

Usability and User Experience of an mHealth App for Therapy Support of Breast Cancer Patients: A Mixed-Methods Approach Using Eye-Tracking

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Abstract

Background: Early identification of quality-of-life losses and side effects is a key challenge in breast cancer therapy. Digital tools can implement regular screening for side effects as well as patient education for improved self-management. Enable, a smartphone app, was used in a multicenter, prospective randomized controlled trial in three breast cancer centers. The app simultaneously serves as a therapy companion, as a tool for documenting of quality of life, and patient-reported side effects. The need for the usage of digital tools to improve patient care such as tumor therapy, therapy adherence, and patient satisfaction is continually on the rise. However, the evidence on the effect of such long-term usage of mobile health (mHealth) apps in aftercare for breast cancer patients has been limited. Therefore, evaluating the usability and understanding the user experience of such mHealth apps is an important research question.

Objective: A usability study was conducted to find out how patients rate their engagement with the app, the user experience, and the benefits of using the app.

Methods: A mixed-methods approach was chosen, including an eye-tracking procedure, a standardized usability questionnaire (mHealth App usability questionnaire, MAUQ) and semi-structured interviews. Interviews were transcribed verbatim and analyzed according to thematic analysis. The analysis of the eye-tracking data was carried out using the tracker-integrated software. Descriptive analysis was carried out for the quantitative data.

Results: The MAUQ results indicated good overall usability for two different points of time. The analysis of the eye-tracking recordings and the interviews showed that users found the Enable app easy to use. The design of the app, information about therapies and side effects, and the usefulness of the app as a therapy companion were rated positively by the participants. However, requests for additional app features as well as suggestions for improving the content and usability of the app were also identified. Relevant themes included the optimization of the appointment feature, updating the app's content regularly, and the self-administration of content. A key point is that the app currently informs the patient mainly in a passive way.

Conclusions: The results of this usability study demonstrate good usability of the Enable App as well as the potential for further development. We could conclude from patients' feedback and requests that the app needs to be further developed to allow for active input of patient information and thus encourage continued use of the app throughout therapy. Our findings will also help other researchers in tailoring their mHealth apps towards the actual needs of patients in breast cancer therapy.

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Original Manuscript

Usability and User Experience of an mHealth App for Therapy Support of Breast Cancer Patients: A Mixed-Methods Approach Using Eye-Tracking

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Abstract

Background: Early identification of quality-of-life (QoL) losses and side effects are key challenges in breast cancer therapy. Digital tools can be a helpful component of therapy support. *Enable*, a smartphone app, was used in a multicenter, prospective randomized controlled trial in three breast cancer centers. The app simultaneously serves as a therapy companion (e.g. by displaying appointments), as a tool for documenting of QoL (e.g., by enabling data collection for QoL questionnaires), and documentation of patient-reported side effects. The need for the usage of digital tools is continually on the rise. However, evidence of the effects of long-term usage of mobile health (mHealth) apps in aftercare for breast cancer patients is limited. Therefore, evaluating the usability and understanding the user experience of this mHealth app could potentially contribute valuable insights in this field.

Objective: A usability study was conducted to explore how patients with breast cancer under neoadjuvant, adjuvant, or palliative outpatient treatment rate their engagement with the app, the user experience and benefits of using the app.

Methods: A mixed-methods approach was chosen to combine subjective and objective measures, including an eye-tracking procedure, a standardized usability questionnaire (mHealth App usability questionnaire, MAUQ) and semi-structured interviews. Participants were surveyed twice during the study. Interviews were transcribed verbatim and analyzed according to thematic analysis. The analysis of the eye-tracking data was carried out using the tracker-integrated software. Descriptive analysis was carried out for the quantitative data.

Results: The MAUQ results (n=105) indicated good overall usability for two different points of time (4 weeks: 89.15, 10 weeks: 85.57). The qualitative analysis of the eye-tracking recordings (n=10) and the interviews (n=16) showed that users found the *Enable* app easy to use. The design of the app, information about therapies and side effects, and the usefulness of the app as a therapy companion were rated positively. In addition, participants contributed requests for additional app features and suggestions for improving the content and usability of the app. Relevant themes included the optimization of the appointment feature, updating the app's content regularly, and the self-administration. In contrast to the app's current 'passive method of operation, participants expressed desire for more active engagement by means such as messaging, alarms or emails.

Conclusion: The results of this study demonstrate good usability of the *Enable* App as well as the potential for further development. We concluded from patients' feedback and requests that mHealth apps could benefit from giving patients a more active role (e.g., being able to actively document side effects as they occur). In addition, regular updates of app content could further contribute to encouraging continued use of mHealth apps. Our findings may also assist other researchers in tailoring their mHealth apps towards the actual needs of patients undergoing breast cancer therapy.

Keywords: mHealth, usability, breast cancer, eye-tracking, user interface, mixed-methods

Background

Breast cancer is the most common tumor detected in women in the Western world. One in eight women will develop breast cancer during her lifetime. In Germany, there are 69,000 new cases per year [1]. The diagnosis is a drastic event in the lives of those affected. Even though the mortality rate has decreased in recent years, processing and dealing with the new life situation is a great challenge for patients and their social environment [2]. At the onset of therapy, patients can have a high desire for education and information. Providing patients with reliable sources for information and support services is therefore a major and important task for the treatment team. Digitalization in medicine offers great potential for supporting the exchange of information and communication between patients and health care providers [3–5]. These benefits can be realized through the use of mobile health applications (mHealth apps), which can encompass several helpful functions for patients, such as provision of educational materials, appointment or medication reminders, and diaries. For the cohort of patients with breast cancer, many of these mHealth apps are already available or in development [6]. This cohort also showed a high readiness for using health technology, indicating that mHealth apps are an appropriate means of support in the early phase of breast cancer treatment.

A recent study by Chen et al. [7] also found that remote monitoring of symptoms between clinical visits could not only improve patient-provider communication, but also prepare patients for subsequent chemotherapy cycles and support symptom management. Within the joint project "Center for Innovative Care" (ZIV), a network of five university hospitals in southwest Germany, a new mHealth app for patients with breast cancer was developed. This therapy support tool, called the *Enable app*, aimed to combine known benefits of mHealth tools with an innovative reactive assessment of patient reported outcomes (PRO). It was conceptualized as an iOS/Android mobile application for smartphones and developed by members of the research team with support of software developers. It contains educational content, information about the side effects of therapies, medications, and information about other support services such as psycho-oncology or nutritional counseling in the form of static text and images. A progress bar visualizes the patient's individual therapy status in terms of clinical treatment over time (i.e. cycles of treatment). In addition to its role as a therapy companion, the app serves as a measurement tool to systematically

record patient satisfaction, health related quality of life (HRQoL), and patient-reported adverse events (PRO-AE). It monitors both the neoadjuvant, adjuvant and follow-up situation in patients with indications for surgery, chemotherapy, radiation, or systemic therapy with primary or metastatic breast cancer. Figure 1 shows exemplary screenshots of the *Enable* app's start page, the questionnaire display, and information about treatments. Since studies have shown that physicians generally underestimate a large proportion of relevant side effects patients are empowered to report PRO data and side effects directly through the app. In cases of significant treatment-related deterioration, the care team is alerted and recommendations are sent to the patient. This more relevant treatment information, in turn, helps improve therapy monitoring, treatment quality and patient satisfaction [8,9].

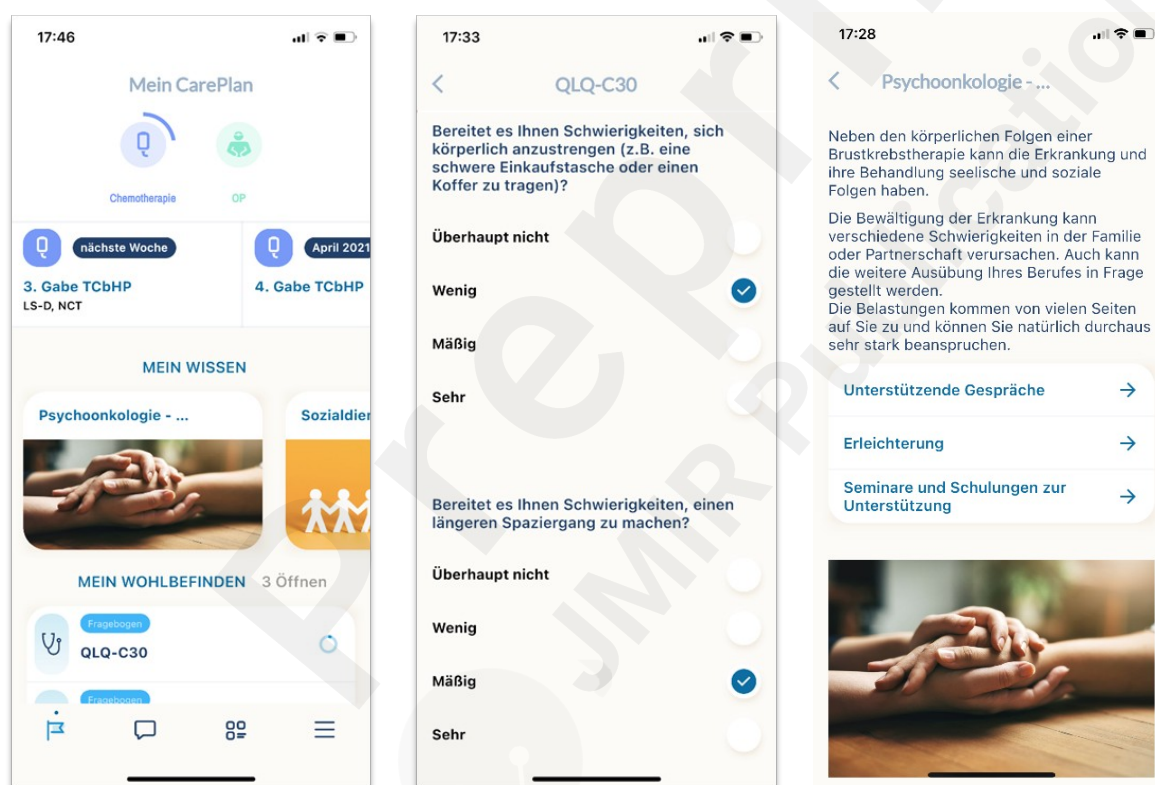


Figure 1 Exemplary contents of the *Enable* app

Clinical outcomes of the use of the *Enable* app were studied in the ENABLE RCT. Other research questions addressed in the ENABLE RCT relate to improving patients' adherence to therapy, recognizing, and treating critical side effects in a timely manner as well as measuring HRQoL of different therapy strategies. All study participants underwent quality of life assessments at six time points during and after adjuvant or neoadjuvant chemotherapy. In the intervention group, an additional short

weekly quality of life questionnaire (EQ-VAS) was administered. In case of deteriorating results, further screening for side effects was triggered, alerting study staff and enabling an immediate contact with the patient to provide support in all phases of breast cancer therapy (reactive patient reported outcome (PRO) assessment). The control group received only the app without the reactive PRO assessment.

The body of scientific literature shows that good usability is an important factor for the success of an mHealth app. More specifically, usability can influence patients' acceptance and adoption of mHealth [10,11]. Usability is defined by Nielsen [12] as a *"quality attribute that assesses how easy interfaces are to use"*. According to ISO 9241–1, usability is the *"extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use"* [13]. While usability focuses exclusively on the process of using an app or device, user experience involves the users' subjective feelings that result from the use or anticipated use of a system or a product. For the evaluation of mHealth, both concepts are relevant in order to get a comprehensive view of influencing factors [14].

Good usability can help ensure that the app can be used intuitively by patients and health care providers, which in turn improves compliance and increases the effectiveness of the app. A review from Zapata et al. [10] demonstrates the importance of adapting mHealth apps to patients' needs. Relevant usability themes of similar apps were, for example, a streamlining of the navigation paths, a clearer information architecture or the desire for personalization [15,16]. Recent research also shows that usability assessment is an essential step in the mHealth app development process [17,18]. It is important to ensure that the app is easy to use for the target group and provides the desired benefits [12]. However, a systematic review by Jongerius et al. [6] showed that only one of 29 mHealth apps for breast cancer care, which were studied in their work, underwent and published a usability assessment. In order to address the aforementioned requirements and to achieve sustainable and effective use of the *Enable App*, investigation of usability and user experience is indispensable. Therefore, the study presented in this paper intended to gain an understanding of how patients use the app. The aim was to investigate how patients evaluate their engagement with the app, the user experience, and the benefits of using the app. These findings will serve as a basis for further optimization and adaptation of the app to the patients' needs.

A mixed method approach provides the opportunity to collect, triangulate and analyze qualitative and quantitative data allowing for the possibility to interpret the findings from one research approach (i.e., qualitative and quantitative) to explain the data generated from the other research approaches. Furthermore, it allows for the use of a qualitative approach to illustrate quantitative findings or the integration of various research approaches to provide a thorough and comprehensive picture of the study [19,20] Previous studies [15,21,22] have indicated that interviews and usability questionnaires are prevailing methods employed for assessing usability of mHealth apps. However, there are limited studies regarding the real-time capture of users' visual interactions and the subsequent retrospective analysis of user engagement of mHealth apps through techniques like eye-tracking. Eye-tracking, a sensor technology, is employed to ascertain an individual's presence and record their real-time eye movements. This approach is also utilized to assess the usability of technologies by showcasing decision-making processes through the analysis of eye movement patterns [23,24].

Developing new mHealth applications can be time-consuming and requires several iterations of testing and evaluation. The *ENABLE* project aims to evaluate both usability and clinical outcomes of the *Enable* app within the same RCT, which could be a promising approach to speed up development, testing, and planning for further implementation. This paper presents a usability study, nested in the *ENABLE* RCT, and following a mixed-methods approach incorporating the eye-tracking method. The objective of this usability study is to explore how patients with breast cancer under neoadjuvant, adjuvant, or palliative outpatient treatment rate their engagement with the app, the user experience and benefits of using the app.

Methods

Study Design

This study was designed following a mixed-methods approach, combining real world user experience and standardized observations in a lab setting. The study took place at the Department of Gynecology and Obstetrics, Heidelberg University Hospital, Germany. All participants gave written informed consent. Confidentiality and anonymity were ensured throughout the entire study. The study was conducted in accordance with the Declaration of

Helsinki and was approved by the Ethics Committee of the Heidelberg University Hospital (S-685/2020).

Procedure

Study population and recruitment

Study participants were recruited from the intervention and control group in the *ENABLE* RCT patient cohort. The *ENABLE* RCT had the following inclusion criteria: Diagnosis of invasive or metastatic breast cancer and planning neoadjuvant, adjuvant, or palliative therapy in an outpatient treatment setting (indications for surgery, chemo-, radio- and systemic therapy), minimum age of 18 years, German language skills, and possession of a smartphone with internet access. Due to technical requirements for eye-tracking, patients wearing bifocals were excluded from participation. At study enrolment, patients were asked about their interest in participating in the usability study. All interested patients at the Department of Gynecology and Obstetrics, Heidelberg University Hospital, Germany received written and verbal information regarding the content and aim of the study and the respective data protection regulations. On the informed consent form, patients could indicate if they were interested in participating in the usability aspect of the *ENABLE* RCT. Patients who consented to participate in the nested usability study were contacted individually to schedule appointments for their participation following a convenience sampling strategy. No reimbursement was provided. The target sample size was planned to be 100 questionnaires, 15 qualitative interviews and 10 eye-tracking studies. Patient recruitment took place from March 2021 until September 2023.

Instruments

The mHealth-App Usability Questionnaire (MAUQ) [25] in a German translation was chosen to quantitatively assess the usability of the *Enable* app [26]. The MAUQ enables the usability assessment of mobile health apps from the user's perspective. The MAUQ standalone version was formulated to evaluate three constructs of usability, Ease of use, Interface and Satisfaction, and Usefulness as well as the overall usability score for the app through descriptive statistics. Each of the items of the MAUQ are rated on a Likert scale ranging from 1 (strongly agree) to 7 (strongly disagree) with the overall score spanning from 0 to 100. In addition, the questionnaires were complemented with a set of questions developed by the authors. Newly added questions concerned the use of other mHealth apps, smartphone ownership, sociodemographic questions, and a free-text field to be able

to describe the study sample more precisely. The target sample size was $n = 100$.

In addition to the questionnaire survey, open-ended, semi-structured, guide-based interviews with patients were conducted to explore their perspectives on the usability of the *Enable* app. The interviews were conducted by two female researchers (CA and LW) with a professional background in Health Services Research and Implementation Science. Both researchers have profound experience in qualitative interviewing. The interview guide (Appendix 1) was developed by a team of health services researchers (LW and JM) based on an extensive literature review and recommendations from the app developers. Afterwards, the interview guide was pre-tested. This study is reported according to the COREQ reporting guideline (Appendix 2) for qualitative research [27].

Furthermore, to objectively assess how patients interact with the app and to identify potential usability issues, an eye-tracking study was conducted. The eye-tracking study was carried out by a usability expert (PM) and a team of health services researchers (CA and LW). A total of five tasks were formulated for the eye-tracking study (Appendix 3) such as app login, filling in a questionnaire, searching and reading an article, and logging out from the app. To determine the comprehensibility of the tasks, the duration of the study as well as the working of the *Enable* app, two pilot tests were conducted. Following the pilot test outcome, the eye-tracking studies were carried out for 60 minutes with each participant, including the eye tracker setup and the retrospective interview.

The chosen mixed-methods approach is designed to systematically collect, cross-validate, and analyze both qualitative data (derived from semi-structured interviews and eye-tracking) and quantitative data (obtained through the MAUQ questionnaire). The inclusion of the eye-tracking method within the usability study enriches the capacity to integrate subjective and objective metrics. The qualitative aspect of the eye-tracking analysis enhances the understanding of the user's app perception within the context of individual interactions and app usability. Simultaneously, semi-structured interviews enable an assessment of the practicality of integrating the *Enable app* into daily routines. In contrast, the quantitative data derived from the questionnaire provides precise metrics related to usability measurements.

Hence, the mixed-methods approach investigates the "why" and "how" aspects through qualitative inquiry, supplementing conventional quantitative and visual data analyses. The

fusion of direct observations of user interactions with the app, post-study retrospective interviews, semi-structured interviews, and the usability questionnaire collectively supports the contextualization and comprehensive interpretation of the gathered data.

Data collection and analysis

Quantitative measures

The MAUQ and the socio-demographic questionnaire were mailed twice to all patients after inclusion into the RCT. Data collection lasted from May 2021 to October 2022. Study data were collected and managed using REDCap electronic data capture tools [28] hosted at the Heidelberg University Hospital. REDCap (Research Electronic Data Capture) is a secure, web-based software platform designed to support data capture for research studies. After completion, all data were exported from REDCap to R statistical software (version 4.0.4, R Foundation for Statistical Computing). All data were checked for completeness and analyzed by study team members. A descriptive analysis of the questionnaires was performed using R. Means and absolute and relative frequencies were calculated.

Qualitative measures

Interviews were performed after participants used the app for eight weeks. The interviews took place partly face-to-face at the clinic and by telephone, in consideration of current guidelines for preventing infections with SARS-CoV-2 (i.e., participants and researchers wore appropriate masks and distance was kept at all times). Non-participants were not present during the interviews. No relationship with participants was established prior to study participation. No repeat interviews were carried out. No field notes were taken. All interviews were audiotaped, pseudonymized, and transcribed verbatim. Transcripts were not returned to participants for verification. Data were transcribed, managed, and analyzed with MAXQDA Standard 2020 Verbi software (Release 20.4.1). After 16 interviews, data saturation was discussed among the researchers. As no themes occurred in the later interviews, the researchers agreed that data saturation has been reached and no additional interviews were necessary. After completed data collection, data analysis was conducted independently by two researchers (CA and LW) according to thematic analysis [29]. First, the researchers reviewed the transcripts independently and identified themes from the literature and the interview guide and inductively from data. Second, discrepancies were discussed in iterative cycles until consensus on themes and the final coding scheme was reached. All themes were organized into main- and subthemes. Each theme was clearly

defined by a quote from the interview transcripts (Appendix 4). Quantitative and qualitative data were analyzed separately.

For the eye-tracking data collection process, an assigned room at the hospital was used in which the Tobii Pro Nano (Tobii AB, Danderyd, Sweden) was installed, an eye-tracking device specifically designed for small screens, including smartphones. This hardware features a sampling rate of 60Hz and possesses dimensions measuring 17 cm x 1.8 cm x 1.3 cm, along with a USB Type A connector. The Tobii Pro Nano was securely affixed to the mobile stand alongside the *Enable app*, which had been installed on a smartphone. To facilitate data capture, both the smartphone and the eye tracker were connected to a laptop running the Tobii Pro Lab software (Lab version 1.194) via USB cables. For the purposes of this study, both an Android device (Samsung Galaxy 10, Android version 11) and an iOS device (iPhone 11, iOS version 14.6) were available for users. The choice of smartphone was contingent upon the user's preferred operating system. The eye tracker records the participants' interaction with the *Enable app* such as task completion time, participants' navigation, gaze plots, and heat maps [30–32]. A heat map is used when fixation-duration data is collected [30,31] and a gaze plot is used when the location of eye movement data is collected [33,34]. For this study, after the completion of tasks, the study moderators composed post hoc questions pertaining to the interactions, participants' experiences, and usability issues observed during the procedure. The post hoc questions were discussed with the participants in a short debrief. The debrief sessions were held to gather direct feedback from participants after having interacted with the *Enable app*, allowing for a deeper understanding of the participants' behavior and interaction with the app. Through these debrief sessions, the participant can provide context and commentary on their behavior and interaction [35]. Engaging users with post hoc questions, such as using images or live content from recorded sessions, allowed for a better understanding of the real-life context with minimal disruption, as it facilitated the recall of situational information prompted by data, sound, or visual imagery.

The data analysis was based on the recordings of the study sessions concurrent with the eye movements of participants. The retrospective analysis involved transcribing participants' feedback from the audio recordings obtained during the debrief sessions. Data analysis also included the completion of predefined tasks by the participants, task completion time, and the completion status of the tasks. The analysis focused on task

performance analysis, and the problem analysis of eye-tracking metrics and participants' feedback.

Results

The MAUQ was sent to 165 patients recruited within the *ENABLE* RCT. The response rate was 64% for the MAUQ at week 4 and 56% for the MAUQ at week 20. A total of 105 questionnaires for the MAUQ at week 4 (including sociodemographic data) and 93 questionnaires for the MAUQ at week 20 were analyzed. Sixteen patients were recruited for the interviews and 10 for the eye-tracking procedure. The mean duration of the interviews was 25 minutes.

Sociodemographics

The sociodemographic data of participants in the *ENABLE* usability study are shown in Table 1, and additional characteristics of participants regarding smartphone and app usage are shown in Table 2. The mean age of all participants (n=105) was 51.3 years (SD 10.9).

Table 1 Sociodemographic characteristics of the participants

Characteristics	Interview participants (N=16)	Eye-tracking participants (N=10)	Questionnaire participants (N=105)
Gender, n (%)			
Female	16 (100)	10 (100)	105 (100)
Age group (years), n (%)			
<30	2 (12.5)	2 (20)	2 (1.9)
30 to 40	2 (12.5)	1 (10)	16 (15.2)
41 to 50	6 (37.5)	3 (30)	32 (30.5)
51 to 60	4 (25)	2 (20)	33 (31.5)
61 to 70	1 (6.3)	-	16 (15.2)
71 to 80	1 (6.3)	-	6 (5.7)
Education, n (%)			
Academic degree	9 (56.3)	6 (60)	37 (35.2)

High school education	-	-	13 (12.4)
Lower or intermediate secondary school	5 (31.3)	4 (40)	54 (51.4)
Prefer not to say	2 (12.5)	-	1 (1.0)
Employment, n (%)			
Employed	11 (68.8)	9 (90)	66 (63)
Unemployed	-	-	17 (16.2)
Studying or vocational training	1 (6.3)	1 (10)	1 (1.0)
Retired	2 (12.5)	-	18 (17.1)
Prefer not to say	2 (12.5)	-	3 (2.9)

Table 2 Additional participant characteristics on smartphone and app use

Characteristics	Interview participants	Eye-tracking participants	Questionnaire participants
Usage of smartphone (years), n (%)	N=13	N=8	N=105
≤ 10 years	9 (69.2)	5 (62.5)	56 (53.3)
> 10 years	4 (30.8)	3 (37.5)	44 (41.9)
Prefer not to say	-	-	5 (4.8)
Usage of other mHealth apps, n (%)	N=14	N=10	
Yes	4 (28.6)	5 (50)	33 (31.4)
No	10 (71.4)	5 (50)	71 (67.6)
Prefer not to say	-	-	1 (1.0)
Frequency of app use, n (%)	N=11	N= 8	
Daily / several days a week	5 (45.5)	3 (37.5)	-
Once a week	5 (45.5)	4 (50)	-
Once a month or less	1 (9.0)	1 (12.5)	-

Quantitative measures

The MAUQ questionnaire [25] was used to collect quantitative data on the usability of the *Enable* app. The data was collected in Week 4 and Week 20 starting from the baseline of the study. Quantitative data gathered from the MAUQ was analyzed using descriptive statistics. Only complete questionnaires were evaluated for which the MAUQ score could be calculated. Hence, 34 incomplete questionnaires collected at week 4 and 27 at week 20 were excluded from analysis. According to Zhou et al [25] the usability of an app is calculated based on the average of the responses to all statements. The higher the overall average, the higher the usability of the app. In this study, the overall usability scores for both week 4 and week 20 were 89.15 (SD= 9.65) and 85.57 (SD= 12.88) respectively. The mean for each of the subscales from Week 4 and Week 20 were also calculated and is presented in Table 3. The results show that the usefulness score has declined over time from Week 4 (80.89) and Week 20 (77.33). Besides, the interface and satisfaction score also reduced but not as much as the subscale usefulness. However, the ease of use score on the other hand has remained constant both in week 4 and week 20.

Table 3 Quantitative Analysis of the MAUQ and subscales

	Overall	Ease of Use	Interface and Satisfaction	Usefulness
Week 4 (n=71)	89.15	92.41	91.6	80.89
Week 20 (n=66)	85.57	92.27	88.23	77.33

Qualitative measures

Interviews

In total, 527 text passages were coded in the interviews. 9 themes and 60 subthemes were identified, of which each can still be categorized under the superordinate themes of preconditions to app use, usability, and reflection. The themes are summarized in Figure 2.

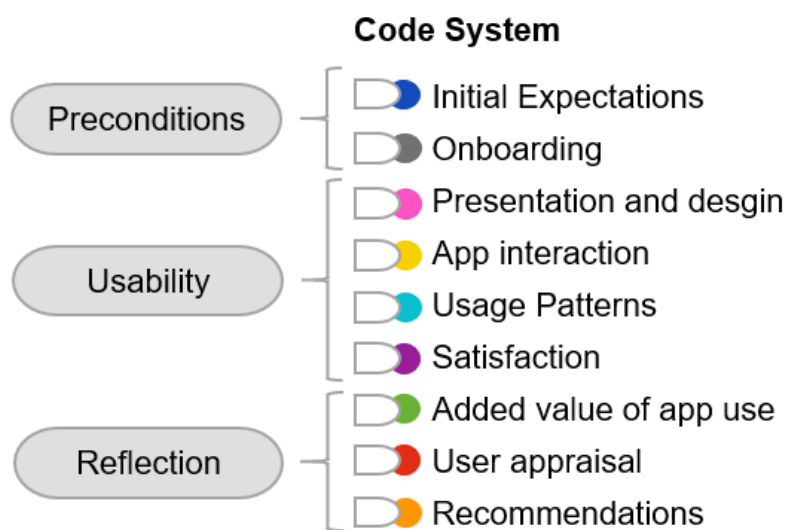


Figure 2 Overview of identified themes

I. Preconditions

Initial Expectations

As an opening question of the interview, patients were asked about their initial thoughts when they first heard about the *Enable* App. The most frequently mentioned expectations were related to the quality of information. Patients expected information in the app to be updated regularly, understandable, and in line with the latest research. In addition, another expectation was that the app would provide contemporary therapy support and be perceived as modern, including replacing printed brochures. Patients expected the app to provide guidance over the course of therapy, contact options, and easy access to relevant information. About half of the participants had a neutral expectation of the app.

Yes, I already thought that it (the app) would support me through everyday life and therapy, that I can also use it to organize myself a bit.

[Interview 9, Transcript position (TP) 2]

Onboarding

The aspect of the onboarding process was not part of the interview guide. However, individual participants reported that they felt well supported by study staff at the beginning of their app use. Even if they were initially overwhelmed with the app or experienced technical difficulties, participants expressed that they received the necessary support and

were able to handle the app.

Oh dear, now I have to dig into yet another app. I don't know if I can handle it. But the more I got a grip on it, the better it worked. [Interview 3, TP 2]

II. Usability

Presentation and design

Patients were asked to describe their impression of specified design aspects. Overall, patients were content with the color scheme and perceived it as pleasant without being boring or flashy. For some patients, this cheerful aesthetic contributed to a sense of joy when using the app and encouraged them to use it more often:

(The design is) very friendly. Very beautifully visualized. I always enjoy opening the app. It is also well designed, you always have the feeling that it is not draining in any way, it is more playful with all these images and visualizations. I find it very very clear. [Interview 11, TP 34]

Concerning the layout of the written information, patients appreciated how the most relevant parts were highlighted through the positioning of boxes. Font size, design, and structuring of information were seen as adequate. The selection of accompanying images was described as empathetic and not too explicit. The app included a personalized visual representation of the therapy progress. This display was also rated as clear and useful. Patients explained that the presence of this display motivated them:

I found this progress bar, which shows me how long I will be in therapy for, especially beautiful. It [...] motivated me, showing me that there is always a path forward and that the therapy will soon be over. [Interview 13, TP 43]

App interaction

Regarding usability, four important aspects emerged while interacting with the app. Both the positioning and design of app icons were not perceived as entirely intuitive. Patients, however, grew acclimated to the icons and thus did not further impede usability:

Yes, the icons that were down in this bar. In the beginning, I didn't know the meaning of each icon. But when I took a closer look once, I knew it for the next time.

[Interview 7, TP 39]

Login and logout procedures were described as easy and quick and did not pose any problems for the patients in this study. Most patients had no issues working with the app's structure. They could easily navigate within the app and were able to find what they were looking for:

I found my way around the app really quickly. I haven't tried all the features yet, I haven't clicked on everything because I don't need it all. But I have always been able to find the things that I wanted very quickly, and everything is right there when you click on it. [Interview 11, TP 44]

Overall, patients liked using the app as it enabled them to access information "on the go". Patients described that having their smartphones with them at all times allowed them to read information, given the absence of other electronic devices such as laptops or tablets. However, few patients mentioned the additional benefits of having a web-based app of the *Enable* app.

Usage patterns

This code encompasses descriptions of how and when patients used the app. Most patients experienced changes in the frequency of app use. In the beginning, they often used the app, some patients used it multiple times per day:

In the beginning, shortly after my diagnosis, I had a lot of questions - for my physicians, how things work and so on. During this time, it (the app) really helped me a lot. [Interview 10, TP 24]

Over time, usage declined. This development was mostly due to lower demand for support and information, as patients became used to therapy proceedings. Patients also used the app less, because they felt like they had already read everything.

After this initial phase, patients reported using the app whenever they needed to look up appointments, had free time (e.g., during waiting times before doctor's appointments), had or experienced new side effects from their treatment, were prescribed new medications, or were prompted by push notifications.

I always used it shortly before my (chemotherapy) appointments. Or when I had

questions regarding diet and exercise. And sometimes there were questionnaires I had to fill in. And yes, as soon as the app said "there is news", I opened it. [...] And to look up times for my appointments. [Interview 10, TP 12]

Satisfaction

Patients praised the general aspects of the app and liked the idea of having a digital tool accompanying them throughout their therapy, for example, the app provides a good overview of relevant topics, especially at the beginning of the disease. Except for one interviewee, all participants would recommend the app to others.

[...] because it really provides a great overview [...], because so many aspects are addressed. Not only the type of therapy, but also just different things about cancer. - Especially at the beginning these keywords -- Yes, these terms in the boxes from tiredness to fatigue and polyneuropathy and different things. [Interview 7, TP 47]

III. Reflection

Added value of app use

When asked about the concrete benefits of the app in everyday life, several aspects were mentioned. The most important aspect for the participants was the information on therapies and side effects, which was perceived as helpful, especially in the initial phase of therapy. The quality of the information was praised, as the app's information was considered understandable and its origin reliable.

You feel informed, you feel - that gives you a form of security, because you say to yourself: Well, if I have the information from here (the app), then it was completely clear to me: I don't have to look it up again. That's true for me because these are reliable information providers who wrote this. [Interview 12, TP 81]

The comprehensibility and the level of language were also perceived as adequate. Statements on the amount of information were heterogeneous according to individual information needs. However, the amount of information was predominantly perceived as sufficient in the context of the app. Furthermore, the appointment display, the contact information and the progress bar were found to be helpful and clear. With regard to the contact information provided in the app, the fact that it was easy to find was rated positively.

Some patients reported that the questionnaires in the app gave them a positive feeling,

because they reflected on their condition and (in the intervention group) it was experienced positively that the questionnaires were read by the study staff and that staff could react proactively to them if necessary. Overall, patients perceived the app as a good therapy companion that guides and supports them through the various phases of the disease and therapies.

User appraisal

Users' opinions on the already existing functions and features of the app were added to this category. The majority of patients complained about the appointment display because the date and time on the app did not always correspond to the actual clinic appointments, e.g., in the case of last-minute postponements.

It's a shame that the - I don't know how the appointments displayed in the app, how often those are matched. I've had frequent differences there. Especially when appointments had to be postponed, the chronology was no longer correct for me.

[Interview 9, TP 2]

Regarding the quantity of information, some patients wished for more in-depth information or links to further information platforms. It was remarked that the amount of information available varied depending on the topic. As for the quality of the content, patients noted that the collection of listed side effects or drugs was grouped differently. For instance, the patient was unable to locate paclitaxel because it belonged to the drug class taxanes. Two patients in particular perceived errors in spelling, punctuation and grammar as distracting. The presentation of the contact information on the app was described as difficult to find, especially in emergencies. The additional pop-up notifications of the app's updates were rated negatively as it was not apparent to the user what exactly is new in the app. Furthermore, respondents ascertained that the menu navigation is not intuitive enough and therefore needs to be improved.

Recommendations

Statements about features of the app which are not yet offered were classified as recommendations or wishes. Most wishes were mentioned in relation to the appointment display. Patients would like to have additional information about appointments, such as directions, a reminder function, the ability to export appointments from the app to private calendars (e.g., Google or Outlook calendars), or the ability to make appointments directly

from the app. The desire for self-administration, i.e. areas such as appointments, questionnaires or therapy progress can be actively managed by the patient, was also frequently voiced. Additionally, some patients wished to view the questionnaires that have already been completed in order to be able to monitor their condition over the course of therapy.

With the exception of filling in the questionnaires, you can't work with the app yourself. Therefore, if you could manage things in the app by yourself, then of course I would think that would be great. [Interview 9, TP 2]

Patients also wanted the content of the app to be updated, expanded, and adapted to new scientific findings. In this context, there was a desire for more explanatory videos to be included in the app. Patients also suggested that the app should offer more information about current and upcoming clinical trials for breast cancer patients. In order to see what content in the app has already been read, patients suggested a read status, where content that has already been read is highlighted. Emergency contacts should also be highlighted in the app to make them easier to find, for example by displaying them on the home page.

Especially the emergency numbers, I don't know how to get something like that into the app, but that might be an idea, because I've been looking a lot for the right contact person. Maybe that would also be something that you could highlight a little bit or display as a button. [Interview 4, TP 32]

To be able to find certain topics more quickly, the need for a search function was mentioned several times. Furthermore, to improve the readability of the content, patients would like to be able to adjust the font size. It was also suggested that the app could also be used on other devices, such as a tablet.

Eye-Tracking

The analysis of the data collected from the eye-tracking recordings as well as the retrospective interview showed that the participants found the app was easy to use. We observed that most participants completed the given tasks, although the time taken to complete a few tasks proved to be challenging. On the observations and the retrospective interviews during the eye-tracking study, we discovered three noticeable patterns relating to the design and layout of the app, content and navigation through the app and the additional

features the participants would like to have in the app. Figure 3 shows exemplary heat maps from the eye-tracking analysis. The data collected during the task performance such as the task completion rate and the task completion times are provided in appendix 5.

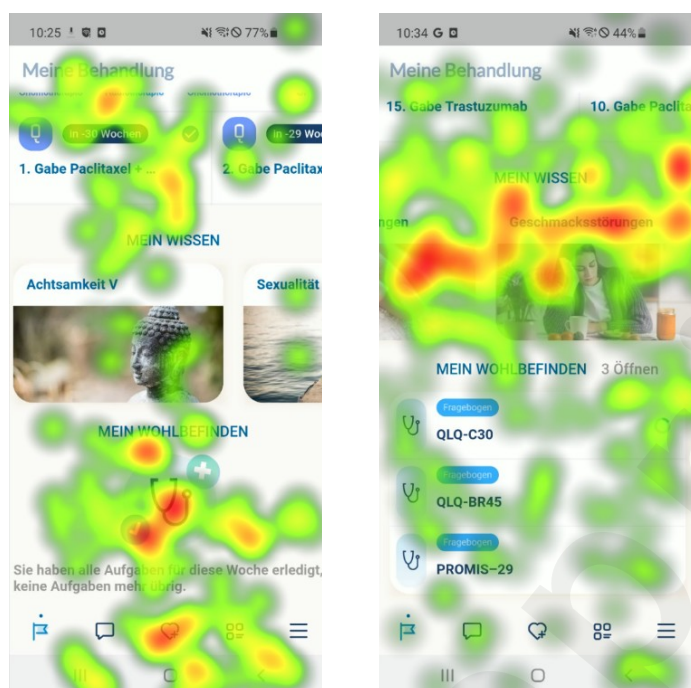


Figure 3 Heat maps from the eye-tracking analysis

Design & layout of the app

Many of the participants had problems understanding and interpreting the icon at the bottom of the screen. The eye-tracking data show fixations at the bottom of the screen, while the patient clicks each of the icons displayed to view the content of the page. Patients expressed a preference for finding the most important information, such as appointment dates and progress of a questionnaire, at the top of the screen. This finding indicates that patients expect important information to be located at the top of the app's layout. Furthermore, the patients actively mentioned that the retrievability and the visibility of the questionnaire were low. While the questionnaires are available on the home screen of the app, patients believed that the questionnaires are available in the menu. On the other hand, patients found the overall layout of the app to be acceptable.

Content & navigation of the app

Regarding the content of the app, patients showed more interest in the title of the articles

(e.g., topics like symptoms or side effects) rather than the images displayed. When asked during the retrospective interview, patients mentioned that they do not pay attention to the images since they provide no information on what the article is about. Patients preferred to read the title of the article as it gave them information about its content, as shown by the red areas of the heat maps in Figure 3. Moreover, many participants explored the app to find the right information or icon to perform the tasks. This, however, correlates with how frequently patients used the app. During the interview some patients said they use the app frequently, for example, every day, to read articles on side effects or symptoms and fill in questionnaires regularly. Whereas some patients used the app frequently at the start phase of the *ENABLE* RCT and later minimized the usage of the app except to fill in questionnaires. The data showed that patients also had issues navigating through the app, especially relating to the task to find a specific article. Analysis of the recorded data of the participants' navigation and gaze plots from the Tobii Eye Tracker showed that patients looked for a search function. Most patients clicked the menu icon however, did not proceed further to find the article nested under the Symptoms category in the menu. Additionally, some patients also searched for the article on the start page along with the other articles already displayed.

'Would-like-to-have' (Wishes)

Participants identified a need for additional features in the *Enable* app as a consequence of the challenges they encountered during the eye-tracking study tasks. These suggested features were considered as "nice-to-have" options and were based on the specific problems faced by the participants during the study. Firstly, the availability of an option to mark an article as favorite and be able to view the favorite article on the start page. Secondly, patients desired to have more articles or information about the symptoms and side effects of breast cancer and treatments. Thirdly, the icon currently representing contact information for health care providers (My Careteam) was misleading. Patients preferred to have another icon that indicates contact or communication as this would enable them to contact the study nurses more quickly. Finally, the search option was suggested by all participants.

Discussion

Principal findings

The aim of this study was to investigate how patients with breast cancer rate their engagement with the *Enable* app, the user experience, and the benefits of using the app. In particular, design, layout, navigation, content, and requests for new features were identified as important outcomes of interest for evaluating the app and further improving it to meet user needs. The interviews provided valuable suggestions for optimizing the app and the implementation process. The design and color scheme were rated very positively overall. In terms of usage patterns, it was noticeable that the frequency of use of the app decreased over the therapy period.

Patients found the app easy to navigate. However, there was some criticism that the menu icons were not intuitive enough, especially at the onset of use. Perceived benefits were discussed extensively in the interviews. Patients found the information on therapies and side effects very useful. The appointment display and progress bar were also found to be helpful and motivating. At the same time, the appointment display was most often criticized and for which there were the most recommendations for change, e.g. to be able to manage appointments autonomously in the app or to set reminders. In terms of content, it was mentioned that there was a lot of information on some topics and not enough on others. Patients also wanted more content updates within the app, e.g. on current topics such as the COVID-19 pandemic, and a search function to access specific content.

A study by Ansaar et al. [36] showed that nearly 78% of all usability evaluation studies in their systematic review used a questionnaire-based method. Yet, using mixed-methods approaches in usability evaluation studies provides benefits such as the possibility to balance advantages and disadvantages of the different methods. Moreover, by applying the mixed-methods approach, both subjective and objective aspects could be combined to assess usability [36]. In many aspects, such as the codes navigation, recommendations and perceived benefits, the results of the different survey methods support each other. However, the interviews and the eye-tracking sometimes provided different findings. For example, the importance of images within the app was positively highlighted in the interviews. In contrast, the eye-tracking and retrospective interviews revealed that images played a subordinate role for patients, with titles being more important for finding relevant

content in the app. While participants reported in the interviews that they were able to navigate easily within the app and find the content they were looking for, we observed in the eye-tracking that there were difficulties with finding specific content. Furthermore, the interview inquiries primarily centered on the practicality of incorporating the *Enable app* as an follow up intervention in daily life. Meanwhile, the utilization of eye-tracking technology allowed for direct, real-time observation of user behavior while engaging with the app through task performance. Despite patients reporting the ability to regularly use the app without difficulty, the eye-tracking study's direct observation unveiled valuable insights into their actual usage patterns within their everyday routines. In this context, disparities between the results obtained from the two methods emerged, possibly stemming from users' lack of awareness regarding any issues until prompted with specific inquiries.

Comparison with prior work

Our results of the MAUQ indicate good usability. The results for the total scale showed that usability decreases from 4 to 20 weeks. A decrease in usability over time has also been observed in previous studies [37–39]. Possible explanations for this decline in our study can be found in the interviews, indicating that the extent of app usage also decreases over the course of therapy. Patients found the app to be particularly advantageous at the start of their therapy due to their high need for information. However, as they gained more knowledge about the disease and treatment, their demand for information decreased over time. Additionally, patients reported that the app lost its appeal once all of the available articles have been read, often leading to a desire for new content to be added. Patients also expressed a need for additional features or improvements as they continued to use the app. As a result, the decrease in the app's usability score could be attributed to patients perceiving it to be less useful after an extended period of use due to the lack of content updates and unmet desires.

Looking more closely at the subscales of the MAUQ, 'usefulness' has the lowest score compared to ease of use, user interface and satisfaction. These items survey whether the app is helpful and useful for patients' health and well-being. This relation is also apparent when looking at the category 'usage patterns' from the interview analysis. It seems that patients are less likely to use the app due to the lack of new content. This is consistent with the findings of other studies on mHealth apps for breast cancer patients [16,40,41]. As an implication for similar apps for other chronic conditions, it seems important to update the

app content on a regular basis to provide patients with an incentive to continue using the app as well as strengthening patients' satisfaction and information needs. Consistent with the findings from the interviews and eye-tracking, only the subscale 'ease of use' remained almost stable over the duration of app use.

In the context of other usability studies on mHealth apps, the importance of paying more attention to the user group of the elderly is emphasized. The different age range of patients and the different levels of technical affinity for aged patients are mentioned as possible factors causing usability problems. Some studies emphasize that these factors are often overlooked and need to be considered when developing mHealth apps [42,43]. In our study, these aspects were less evident. With an average age of 51 years, our study participants do not represent a predominantly older population, but are close to the German population average for women, which is 46 [44]. On the other hand, study participants are also far below the average age of 64 years for breast cancer patients. Therefore, further research on app development and usability with a focus on older participants should be conducted to more adequately represent the typical breast cancer patient population.

Considering the preferred device for using the *Enable app*, most participants were content with using the app on the smartphone. However, there were isolated requests to be able to increase the font size of the content and use the app on a larger scale device such as a tablet or PC. This issue was also mentioned by users in a usability study by Jessen et al [45], in which an mHealth app for self-management of chronic diseases was evaluated.

Although the onboarding process was not part of the interview guide, some patients actively recalled how they were introduced to the app as well as how they perceived the technical onboarding process. The patients did not experience issues with these steps and reported being content with the process, mostly due to the strong support by the study team. Previous research has pointed out that complex registration and log-in procedures can be perceived as especially cumbersome by patients and can lead to stopping app use [46–48]. Our study identified the strong interpersonal connection and continued support by the study team as a positive influence on the perceived ease of onboarding. This support took place in the context of a research study and is not viable in a real-world implementation. However, the issue technical support arose exclusively during the qualitative interviews. We did not collect any quantitative data on this topic. Thus, further streamlining of the onboarding process while being mindful of health care workers' limited time resources should be an

area of future research.

Strengths and Limitations

The chosen mixed-methods approach can positively support the further development of the app. The expansion of the classic social science method spectrum to include technical methods such as eye-tracking made it possible to combine the subjective patient perceptions reported in interviews and questionnaires during everyday use with objective measurements under laboratory conditions.

Yet, the integration of qualitative results and the objective measurement from the eye-tracking procedure introduced discrepancy. As noted before, interviewees appreciated the use of images in the app, while eye-tracking results show that more time was spent on the article titles than on the images. Another example is that the interviews and the questionnaire produced good ratings of the usability, but the eye-tracking showed that patients found it difficult to find defined content. Although difficult to analyze, these discrepancies are common in mixed-methods studies [19]. In our study, the mentioned discrepancies can be explained by methodological differences. For example, reading a title naturally takes longer than glancing at an image, leading to a long fixation time. So, this result does not allow for the conclusion that titles are more important than images. Here, the qualitative interviews were helpful in interpreting this finding. Regarding the second example, overall good usability scores in comparison to eye-tracking times, several interpretations appear plausible. Firstly, it is possible that social desirability led patients to rate the usability more favorably in both the interviews and the questionnaire. Consequently, the objective measure via eye-tracking revealed that usability is worse than in subjective measures. Secondly, the setting of the eye-tracking procedure (e.g., unusual or uncomfortable sitting position, being observed by two or more researchers, using a different device) could have led to changed patterns in (app usage) behavior. While we acknowledge these discrepancies, we conclude that the mixed-methods approach and its results deepened the understanding of the studied topic and produced valuable insights, with discrepancies leading to vigorous and fruitful discussions among the researchers.

However, the generalizability of the study results is limited by several factors. To assure that patients with lower digital health literacy could participate in the quantitative data collection without constraints, we decided to use printed surveys sent by mail. Patients returned them at their discretion. Hence it cannot be verified if the surveys were filled in at the correct time.

In addition, some values were missing from the returned surveys and manual data entry could have led to documentation errors. Incomplete or inconclusive questionnaires had to be completely excluded from the analysis, as it was not possible to calculate the score. While all necessary steps were taken to ensure high quality and reliable data (e.g., data entry was always checked by another researcher), using an online survey instead of a printed survey could have made data collection easier, faster, and collected data more reliable. These trade-offs have to be balanced in future research projects.

This study population contains an above-average proportion of academics, especially among the subgroups of interviewees and eye-tracking participants. This should be taken into account when interpreting the presented results. A systematic review of Niazkhani et al. showed that patients with lower educational attainments and limited health literacy were less likely to intend to use an electronic patient health record and were more likely to use it ineffectively [49]. Moreover, prior experience with computers or health technology was associated with increased acceptance and acceptance increased with higher education [7]. Although these results refer to electronic health records, they indicate that this aspect should be further investigated in future studies. Given the median age at breast cancer diagnosis of 64 years and the relatively younger median age of this study cohort, conclusions from this study must be interpreted with caution as they may not represent the views and digital literacy of older women with breast cancer [50].

The *Enable app* was developed specifically for breast cancer patients. Consequently, our study sample included only female patients with breast cancer. Some of our results and recommendations could have limited generalizability for other patient populations. Nevertheless, we think that aspects such as the relevance of content updates, the accuracy of displayed appointments or the intuitiveness of the app navigation might also be relevant beyond the target group. This should be verified by further research.

As part of the *ENABLE* RCT, reasons for dropping out were documented where available. These reasons were examined to see if there were any indications of usability problems. A small proportion of included study participants in the RCT dropped out due to physical exertion or feelings of being overwhelmed with the app. In this respect, further research is needed to understand how patients in later stages of the disease or greater disease burden perceive the usability and benefits of the intervention. Furthermore, mHealth apps should be designed to be usable and helpful for these patient groups as well, especially in the

context of patients living with cancer. Since the mean age of study participants in this study is relatively low, it can be assumed that there is a risk of selection bias. It is possible that more younger patients decided to participate in the study and use the app, due to a higher affinity for smartphones [11].

Additionally, using the eye-tracking device led to further limitations. Potential participants for the eye-tracking study had to go through an additional screening process to exclude patients wearing bifocal glasses. Although patients were recruited for the study, this criterion did not allow us to cast a wider net for the participant recruiting process. Furthermore, we also had the challenge of asking patients to sit still so that the eye-tracking data can be captured without breaks. This request, however, is generally against the natural way how users sit and interact with mobile devices. Another point to note is that the execution of the tasks on the app by the patients was deviated since the tasks were presented on paper and this retracted some of the gaze points of the patients. This is in general a common problem when tasks are not integrated into the mobile apps during the development for testing purposes.

Conclusion

The results of this usability study demonstrate good usability of the studied application and potential for purposeful development. The design and color scheme were rated very positively overall. However, there was some criticism that the menu icons were not intuitive enough, especially at the onset of use. Noticeably, the frequency of use of the app decreased over the therapy period. Perceived benefits of the app were information on therapies and side effects. The appointment display and progress bar were also found to be helpful and motivating. Still, participants offered recommendations for changing the appointment display, e.g., to be able to manage appointments autonomously in the app or to set reminders. In terms of content, it was mentioned that there was a lot of information on some topics and not enough on others. Patients also wanted more content updates within the app, e.g. on current topics such as the COVID-19 pandemic, and a search function to access specific content. The interviews and eye-tracking revealed valuable suggestions for improvement as well as requests for additional app features. An important point is that the app currently provides information to the patient mainly passively. The patients' wishes indicate that the app needs to be further developed so that they can actively enter

information into the app and work with it. The overlap between decreasing usability and decreasing usefulness also suggests that the app needs to be regularly updated with new content in order to maintain its usefulness over time. These findings will be incorporated into the further development of the *Enable app*. We concluded from patients' feedback and requests that similar mHealth apps could benefit from giving patients a more active role (e.g., being able to actively document side effects as they show up instead of being prompted to do so). In addition, regular updates of app content (e.g., adding new informational pieces), could further contribute to and thus encourage continued use of mHealth apps.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Heidelberg University Hospital (S-685/2020). All participants gave their written informed consent for participation, audio recording of the interviews, and video recordings during the eye-tracking procedures.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declared to have no competing interests.

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Authors' contributions

CA, PM, and LW collaborated on the draft of the manuscript. MW is the overall principal investigator for the *ENABLE* project. LW, JM, and PM were responsible for the study design and study protocol, OH contributed. MW and TD prepared and submitted the study protocol, LW, JM, and PM contributed. LW, JM, and PM collaborated on the construction and testing of the interview guides and the quantitative data collection tools, LS supported finalization of these instruments. CA and LW conducted the interviews, analyzed transcripts, and interpreted the interview data. PM, CA, and LW conducted the eye-tracking and retrospective interviews. PM analyzed and interpreted eye-tracking data. PM analyzed and interpreted the survey data, CA and LW supported data interpretation. OH contributed to the acquisition of funding. All authors provided substantial comments and approved the final version of the manuscript.

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Abbreviations

COREQ	Consolidated criteria for reporting qualitative research
HRQoL	Health Related Quality of Life
MAUQ	mHealth App Usability Questionnaire
PRO	Patient Reported Outcome
PRO-AE	Patient Reported Adverse Events
TP	Transcript position
ZIV	Center for Innovative Care (Zentrum für innovative Versorgung)

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Supplementary Files

Untitled.

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Multimedia Appendixes

Interview Guide.

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COREQ checklist.

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