Testing the effectiveness of a supportive digital information tool for patients recovering from bowel surgery, their surgeons and nurses.

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ABSTRACT

Colorectal surgery is a common procedure for bowel cancer, with communication of information playing a key role in patient surgery preparation and recovery. Previous research has shown that surgery e-health tools are effective in many medical contexts. With this I mind, an interactive app was developed using an iterative user-centred design and research process and a multi-methods approach. The aim was to enhance communication between patients and medical staff and empower patients throughout their recovery. Results showed the superiority of a mobile app in communicating information when compared to a printed booklet, as well as a tablet app variant.

Key words: Information Design, Interactive Design, Information Visualization, User-Centred Design, Co-Design, Performance Testing, Patient information, Healthcare Information, Bowel Cancer, Surgery recovery

1. INTRODUCTION

1.1. Background

Colorectal cancer is a prevalent disease that affected over 1.9 million people worldwide in 2020, resulting in over 93,000 deaths in the same year (WorldCancerCentreFund, 2022). This remains the third most common cancer worldwide, being the third most frequent cancer in men and second in women (WorldCancerCentreFund, 2022). Early-stage diagnosis and successful existing treatments has allowed for a 78.3% survival rate one year after diagnosis between 2013-2017 in the UK, dropping to 52.9% after ten years (CancerResearchUK, 2022). This relatively high survival rate, compared to other cancers, means that patients can be impacted by long-term complications such as infertility, sexual performance issues, and urinary and faecal incontinence (Giglia & Stein, 2019), alongside long recovery and self-management periods (Kim et al., 2018).

Surgery is the primary treatment for colorectal cancer (Mizuno et al., 2007) and has the potential to cure the disease (NHS, 2022). This common procedure is also used to treat other harmful digestive system diseases such as Crohn's disease, ulcerative colitis, and diverticulitis (CircleHealthGroup, 2022). However, these surgeries often require intensive preparation processes by the patient to be successful (Smith et al., 2012), later resulting in prolonged recovery periods that can cause significant suffering and lifestyle modifications (Brown & Randle, 2005).

1.2. Problem identification

The majority of colorectal surgery patients experience increased levels of pain and fatigue post-surgery, including complications with their diet, bowel movements, and mobilisation (Kim et al., 2018), as well as susceptibility to psychological distresses such as anxiety and depression (Dunn et

al., 2013). The enhancement of self-care recovery after surgery is important to ensure long-term health and quality of life (Howell et al., 2017). It has also been recognised that the transitional period from hospital care post-surgery, to self-treatment at home, is the most challenging time for colorectal surgery patients where they may feel most vulnerable (Kim et al., 2018). To address these difficult complications, Enhanced Recovery After Surgery (ERAS) programs have been developed to reduce surgical stress and accelerate the patient recovery and treatment periods (Ansari et al., 2013; Pagano et al., 2021). ERAS programmes have been found to successfully reduce hospital stay lengths, medical complications, and accelerate normal patient function after colorectal surgery (Eskicioglu et al., 2009; Ban et al., 2019).

However, the resultant reduction in hospital stay length with ERAS programmes can result in limited self-care recovery education prospects for the patient, with reduced opportunities to interact with medical professionals (Kim et al., 2017). Patients reported that post-surgery support in a colorectal surgery ERAS programme needed to be improved (Taylor & Burch, 2011). Advice was often requested by the patients in this recovery period, with attempts to directly contact the hospital, their surgery ward, or their surgeon to receive this support. It is recommended that ongoing support after surgery address these concerns, and could help to reduce unnecessary patient distress or poor quality care (Taylor & Burch, 2011).

The challenges with colorectal surgery recovery also remain true regardless of the presence of ERAS programmes. Lo et al. (2021) emphasised the psychical and phycological challenges in shifting to self-management strategies after colorectal surgery, and found that patients would seek support when in discomfort through information resources or contact with medical professionals. They also recorded that some patients found that the information they received related to post-surgery dietary changes was insufficient. Similar conclusions were established by Hoekstra et al. (2014), whose systematic review revealed the need for information by cancer patients, with information about recovery being the most commonly described. Again, a form of contact between the patient and the medical professionals during the recovery period was also emphasised as important by the patients in the studies reviewed. Self-care information after surgery is an important necessity that the patient looked to receive from their medical treatment team (Lo et al., 2021).

Gustafsson et al. (2011) found that patients undergoing colorectal cancer surgery in ERAS programmes recovered significantly better if they adhered highly to the ERAS recovery protocol. In this study it was found that high instructional adherence resulted in a 25% reduction in surgery complications and a 50% reduction in post-operative symptoms that might delay discharge, as well as improvements in presence of disease and hospital readmission rates. The intake of a preoperative carbohydrate drink was one of the main independent factors influencing postoperative outcomes, suggesting that patient adherence to pre-surgery instructions is a significant factor in the success of colorectal surgery. Research by Pecorelli et al. (2021) investigated patient adherence in the context of pancreatic cancer surgery in an ERAS programme, again, finding that higher adherence correlated with better recovery outcomes. Alternatively, they recorded post-operative variables had the greatest impact on successful recovery, concluding that resources that increase patient adherence to post-operative recovery should be included in surgery programmes. The researchers also endorsed the exploration of mobile technology to optimise patient-healthcare professional communication post-surgery to improve recovery at home outcomes (Pecorelli et al., 2021). Additionally, patient

post-surgery mobilisation and diet have been found to critically impact recovery outcomes (e.g., length of stay, and complications) for colorectal surgery (Larson et al., 2014). These are factors that have been recognised as reliant on patient compliance (Pecorelli et al., 2018).

A scoping study in the format of a focus groups was conducted by Chapman et al. (2020) to more directly ascertain and define patient information needs, barriers to effective understanding, and insights into how information provision may be improved. The focus group was conducted in the UK looking at information provided by the National Health Services (NHS). Participants were recruited via a national charitable body (Bowel Cancer UK) and all had previously undergone abdominal surgery for the treatment of bowel disease. The group included 11 participants with diverse characteristics and able to offer a range of constructive experiences. Five non-participating representatives from charitable bodies and an information designer (one of the authors of this paper) were present for observation but sat away from the main group to avoid influencing the group dynamic.

The findings from the focus group identified that: 1) information provision is not prioritized by healthcare providers; 2) a high emotional state of the patient precludes effective understanding of information; 3) appropriate information design facilitates patient understanding; 4) information provision should be personal to the patient; 5) information provision should aim to empower the patient; 6) information-provision should aim to support patients; 7) patient information needs persist long after discharge.

A previous study conducted by the authors already looked at how redesigning an existing booklet could address findings 3 and 6 (Lonsdale, Sciberras, et al., 2020). However, while significantly improving patient understanding of the information and consequently supporting patients, the sole redesign of the existing booklet did not enable the authors to tackle the other, and in our view, more challenging problems. To that end, the research here presented looks to develop a tool that can define and address these problems and needs in the context of colorectal surgery procedures. These include making information personal to patients and empowering them to self-manage their recovery before and after discharge (findings 4, 5 and 7). Moreover, within finding 2 participants also pointed out that in order to help them overcome the difficulties of understanding information during emotionally challenging situations “information must be clear, consistent and reinforced across a broad range of formats” (Chapman et al., 2020, p.5). The tool devised in the study we are presenting in this paper also aims to increase the range of information formats beyond the tradition printed booklet used in the NHS in the UK.

All in all, the studies discussed in this section emphasise the need for optimised information communication in both the pre-surgery and recovery periods. This evidence suggests that information design outputs that can increase patient adherence to higher levels have the potential to improve surgery outcomes. There is a patient need for Information to be clear, consistent and structured in a way that enables the rationalisation of large volumes of content to help patients to retain it (e.g., Chapman et al., 2020). This applies to both before and when recovering from colorectal surgery, as well as contact with medical professionals during the recovery process.

1.3. E-health tool

Digital health solutions have expanded with the development of online technology in recent years, with practices such as mobile apps to encourage patient self-management (Guo et al., 2020), and wearable health tracking technology (Dinh-Le et al., 2019) becoming more commonplace in modern medical practices. The development and implementation of e-health tools to facilitate the communication of information between patients and medical bodies during surgery has recently increased considerably, driven, in part, by the limited access to in-person interaction during the covid-19 pandemic (Taha et al., 2021). Healthcare communication has evolved from a paternalistic relationship between patient and clinician, to more collaborative decision making, caused by better informed patients that has been further driven by the emergence of digital health tools (Meskó et al., 2017). Additionally, the implementation of e-health tools can improve the communication between patients and providers, increase patient engagement with symptom control and self-management, and increase accessibility of information to rural and isolated communities (Penedo et al., 2020).

The increasing presence of e-health tools may also be driven by economic advantages as they are largely cost-effective through reduction in costs and improvements to health outcomes (Gentili et al., 2022). However, the replacement of in-person consultation with digital tools has been recognised to potentially dehumanise healthcare (Lekka et al., 2022), and can exclude certain patient groups, potentially increasing the risk factors of patients with limited digital knowledge or internet access (Granath et al., 2022). Additionally, digital health tools have occasionally displayed negative paradoxal effects, also impacting power dynamics between health professionals and patients, potentially increasing cynicism of advice from medical professionals (Ziebland et al., 2021). However, communication between marginalised groups and clinicians has also been shown to benefit from digital communication tools, despite previous concern that such technology would intensify current disparities (Huxley et al., 2015). Overall, advantages of digital communication appear well supported, with beneficial patient outcomes being well evidenced after e-health implementation in surgery recovery programmes.

Existing research specifically in e-health apps has lately gained great interest, with many publications around the subject in recent years. A review by Wikström et al. (2022) explored 15 studies that utilised e-health applications to augment patient self-care practices during the perioperative process. Their review found that patients using e-health resources returned to regular activities after surgery earlier than patients who received care without supportive e-health resources. However, they noted that research exploring patient motivation, adherence, and willingness for self-care using e-health resources was lacking. Additionally, studies have shown that mobile health apps can help medical staff recognise surgical complications (Hwang & Mun, 2012), augment patient-medical staff communication (Chang et al., 2018), and improve patient adherence to rehabilitation practices (Belarmino et al., 2019).

The usability of health apps during the surgery process has recently been explored in multiple medical surgery contexts, including breast cancer surgery (Ponder et al., 2021), spine surgery (Hou et al., 2019; Ponder et al., 2020), lung cancer surgery (Kneuertz et al., 2020), jaw surgery (Sousa & Turrini, 2019), and joint replacement surgery (Timmers et al., 2019; Joshi et al., 2022) to name a few

of the many examples. All of these studies found positive outcomes for the implementation of mobile apps for patient surgery education, leading to the recommendation for the inclusion of a health app as standard practice post-surgery to optimise patient self-management (Timmers et al., 2019).

The same positive outcomes have been found in the context of colorectal surgery. A colorectal recovery programme, centred around an app to support patients in the post-surgery process, found high usage and a resultant reduction in patient readmission rate from 18% to 6% compared to traditional practices (Keng et al., 2020). The researchers noted that the surgery team found the app particularly useful for efficient daily patient monitoring, a practice that is typically unrealistic due to labour intensive phone calls or home visits. Comparable findings were observed by Eustache et al. (2022), who found patients using a colorectal surgery app correlated with fewer preventable emergency department visits and shorter length of hospital stay, compared to a control group. Additionally, mobile apps integrated into colorectal surgery ERAS programmes have resulted in meaningful reduction in patient depression and anxiety, and improvement in self-efficacy (Kim et al., 2018), and can help patients meet daily recover goals and increase motivation (Pecorelli et al., 2018).

There is clear evidence that an interactive app is beneficial tool to aid in recovery from colorectal surgery. However, of the colorectal surgery app publications reviewed, only Pecorelli et al. (2018) included examples of their final design output, meaning the design quality of the majority of the research is unclear. Additionally, when considering the colorectal surgery app studies reviewed (Kim et al., 2018; Pecorelli et al., 2018; Keng et al., 2020; Mata et al., 2020; Bertocchi et al., 2021; Eustache et al., 2022), minimal detail was provided on the methodology used to develop/design the app. Robinson et al. (2020), on the other hand, conducted a review to explore the growing research in digital and mobile technology to support surgery patients. Their review emphasised the importance of user driven design outputs, and tailoring the app to both the context of the disease and the individual need of the patient. User-centred design was recognised as a crucial solution to encourage meaningful behavioural change and uphold engagement with the resource.

1.4. Objectives

- To develop a digital healthcare communication design tool (app) that supports communication between stakeholders (patients/nurses/doctors), and consequently enhances the patient recovery process after a bowel operation.
- To give agency to patients, nurses and doctors in co-creating a digital healthcare communication tool (app) for bowel cancer surgery recovery.
- To help patients understand the actions they need to do in the recovery process through interactive features that allow for better communication with medical staff.
- To compare an interactive app with a traditional printed information leaflet to identify whether there is any improvement in efficiency (accuracy in finding and understanding information) when adopting digital healthcare tools for communication during bowel cancer surgery recovery.

2. METHODOLOGY AT A GLANCE

A multi-methods user-centred design approach was employed in the development process for the design materials tested in this study. The stakeholders involved in the surgery recovery process includes the patients, the surgeon performing the operation(s), and the nurses providing care to the patient. This results in a three-way communication channel between the stakeholders that formed a core consideration for the development of the design materials. Consequently, the aim of the design outputs generated here was to create a solution centred around these users: a) looking to optimise communication between users; b) encourage better understanding; and c) enhance engagement with the information. This was addressed through multiple stages of detailed user centred design methods that are described below.

In addition to a multi-methods user-centred design approach, communication of bowel cancer surgery information in three formats was compared. This included: 1) a mobile app; 2) a tablet app adjusting the mobile app to a different platform (bigger size and that is most commonly used in landscape mode, while mobiles tend to be used in portrait mode); and 3) a traditional printed booklet, each containing similar information. This booklet was sourced from the NHS Leeds teaching hospital, and currently given to patients to provide them with both the pre-surgery and post-surgery information.

The mobile and tablet apps followed a user-centred and iterative design and research process. This design was then improved through an iterative process, making changes in response to usability testing and feedback from the specialist designers and researchers to create a bespoke mobile and tablet app that addressed the needs of the intended users. The app design development methodology used in this study is summarized in Tables 1 and 2.

METHODOLOGY AT A GLANCE		
SECTION 3: DESIGN PROBLEM AND USER NEEDS		
	Sample	**Procedure**	**Research material**
Online questionnaire	• 9 former patients • 50-69 age group • UK participants	• Section 1: Previous experience • Section 2: Existing designs • Section 3: Design preferences • Section 4: Existing content	• Google form questionnaire • Patient experience questions • Visual examples of images and color palettes
Stakeholder interview 1	• 1 surgeon	• Questions about patient/ medical professional contact, and health data presentation	• Interview script
Visual survey	• 17 surgery recovery apps	• Analysis of information content • Analysis of design features: typography, color, layout, visualization, etc.	• N/A
Co-design with stakeholders	• 2 former patients • 3 bowel surgery healthcare professionals	• Review and analysis of existing surgery recovery app features • Information card sorting • Analysis of missing information	• Screenshots of 15 features from existing apps • Topic cards • Visualization stickers

Table 1. Summary of the methods employed in section 3 to define the user needs and design problems.

METHODOLOGY AT A GLANCE			
SECTION 4: DESIGN DEVELOPMENT			
	Sample	**Procedure**	**Research material**
Literature review	• 41 research-based publications related to interactive information design	• Exploration of current research applicable to app design • Definition of design principles based on analysis	• N/A
Prototype development	• 1 Information designer	• Development of 3 initial design solutions that implement all previous research findings	• N/A
Usability testing with potential patients	• 30 participants from the general public	• Stage 1: Review and rate the design features of the six core sections of the app • Stage 2: Task analysis, requiring participants to complete a task and provide feedback	• Online usability testing resources • Testing task instructions • Current app iteration
Designer feedback 1	• 1 expert information designer	• Review of current app iteration • Record suggestions to improve • Review and implement changes	• N/A
Designer feedback 2	• 1 expert digital and interactive designer	• Review of current app iteration • Record suggestions to improve • Review and implement changes	• N/A
Usability testing with medical stakeholders	• 2 ward nurses	• Use app in its current iteration • Record suggestions to improve • Review and implement changes	• Current app iteration

Table 2. Summary of the methods employed in section 4 for the design development Stage.

3. DESIGN PROBLEM AND USER NEEDS

3.1. User needs

3.1.1. Online questionnaire with patients

The initial stage looked to understand the needs of the intended users of the design output to ensure that future design development was addressing the specific needs of the user. This occurred in two parts, the first was an online questionnaire with post-surgery patients, and the second an interview with an NHS surgeon.

The questionnaire was conducted online with 9 participants who had previous experience of recovering from bowel surgery in the UK. The patients ages ranged from 50-69, all were living in the UK with a higher education background.

The first section of the questionnaire investigated existing experiences with surgery recovery information. The second section of the questionnaire investigated the users' experience and opinion on digital communication of surgery recovery information, as well as desirable design features of a future digital output. Some information was also collected regarding user opinion on the style and color palette of app icons and pictograms that could be used in the digital resource that was later developed.

3.1.2. Interview with surgeon

Following the questionnaire and the data collated, an interview with an NHS surgeon with experience in bowel surgery was undertaken. This aimed to further understand the existing communication that occurs between patients and medical professionals post-surgery, once the patient has left the hospital.

The findings from both the questionnaire and interview are displayed in Table 3. These findings were used as initial scoping research to understand the needs of the target users of a digital resource that would be used to provide information to post-surgery patients, as well as to communicate with healthcare professionals.

Summary of the findings from the questionnaire and interview
• Direct communication with medical staff occurred at least once a day; typically this occurred two or three times a day; and sometimes up to ten times (1 out of 9 participants).
• After leaving hospital and recovering at home the communication was less frequent with most of the participants communicating between two to three times a week to once a month.
• Post-surgery information was not communicated using digital formats.
• The most common form of communication in hospital was verbal.
• The most common form of communication at home was printed material.
• The majority of patients had used a website to find surgery recovery information, and this was typically found to be useful. None of the participants had previously used a healthcare app to assist with surgery recovery
• The most common problems when using a healthcare website were that there was not enough information, or the information was hard to find.
• The most common reasons for using digital resources were to find basic knowledge about the recovery process, or for personal recover monitoring (e.g., diet, bowel activity, and exercise tracking).
• The three factors that were of most concern when using an app or website were: 1) Quality of the service and information; 2) Authenticity and authority of the medical organization; 3) Ease of use.
• A mobile app would be the most appropriate method to communicate with medical professionals in a hospital and home setting.
• The use of simple pictograms and app icons that clearly display their meaning in a flat style is most appropriate for use in a digital resource. Consider a yellow or blue color palette.
• The recording of health data may be a useful function of a digital resource to help with the post-surgery review that occurs around four weeks after surgery.

Table 3. Outline of the main findings from initial stakeholder need investigations.

3.2. Design problems

3.2.1. Literature review

A detailed literature review was conducted looking to define research-based design guidelines that are applicable to interactive app design and can optimise the design of the interactive mobile and tablet app. This was undertaken to inform the survey of existing apps (as presented next), but to also ensure that the design development process focused not only on initial user research, but also considered other existing research studies to define principles that could optimise the interactive design outputs.

This review was conducted by a group of information design researchers. It grouped the principles into five categories covering the core elements of app design, including: layout, typography, color, visualization, and interaction. The design principles defined in the review are presented in Appendix 1.

3.2.2. Visual survey

The potential for the interactive display of medical information to patients has clearly been identified. A heuristic evaluation of existing mobile app resources that communicate the same and/or similar content was performed, aiming to identify good and bad practice. The resources were analysed using the design principles defined through a literature review to understand which principles are currently being applied and common usability problems with existing interfaces.

A total of 17 mobile apps were included in the survey and the five core design categories covered in the literature review (layout, typography, color, visualization, and interaction) were considered, as well as the content of the surveyed mobile apps. The findings of the survey, displaying existing good practice and features to improve, are summarized in Tables 4.1 and 4.2.

	SURVEY FINDINGS
POSITIVE FEATURES (+)	
Layout	• An organized grid structure was used in 88% of cases. • The text was left justified in every resource.
Typography	• Typically only one font is used throughout the app interface. • The text was left-justified in every resource. • A sans-serif font was typically used to display any text.
Color	• Blue was the most popular dominant color displayed in the apps (53%). • Green was the next most used dominant color after blue, which accounted for around 18%, followed by purple at 12%. • Color used was effectively limited; 94% of the apps used no more than five colors, 81% of the apps used no more that three colors. • The majority of resources used the logo as their dominant color, typically using the same color in navigation bars. • The dominant color, or black, was typically used in the display of headings.
Visualisation	• The most common forms of visualization were icons (94%), followed by photos (71%), and illustration (59%), and videos (41%).
Interaction/ content	• The most common form of navigation was a bottom navigation bar (82%), followed by card navigation (selectable shapes) (71%), then tab-based navigation (59%). • Typically, only 1-2 words were used to label navigation categories in menus and tabs (88%). • Most of the apps used a highlighting technique to emphasize the navigation options (94%).

Table 4.1. The summarized findings from the survey of existing bowel cancer related mobile apps.

SURVEY FINDINGS (cont.)	
FEATURES TO IMPROVE (–)	
Layout	• Over half of the app resources did not display enough white space (53%).
Color	• Color was applied inconsistently in 24% of the apps surveyed.
Visualisation	• 71% displayed complex photograph images.
Interaction/ content	• Some of the apps did not include a privacy policy (35%) • The majority did not include a calendar page to track patient information and set daily goals (53%). • Some of the apps did not include a search bar at the top of the page (39%). • Most did not display a reminder/error message to prevent users from making errors (61%).

Table 4.2. The summarized findings from the survey of existing bowel cancer related mobile apps (continued).

3.2.3. Co-design with stakeholders

Co-design is a design method that requires the involvement of the stakeholders of the eventual design outcome. This collaborative design technique includes stakeholders in the problem-solving process, collecting detailed insights into the needs of the user, and designing responsively to this data. There are multiple examples of this method being successfully utilised in research to inform the development of mobile apps displaying health information to patients, including contexts such as: arthritis care, health disease, dementia, chronic disease self-management, diabetes, etc. (e.g. Ogrin et al., 2018; Fox et al., 2022; Mrklas et al., 2020; Song et al., 2021; Tong et al., 2022; Woods et al., 2019).

The co-design sessions were undertaken with the two user groups of the app. This included two bowel cancer patients, and three medical staff members involved in patient care. A convenience sampling approach was used where invitations to patients to take part were sent to the participants in the scoping focus group conducted by Chapman et al. (2020) as this would allow for continuity. Moreover, at the focus group, participants were quite positive and eager to be involved in any future study that would develop and design information tools to support bowel surgery patients. With the outbreak of Covid-19 starting to emerge in the UK at the beginning of 2020, however, only two participants were willing to travel and be part of an in-person co-design session. But since these participants had been involved in the focus group conducted by Chapman et al. (2020), and that sample already included a broad sample of participants across the national setting (most

geographical regions of the UK), the two participants were considered enough to be able to offer a diverse range of views and represent the views of other fellow patients. The same limitation in recruitment applied to the medical staff, yet three participants were still recruited, allowing for the collection of a diverse range of views and solutions.

Both sessions were divided into two activities as described next.

3.2.3.1. Co-design: activity 1

The first co-design activity required participants to engage with and discuss features of existing bowel cancer apps. Screenshots of existing apps featuring various content pages were presented to participants. Participants were asked to rate 15 healthcare app features as 1 = Negative, 2. = Neutral, or 3 = Positive, and express their opinion on the design.

Overall, positive, mixed, and negative opinions were expressed for the various features presented to participants. An analysis was undertaken to summarize the findings by creating an overall rating score. The expression of positive opinions by a participant was given a +1 score, a negative rating a –1 score, and a neutral opinion a score of 0. The features were then ranked from most positive to most negatively received. The findings are summarized in Table 5.

CO-DESIGN ANALYSIS	KEY: + positive	− negative	= neutral
FEATURES IN EXISTING HEALTHCARE APPS	**Patients**	**Medical staff**	**Total**
1. Video tutorials for exercise	+ +	+ + +	**5**
2. Line chart to track and monitor health data	+ +	+ + =	**4**
3. Details of daily diet plans	+ +	+ + =	**4**
4. Daily patient symptoms/update scale	+ =	+ + +	**4**
5. Interactive breathing exercise	+ +	+ + =	**4**
6. Pain index to record daily pain level	+ +	+ + =	**4**
7. Search function with text or audio	+ =	+ = =	**2**
8. Personal health info hub for recovery plan	+ =	+ = =	**2**
9. Virtual medical assistant	+ =	+ = =	**2**
10. Checklist for recovery plan	+ −	+ + −	**1**
11. Visualization of diet nutritional data	+ =	+ − =	**1**
12. Personalized exercise plan	+ −	+ = =	**1**
13. Social rewards and leader board	+ −	+ − =	**0**
14. Calm-down music	+ =	− − =	**-1**
15. Record of time of pain	= =	− − =	**-2**

Table 5. Summary of the main findings from the first co-design activity.

Features 1-12 were considered based on the positive outcome. Given the negative reception of features 13, 14, and 15, they would not be considered for the surgery preparation app.

Further discussion of the existing app features with the participants also revealed that the visual display and app functions should be easier to understand and more user friendly. It was also suggested that some form of goal setting or checklist would be useful to the patients using the app. It was also thought that a form of instant communication between patients and medical professionals should be included or improved. Additionally, features that encouraged individual motivation was important (as previously identified in the focus groups conducted by Chapman et al., 2020), but social features that allowed competition or patient interaction was unnecessary. Finally, pain or symptom rating features were thought to be important, but these need to be accessible on a patient level so they understand the terminology used.

3.2.3.2. Co-design: activity 2

The second co-design activity was content specific, looking to identify information that was missing or needing clarification from the patient information booklet that the app was being adapted from (an existing JGCSU bowel cancer surgery booklet). This required participants to engage in a card sorting task to encourage discussion. Participants were presented with static app prototypes that displayed information, and asked to discuss what content may be missing that would be important to them. Generally, the information from the booklet was thought to be comprehensive by the patients, so only small additional details needed to be addressed. More detailed changes were described by the healthcare professionals. The summarized comments from the activity can be viewed in Table 6.

	PATIENTS	HEALTHCARE PROFESSIONALS
Hospital stay		• There should be background information and tutorials behind coughing (in the right way). • Missing spirometer information. • Food and Drink – "soft diet" – e.g., yoghurt, "full diet"= e.g., sandwiches (should be visualized with photos). • Nurses should have control over what constitutes as "full diet" – patients can access foods that have been highlighted "green". • Movement – nurses record movement, doctor can check – "reasons why socks are useful". Nurses should be in control. • Text should not be included or too specific – doctors and nurses should just state as it varies so much.
Directions		• No more examples apart from the bottom left (bed to toilet). • How many times to walk per day should be "as many as you can", important to record, as too little exercise could be harmful. • Could be a checklist? Only thing the patient could do is record whether they have passed stool. Nurse should record frequency. • Comfort is more important than speed. • State steps as opposed to meters. • Set goals.
Discharge day	• Does the blood test need to be done the day before? • Is there a prescription?	• Bowel Symptom – give examples. • Stoma = patient records whether it is sore, etc. • Do not need blood tests that day. • 4 weeks – review no necessary actions beyond discharge , as long as they are back to baseline. Compare after surgery with normal life. • Doctors give suggestions on healthy eating however, they eat bad stuff – Suggestion: do not state what to eat, tell what not to eat. • Stoma Care – more relevant to nurses than surgeons.
Managing at home: diet	• Recommendations need to consider use of stoma. • Patients need to try different foods to see how their body reacts.	• Concern about appetite, might be good to have a scale. • Patients can access nutritional info – text and image. • At the beginning, suggest six small frequent meals (and why). • Plate image with all the different types of was approved.
Managing at home: exercise		• Line graph should be used to represent "back to baseline". • The patients would like the icons to be interactive. • Possibly set targets.
Back to everyday activities	• Need daily info about sports and hobbies. • It is inspiring to see other patients fully recovering and returning to normal.	
Complications at home	• Cross on image indicates patient cannot do something. • This should be changed to another symbol (e.g., star).	• If there is an emergency, the communication needs to be face to face. • Display information, text alone. • Suggestions: Virtual Assistant, System Checker – e.g., fever, cold.
Others	• Reference points for pain management. • Need more info on the pros and cons of painkillers. • Need more info on the effects of stoma on daily life.	• Bowel Function (e.g., Have they passed wind? Is their bowel open?). • How many times and what does it look like? Use the Bristol Stool Chart. • A separate section for Bowel Movement. For example, if you have blood patients should get told to see the doctor immediately.

Table 6. Summary of the main findings from the second co-design activity.

4. DESIGN DEVELOPMENT

4.1. Initial prototype development

The design development took into account the research findings from the questionnaire, interview, visual survey, literature review, and co-design workshop. The aim was to create design outputs that address the defined needs of the target users (including both healthcare professionals and patients), while also following research-based design principles. An iterative design process was used to adjust to feedback from the target audience in multiple stages. This allowed the development process to address usability issues and create a bespoke final design output.

An interactive app was designed to allow patients to quickly find and easily understand the information on how to prepare and recover from bowel surgery, i.e., easy to use and accessible. The objective was to also communicate the information in an attractive and engaging interactive format. It was also important to create a communication pathway between the intended stakeholders, allowing patients, surgeons, and nurses to connect and relay relevant information between one another.

The first step of the design process was the generation of wireframe concepts. Wireframes are developed to explore potential layout and structure of interactive digital outputs, such as the health-related apps that were developed here. Three initial design concepts were created with a variation of design styles (e.g., different color palettes, layouts, typefaces, icon design). The creation of three initial design concepts follows the common school of thought in design practice that three concepts allow to assess a good range of variations without making the process too time-consuming and costly. Each concept also focused on specific content features: Concept 1 – focused on ‘Checklist’, ‘Progress’, ‘Info’, and ‘My’ features; Concept 2 – focused on ‘Home’, ‘Track’, ‘Breathing’, and ‘My’; and Concept 3 – focused on ‘Home’, Community’, ‘Messages’, and ‘My’ features.

The three concepts were then merged into a singular concept that included the most important content features and most appropriate design features. In this combined concept the bottom button navigation options were merged to create five main sections of the app, which resulted in the generation of the first prototype design output.

- Home – homepage of the app displaying a checklist of daily tasks to the user alongside a calendar of future events. Pop-up interaction was created that appeared when the user tapped the illustration, allowing the patient to access step-by-step guides for more detailed information.
- Track – was created to encourage patients to record their health data, display a visualized summary of their data, and interact with the data using sliding scales to record personal health information, and document time for specific records.
- Community – a social platform, allowing patients to read shared related stories, and ask questions to the community of users. This aimed to encourage active learning and allow interaction between patients to reduce feeling of loneliness during the surgery recovery process.

- Messages – was created to allow patients to communicate through text message with medical staff, looking to be particularly useful during the patient home recovery process.

Additional features were included in the app in response to the previous user needs and existing design problem definition. These included video tutorials for tasks such as exercising and ways to get active, as well as a meditative breathing exercise, and a virtual medical assistant to answer common queries. A tracking and rewards system was also included to encourage patients in an active recovery process.

4.2. Iterative process

4.2.1. Iteration 1 – Usability testing 1 (general public)

Once the first prototype was developed, this was taken to the first stage of usability testing. The usability testing aimed to evaluate the current level of effectiveness of the prototype app, identify any problems users were having with the app, and gather initial opinions on the design features and app functionalities.

The testing was conducted online due to the Covid-19 lockdown in the UK, with 30 participants from the general public that were recruited via email and social media dissemination. The testing included 6 sections. Sections 1 to 5 included questions to gather quantitative data, asking participants to rate the app in terms of ease of use, page layout, color palette and legibility of typography for the following pages of the app: 1) log page; 2) homepage; 3) track page; 4) community page; 5) message page. Section 6 asked general open-ended questions to gather qualitative data on participant opinion and preference.

The general public were utilised at this stage of the research, given that any member of the general public may be susceptible to cancer, so were representative of potential future users of a surgery preparation app. Moreover, it was beneficial to have new users (instead of former patients who already knew the content too well) to assess the design with no previous experience, at this initial stage of development.

4.2.2. Iteration 2 – Feedback 1 (Information designer and researcher)

After the changes were implemented, the next stage of design development involved the feedback of an information designer and researcher who was asked to use and evaluate the design for any design issues that should be addressed to improve the design appearance and functionality.

4.2.3. Iteration 3 – Feedback 2 (Digital and interactive designer)

After the changes were implemented, a second stage of feedback was conducted with a digital and interactive designer and researcher. who was asked to use and evaluate the design for any design issues that should be addressed, focusing on the interactivity of the design.

4.2.4. Iteration 4 – Usability testing 2 (medical stakeholders)

Once the previously defined improvements had been applied, the design prototype was taken to a final stage of iterative testing. This took the form of a second stage of usability testing with stakeholders of the design output. Where the first stage of usability testing involved potential patient users, this stage involved medical staff with two surgical ward nurses. This ensured that the needs of both core user groups were considered during the design process; by including usability testing with both patients and medical staff. Again, the aim here was to identify any usability problems the stakeholders were having with the design, to be addressed before finalising the design output.

The changes made to the app throughout the 4 stages of iteration described in this section are listed in Table 7.

DESIGN CHANGES MADE IN ITERATIVE DEVELOPMENT PROCESS		
Design development research stage	**Chapter section**	**Design changes made**
Usability testing 1 (general public)	4.2.1.	1. The section name 'home' was replaced with 'checklist'. 2. Tick buttons were added to the 'checklist' section to allow the user to tick off tasks once they had completed them, allowing users to track their progress and encouraging completion of the checklist. 3. The 'checklist' page was shortened to reduce the amount of information initially shown. This was replaced with an expandable interactive option that allowed the user to access more detailed information where they required. 4. The 'tracking' options were redeveloped to include more detail and maximize accuracy. 5. The options displayed in the top menu tab were redesigned to make the options clearer. 6. The background shapes used as enclosures for the information displayed in the app were altered. Smooth corners were added to shapes to create a friendlier appearance (sharp corners are seen as less friendly). 7. More white space was included between the background shapes to better define each section of information.
Feedback from information design expert	4.2.2.	1. A cancel button was added to the 'event created' screen. 2. Contrast was increased between UI and background elements. 3. Individual and group chat features were combined. 4. Clickable illustration/icons were redesigned to make it look interactive. 5. In the 'checklist' section, checklists for 'recovery at home' and 'discharge day' were added. 6. In the 'track' section, a summary feature was added on this main page. This displayed the overall user score of the individual's recovery progress, based on the tracking checklist. 7. The progress charts were added for health data, to make it clearer for the user. 8. In the 'community' section, a function was added that allowed for audio playback for the displayed articles, aiming to allow articles to be listened to for those with eyesight difficulties. 9. The layout was rearranged to increase clarity. 10. Interactive buttons were enlarged to increase ease of use. 11. Interactive features and UI elements modified to increase ease of use.
Feedback from interactive design expert	4.2.3.	1. The 'diet' page was re-arranged to avoid confusion. 2. The icon of the patient in bed was changed, as the current image may be demotivating. 3. The hit area of some of the icons was enlarged to prevent the user from mis-clicking. 4. The similarity of the clickable buttons was improved to prevent confusion. 5. The visibility of the 'just now' section and the related icons were improved. 6. The top status bar was fixed. 7. The automatic transition on the splash screen was improved. 8. The interactivity of the swiping introductory screens was improved.
Usability testing 2 (medical stakeholders)	4.2.4.	1. The 'community' and 'message' sections were redesigned slightly to ensure the sections appeared distinct with less overlapping features. 2. The complex sign up process was removed, and the patient was required only to input their name and patient ID to sign in. 3. The leader board feature was removed.

Table 7. Summary of the changes made to the app in response to the research collected in the iterative design process.

4.6. Final design output

The design output was finalised after applying the changes from the last stage of usability testing. Mock-up visualizations, to show how the app would look when displayed on a mobile device of the mobile app can be viewed in Figures 1.1, 1.2 and 1.3.

Figure 1.1. Mock-up visualization of the app displayed on a mobile device.

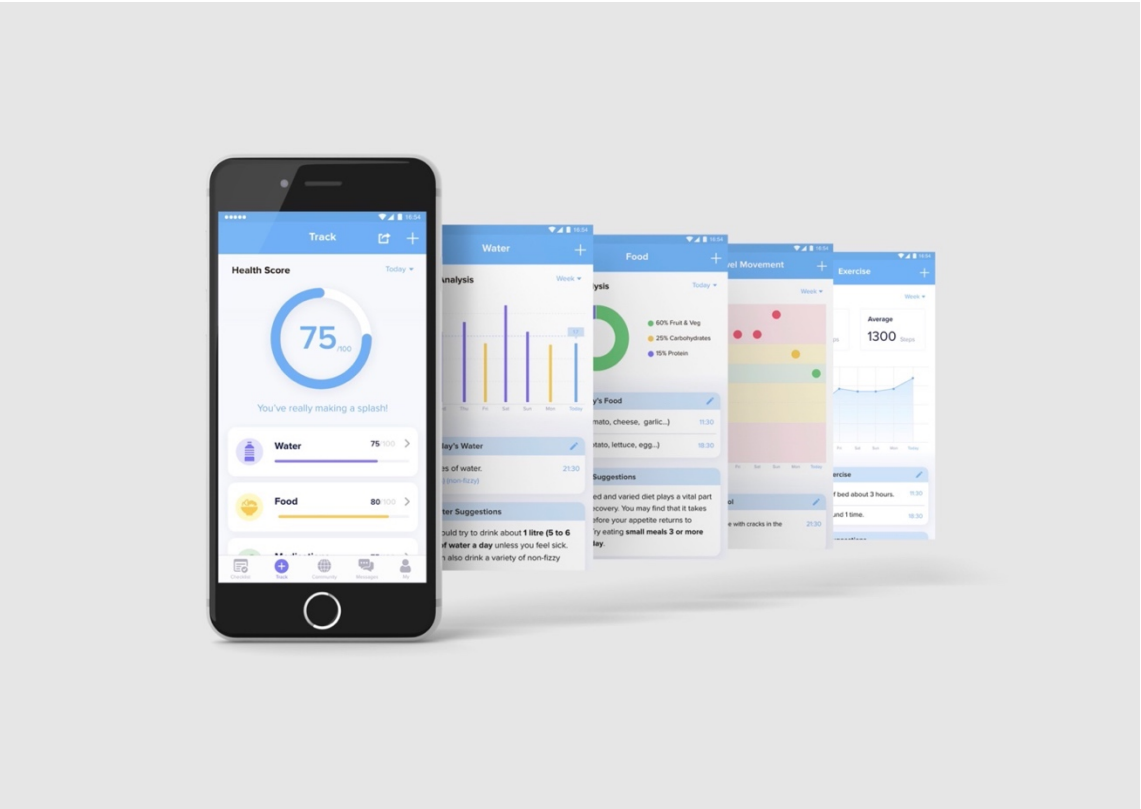

Figure 1.2. Mock-up visualization of the app displayed on a mobile device (continued).

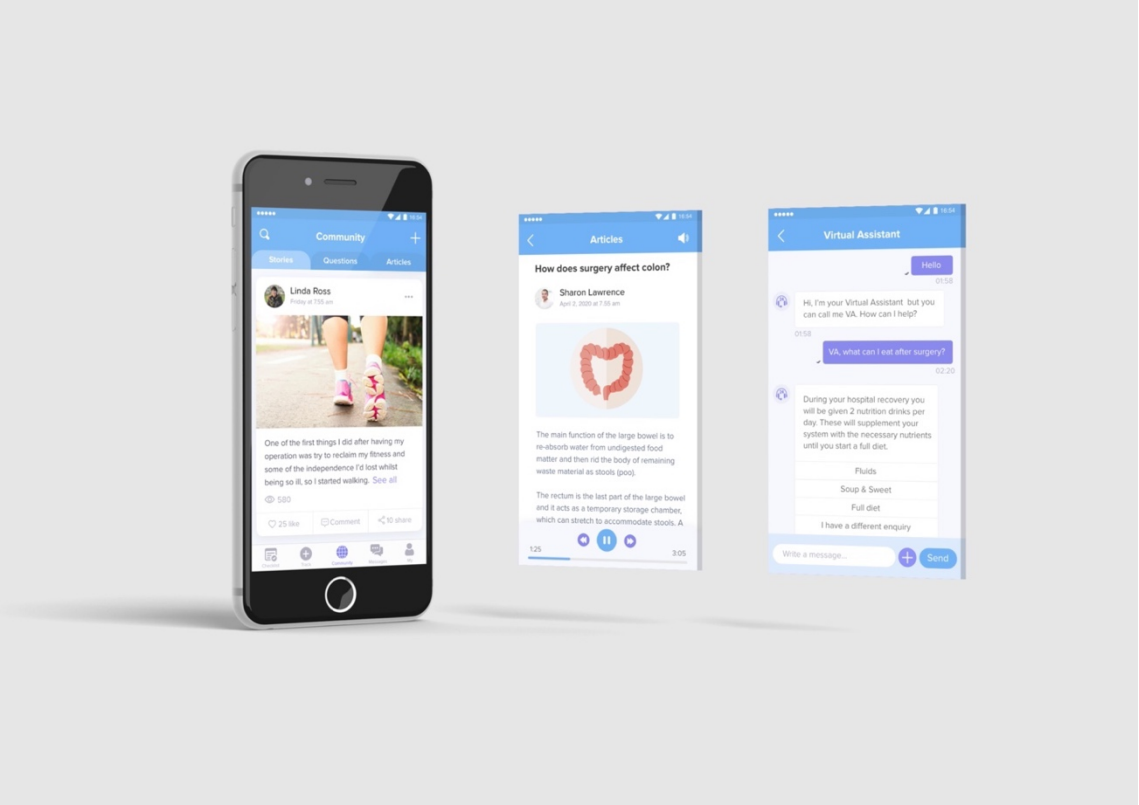

Figure 1.3. Mock-up visualization of the app displayed on a mobile device (continued).

4.7. Additional outputs

A design output was also created to be compatible on tablet devices. This tablet design version was adapted from the mobile design version and therefore contained the same information, interaction, design style, and features. The only difference for the tablet version was that the layout of each page had to be adjusted to address for the larger scale, and landscape orientated screen that the app would be displayed on. This meant that more information could be displayed on a single page, reducing the need for the user to scroll. A mock-up visualization of how the tablet app would look when displayed on a tablet device can be viewed in Figure 2.

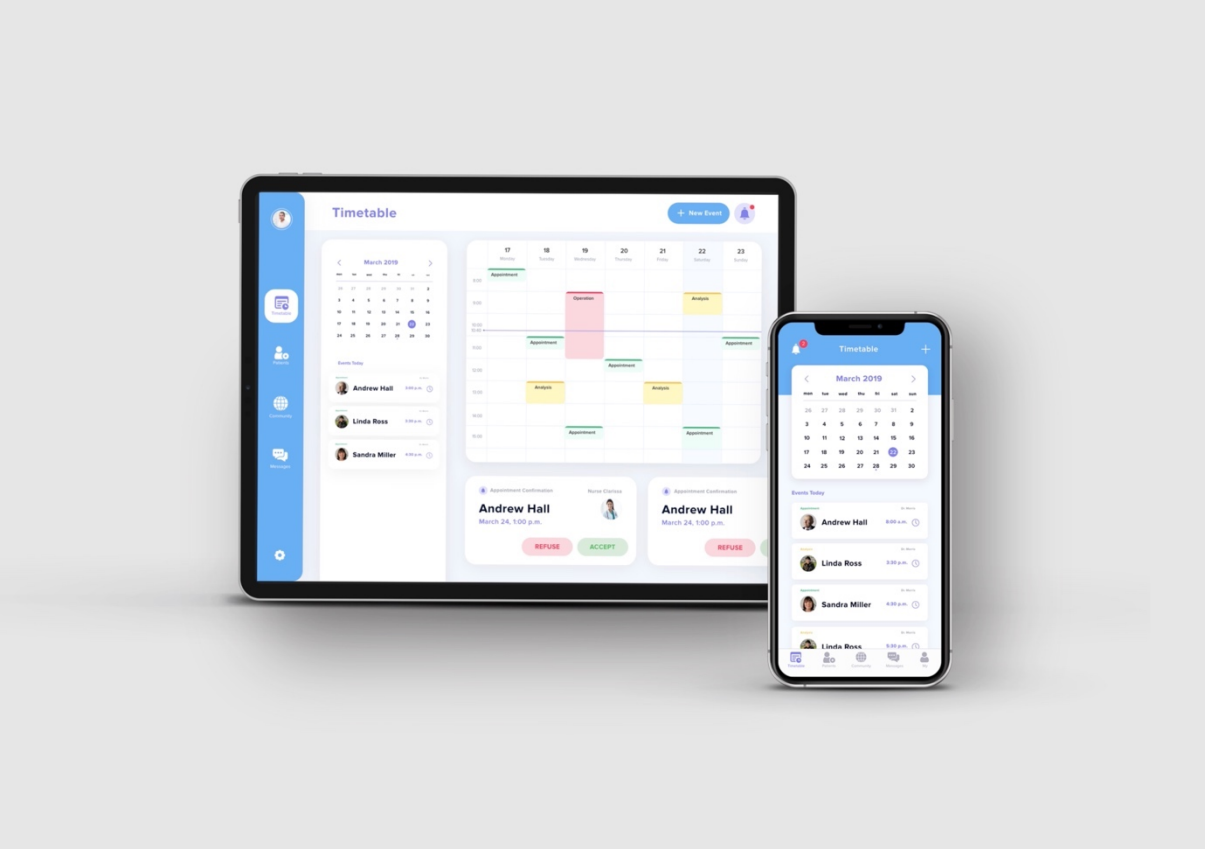

Figure 2. Mock-up visualizations of the app displayed in the mobile and tablet format.

In addition to a tablet version, two different versions of the app were also created to address the needs of both categories of stakeholders. This included a version for patients and another for medical staff. Much of the app was the same for both groups of users. However, additional features were added to the medical staff version: event management and patient monitoring features in the form of a 'timetable' and 'patient' feature. The 'timetable' feature was designed to allow medical staff to organize their daily events (e.g., scheduled consultations and surgeries), with an invite system that allowed for the creation and ability to accept event requests. The 'patient' feature allowed medical staff to manage their current patients, with the ability to adjust and observe their patients' checklists according to their recovery process. It also allowed for monitoring of patient health data, and the means to provide feedback and suggestions to individual patients. These additional features ('timetable' feature, 'patient' feature, and tablet version) are displayed in Figure 3.

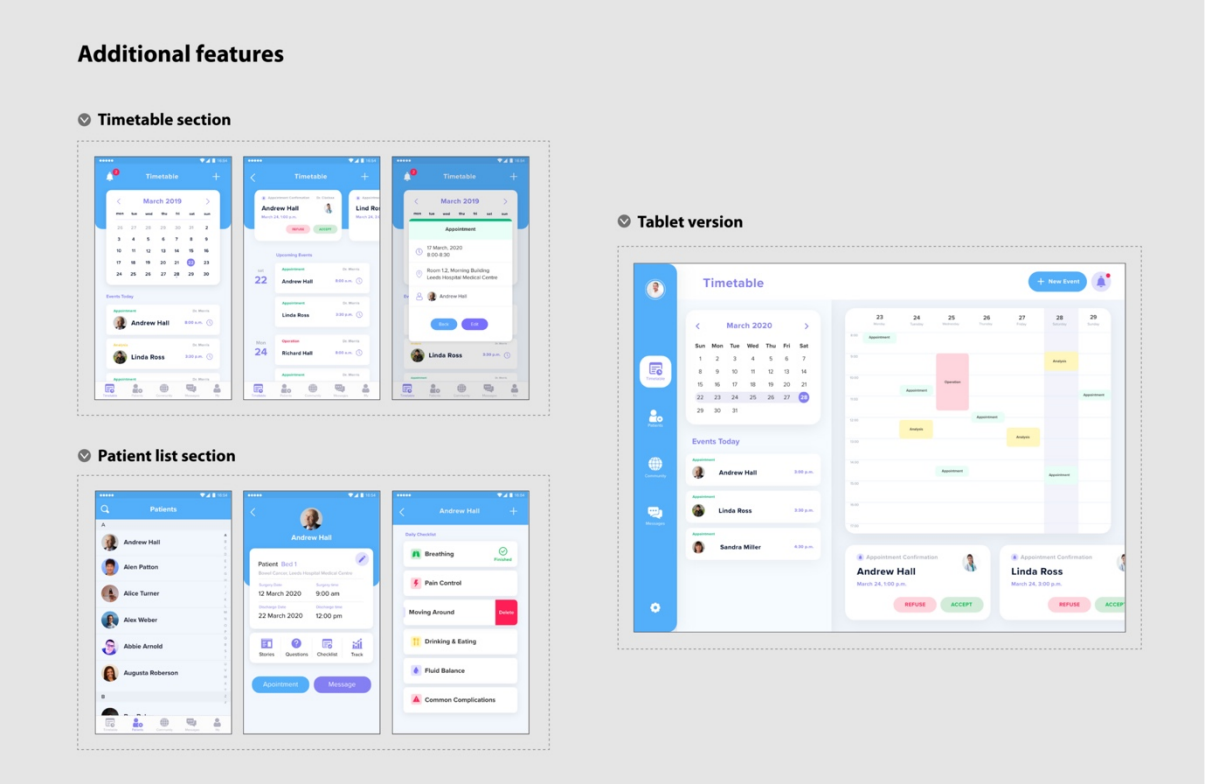

Figure 3. Screenshots of the additional features included in the medical staff version of the app.

4.8 Lessons learned

Multiple stages of informative research and iterative design stages were utilised to create the final design output. This iterative process was key in generating a bespoke design output that addressed the needs and common problems of potential users. The key lessons learned from this detailed process are summarized in Table 8.

	LESSONS LEARNED FROM METHODOLOGY AND DESIGN DEVELOPMENT	
	SECTION 3: DESIGN PROBLEM AND USER NEEDS	
	Article section	**Summary of lessons learned**
Online questionnaire with patients	3.1.1.	• Typically colorectal surgery information is communicated to patients either verbally or through a printed leaflet, with no digital information. • Patients currently use websites to independently learn more about their surgery, but not apps. • Most preferred method of patient clinician communication outside of hospital is a mobile app.
Interview with surgeon	3.1.2.	• Patient record of health data would be useful for post-surgery review, so should be explored as a feature for surgery recovery apps.
Literature review	3.2.1.	• A literature review is a vital process for the generation of research-driven information design outputs, a large body of published design principles are now available that are applicable to app design.
Visual survey	3.2.2.	• Visual survey, as a method, provided useful insight into existing practice implemented in surgery-related apps, highlighting areas that should be improved. • Common features that should be improved on health related apps were: insufficient use of white-space, inconsistent color application, use of complex photography, no search option, no privacy policy, no patient event timeline.
Co-design with stakeholders	3.2.3.	• In the context of app design, co-design is a very useful method for understanding the interactive features that users would benefit from if present in the final outcome. • It was also useful to understand the content that user expected to see in the app, specifically the identification of missing information that should be addressed in the design output development. • The most desirable features for a colorectal surgery-related app were: video tutorials for exercise, health monitoring graph, daily diet plans, daily symptom tracking, interactive breathing exercise, daily pain index monitoring.
	SECTION 4: DESIGN DEVELOPMENT	
Usability testing with general public	4.2.	• Usability testing was key in identifying areas of the prototype that the users were having difficulty navigating or using as intended. • The majority of feedback was related to the addition or alteration of features within the app, rather than design changes.
Feedback from information/ interactive designers	4.3.– 4.4.	• Feedback from design experts was useful for identifying opportunities to improve areas of the design (e.g., text legibility, color contrast, layout adjustment, scale of design elements). • Including feedback from an expert with UX expertise was key in further identifying specific interactive features that could be improved (e.g., icon redesign, increase ease of interaction, clarifying visual similarities of clickable elements, interactive gestures).
Usability testing with medical professionals	4.5.	• A second stage of usability testing with medical professionals ensured that feedback from both potential stakeholders (patients and medical staff) was considered. • Again, feedback was focused problems with app features and navigation.

Table 8. Summary of the lessons learned through the process of the methodology and design development stages.

5. EVALUATION AND VALIDATION

Section 5 describes a performance test that was created and launched by Credamo for the three instructional materials, including the: mobile app, tablet app, and booklet, i.e., three design conditions. Credamo is a global research platform that was used for the recruitment of participants and testing due to the covid-19 lockdown in the UK that happened several times.

The aim of the performance test was to investigate and compare the effectiveness of these instructional materials. This was determined through an information location task alongside the collection of supporting qualitative data. It involved collection of the following data: information location data (time), accuracy of answers, user design and task rating, and opinion interviews.

5.1. Participants

A total of 158 participants took part in the performance test, comprising of 58 participants for the mobile app group, 50 participants for tablet app, and 50 participants for the booklet. Purpose sampling was done so that all participants: a) were based in the UK and users of NHS services; b) were over 50 years old (with an average age of 56.6) to reflect the age of bowel screening in the UK (currently from 60 but to expand to 50 and over for early detection of bowel cancer). A summary of participants data can be viewed below (Table 9). As observable, both age and education level were similarly distributed across all three design conditions.

	PARTICIPANT DATA DISTRIBUTIONS		
	Mobile app (N=58)	**Tablet app** (N=50)	**Booklet** (N=50)
Age group			
50-54	18 (31%)	13 (26%)	19 (38%)
55-59	27 (46.6%)	27 (54%)	23 (46%)
60-64	12 (20.7%)	10 (20%)	5 (10%)
65-69	1 (1.7%)	0 (0%)	2 (4%)
70+	0 (0%)	0 (0%)	1 (2%)
Average age	**56.8**	**56.8**	**56.1**
Education level			
Secondary school	9 (15.5%)	6 (12%)	5 (10%)
Undergrad degree	31 (53.3%)	31 (62%)	31 (62%)
Masters degree	17 (29.3%)	17 (24%)	14 (28%)
PhD	1 (1.7%)	1 (2%)	0 (0%)

Table 9. The participant age and education level data for each design condition.

5.2. Quantitative results

Each test consisted of three parts: 1) information location task; 2) visualization evaluation; and 3) an interview. In the Information location task, participants were asked 11 information location questions. Participants were informed that the answer to these questions could be located somewhere in the material that they were using. The first location question was used as a sample question, so was not included in the data analysis, leaving the results of the remaining 10 questions to be analysed. The sample question was included to allow participants to familiarise themselves with the instructional material and the experimental process. It also allowed participants within the mobile app and tablet group to freely undergo the introduction process present in both of these conditions, where initial contextual information was displayed on opening the app before being taken to the homepage.

If the information could not be found, participants were asked to state an 'I can't find it' option. Their answers and timing-length for each question were recorded, so the time data from the 10 information location questions was used to later determine information location efficiency with each design variation. Participants were asked to imagine they were a hypothetical patient, having had bowel surgery and using the material to find information about their recovery process. The 10 information location questions can be observed in Figure 4. Additionally, this data collection stage was used to evaluate the accuracy of the answers provided by participants, by assessing the number of correct answers to the information location questions. Again, using the answers from the same 10 questions. The mean results of the accuracy and time data is also summarized in Figure 4.

QUANTITATIVE DATA | INFORMATION LOCATION QUESTIONS (Q = Question)

Q1	What are the different methods of pain control available?	**Q6**	How many times should you eat each day?
Q2	How many hours will you be able to get out of bed and sit in a chair on the first day?	**Q7**	How can you plan your walking?
Q3	How many nutrition drinks will you be given today?	**Q8**	When should you be able return to work?
Q4	Before you are discharged and go home, what tasks do you need to be able to carry out on your own?	**Q9**	When should you be able to start driving?
Q5	When will your stitches be removed?	**Q10**	During the first one or two weeks, what kind of complications with your wound would you need to seek immediate medical attention for? List only two complications.

QUANTITATIVE DATA | ACCURACY and CORRECT TIME RESULTS

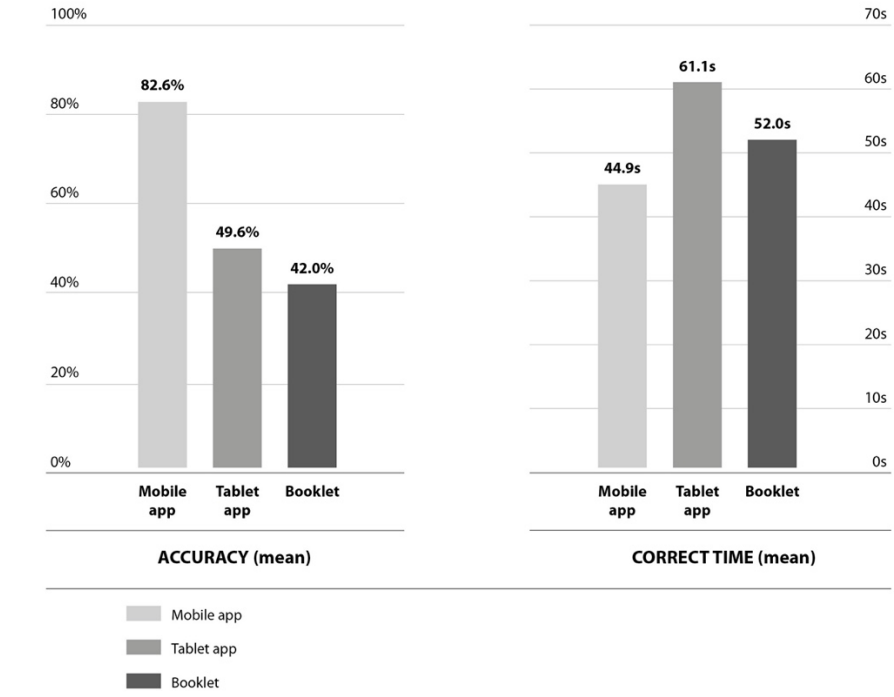

Figure 4. Graph comparing the mean accuracy and correct time data for participants using the three design variations.

5.2.1. One-way ANOVA results

One-way ANOVA tests were performed between conditions to compare accuracy and speed of correct answer location performance between participants using the mobile app, tablet app, and the booklet. (ANOVA stands for Analysis of Variance, and is a statistical test used to analyse the difference between the means of more than two groups). This was to investigate if the way the information was presented (Mobile app, Tablet app, and Booklet) had a significant influence on two different factors:

1. Average accuracy rate (for the information location questions).
2. Correct information location time (average time to locate a correct answer).

The one-way ANOVA for accuracy revealed that there was a statistically significant difference in mean accuracy score between at least two groups (F(2, 1577) = [122.539], p<.001). The Tukey's HSD tests for multiple comparison revealed a significant difference in accuracy performance between the mobile app and the tablet app (p<0.001, 95% C.I. = [0.27, 0.40]), the mobile app and the booklet (p<.001, 95% C.I. = [0.34, 0.47]), and the tablet app and the booklet (p=0.029, 95% C.I. = [0.01, 0.14]). This shows that participants using the mobile app were significantly more accurate than participants using both the tablet app and the booklet. Additionally, participants using the tablet were also significantly more accurate than participants using the booklet.

The one-way ANOVA for correct answer location time revealed that there was a statistically significant time difference between at least two groups (F(2, 934) = [4.080], p=017). The Tukey's HSD tests for multiple comparison revealed a significant difference in correct answer location time between the mobile app and the tablet app (p=0.013, 95% C.I. = [-29.43, -2.81]). There was no statistically significant difference in correct answer location time between participants using the mobile app and the booklet (p=0.465), or between participants using the tablet app and booklet (p=0.379). This shows that participants using the mobile app located correct answers significantly faster than participants using the tablet app. This was the only significant result for correct answer location time. Descriptive statistics from the results can be viewed in Tables 10.1 and 10.2.

	Performance ANOVA results					
	Sum of squares	**df**	**Mean square**	**F**	***p***	
Accuracy						
Between groups	51.315	2	25.657	122.539	p = <.001	**p < .001**
Within groups	330.194	1577	0.209			
Total	381.509	1579				
Correct answer time						
Between groups	42852.893	2	21426.447	4.080	p = .017	**p < .001**
Within groups	4905400.13	934	5252.034			
Total	4948253.02	936				

Table 10.1. Detailed statistics for the on-way ANOVA tests comparing performance between the design conditions (mobile app, tablet app, booklet).

	Tukey HSD multiple comparison tests					
	n	**M**	**Mean diff**	**SE**	***p***	
Accuracy						
Mobile app	58	0.826	0.332	0.028	p < .001	**p < .001**
Tablet app	50	0.496				
Mobile app	58	0.826	0.406	0.028	p < .001	**p < .001**
Booklet	50	0.420				
Tablet app	50	0.496	0.074	0.029	p = .029	**p < .05**
Booklet	50	0.420				
Correct answer time						
Mobile app	58	44.9	16.117	5.669	p = .013	**p < .05**
Tablet app	50	61.1				
Mobile app	58	44.9	7.078	5.998	p = .465	NS
Booklet	50	52.0				
Tablet app	50	61.1	9.039	6.796	p = .379	NS
Booklet	50	52.0				

Table 10.2. Detailed statistics Tukey HSD tests comparing performance between the design conditions (mobile app, tablet app, booklet).

5.3. Qualitative results

5.3.1. Visual evaluation

Detailed qualitative methods were also employed to investigate user opinions on various aspects of the designs. Participants were asked to evaluate the test materials regarding specific design features, by rating the statements covering visual design evaluation. They were asked to agree/disagree with the statements on a 7-point Likert scale, ranging from strongly disagree to strongly agree. After this was complete, a short interview section took place covering 5 questions to gather further opinion on the design they had used. This is described in Figure 5.

The average opinion ratings for the three design variations (mobile app, tablet app, booklet) in the visual evaluation section were all relatively high. The visual evaluation section asked participants to rate specific design features of the material they used, covering: information location and understanding, text, color, graphics and layout.

The meaning of the statements (S1, S2, etc…) can be observed in the methodology section above. There was no rating below 5, meaning that on average every statement was 'slightly agreed' with or higher. However, across all 9 statements, the mobile app was rated the highest, followed by the tablet app, with the booklet being consistently rated the lowest. See Figure 5.

OPINION | VISUAL DESIGN EVALUATION QUESTIONS (S = Likert scale statement, I = Interview question)

S1	The information is easy to find.	**S9**	The interaction design is adequate.
S2	The information is easy to understand.		
S3	Text is legible.	**I1**	Any specific comments regarding the general design and visuals?
S4	Font size is adequate.		
S5	Color scheme is appropriate.	**I2**	Please list up to 3 positive features of the design?
S6	Images/icons/ illustration clarify the information.	**I2.2**	Please explain why.
S7	Images/icons/ illustration style is appropriate.	**I3**	Please list up to 3 improvements the design needs?
S8	Page layout is clear.	**I3.2**	Please explain why.

OPINION | PARTICIPANT VISUAL DESIGN EVALUATION SCORES

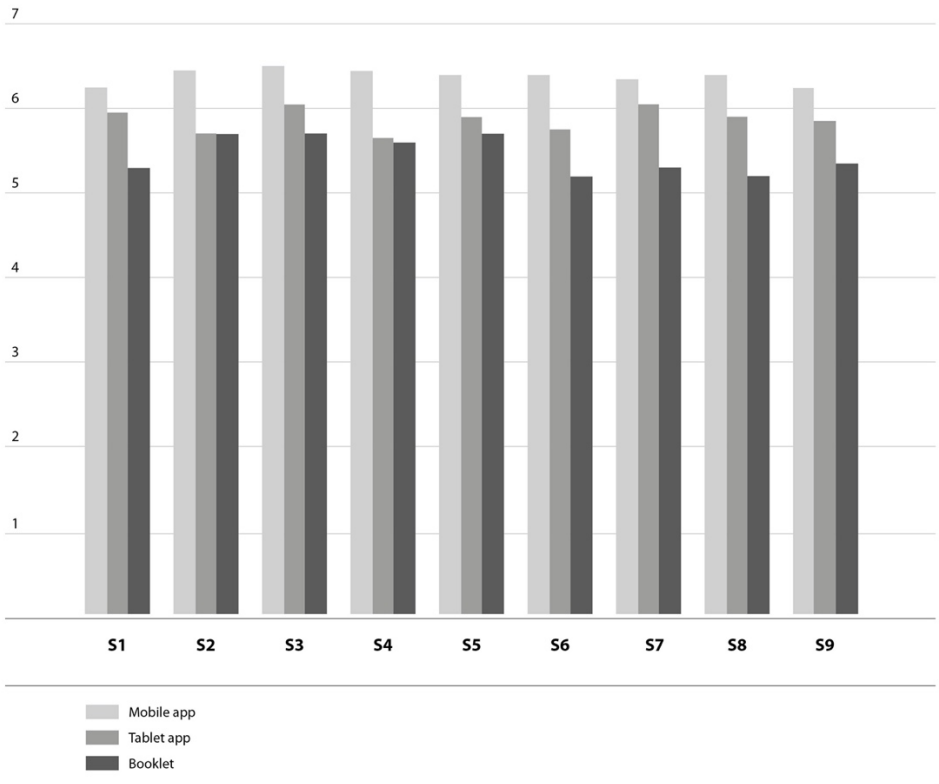

Figure 5. The visual evaluation statements and mean results for the mobile, tablet, and booklet conditions.

5.3.2. Interactive evaluation

An interactive evaluation was included for the 108 participants (out of the 158) using an interactive design (either the mobile, 58 participants; or the tablet app, 50 participants), assessing the ease of specific tasks that could be carried out on the mobile or tablet app. This involved the description of two different scenarios where participants were provided with the description of a hypothetical user, this being either a patient or a medical professional. They had to imagine they were this user and were given a task, then asked to rate the ease of completing these 12 tasks on a 7-point Likert scale ranging from very difficult to very easy. After both scenario task ratings were complete, participants were also asked 3 interview questions to gather further information. The scenarios, tasks, and interview questions are described in Table 11. Again, the average ratings were high with no score below 5 (slightly easy). The mobile app scored higher than the tablet app in 11 of the 12 tasks, only in task 3 did the tablet score slightly higher. See Figure 6.

OPINION | INTERACTIVE DESIGN EVALUATION QUESTIONS (T = Likert scale task, I = Interview question)
- Used for the mobile app/tablet app only

Scenario 1: Patient perspective 'You are Andrew Hall, a patient who had bowel surgery. You are now recovering from surgery.'	**T1**	Find the information regarding your recovery.
	T2	Record your health-related data (water, food, symptoms, bowel movement etc.)
	T3	Monitor your recording data through diagrams.
	T4	Read, add, comment and share stories, questions and articles on 'Community'.
	T5	Send, read, find messages on 'Message'.
	T6	Get personal information on 'My'.
Scenario 2: Health professional perspective 'You are Sharon Lawrence, a doctor in charge of bowel surgery recovery and you are at work.'	**T7**	Find the detail of the appointment with Andrew Hall.
	T8	Accept or refuse the event invitation.
	T9	Add a new appointment with Andrew Hall.
	T10	Find patient detail of Andrew Hall.
	T11	View the track data of Andrew Hall and add suggestions.
	T12	Send a message to Andrew Hall.
Scenario 1 and 2: Interview questions	**I1**	Any specific comments regarding features of the App when using it as a patient?
	I2	Please list up to 3 positive features of the material you used? Please explain why.
	I3	Please list up to 3 improvements the material needs? Please explain why.

Table 11. The interactive evaluation statements and questions used to assess the interactivity in mobile and tablet app.

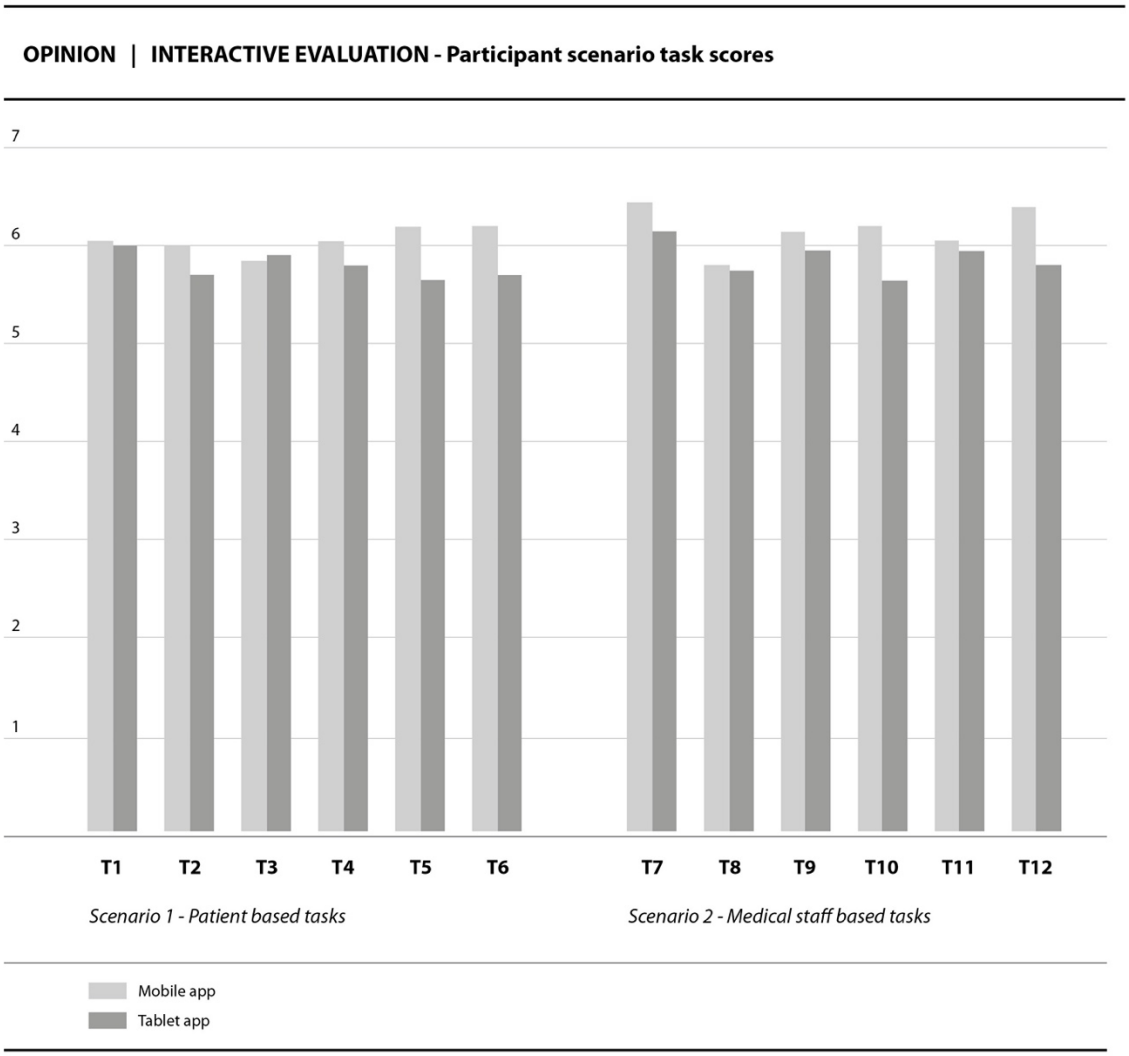

Figure 6. Comparison of the mean interactive evaluation scores for the mobile and tablet app.

5.3.3. Interview results

During the interview at the end of the performance test (the final stage of the evaluation and validation test/study), the 158 participants were asked to describe any comments they had on the designs they used, improvements they thought necessary, and positive features of the design.

For the mobile app the most common comments included that the design was functional and useful with a clean appearance. Participants also thought it was easy to use with good design features. To improve the mobile app, they suggested that more features were required, such as an introduction or tutorial on how to navigate and use the app, a help menu or search option, and a more detailed calendar. They also thought that the design should include more information, such as the display of patient or medical staff information. The main positive features of the mobile app included the ease

of use with simple navigation that allowed information to be found easily, concluding that the design was informative. They thought it was clear and user friendly with an appropriate color scheme and an overall attractive appearance.

For the tablet app, overall, participants commented that it had an appealing user-friendly design. Some did state that the color scheme should be adjusted. To improve the tablet app, they suggested that more features were needed. Examples of this include: a navigation tutorial, search option, help option, a video call feature, and health tips/checklist. They also thought the message feature should be improved, with notifications for unread messages or the option for messages to be read aloud. Positive features of the tablet app included the user-friendly and easy to use interface, as well as the clear and simple layout and the informative purpose of the app.

For the printed booklet, the most common comments had a mixed response with some stating the design was appropriate and useful, and others finding it hard to remember and navigate. The booklet was A5 format, 27 pages long of text dense information. Only 5 photographs were included, which did not explain the information and were only present for ornamental purposes, displaying images of a nurse/carer and a patient, or of a flower(s). There were 11 main sections in the booklet: Before you operation; Preparing for your operation; After your operation; The evening after your surgery; Day 1 – Day after surgery; Day 2-3 after surgery; Day 4-7 after surgery; Getting ready to go home; Complications and side effects; Looking after yourself; Contact details.

Some participants thought the design and features of the printed booklet could be improved, stating that there should be, for example, more lists and bullet points because information was sometimes hard to find. The main positive feature of the booklet was said to be the easy-to-read text, using what the participants included in the study believed to be an appropriate size and good choice of font. Participants also thought it was easy to understand with the use of simple language, being concise but still with well explained content. Suggested improvements for the booklet included the need for a larger font size (despite in general participants considered the font size to be appropriate) and the inclusion of more lists/bullet points. Some also suggested the inclusion of more images with a more colorful color scheme.

Thematic analysis was undertaken for the opinion data collected in the interviews. This was to identify common themes that were voiced by participants, and to analyse the frequency of their expression. Figure 7 shows a summary of the most common comments by participants.

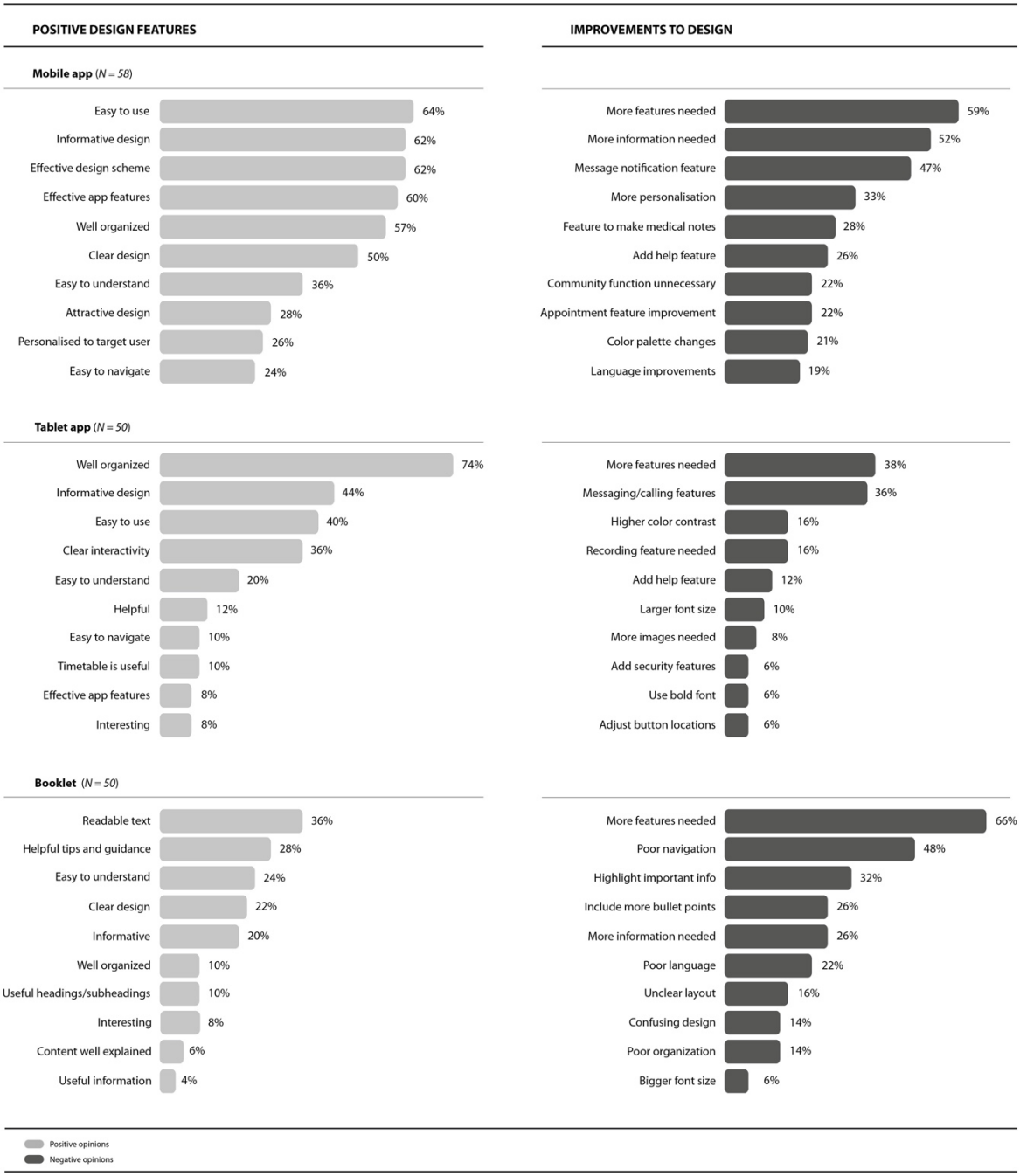

Figure 7. Summary of opinion analysis from the three design conditions.

6. DISCUSSION/CONCLUSION

It is apparent that research interest in health-related apps has recently increased, leading to a multitude of publications exploring the integration of e-health apps in many medical contexts, including surgery preparation and recovery. A vast collection of evidence now supports the use of interactive apps, finding them to benefit patient outcomes, when integrated with surgery recovery programmes. Improvements related to the communication of information have also been recorded, such as patient satisfaction with information and perceived hospital involvement (Timmers et al., 2019). Despite our research not yet testing the developed app within a real-world surgery recovery programme, the improvement in accuracy and user opinion when using the mobile app output suggest similar positive outcomes may also be observed if incorporated in colorectal surgery recovery practices.

More specifically, many apps have been developed looking to optimise the patient recovery process after colorectal surgery. However, user-centred design methods in the context of colorectal surgery have been explored very little, favouring feasibility type studies that investigate the medical benefit of integrating e-health resources. Additionally, though co-design has been well documented in health apps, an in-depth multi-methods approach (user-centred and iterative where possible) that has been proven as successful in other information design outputs (e.g. Lonsdale, Ni, et al., 2020; Lonsdale, Sciberras, et al., 2020) has yet to be considered in the context of supportive digital tools for bowel surgery preparation and recovery.

This study expanded on this existing evidence, by exploring the development of an e-tool employing a user-centred and multi-methods design and research approach, in order to enhance the patient preparation and recovery process with focus on interactive and communication app features. Ultimately the iterative design development process aimed at creating a bespoke design output with optimised usability: first establishing the needs of the stakeholders; then developing a mobile app that was improved in various stages to address these needs and adjust to stakeholder feedback.

The effectiveness of the final output was then assessed using a multi-methods approach, informed by health app research methodologies. With this in mind, the usability of the developed app was examined in appropriate depth, exploring the effectiveness and efficiency of the tool, as well as user satisfaction. This was achieved through the collection of qualitative and quantitative data, aiming to examine user performance through information location efficiency, accuracy, and user opinion data.

Many of the existing studies examining the effectiveness of a surgery information app test the design in a feasibility study without comparing it to more traditional communication methods (e.g. Semple et al., 2015; Ponder et al., 2020; Ponder et al., 2021; Joshi et al., 2022; Valk et al., 2022). By comparing the developed app to traditional patient education practices (e.g., verbal or printed information), it further allows us to understand if the developed app is a more effective communication tool. Therefore, in this study performance with the health app was compared with a printed information booklet that displayed the same information in a static format. Moreover, apps can be displayed in both mobile phones or tablets, which require a different layout and interaction. Therefore, this study also compared the difference in performance and user opinion between a mobile app and a tablet app.

In terms of performance testing and quantitative analysis, participants using the mobile app were significantly more accurate at finding information than participants using both the tablet app and the booklet; and participants using the tablet app were also significantly more accurate at finding information than participants using the booklet. When assessing the speed of locating the correct information, however, a significant difference was only found between the mobile app and the tablet app.

What is of interest from these results is that from early 40s, many adults start to have difficulties with their vision at close distances, especially when using digital platforms. Therefore, one would assume that: 1) a printed booklet would be the favourite means of engaging with communication; 2) a bigger digital platform (like a tablet in comparison with a mobile) would facilitate quicker and more accurate location of information. However, the results show the opposite. The results from this study show that participants engage very well with interactive e-tools despite being over 50 years older. Moreover, a smaller platform like a smart mobile phone (that can be 2 to 3 times smaller than a tablet), was in fact the platform with which participants engaged with interactive bowel surgery recovery information better. This therefore shows the power of information design in enhancing or hindering performance and ease of access to information, independently of the age of its users and the size of the platform used.

Therefore, a multi-methods research approach is key if we want to generate valid and reliable results as well as tailor-made outputs. It was through the additional methods to performance testing (i.e., visual evaluation, interactive evaluation, and final interview) that we were able to understand why, according to participants' perception and opinion, the mobile app might have performed better overall. The mobile app was clearly the most visually appealing and easiest to navigate. According to participants, this was due to the ease of use with simple navigation, clear and user-friendly information design with an appropriate color scheme, and an overall attractive appearance.

The tablet app, on the other hand, received positive comments but with a common negative observation. While the tablet app was considered easy to use and useful, the navigation was considered unclear, both from a patient and medical staff's perspective. So, while the design 'look and feel' was the same as the one used for the mobile app, the way information was adjusted to the tablet landscape layout, was not as successful. This therefore provides evidence that a lot more strategic and creative thinking and testing is needed when adapting a design to a different platform. For example, the type of interaction, the position of visual and interactive elements on the page, the layout, etc., all need to be carefully thought through and adjusted as needed.

As for the booklet, the mixed response between it being appropriate and useful, and it being hard to remember and navigate (i.e., information was hard to find) confirm what Lonsdale (2022) explains and illustrates in detail in her book to show the power of information visualization (and respective user-centred research methods) in making information more accessible, engaging, and easier to remember. The booklet tested in this study, which is the default information tool used by NHS hospitals in the UK, is text dense and was not designed considering research-based information design principles and theories, nor designed with the user and for the user. The mixed response,

here, illustrates the need for the implementation of research-based design processes when communicating important medical information.

Despite the superiority of the mobile app, improvements were suggested for all three outputs (mobile app, tablet app and booklet). For the mobile app, more features are required such as: an introduction or tutorial on how to navigate and use the app, a help menu or search option, a more detailed calendar, and the ability to display more patient or medical staff information. For the tablet app, more features are needed such as: a navigation tutorial, search option, help option, a video call feature, health tips/checklist, notifications for unread messages or the option for messages to be read aloud. (It is important to note that while we are listing these features separately as reported by participants for each e-tool, all features should be beneficial and considered for both mobile and tablet app.) The main improvements suggested for the booklet, as expected, include images with a more colorful color scheme, more lists/bullet points, and larger font size. All these are important suggestions that should be considered in future research devising and testing e-tools for healthcare contexts such as cancer and surgery recovery.

Finally, and in more general terms, this study is key in filling research gaps in the field of information design for healthcare settings by providing e-tools that are designed to be inclusive of both patients and medical staff during bowel surgery recovery. In addition, it also strengthens previous studies and claims, by reiterating that:

- Adherence to ERAS protocol improves surgery outcomes (Gustafsson et al., 2011; Pecorelli et al., 2021). Therefore, approaches that can optimise patient compliance to both pre- and post-surgery instructions are key.
- Although there are self-care prospects with common ERAS programmes, the opportunity to interact with hospital staff has reduced due to shorter hospital stays (Kim et al., 2017; Taylor & Burch, 2011). Therefore, more emphasis needs to be given to patient self-recovery at home.
- Better information is needed for patients post-surgery (Hoekstra et al., 2014; Lo et al., 2021). Therefore, better communication tools and methods between medical staff and patients while recovering at home are key.
- The development of healthcare apps to enhance the patient recovery process after colorectal surgery is well researched and supported (Kim et al., 2018, Pecorelli et al., 2018, Keng et al., 2020, Eustache et al., 2022). However, current research focuses on medical outcomes of the implementation of an app rather than the design development processes than can optimise the design and maximise patient adherence. Therefore, more attention and time need to be dedicated to the design of healthcare apps to make sure that these are: informed by solid research and theories; user-centred (ideally co-created with the target user); and tailored to the disease and needs of the patient.

7. LIMITATIONS AND FUTURE RESEARCH

As already discussed at the start of this paper, the small sample for the co-design sessions was dictated by the surge Covid-19 in the UK when the study started to be conducted, and the respective lockdowns that took place until 2021. While this can be seen as a limitation of the study, the two patients had already taken part in a focus group (Chapman et al., 2020) with 9 other patients, where all 11 patients together represented a broad sample of patients across the national UK setting (including most geographical regions). We are therefore confident that these two patients were able to represent the views and needs of bowel surgery patients in general in the UK (extracting from all that was discussed in the focus group). With this in mind, we believe that the data are sufficiently reliable and stable to extract meaningful guidance for the development of the design outputs here presented.

Another limitation of the study was the non-involvement of family and carers. This was for two main reasons. Firstly, in the focus group conducted by Chapman et al. (2020) the primary concern and need as reported by participants, was to devise information that focused on the patient as the primary consumer of information (not their family and carers). It was clear that while some patients are supported by family and friends, some reported to live on their own without such support. Secondly, this study started to be conducted during the Covid-19 outbreak in the UK and the first full lockdown from March 2020 lasting for months. This made it even more prominent that the need was to primarily devise information that met the needs of the patients themselves first and foremost since many of patients found themselves isolated and on their own, having to self-manage their recovery without family and carers' support. Nevertheless, it would be important for future research to also involve carers and look at the importance of designing information with the input of carers too.

As indicated earlier in the paper, the general public were utilised for usability testing 1 and the experimental testing to avoid carry over effects that bowel surgery patients who already knew the information could bring. Nevertheless, we acknowledge the limitation that this brings in the sense that participants who are not patients or former patients will be in a different cognitive, psychological and biological state. As discussed by patients in the focus groups conducted by Chapman et al. (2020) there are difficulties of understanding information during emotionally challenging situations, which include feelings of shock, fear and uncertainty after receiving bad news such as having bowel cancer. Patients will also be in pain and feel a level of discomfort while recovering after surgery. However, at this stage of the research, it was not our aim to involve patients who were recovering in hospital or at home, as they would have the information very present in their mind and this would mask the results. Nevertheless, this is another area of further research to consider in the future.

Finally, as the study started to be conducted at the start of the Covid-19 surge, no comparison has been made in this paper with other tools that have grown in popularity more after Covid. Examples include telemedicine approaches, doctors and nurses available through phone consultation, etc. Future research should investigate further and make this comparison to ascertain what other information tools are as beneficial or more than an app as the one described in this paper.

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Appendix 1 | Summary of the design principles defined in the literature review that were considered in the development of the apps

	INTERACTIVE APP PRINCIPLES	References
Layout	• Web pages with cleanliness and low visual complexity are more attractive to the users.	(Michailidou et al., 2008; Tuch et al., 2012)
	• Using appropriate white space on a web page can highlight the important elements and convey information effectively.	(Hornof and Halverson, 2003; Tselentis, 2012)
	• Webpage items should be aligned appropriately and consistently to allow the user to locate them easily.	(Hornof and Halverson, 2003; Lipton, 2011; Beukes et al., 2016)
	• Place related options next to each other in a vertical list and left-align keywords.	(Hornof and Halverson, 2003)
	• The design elements on the webpage (e.g., the amount of information, the ratio of pictures and texts, font, etc.) should be balanced.	(Karlsson, 2007)
	• Use arrows, bullet points, lines and symbols in various colors.	(Pettersson, 2010).
	• Use margins, repetition and white space to highlight related information.	(Pettersson, 2010)
	• The organization logo should lead to the homepage, be an appropriate size and be placed in the same position on each webpage (generally in the upper left corner).	(Leavitt and Shneiderman, 2006; Loranger, 2017)
	• Information should be placed in the order of usefulness to the users (e.g., important information higher on the page to be quickly located) on each webpage.	(Loranger, 2017; Fessenden, 2018)
	• Start breadcrumbs with the Home link. Have no more than one home button on the same webpage.	(Loranger, 2017)
	• Keep the tab title in one row and place on top of the tab pane.	(Nielsen, 2016)
Typography	• Be selective with the content you display and only show what is important.	(Lipton, 2007)
	• Font size is related to the importance of text content (larger = more important).	(Lipton, 2007)
	• A consistent design style imparts a sense of familiarity.	(Lipton, 2007)
	• Use text no smaller than 9-point and no bigger than 12-point.	(Lipton, 2007)
	• Try to keep backgrounds consistent as it's hard to read type over changing backgrounds.	(Lipton, 2007)
	• Avoid using type over images.	(Lipton, 2007)
	• Choose fonts familiar to readers when designing.	(Lipton, 2007)
	• In a book or manual layout, aim to use 50-70 characters per line for optimal reading speed (including word spaces and punctuation points).	(Lipton, 2007)
	• Use sans-serif fonts to emphasize key messages.	(Silverman, 2004)
	• Sans-serif fonts are appropriate for titles.	(Silverman, 2004)
	• Use appropriate font styling to attract attention to important content: users rely on elements like headers and bolded text to identify when information is important and to locate new segments of content.	(Nielsen, 2010)

	INTERACTIVE APP PRINCIPLES (cont.)	References
Color	• Consider brand colors and regional color associations when choosing a color scheme.	(Pipes, 2011; Babich, 2017)
	• A simple color scheme (two or three colors) is optimal for the design.	(O'Donovan et al., 2011; Babich, 2017)
	• Use complementary colors carefully to keep the content from being visually jarring. Choose a dominant color and use its complementary color for accents.	(Babich, 2017)
	• Match the background color with your dominant and accent colors.	(Wong, 2019)
	• Use your dominant color sparingly important information (e.g., logo, menu tabs, title or headlines, button) or if you want your visitors to take certain actions (e.g., call to action button, fill in a contact form, sign up to a newsletter).	(Wong, 2019)
	• Use color meaningfully to: show difference and similarities; help the user navigate information; help the user recall information; emphasize information; encourage user to move through information; convey meanings.	(Lipton, 2007)
	• Use color to structure and group items on the page.	(Travis, 2016)
	• High color contrast is the best choice for important content or key elements, but avoid using too much color contrast which may cause color bleeding.	(Babich, 2017; Sandnes, 2017)
	• Check the color contrast ratio to have a fair amount of contrast between elements.	(Babich, 2017; Kirkpatrick et al., 2018)
	• Use a light or a dark background color appropriate to the content, and then use a color with good contrast for the figure or text.	(Pettersson, 2010).
	• Colors should work well together and complicated backgrounds are avoided.	(Travis, 2016).
	• Make sure that differences between colors are clear and obvious.	(Pettersson, 2010).
	• Combine colors with shape in warning signs.	(Pettersson, 2010).
	• Use color-coding on websites and make sure that the coding scheme can be quickly and easily understood.	(Leavitt and Shneiderman, 2006)
	• Blue is the ideal choice for medical website/app, it is associated with credibility, trust, knowledge, confidence, professionalism, cleanliness, calmness, seriousness and serenity, which are valued in the medical community. Some of the other colors commonly chosen for medical logos include: •(Bright) yellow and (mild) orange –happiness, friendliness and cheer. •(Light) green –growth, balance, prosperity and wellbeing. •(Baby) pink –warmth, nurture, softness, innocence, bliss and sweetness.	(Smith, 2016; Rogers, 2017; Reed, 2020)
Visualization	• Use clear and high-quality images sparingly and keep the background image simple to allow the user to understand the visuals quickly.	(Leavitt and Shneiderman, 2006; Pettersson, 2010)
	• Make the text which that accompanies an image bold and with high readability.	(Pettersson, 2010)
	• Write legends to explain images used in information materials.	(Pettersson, 2010)
	• Icons should be visually and conceptually distinct yet still be consistent. They should follow the same structure (e.g., line width, border radius, line angles, fill and palette).	(Travis, 2016; Justas, 2015)
	• Use icons and graphics which are standard and intuitive.	(Travis, 2016)
	• Use icons in navigation only if they help users to recognize a class of items immediately.	(Nielsen, 2001)
	• Use a graphic format to display data when users must monitor changing data.	(Leavitt and Shneiderman, 2006)
	• Graphics should not be confused with banner advertisements.	(Leavitt and Shneiderman, 2006; Travis, 2016)
	• Use illustrations to facilitate faster learning of key concepts.	(Leavitt and Shneiderman, 2006)
	• Use animations meaningfully and intentionally, provide anintroductory text for animations/ videos.	(Leavitt and Shneiderman, 2006)

	INTERACTIVE APP PRINCIPLES (cont.)	References
Interaction	• The terminal text should be no more than 5 clicks from the homepage.	(Lynch, 2008; Travis, 2016).
	• Show all the main options on the home page.	(Fessenden, 2018; Travis, 2016)
	• A menu with 5 to 7 links are optimal.	(Lynch, 2008)
	• Use breadcrumbs to indicate the current location and instruct the next steps.	(Beukes et al., 2016)
	• Avoid an unnecessary sign in process.	(Travis, 2016)
	• Use keywords that describe the link's destination (e.g., 'Learn more' button.	(Sherwin, 2015)
	• Change the color of clickable links and buttons, to show it is clickable and support the navigation of the design.	(Nielsen, 2001; Whitenton, 2015; Beukes et al., 2016)
	• Do not use thin, horizontal, roll-over activated sub-menus.	(Cardello, 2013)
	• Use mega menus for accommodating a large number of options.	(Nielsen and Li, 2017)
	• Use separate pages instead of endless scrolling to optimize information location.	(Loranger, 2014)
	• Do not use the word 'link' to indicate a link on the page.	(Nielsen, 2001)
	• Links should be easily identifiable and clearly indicate their destinations.	(Farkas and Farkas, 2000)
	• Non-clickable elements should not appear like links.	(Beukes et al., 2016)
	• Use a clickable link ('list of content') on long pages.	(Leavitt and Shneiderman, 2006)
	• Use hyperlinks rather than repeating information found elsewhere.	(Pipes, 2011)
	• Avoid repeated content links.	(Nielsen, 2001; Cardello, 2013; Loranger, 2016)
	• Do not include an active link to the homepage on the homepage.	Nielsen, 2001; Loranger, 2017)
	• Use breadcrumbs that reflect the information hierarchy of your site to support wayfinding. On mobile, avoid using breadcrumbs that are too tiny or wrap on multiple lines.	(Laubheimer, 2018)
	• Avoid "scroll stoppers" on pages by avoiding the illusion that users have reached the top or bottom of a page when they have not.	(Travis, 2016)
	• Reserve the top of the page for high-priority content: key business and user goals. The lower parts of the page can accommodate secondary or related information.	(Nielsen, 2010)
	• The illusion of completeness can interfere with scrolling. Include signifiers (such as cut-off text) to tell people that there is content below the fold.	(Nielsen, 2010)
	• Use tabs only when users do not need to see content from multiple tabs simultaneously.	(Nielsen, 2016)
	• Logically chunk the content behind tabs so users can predict the content.	(Nielsen, 2016)
	• Design tabs that are parallel in nature.	(Nielsen, 2016)
	• You can mark the current tab by size, a bold faced label, an icon, or front arrangement.	(Nielsen, 2016)
	• The unselected tabs should be clearly visible and readable, reminding the user of the additional options.	(Nielsen, 2016)
	• Write short tab labels and use plain language, rather than made-up terms. Tab labels should usually be 1–2 words.	(Nielsen, 2016)
	• Ensure the important links appear high enough on the page to be visible without scrolling.	(Farkas and Farkas, 2000)
	• When pages must scroll, provide visual cues to encourage users to scroll down to links that are below the scroll line.	(Farkas and Farkas, 2000)
	• The search interface should typically be configured both for users who simply type a word or phrase, and for those who wish to formulate more complex searches. The interface, however, should be optimized for the kind of searches that will most often be performed.	(Farkas and Farkas, 2000)
	• Search results should be listed in the most appropriate order and should provide enough information about each Web page for the user to differentiate successfully among the choices.	(Farkas and Farkas, 2000)
	• Contrast between figures, texts, and backgrounds enhances visual usability and interaction with the user interface.	(Silvennoinen and Jokinen, 2016)
	• Have an easily identifiable search box in the top of the screen, with an open-text field.	(Babich, 2016b)
	• Have a privacy policy if the app collects any form of personal information	(Oragui, 2019)
	• Error message in the app is better to prevent users from making errors in the first place by offering suggestions, utilizing constraints, and being flexible.	(Babich, 2016a)