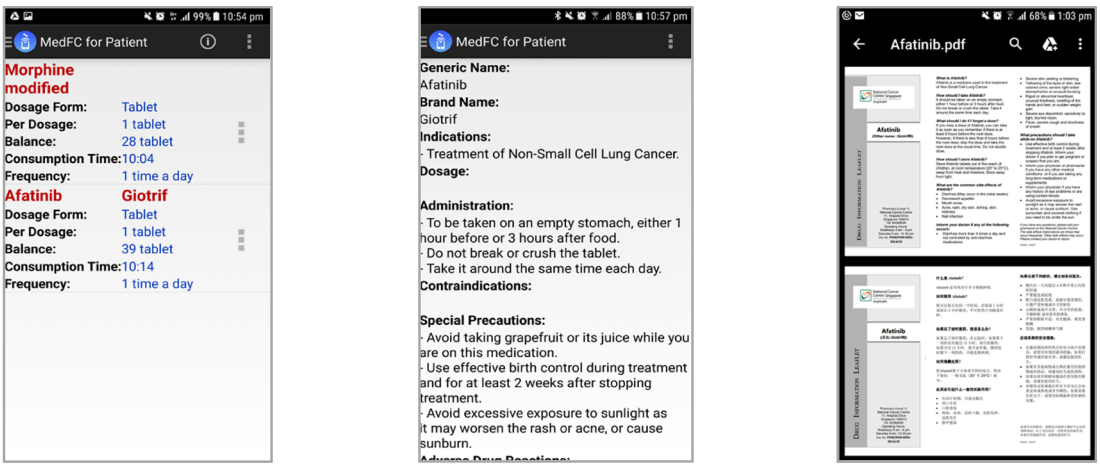
Ethics approval was obtained from the SingHealth Centralised Institutional Review Board. Participation was voluntary, participants were aware of their rights to withdraw from the study at anytime and written informed consent was obtained before commencing the study. In an effort to maintain participant anonymity, all potentially identifying details revealed during the interview process were masked in the transcripts and access to raw data was restricted to members of the study team.

1. Components of the prototype app for patients

A. Login and home menu



B. Medication list and information



C. Reminders and monitoring

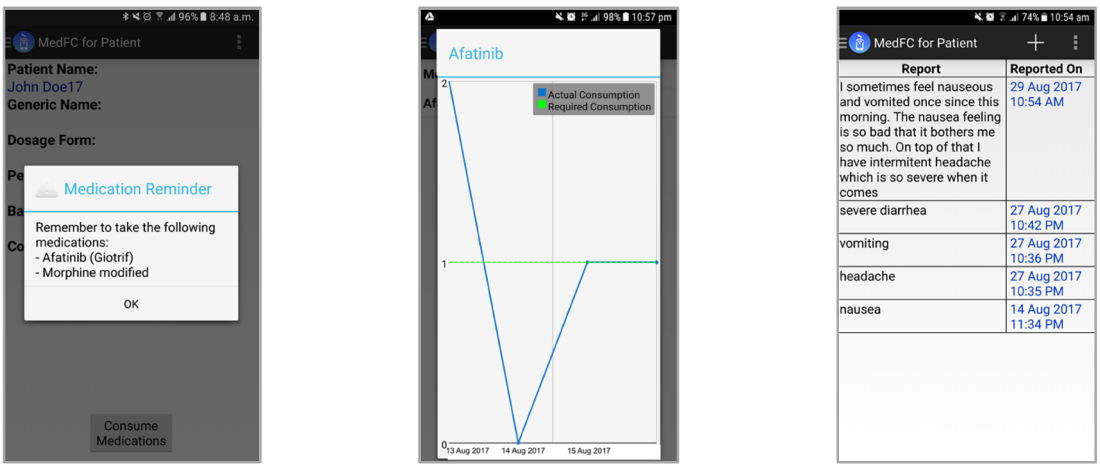
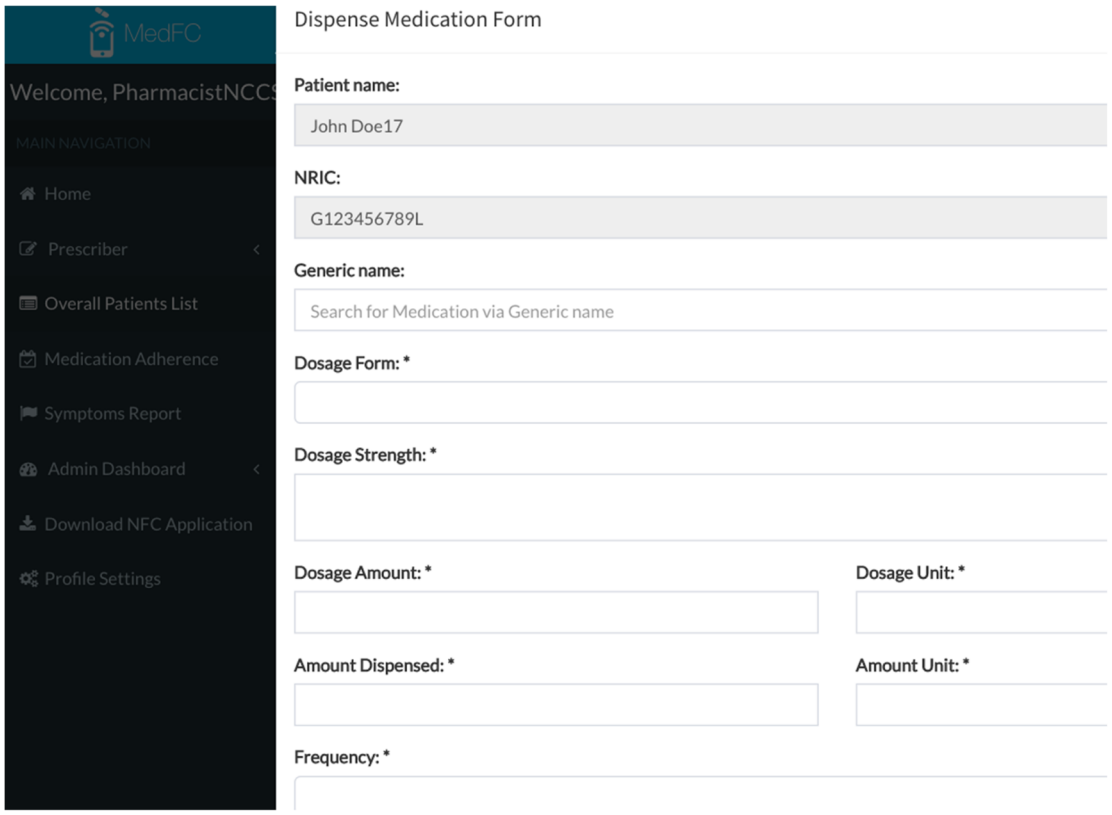


Fig. 1 Screenshots of the different components of the prototype system used in the interviews

2. Components of the web interface for pharmacists

A. Dispensing medication

1. Dispensing form



2. Medication list for a specific patient

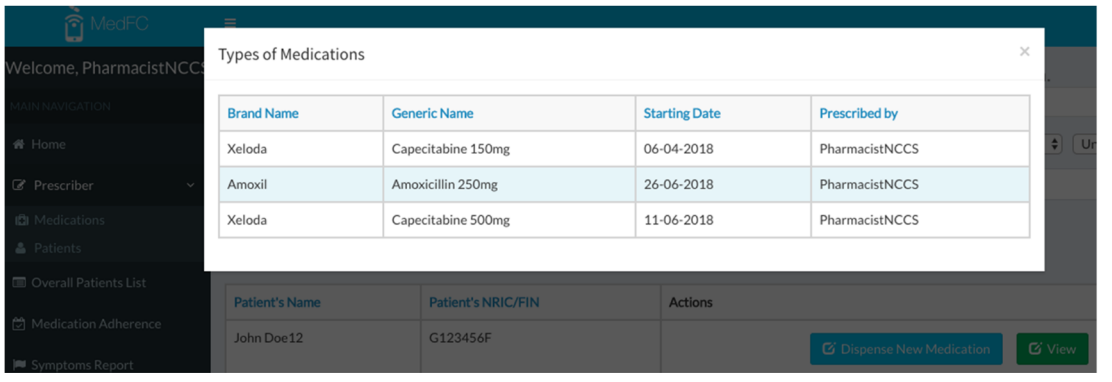
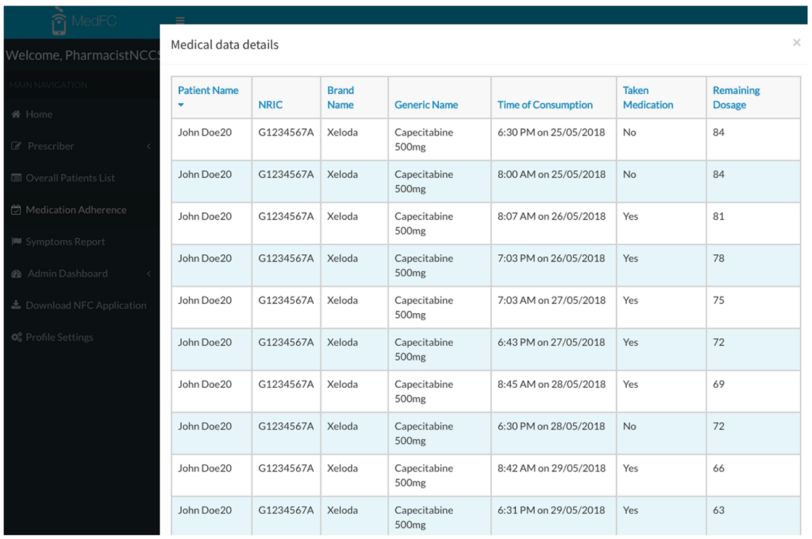
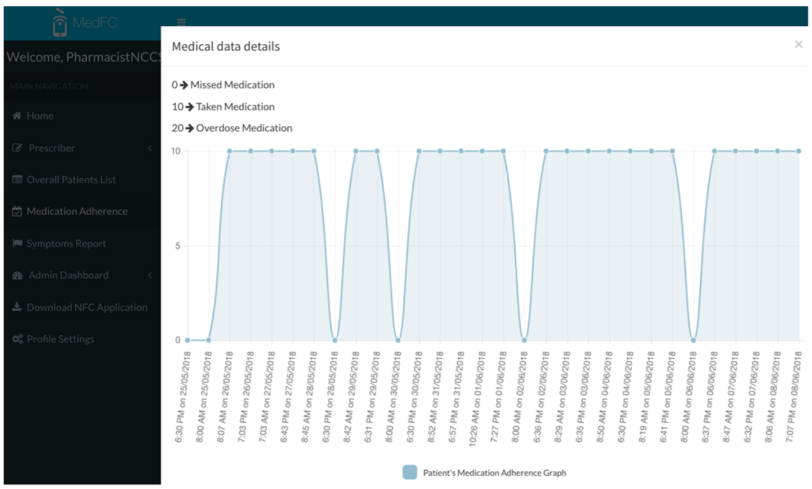


Fig. 1 (continued)

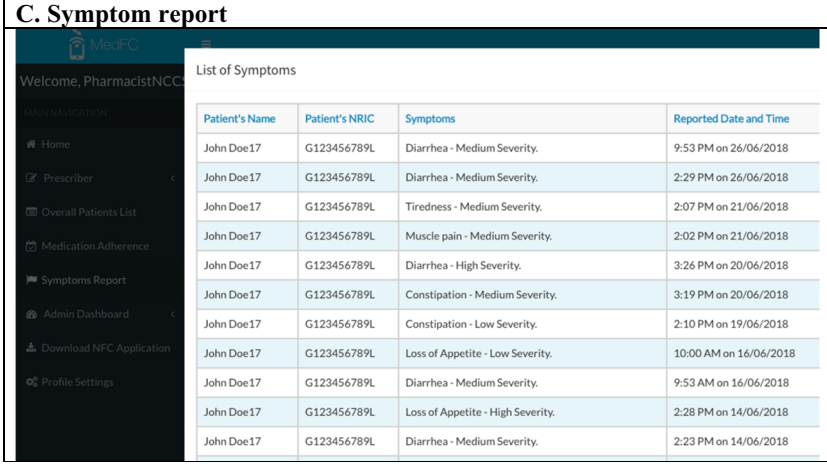
B. Adherence monitoring



Patient Name	NRIC	Brand Name	Generic Name	Time of Consumption	Taken Medication	Remaining Dosage
John Doe20	G1234567A	Xeloda	Capecitabine 500mg	6:30 PM on 25/05/2018	No	84
John Doe20	G1234567A	Xeloda	Capecitabine 500mg	8:00 AM on 25/05/2018	No	84
John Doe20	G1234567A	Xeloda	Capecitabine 500mg	8:07 AM on 26/05/2018	Yes	81
John Doe20	G1234567A	Xeloda	Capecitabine 500mg	7:03 PM on 26/05/2018	Yes	78
John Doe20	G1234567A	Xeloda	Capecitabine 500mg	7:03 AM on 27/05/2018	Yes	75
John Doe20	G1234567A	Xeloda	Capecitabine 500mg	6:43 PM on 27/05/2018	Yes	72
John Doe20	G1234567A	Xeloda	Capecitabine 500mg	8:45 AM on 28/05/2018	Yes	69
John Doe20	G1234567A	Xeloda	Capecitabine 500mg	6:30 PM on 28/05/2018	No	72
John Doe20	G1234567A	Xeloda	Capecitabine 500mg	8:42 AM on 29/05/2018	Yes	66
John Doe20	G1234567A	Xeloda	Capecitabine 500mg	6:31 PM on 29/05/2018	Yes	63



C. Symptom report



Patient's Name	Patient's NRIC	Symptoms	Reported Date and Time
John Doe17	G123456789L	Diarrhea - Medium Severity.	9:53 PM on 26/06/2018
John Doe17	G123456789L	Diarrhea - Medium Severity.	2:29 PM on 26/06/2018
John Doe17	G123456789L	Tiredness - Medium Severity.	2:07 PM on 21/06/2018
John Doe17	G123456789L	Muscle pain - Medium Severity.	2:02 PM on 21/06/2018
John Doe17	G123456789L	Diarrhea - High Severity.	3:26 PM on 20/06/2018
John Doe17	G123456789L	Constipation - Medium Severity.	3:19 PM on 20/06/2018
John Doe17	G123456789L	Constipation - Low Severity.	2:10 PM on 19/06/2018
John Doe17	G123456789L	Loss of Appetite - Low Severity.	10:00 AM on 16/06/2018
John Doe17	G123456789L	Diarrhea - Medium Severity.	9:53 AM on 16/06/2018
John Doe17	G123456789L	Loss of Appetite - High Severity.	2:28 PM on 14/06/2018
John Doe17	G123456789L	Diarrhea - Medium Severity.	2:23 PM on 14/06/2018

Fig. 1 (continued)

Results

Participant characteristics

A total of 31 interviews were conducted. From these, 16 (51.6%) involved pharmacists, 12 (38.7%) involved patients and three (9.7%) involved both patients and caregivers. Most of the pharmacist participants were female (9/16, 56.2%) and 54 years or younger (14/16, 87.5%). Moreover, most of the patient participants were female (8/15, 53.3%), 55 years or older (8/15, 53.3%), married (8/15, 53.3%) and with secondary level education (8/15, 53.3%) (Table 1).

Findings of thematic analysis

Thematic analysis identified four main themes in the areas of monitoring medication-related problems, medication information, replacement of or integration with current systems, and accessibility of app content on devices other than smartphones. A summary of the list of themes, subthemes, suggested design considerations and their corresponding quotes from interviews is provided in Table 2. Detailed descriptions of the findings under each theme are presented below.

Theme 1 monitoring medication-related problems

This theme explained the opinions of pharmacist and patient/caregiver participants about the importance of features for monitoring medication-related problems. These were described in terms of mobile app features for patients and/or web interface features for pharmacists. Four subthemes were identified that explained the functionality and user interface design considerations that were deemed crucial. These were: flexible data input methods, displaying monitored reports/information, expected mode of intervention and reminder options.

Table 1 Participant characteristics

	Patients n (%)	Caregivers n (%)	Pharmacists n (%)
Total sample	15 (100)	3 (100)	16 (100)
Gender			
Male	7 (46.7)	2 (66.7)	7 (43.8)
Female	8 (53.3)	1 (33.3)	9 (56.2)
Ethnic background			
Chinese	12 (80.0)	2 (66.7)	15 (93.7)
Other ethnicities [a]	3 (20.0)	1 (33.3)	1 (6.3)
Age			
≤54 years	7 (46.7)	2 (66.7)	14 (87.5)
55–64 years	4 (26.7)		2 (12.5)
≥ 65 years	4 (26.7)	1 (33.3)	
Marital status			
Single	5 (33.3)	1 (33.3)	n.a
Married	8 (53.3)	2 (66.7)	n.a
Divorced/Widowed	2 (13.3)		n.a
Education level			
Secondary	11 (73.3)	1 (33.3)	n.a
Pre-university and university	4 (26.7)	2 (66.7)	n.a
Site of cancer			
Breast Cancer	7 (46.7)	n.a	n.a
Colorectal cancer	4 (26.7)	n.a	n.a
Other cancers [b]	4 (26.7)	n.a	n.a
Presence of chronic conditions other than cancer			
No other condition	9 (60.0)	1 (33.3)	n.a
1 or more chronic conditions	6 (40.0)	2 (66.7)	n.a

[a] Other ethnicities: Malay, Indian, Arab

[b] Other cancers: liver, prostate, stomach

n.a: Not applicable

Table 2 Key themes, sub-themes and corresponding quotes from interviews

Theme/sub-theme	Design suggestions	Quotes from interviews
Theme 1. Monitoring medication-related problems		
Flexible data input methods	Designated button to report taken doses Report symptoms using checklist of common symptoms with a potential for personalisation, free text entries, audio-records, pictures	"*It would be easier if you can just… tap one time to record the medicine and keep pressing whenever I take the medication just like that.*" *[Patient 10, Male]* "*Checklist should be easier and the typing in would be helpful because I can give a clearer picture on what kind of side effect I am having*" *[Patient 3, Female]* "*I probably would list the top five side effects for each drug. So, it is different for every drug. It means the dispensing pharmacist will sort of customise the side effects to the particular patient. And every option can have severity level.*" *[Pharmacist 8, Female]* "*For me…to feedback what is my side effect, I can speak but I cannot spell. One more thing is, some people will be lazy to write, maybe they prefer to talk, may be you can put a recorder*" *(Patient 5, Female)* "*Sometimes when we serve patients over the phone we can only ask we cannot see, we cannot judge how severe the symptom is. So, with the app, they [patients] can take photo and attach. I mean like WhatsApp. Then you could advise them better*"*[Pharmacist 16, Female].*
Displaying monitored reports/information	Graphical visualisation of trends in patients' medication consumption patterns and reported side effects [Pharmacists] A list of symptoms and display of medication consumption records on a daily basis [Patients]	"*I guess the graph is a good pictorial depiction. If you want to have a quick screen of whether the patient is adherent, you would know. This would help, because we don't need to study it very tediously.*" *[Pharmacist 2, Female]* "*It helps me to relate to the time of drug administration relating to the symptoms… as in… if the symptoms are due to the medication. So, with that in mind I think it is extra valuable if we have this information [symptom report] and the drug administration timing side-by-side, different colour.*" *[Pharmacist 1, Male]* "*Once I have taken my medication then [the app] says I have taken, period. And maybe there should be a column there that says, I have taken my medication, tick. If I have not taken then maybe there is a red cross or something.*" *[Caregiver 1, Male]* "*I don't want to go and think if I haven't taken my medication. Then, I will have a very hard life you know. I don't think it is logical to go back to the time and see whether you took medication or not. What has passed is passed already.*" *[Patient 7, Female]* "*The doctor gives me for 5 months. Then if I finish the medicine before 5 months then I can see [on the app] the balance that is left and I can call the doctor*" *[Patient 14, Female]*
Expected mode of intervention	Near real-time management recommendation via phone calls and in app notifications Chat-based real-time support Involvement of nearby pharmacies in management of medication-related problems	"*If the app, in case of side effects, tell them what to do, it may lessen our work load. Like… if you have diarrhoea do this… if it is serious… do this. They can take charge of their own medication or condition.* *[Pharmacist 12, Female]* "*…if it is just some side effect that is bothering them, but it is not too severe, they could just report inside [the app] so when they come here [the pharmacy] we could review it when we are dispensing.*" *[Pharmacist 4, Male]* "*Most important is that if they [patients] report symptom there must be a follow up. Of course it may depend on how severe the symptoms are. Then the time to respond may vary*" *[Pharmacist 16, Female]* "*Just like me you see, my symptoms come after midnight… pain… I go A&E (Accident and Emergency department). It is always in the midnight. So, this app must standby midnight… call. If not, no point having it already*" *[Patient 7, Female]* "*I think it will be more meaningful if it allows the patient to also communicate with the pharmacist. May be they can send in… they will let the pharmacist know… pharmacist can also reply like a WhatsApp text.*" *[Pharmacist 9, Female]* "*Instead of having a dedicated line 24/7, you spread out the service… you develop some kind of computer system that allows you to… the patient that put the symptoms could be able to grade the severity then, if it is like in danger zone… then it will send SMS to a pharmacy nearby. They*

Table 2 (continued)

Theme/sub-theme	Design suggestions	Quotes from interviews
		would know on the spot. So, it is kind of like grab taxi (a ride sharing service)." *[Pharmacist 2, Female]*
Reminder options	Options to customise the number of reminders and snooze	"*Maybe 2 to 3 reminders would be alright but more than that it would be annoying. Unless there is a feature so you can set it as and when you please. That means you have the full control*" *[Caregiver 1, Male]* "*What if there is another reminder may be nearer the end time, the last time they can take the medicine. May be at that time they are home. Because sometimes they may be out… that is why they don't have the medicine. So, they don't take it… so… if we have the reminders too frequent… and they are not home yet… then they may forget*" *[Pharmacist 7, Female]*
Theme 2. Medication information		
	Focused information on the most important aspects of medication Avoid essay type narrations Enable personalisation of medication information.	"*Medication information should not be in essay form. If possible, [make it] in pointer form so we can really say like, one is done, two is not done…*" *[Patient 4, Female]* "*Maybe keep… which is important, that we need to know about the medicine. People rather play game than to read…you know…*" *[Caregiver 3, Female]* "*What if we are able to edit the medication information part specific for every patient, which is to say like… if we know that this patient is very anxious, we would not want to put too much information that will freak him out. Whereas, if this patient is more like… learner… and they want to have more knowledge, we can put more stuff in for their own reading.*" *[Pharmacist 3, Male]*
Theme 3. Replace or integrate with the current system		
Minimise the need for typing	Auto-fill features and ability to fetch medication data from patients' electronic medical records	"*For the pharmacist… keying things again and again is quite tedious and may be error prone… so it is best to automate.*" *[Pharmacist 7, Female]* "*It will be better if it [dispensing information] can flow from the dispensing or prescribing software that we are using here… then I can enter anything*" *[Pharmacist 6, Male]*
Alerts/notifications in dispensing system (Tell me when something is wrong)	Enable effortless identification of abnormal medication adherence and symptom reports by the pharmacist at the point of patient care	"*If the patient is not adherent, it would be helpful in how we manage the patient…if it can link to the existing system and if it can trigger an alert. I think it will be good.*" *[Pharmacist 12, Female]*
Theme 4. Accessibility of app content on devices other than smartphones		
	Optional provision of app contents on the web to make them accessible from personal computers.	"*In terms of convenience, the phone is more convenient. Because, the computer, you can only do it in the office or at home. For me, I use the computer only when I have to key in my accounting. If not, I don't want to see this thing [a laptop].*" *[Patient 6, Male]* "*I would feel like computer or laptop is not suitable for me. Because you know, like… the cursor must keep on run here and there… So for me hand phone is much easier to operate. For our age we want to touch all this (pointing to the phone screen). Maybe iPad…iPad also touch screen, right?*" *[Patient 5, Female]* "*The hand phone will be better. Just that… when you are at home, then you will use the computer. It is more convenient and bigger.*" *[Patient 13, Female]* "*Setting up reminders and whatever I need to set up, it would be easier to set up on the PC rather than the phone. Personally for me that's what I think. If it syncs up, it would be a lot easier.*" *[Patient 10, Male]*

Flexible data input methods

Pharmacist and patient/caregiver participants had varied preferences on how adherence and side effect reports could be entered to the app. Their opinions mainly focused on improving the usability of the app. Accordingly, reporting taken medications by the touch of a button in the app was suggested by both pharmacists and patients as an input method to monitor adherence. Patients were in favour of easy entry of their symptoms by selecting from a pre-set checklist with

optional use of free text to provide details of their symptoms. In contrast, pharmacists suggested tailoring the symptom checklist based on the medications for individual patients and providing a way to report the level of symptom severity. Both pharmacist and patient participants suggested some unique input methods for reporting side effects. Audio-recording and taking pictures were recommended to facilitate the easy reporting of side effects (Table 2).

Displaying monitored reports/information

Design considerations under this subtheme included those suggested on the web interface for pharmacists (opinions restricted to pharmacist participants) and the patient app (involving opinions from patients). Pharmacists preferred the graphical visualisation of trends in patients' medication consumption patterns and reported side effects on the web interface. Such visual depictions were required to have features that facilitate easy identification of potential medication-related problems. Suggested design requirements to improve usability included the utilisation of different colours to depict variations in the levels of reported symptoms and medication adherence, easy access to all of patients' medication administration reports on one screen and options for the combined visualisation of adherence and symptom reports (Table 2).

In contrast, a list of symptoms with the date and time of report was a sufficient functionality for patients. Patients also showed clear preference towards a feature that displayed their daily medication administration status i.e., taken and missed doses and time of next dose rather than a graphical depiction of trends, which was utilised in the prototype app shown to them (Fig. 1). Moreover, getting easy access to information about remaining balance of medications was considered a very important component of tracking adherence (Table 2).

Expected mode of intervention

Pharmacist and patient participants suggested similar design considerations under this subtheme and their recommendations focused on the inclusion of additional functionalities. Accordingly, in-app notifications of side effect management advice, near real-time phone call-based feedback and review by a health professional on patient's next visit were the suggested interventions for medication-related problems (Table 2).

The kind of medication-related problem i.e., whether it was non-adherence or side effect and the level of severity, influenced participants' preferences for the different alternative modes of intervention. Participants asserted that reports of severe medication side effects and persistent non-adherence should get immediate attention from the clinician while simpler cases of side effects and medication non-adherence could be managed via in-app notifications or during the patient's next visit. However, for some patients, a real-time or near real-time feedback from the clinician was considered compulsory for their adoption of an app to monitor medication-related problems (Table 2).

A chat-based real-time support and involvement of nearby pharmacies in managing side effects were suggested as unique intervention mechanisms for patients who report their symptoms (Table 2).

Reminder options

When it came to the issue of reminding patients to take their medications, the number of reminders (snooze) was considered an important functionality requirement. The general idea forwarded by all groups of participants was that reminders and snooze options should be limited in number. Moreover, pharmacists suggested that there should be a specified duration between the right time the patient should take his/her medication and the last time the reminder for that specific dose could be snoozed. This was to ensure that patients would take their medications while avoiding overdose. Having the option of choosing preferred reminder settings by the user was also suggested as an alternative (Table 2).

Theme 2 medication information

Provision of medication information was considered a crucial aspect of medication management for patients. Participants' suggestions focused on the content and user-friendly presentation of medication information. With respect to content, both pharmacist and patient participants agreed that information should focus on the most important aspects of medication taking behaviour. Patients and caregivers suggested presentation of medication information in bullet points, in language that would be simple to understand and in a way that the most important information could be grasped at a glance. One pharmacist also raised the possibility of personalised medication information depending on the needs of individual patients.

Theme 3 replace or integrate with the current system

This theme was specific to only the pharmacist participants of the study and depicted their opinions about how an app-based medication management system should interact with their current dispensing systems. Many argued that the utilisation of an app-based system by clinicians would depend on the level of integration of the system with their current electronic medical record and related dispensing systems. The subtheme 'minimise the need for typing' focused on the usability-specific design suggestions. In contrast, the subtheme 'alerts/notifications in the dispensing system (tell me when something is wrong)' depicted the functionality requirement suggested by participants (Table 2).

Minimise the need for typing

The process of pharmacists helping to create patients' medication list should not require too much typing by pharmacists. This was to minimise potential errors and time required for patient care. Auto-fill features and ability to fetch medication data from patients' electronic medical records were suggested to minimise the need for typing by pharmacists (Table 2).

Alerts/notifications in the dispensing system [tell me when something is wrong]

According to pharmacists, integration of the app-based medication adherence system with facility-based dispensing systems should be further enhanced by incorporation of alert and notification mechanisms. The alert system would enable effortless identification of abnormal medication adherence and symptom reports by the pharmacist at the point of patient care. The suggested features ranged from simple notifications of whether the patient had been reporting their symptoms and medication taking patterns to mechanisms that could identify problems in patients' adherence behaviour and symptom reports (Table 2).

Theme 4 accessibility of app content on devices other than smartphones

This theme mainly reflected patients' opinions on the accessibility of app contents on devices other than smartphones. Patients considered the accessibility of contents of the app on non-mobile devices to be optional. This was partly due to their perception that smartphones were more convenient. For some patients, their perceived lack of competency in using personal computers was a major reason for not using computers. For others, the issue of accessing app contents on devices other than smartphones was only relevant in the contexts of the place where they want to access the information and the perceived convenience in keying in important details (Table 2).

Discussion

This study identified important functionality and interface design considerations in the development of an app-based system for enhancing OAM adherence. Consistent with UCD principles, the study employed a robust qualitative research methodology that involved patients, caregivers and oncology pharmacists who were potential end-users of such systems [40, 47, 52–54]. This contributes to research in the development of solutions that target the adherence needs of patients taking OAMs.

Monitoring patients' medication adherence behaviour and side effects is an important component of adherence enhancing interventions. Such monitoring functions in an app-based system will help in the prevention and timely management of adherence problems [28, 29, 35]. Input methods that involved a checklist of potential symptoms and a button to report medication administration time were suggested as one of the areas of design considerations to facilitate app-based monitoring of adherence behaviour and side effects. Moreover, participants generally suggested designs that promote easy identification of problems in medication adherence and symptom reports and display of information in a manner that is easy to understand at a glance. This was in line with usability recommendations for mobile app and web-based systems [55, 56]. Similar to previous studies, near real-time management was identified to be an important component of interventions for medication-related problems [35, 57]. Moreover, customisable medication reminder mechanisms were suggested especially with respect to snooze functions. This is an important design consideration in that the effectiveness of adherence apps can be impacted by alert fatigue due to inadequately designed reminders [58, 59].

Patients generally face difficulties in interpreting complex information and prefer to avoid the cognitive task of trying to understand long and detailed descriptions about their medications [44, 60, 61]. The implication of the findings in the current study is that developers should pay attention to the amount of medication information and the format in which it is presented. It is generally recommended that the most important information should be displayed on a given page without the need to scroll. [62] Highlighting the most relevant information is also expected to improve interpretation by patients. [48]. Participants also suggested the potential personalisation of medication information. This can be done through integration with patients' medical records and/or by allowing pharmacists to select relevant information for patients at the point of care.

Researchers advocate the inclusion of adherence data in patients' medical records to ensure collaboration among health care professionals and improve quality of care [29]. This will also help in the monitoring of patients' progress and personalisation of care [22]. In this regard, the findings of this study were consistent with the above recommendations. Apart from this, our findings suggest that the pharmacist acceptability of the app-based system largely depended on the level of integration of the app to existing electronic medical records. Developers will thus have to explore the possibilities for the integration of an app-based adherence system to patients' electronic medical records. This will help in ensuring the widespread adoption of the system by pharmacists in addition to improving the quality of patient care,

Strengths and limitations

The use of a qualitative study design with inductive thematic analysis approach provided an in-depth understanding of the design requirements from the perspectives of patients, caregivers and oncology pharmacists. Another strength of this study was the use of a prototype system to help with the elicitation of participants' opinions regarding important design considerations. This helped in familiarizing participants with the workings and potential features of an adherence app and is consistent with approaches taken in similar studies [42, 46]. However, the findings of this study should be interpreted with some limitations in mind. The design considerations presented here represent participants' opinions in the interview sessions of not more than 1.5 h. The effect of longer-term use of an adherence app on participants' opinions was not considered in this study. It should also be noted that the findings reflected opinions of participants from a single public cancer centre. While the study centre served close to 70% of all public sector cancer cases in Singapore, individuals from other practice settings such as private hospitals might have different opinions.

Conclusion

This study identified important functionality and interface design requirements for app-based OAM adherence interventions from the perspectives of potential end users. Monitoring of medication-related problems, provision of medication information and integration with electronic medical records were considered important components of app-based systems for enhancing OAM adherence. The study further confirmed the general acceptability of provision of adherence enhancing interventions on the mobile platform. Developers and clinicians are encouraged to consult these findings in the design of new app-based systems and evaluation of existing ones.

Appendix 1: Questions for interviews with patients, caregivers and pharmacists

1. Can you tell us your overall impressions of the MedFC app? How did it feel to try MedFC?
2. What was the easiest/most difficult feature of MedFC to use?
3. Did you have any problems using MedFC? If so, please tell us what problems you experienced.
4. What features did you like/disliked? Would you say that some features of MedFC are unnecessary? If so, which ones? What was the most/least preferred feature of MedFC?
5. In your opinion, how could MedFC be improved?
6. Do you feel that important features are missing? If so, which features should MedFC provide in order to be of use in your daily treatment (Patient care)?
7. How would you assess the overall appearance and graphics of MedFC?
8. From your point of view, are there any relevant aspects or questions that you feel should be addressed, but weren't mentioned thus far?

Note: MedFC is the name of the prototype app shown to participants before interviews.

References

1. Sabaté, E., Adherence to long-term therapies: Evidence for action. Switzerland: World Health Organization, 2003.
2. Barillet, M., Prevost, V., Joly, F., and Clarisse, B., Oral antineoplastic agents: How do we care about adherence? *Br. J. Clin. Pharmacol.* 80(6):1289–1302, 2015.
3. Greer, J. A., Amoyal, N., Nisotel, L., Fishbein, J. N., MacDonald, J., Stagl, J., Lennes, I., Temel, J. S., Safren, S. A., and Pirl, W. F., A systematic review of adherence to oral antineoplastic therapies. *Oncologist* 21(3):354–376, 2016.
4. Huang, W. C., Chen, C. Y., Lin, S. J., and Chang, C. S., Medication adherence to oral anticancer drugs: Systematic review. *Expert Rev. Anticancer Ther.* 16(4):423–432, 2016.
5. Shafrin, J., Sullivan, J., Chou, J. W., Neely, M. N., Doan, J. F., and Maclean, J. R., The effect of medication nonadherence on progression-free survival among patients with renal cell carcinoma. *Cancer Manag. Res.* 9:731–739, 2017.
6. Chirgwin, J. H., Giobbie-Hurder, A., Coates, A. S., Price, K. N., Ejlertsen, B., Debled, M., Gelber, R. D., Goldhirsch, A., Smith, I., Rabaglio, M., Forbes, J. F., Neven, P., Lang, I., Colleoni, M., and Thurlimann, B., Treatment adherence and its impact on disease-free survival in the breast international group 1-98 trial of tamoxifen and letrozole, alone and in sequence. *J. Clin. Oncol.* 34(21):2452–2459, 2016.
7. Cutler, R. L., Fernandez-Llimos, F., Frommer, M., Benrimoj, C., and Garcia-Cardenas, V., Economic impact of medication nonadherence by disease groups: A systematic review. *BMJ Open* 8:e016982, 2018.
8. Latremouille-Viau, D., Guerin, A., Gagnon-Sanschagrin, P., Dea, K., Cohen, B. G., and Joseph, G. J., Health care resource utilization and costs in patients with chronic myeloid leukemia with better adherence to tyrosine kinase inhibitors and increased molecular monitoring frequency. *J. Manag. Care Spec. Pharm.* 23(2):214–224, 2017.
9. Gandhi, S., Day, L., Paramsothy, T., Giotis, A., Ford, M., Boudreau, A., and Pasetka, M., Oral anticancer medication adherence, toxicity reporting, and counseling: A study comparing health care providers and patients. *J. Oncol. Pract.* 11(6):498–504, 2015.
10. Verbrugghe, M., Verhaeghe, S., Lauwaert, K., Beeckman, D., and Van Hecke, A., Determinants and associated factors influencing

medication adherence and persistence to oral anticancer drugs: A systematic review. *Cancer Treat. Rev.* 39(6):610–621, 2013.
11. Foulon, V., Schoffski, P., and Wolter, P., Patient adherence to oral anticancer drugs: An emerging issue in modern oncology. *Acta Clin. Belg.* 66(2):85–96, 2011.
12. Car, L. T., Papachristou, N., Urch, C., Majeed, A., Atun, R., Car, J., and Vincent, C., Prioritizing medication safety in care of people with cancer: Clinicians' views on main problems and solutions. *J. Glob. Health* 7 (1), 2017. https://doi.org/10.7189/jogh.07.011001.
13. Hershman, D. L., Sticking to it: Improving outcomes by increasing adherence. *J. Clin. Oncol.* 34(21):2440–2442, 2016.
14. Neven, P., Markopoulos, C., Tanner, M., Marty, M., Kreienberg, R., Atkins, L., Franquet, A., Gnant, M., Neciosup, S., Tesarova, P., Barni, S., and Deschamp, V., The impact of educational materials on compliance and persistence rates with adjuvant aromatase inhibitor treatment: First-year results from the compliance of aromatase inhibitors assessment in daily practice through educational approach (cariatide) study. *Breast* 23(4):393–399, 2014.
15. Gebbia, V., Bellavia, M., Banna, G. L., Russo, P., Ferrau, F., Tralongo, P., and Borsellino, N., Treatment monitoring program for implementation of adherence to second-line erlotinib for advanced non-small-cell lung cancer. *Clin. Lung Cancer* 14(4):390–398, 2013.
16. Mathes, T., Antoine, S.-L., Pieper, D., and Eikermann, M., Adherence enhancing interventions for oral anticancer agents: A systematic review. *Cancer Treat. Rev.* 40(1):102–108, 2014.
17. Sommers, R. M., Miller, K., and Berry, D. L., Feasibility pilot on medication adherence and knowledge in ambulatory patients with gastrointestinal cancer. *Oncol. Nurs. Forum* 39(4):E373–E379, 2012.
18. Hadji, P., Blettner, M., Harbeck, N., Jackisch, C., Luck, H. J., Windemuth-Kieselbach, C., Zaun, S., and Kreienberg, R., The patient's anastrozole compliance to therapy (pact) program: A randomized, in-practice study on the impact of a standardized information program on persistence and compliance to adjuvant endocrine therapy in postmenopausal women with early breast cancer. *Ann. Oncol.* 24(6):1505–1512, 2013.
19. Kav, S., and Tokdemir, G., The effect of structured education to patients receiving oral agents for cancer treatment on medication adherence and self-efficacy. *Asia Pac. J. Oncol. Nurs.* 4(4):290, 2017.
20. Spoelstra, S. L., Given, C. W., Sikorskii, A., Coursaris, C. K., Majumder, A., DeKoekkoek, T., Schueller, M., and Given, B. A., Proof of concept of a mobile health short message service text message intervention that promotes adherence to oral anticancer agent medications: A randomized controlled trial. *Telemed. J. E Health* 22(6):497–506, 2016.
21. Nieuwlaat, R., Wilczynski, N., Navarro, T., Hobson, N., Jeffery, R., Keepanasseril, A., Agoritsas, T., Mistry, N., Iorio, A., Jack, S., Sivaramalingam, B., Iserman, E., Mustafa, R. A., Jedraszewski, D., Cotoi, C., and Haynes, R.B., Interventions for enhancing medication adherence. *Cochrane Database Syst. Rev.* (11):Cd000011, 2014.
22. Car, J., Tan, W. S., Huang, Z., Sloot, P., and Franklin, B. D., Ehealth in the future of medications management: Personalisation, monitoring and adherence. *BMC Med.* 15(1):73, 2017.
23. Deloitte., Mobile multiplies: Global mobile consumer survey, 2015. https://www2.deloitte.com/content/dam/Deloitte/sg/Documents/technology-media-telecommunications/sg-tmt-global-mobile-consumer-survey-noexp.pdf. Accessed 14 December 2015.
24. Pew Research Center., Smartphone ownership and internet usage continues to climb in emerging economies, 2016. http://www.pewglobal.org/files/2016/02/pew_research_center_global_technology_report_final_february_22__2016.pdf. Accessed 31 August 2016.
25. Ali, E. E., Leow, J. L., Chew, L., and Yap, K. Y., Patients' perception of app-based educational and behavioural interventions for enhancing oral anticancer medication adherence. *J. Cancer Educ.*, 2017. https://doi.org/10.1007/s13187-017-1248-x.
26. Haase, J., Farris, K. B., and Dorsch, M. P., Mobile applications to improve medication adherence. *Telemed. J. E Health* 23(2):75–79, 2017.
27. Spoelstra, S. L., and Sansoucie, H., Putting evidence into practice: Evidence-based interventions for oral agents for cancer. *Clin. J. Oncol. Nurs.* 19(3 Suppl):60–72, 2015.
28. Tricarico, C., Peters, R., Som, A., Javaherian, K., and Ross, W., Epxmedtracking: Feasibility evaluation of an sms-based medication adherence tracking system in community practice. *JMIR Res. Protoc.* 6(5):e87, 2017.
29. Marcum, Z. A., Sevick, M. A., and Handler, S. M., Medication nonadherence: A diagnosable and treatable medical condition. *JAMA* 309(20):2105–2106, 2013.
30. de Vries, S. T., Denig, P., Lasheras Ruiz, C., Houyez, F., Wong, L., Sutcliffe, A., PGM, M., and Consortium IMIW-RWPb, Interest in a mobile app for two-way risk communication: A survey study among european healthcare professionals and patients. *Drug Saf.*, 2018. https://doi.org/10.1007/s40264-018-0648-0.
31. Berkowitz, C. M., Zullig, L. L., Koontz, B. F., and Smith, S. K., Prescribing an app? Oncology providers' views on mobile health apps for cancer care. *JCO Clin. Cancer Inform.* 1 (1), 2017. https://doi.org/10.1200/CCI.17.00107.
32. Azevedo, R., Bernardes, M., Fonseca, J., and Lima, A., Smartphone application for rheumatoid arthritis self-management: Cross-sectional study revealed the usefulness, willingness to use and patients' needs. *Rheumatol. Int.* 35(10):1675–1685, 2015.
33. Israni, A., Dean, C., Kasel, B., Berndt, L., Wildebush, W., and Wang, C. J., Why do patients forget to take immunosuppression medications and miss appointments: Can a mobile phone app help? *JMIR Publ. Health Surveill.* 2(1):e15, 2016.
34. Kessel, K. A., Vogel, M. M., Schmidt-Graf, F., and Combs, S. E., Mobile apps in oncology: A survey on health care professionals' attitude toward telemedicine, mhealth, and oncological apps. *J. Med. Internet Res.* 18(11):e312, 2016.
35. Kessel KA, Vogel MME, Kessel C, Bier H, Biedermann T, Friess H, Herschbach P, von Eisenhart-Rothe R, Meyer B, Kiechle M, Keller U, Peschel C, Schmid RM, Combs SE (2017) Mobile health in oncology: A patient survey about app-assisted cancer care. *JMIR Mhealth Uhealth* 5 (6):e81.
36. Ali, E. E., Teo, A. K. S., Goh, S. X. L., Chew, L., and Yap, K. Y., MedAd-AppQ: A quality assessment tool for medication adherence apps on iOS and Android platforms. *Res. Soc. Adm. Pharm.* 14:1125–1133, 2018.
37. Dayer, L. E., Shilling, R., Van Valkenburg, M., Martin, B. C., Gubbins, P. O., Hadden, K., and Heldenbrand, S., Assessing the medication adherence app marketplace from the health professional and consumer vantage points. *JMIR Mhealth Uhealth* 5(4):e45, 2017.
38. Santo, K., Richtering, S. S., Chalmers, J., Thiagalingam, A., Chow, C. K., and Redfern, J., Mobile phone apps to improve medication adherence: A systematic stepwise process to identify high-quality apps. *JMIR Mhealth Uhealth* 4(4):e132, 2016.
39. Ahmed, I., Ahmad, N. S., Ali, S., Ali, S., George, A., Saleem Danish, H., Uppal, E., Soo, J., Mobasheri, M. H., King, D., Cox, B., and Darzi, A., Medication adherence apps: Review and content analysis. *JMIR Mhealth Uhealth* 6(3):e62, 2018.
40. McCurdie, T., Taneva, S., Casselman, M., Yeung, M., McDaniel, C., Ho, W., and Cafazzo, J., Mhealth consumer apps: The case for user-centered design. *Biomed. Instrum. Technol.* 46(S2):49–56, 2012.
41. Bernhard, G., Mahler, C., Seidling, H. M., Stützle, M., Ose, D., Baudendistel, I., Wensing, M., and Szecsenyi, J., Developing a

shared patient-centered, web-based medication platform for type 2 diabetes patients and their health care providers: Qualitative study on user requirements. *J. Med. Internet Res.* 20(3):e105, 2018.
42. Williamson, S. S., Gorman, P. N., and Jimison, H. B., A mobile/web app for long distance caregivers of older adults: Functional requirements and design implications from a user centered design process. *AMIA Annu. Symp. Proc.* 2014:1960–1969, 2014.
43. Paolella, G. A., Boyd, A. D., Wirth, S. M., Cuellar, S., Venepalli, N. K., and Crawford, S. Y., Adherence to oral anticancer medications: Evolving interprofessional roles and pharmacist workforce considerations. *Pharmacy (Basel, Switzerland)* 6(1):23, 2018.
44. Hsu, G. I.-H., Crawford, S. Y., Paolella, G., Cuellar, S., Wirth, S. M., Venepalli, N. K., Wang, E., Hughes, D., and Boyd, A. D., Design of customized mobile application for patient adherence to oral anticancer medications utilizing user-centered design. *J. Biocommun.* 41(1):5–14, 2017.
45. Fishbein, J. N., Nisotel, L. E., MacDonald, J. J., Amoyal Pensak, N., Jacobs, J. M., Flanagan, C., Jethwani, K., and Greer, J. A., Mobile application to promote adherence to oral chemotherapy and symptom management: A protocol for design and development. *JMIR Res. Protoc.* 6(4):e62, 2017.
46. Whiteley, L., Brown, L., Lally, M., Heck, N., and van den Berg, J. J., A mobile gaming intervention to increase adherence to antiretroviral treatment for youth living with hiv: Development guided by the information, motivation, and behavioral skills model. *JMIR Mhealth Uhealth* 6(4):e96, 2018.
47. Groshek, M. R., Oldenburg, J., Sarasohn-Kahn, J., and Sitler, B., Mhealth app essentials: Patient engagement, considerations, and implementation. Healthcare Information and Management Systems Society (HIMSS), 2015. http://www.himss.org/mhealth-app-essentials-patient-engagement-considerations-and-implementation?ItemNumber=39175. Accessed 17 March 2018.
48. Fraccaro, P., Vigo, M., Balatsoukas, P., van der Veer, S. N., Hassan, L., Williams, R., Wood, G., Sinha, S., Buchan, I., and Peek, N., Presentation of laboratory test results in patient portals: Influence of interface design on risk interpretation and visual search behaviour. *BMC Med. Inform. Decis. Mak.* 18(1):11, 2018.
49. Ali, E. E., Cheung, K. L., Lee, C. P., Leow, J. L., Yap, K. Y., and Chew, L., Prevalence and determinants of adherence to oral adjuvant endocrine therapy among breast cancer patients in Singapore. Asia Pac. J. Oncol. Nurs. 4(4):283–289, 2017.
50. Braun, V., and Clarke, V., Using thematic analysis in psychology. *Qual. Res. Psychol.* 3(2):77–101, 2006.
51. Huang, R., Rqda: R-based qualitative data analysis. R package version 3.3.2, 2016. http://rqda.r-forge.r-project.org/. Accessed 7 February 2017.
52. Mirkovic, J., Kaufman, D. R., and Ruland, C. M., Supporting cancer patients in illness management: Usability evaluation of a mobile app. *JMIR Mhealth Uhealth* 2(3):e33, 2014.
53. Darlow, S., and Wen, K.-Y., Development testing of mobile health interventions for cancer patient self-management: A review. *Health Inform. J* 22(3):633–650, 2016.
54. Whittaker, R., Merry, S., Dorey, E., and Maddison, R., A development and evaluation process for mhealth interventions: Examples from New Zealand. *J. Health. Commun.* 17(Suppl 1):11–21, 2012.
55. Nielsen, J., 10 usability heuristics for user interface design, 1995. https://www.nngroup.com/articles/ten-usability-heuristics/. Accessed 12 September 2017.
56. Joyce, G., Lilley, M., Barker, T., and Jefferies, A., Mobile application usability: Heuristic evaluation and evaluation of heuristics. In: Advances in human factors, software, and systems engineering. Springer International Publishing, 77–86, 2016.
57. Alpert, J. M., Morris, B. B., Thomson, M. D., Matin, K., and Brown, R. F., Implications of patient portal transparency in oncology: Qualitative interview study on the experiences of patients, oncologists, and medical informaticists. *JMIR Cancer* 4(1):e5, 2018.
58. Finitsis, D. J., Pellowski, J. A., and Johnson, B. T., Text message intervention designs to promote adherence to antiretroviral therapy (art): A meta-analysis of randomized controlled trials. *PloS One* 9(2):e88166, 2014.
59. Liu, X., Lewis, J. J., Zhang, H., Lu, W., Zhang, S., Zheng, G., Bai, L., Li, J., Li, X., Chen, H., Liu, M., Chen, R., Chi, J., Lu, J., Huan, S., Cheng, S., Wang, L., Jiang, S., Chin, D. P., and Fielding, K. L., Effectiveness of electronic reminders to improve medication adherence in tuberculosis patients: A cluster-randomised trial. *PLoS Med.* 12(9):e1001876, 2015.
60. Koster ES, Philbert D, van Dijk L, Rademakers J, de Smet P, Bouvy ML, Vervloet M (2018) Recognizing pharmaceutical illiteracy in community pharmacy: Agreement between a practice-based interview guide and questionnaire based assessment. *Res. Soc. Admin. Pharm. : RSAP.* https://doi.org/10.1016/j.sapharm.2018.01.009
61. Godlee, F., Too much information. *BMJ* 349:g5153–g5153, 2014.
62. Cheng, C., and Dunn, M., How well are health information websites displayed on mobile phones? Implications for the readability of health information. *Health Promot. J. Austr.* 28(1):15–20, 2017.