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Information design for bowel cancer detection. The impact of using information visualization to help patients prepare for colonoscopy screening, using a booklet, a motion graphics and an App.

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Abstract

Colorectal cancer is one of the most commonly occurring cancers in the world, and colonoscopy is the most sensitive procedure to detect it. Colonoscopy success depends on the quality of bowel preparation, but the way information is designed and communicated to patients does not meet their needs. This study investigates the advantage of visualized information in communicating bowel preparation instructions for colonoscopy screening. A user-centered multiple-methods approach was followed. Results show an effect of using information visualization on user performance. A set of guidelines is given to inform the development of bowel preparation instructions and other similar health communications.

1 Introduction

1.1 Context

According to the World Cancer Research Fund (2019), "colorectal cancer is the third most commonly occurring cancer in men and the second most commonly occurring cancer in women. There were over 1.8 million new cases in 2018". Thankfully, colorectal cancer is very treatable, and most patients survive colorectal cancer if it is found early (Cancer Research UK, 2019).

Studies show that colonoscopy is the best procedure to detect colorectal cancer/diseases, with around 95% sensitivity. Colonoscopy enables identification and removal of polyps and the taking of biopsies (Leaper, et al., 2004; Robertson, et al., 2005). However, unlike other health exams, colonoscopy effectiveness depends largely on what happens before the exam. The quality of patient bowel preparation is a key factor in colonoscopy success. Yet, poor bowel preparation occurs in at least 25% of cases (Harewood et al., 2003; Rex et al., 2006; Romero and Mahadeva, 2013; Sidhu et al., 2011).

In many cases, patients are referred for a colonoscopy by a gastroenterologist. They then receive a letter with their appointment, a booklet on how to prepare for it, and a prescribed purgative medicine. The responsibility of accurately consuming the prescribed purgative and adhering to a strict diet falls mainly on patients (Smith, 2012). Therefore, an important factor in the quality of bowel preparation is the clarity of instructions for the bowel preparation (Rosenfeld et al., 2010; Cohen, 2014; Johnson et al., 2014). The way information is communicated, presented and structured affects user performance and their perception of how difficult a task will be (Smith et al., 2012; Tae, et al., 2012; Johnson et al., 2014).

These issues led the researchers to conduct a short survey by downloading and analysing forty bowel preparation instruction booklets from different European countries (England, Portugal, Spain, Italy, France, Germany, Poland and The Netherlands). It is clear from this preliminary survey that the design of bowel

preparation instructions currently provided in these countries does not meet patient needs. This conclusion is supported by an Haute Autorité de Santé (2008) comprehensive study focusing on how to produce information brochures for patients and users of the healthcare system. In general, the instructions have several pages of continuous text, few or no images/illustrations, and little visual clarity and hierarchy. Instructions are also unattractive and project a sense of difficulty and confusion. These feelings can exacerbate the challenges encountered during bowel preparation, which in itself is extremely complex, difficult, uncomfortable and unpleasant (Parker, 1992; Ristvedt et al., 2003).

Layouts conforming to legibility principles have been found to be easier to use, more attractive, and give more confidence to users that they performed a task well (Lonsdale et al., 2006; Lonsdale, 2007, 2014, 2016). Positive emotions can also be induced through the quality of the design of instructional materials, by using visual, typographic, layout, and colour design principles (Tractinsky et al., 2000; Wolfson and Case, 2000; Um et al., 2002). This study will redesign current instructions used in England, aiming to improve bowel preparation understanding, compliance, and thus reduce confusion and anxiety.

Literacy is an important factor when designing bowel preparation instructions. Smith et al. (2012) showed that comprehension of a bowel preparation instruction leaflet was generally low amongst 764 participants in the US, and significantly lower amongst participants assessed as having low health literacy. The authors concluded: "future interventions should aim to improve comprehension of complex medical information by reducing literacy-related barriers" (p.1074).

Although limited, there are some examples of good practice on how to improve patient comprehension and performance and reduce literacy-related barriers. One prospective, endoscopist-blinded, randomised, controlled study conducted in Korea by Tae et al. (2012) showed that bowel preparation education with cartoon visual aids can significantly improve bowel preparation quality (good bowel preparation BBPS score ≥5: 81.6% vs. 93.1%; $\chi 2$-test p=0.02; n=200). Moreover, among patients who received the cartoon visual aids, the colonoscopy was aborted in no patients and the polyp detection rate also increased. Another prospective, assessor-blinded, randomised study conducted in the US (Spiegel et al., 2011) compared bowel preparation quality between outpatients receiving standard counselling versus patients receiving a booklet plus standard counselling. The booklet included various sections based on the needs expressed by previously interviewed patients: importance of compliance; photographs; preparation steps; prohibited foods, etc. The study showed a large improvement in the rate of 'good' bowel preparation for patients who received the booklet in addition to standard counselling (46% vs. 76%; $\chi 2$-test p<0.0001; n=237).

Despite evidence to suggest that design factors are important, no changes have been made to the way bowel preparation instructions are designed and communicated to patients in England. Moreover, according to the literacytrust.org.uk, approximately 5.2 million adults in England can be described as 'functionally illiterate'. The healthliteracy.org.uk also reports that health information in current circulation in England is too complex for 43% of adults (this figure rises to 61% if the health information includes the need for numerical interpretation). The visualisation of complex medical information through infographics (information graphics combining images and text) is an efficient way of delivering information in a concise, accessible and attractive form. It is also more inclusive since infographics are accessible to a larger population, including people with different levels of literacy.

Studies further show a 22% failure rate in colonoscopy attendance (The UK CRC Screening Pilot). Barriers to uptake of colonoscopy are: anxiety, anticipation of pain, embarrassment, vulnerability, inadequate knowledge, and fear (McLachlan, et al., 2012). Patient comfort during colonoscopy, for example, is also dependent on satisfaction with the information provided before the procedure (Voiosu et al., 2014). Therefore, user-friendly bowel preparation instructions could also have an impact on colonoscopy uptake.

In addition to creating a more positive patient experience, information design can also help increase patient wellbeing and reduce costs associated with: 1) The healthcare system – inadequate bowel preparation increases the direct cost of colonoscopy. If the examination takes longer, staff and equipment time is wasted and less colonoscopies are performed per day. If the accuracy of colonoscopy diagnosis is reduced, then early detection rate for cancer decreases, leading to increased late-stage treatment costs and repeated colonoscopies; 2) Patients – repeating colonoscopies increases the risk of complications (e.g. colonic perforation, bleeding), staff costs to care for patients, and patient anxiety. Patients and informal carers also cover the costs of: purgative medicine, transportation to hospital, and time off work. Delayed or misdiagnoses due to poor bowel preparation will also have a significant and obvious impact on patient wellbeing.

1.2 Aim and research questions

This study is unique and pioneering in the field of Design. It aims to tackle a medical problem through a non-medical solution in order to detect colorectal cancer, by designing, testing, and finding the best design solution for bowel preparation instructions. It is led by research curiosity as it develops a new sub-field of knowledge within Design for Healthcare, i.e. Information Design for colorectal cancer detection.

Through the redesign of bowel preparation instructions this project aims to improve ease of finding information and comprehension on how to prepare the bowel to undergo colonoscopy screening, consequently contributing to a better quality of bowel preparation, a higher rate of colonoscopy completion and a reduction in associated costs. Bowel preparation instructions developed according to research-based information design and information visualization principles can create:

- A positive patient-experience snowball effect: good first impression > better understanding > more uptake > more compliance > better bowel preparation > less anxious patient > higher colonoscopy completion > more accurate diagnosis > better wellbeing.
- A cost-reduction snowball effect: good bowel preparation > effective colonoscopy > quicker and less painful examination > less sedation > less staff time > fewer repeated colonoscopies > fewer physical complications

Therefore, the research questions put forward in this study are:

- Question 1: Can information design and information visualization improve ease of finding information and comprehension of bowel preparation instructions for colonoscopy screening?
- Question 2: Does ease of finding information and comprehension of bowel preparation instructions for colonoscopy screening vary according to the output used (e.g. Booklet versus Motion Graphics versus App)?

To answer these questions, England will be used as a case study. Answering these research questions will result in the first patient-centred study using inclusive information design to address this issue, as well as using user-centred research methods that prioritise patient needs and motivations, to enable immediate application of the findings to the healthcare system.

2 Identification of problems and needs

2.1 Survey of existing booklets

The first objective of the study was to collect and survey bowel preparation instructions used mainly in NHS (National Health System) hospitals across England to determine a typical layout and content to be used as a baseline to improve design.

With this in mind, a survey of the visual features of 72 existing bowel preparation booklets was conducted and looked at the content of the booklets, as well as three main design areas: 1) typographic layout; 2) visualization; and 3) colour. A summary of the findings is presented in Table 1.

In summary, the majority of the booklets explained the nature of a colonoscopy and how to take the purgative medicine (while the remaining relied on the instructions provided with the medicine itself). The majority of the booklets also conformed to good typographic legibility principles and used less than 3 colours, with the main text being mostly presented in black. The biggest failing was the lack of visualization.

2.2 Focus group and questionnaire with former patients

The second objective of the study was to engage with people who have had colonoscopies to: 1) collect qualitative data on their understanding and perception of the design and content of bowel preparation instructions booklets; 2) enquire about possible companion outputs to the booklet, to maximise the way information on bowel preparation instructions is communicated to patients. To this end, a Focus Group with members of the public who have had a colonoscopy previously was conducted, followed by an online questionnaire sent a couple of weeks later.

BOOKLETS SURVEY (N = 72)							
%	**Content**	**%**	**Typographic layout**	**%**	**Visualization**	**%**	**Color**
74	• Nature of a colonoscopy	92	• San serif font	40	• Illustrations	82	• Black main text
85	• How to take the purgative medicine	93	• Text justified to the left	12	• Pictograms / Icons	54	• Black headings
47	• Distinct morning and afternoon appointment	57	• Medium X-height	32	• Tables	64	• 3 colors or less
35	• Separate booklets for morning and afternoon appointment	40	• High X-height	73	• Bullet points	38	• Colored visualization
			Average line length:				
		17	• Below 55 characters				
		38	• 56-75 characters				
		46	• Above 66 characters				

Table 1 Results of the survey of existing bowel preparation booklets used in England and mainly from the NHS.

2.2.1 Focus Group

Participants included 2 female and 2 male; 3 participants were aged between 60-69 and one participant was over 70 years old, which is the common age for incidence of bowel cancer (nhs.uk, 2019); they were all native English speakers.

Participants were asked to choose one booklet from the ones surveyed that would serve as the study material and undergo a thorough redesign process. The booklet selected was text dense (no visuals), used two colors (purple for the headings and black for the main text), had a legible typographic layout, and used bold to emphasize important information. Despite moving forward with the most selected booklet, all reasons given for participants' choice (independently of the booklet chosen) were taken into account in later stages.

Regarding the content of the booklet, participants suggested that information for gastroscopy should be excluded to avoid confusion, as it does not apply to colonoscopy patients. Participants pointed out that more emphasis could be made on failure to prepare the bowel adequately. Participants also noted that care is needed to avoid any general content mistakes, as this would make patients distrust the information given. Participants favored booklets written in a friendly (kind) tone but advised avoiding a condescending tone.

In terms of design, participants were pleased to see in one case a table laying out clearly when and what to eat, as it is important for this to be communicated very clearly. They were also pleased to see a diagram on colonoscopy. It was also pointed out that, because patients will vary in the level of detail they want/need, a redesigned leaflet will need to accommodate these differing needs e.g. Finally, a companion video/motion graphics was seen as a way forward to make information more accessible that can be used by patients directly, or by nurses if/when they meet patients for the first time.

2.2.2 Online questionnaire with former patients

Following the focus group, an online questionnaire was conducted with an additional 32 former colonoscopy patients: 20 female and 12 male; 22 participants were 50 years old or over, which is the current age for bowel screening in the UK; their education level varied between Secondary School (6 participants), Undergraduate (17 participants) and Postgraduate (9 participants); they were all native English speakers. As many as 30 participants said they were familiar with reading and understanding visual information such as illustrations, pictograms and infographics.

Participants were first asked to name good and bad things about the booklet they received in the past when referred to a colonoscopy. Participants were from different parts of England, and therefore were screened in different hospitals and received different booklets. It was therefore valuable to seek their experience with different booklets and to find recurring problems. Positive and negative comments are listed in Table 2 (top). Participants were then asked about the content and design of the existing booklet in order to identify their expectations for the redesign, such as: content to be included; design features to be followed; companion outputs to be created (listed in Table 2 – second main heading row).

PREVIOUS BOOKLET (N = 32)

Positive	Negative
• Food list suggestions • Kind and friendly tone • Informative • Precise • Easy to read	• Too much information • Too many words • Lack of diagrams • Unclear information • Vague instructions • Too long • Boring • Looks cheap

REDESIGN OF SELECTED BOOKLET (N = 32)

%	Content that should be included	%	Design features that should be followed	%	Companion outputs
91	• How to take the purgative medicine (some booklets only have the instructions from the drug company)	91	• More visualization of information	53	• Dedicated webpage
84	• Before, during and after the procedure	88	• Visualization using illustrations	50	• Motion graphics
84	• Diet instructions	75	• Visualization using infographics	41	• App
78 50 28	• Importance emphasizing bowel preparation. • Emphasize at the eginning • Emphasize at the beginning and at the end	63	• Information displayed in tables		
72	• Side effects, and how to deal with them	91	• Sans-serif typefaces		
63	• Contact information at the end of booklet	59 44 34	Colours to avoid: • Red • Brown • Yellow		
56	• Instructions for morning and afternoon appointment in the same booklet	69 47	Tone: • Friendly • Light		
53	• Warnings and cautions				
41	• Separate booklets for morning and afternoon appointments				
65	• Booklet should be 5 pages or less				

Table 2 Feedback from former patients regarding previous booklets that they used (top 3 rows) and the content and design of the existing booklet to be used as the test material in this study..

3 Design development, testing and iteration

In addition to all the primary research conducted to identify problems with existing colonoscopy booklets and specific needs of colonoscopy patients, literature was systematically reviewed to identify practice- and research-based design principles that could inform the initial stage of design development. An existing booklet was re-designed (Figure 1), and a patient-support motion graphics and App were also created that could be used as companion outputs to the booklet or to be used as stand-alone outputs. Motion graphics video and App were among the 3 most popular outputs selected by patients in the questionnaire.

3.1 Booklet development, testing and iteration

The development of the new booklet design included various stages of design, testing and iteration. In Stage 1, four design and illustration styles were initially developed to identify characters, color palettes, etc. In Stage 2, four low fidelity prototypes for the patient-support booklet (4 pages per prototype) were created after developing rough drafts. The prototypes contained a fair amount of visualized and logically structured information and included 4 color palettes.

In Stage 3, two prototypes were selected by the research team based on the results of the questionnaire with former patients and information design principles. The two prototypes were developed into high fidelity prototypes and a detachable preparation schedule was also created to meet the request by participants during the focus group to provide a basic summary of what they need to do when preparing. Usability testing was conducted with six participants: 4 female and 2 male; 2 below 50 years old, 4 above 50 years old, with an average age of 48 years old. Results showed that: all participants could find the correct pages and sections in a short period of time; 5 participants could briefly tell how to prepare for the exam; 2 participants could memorize

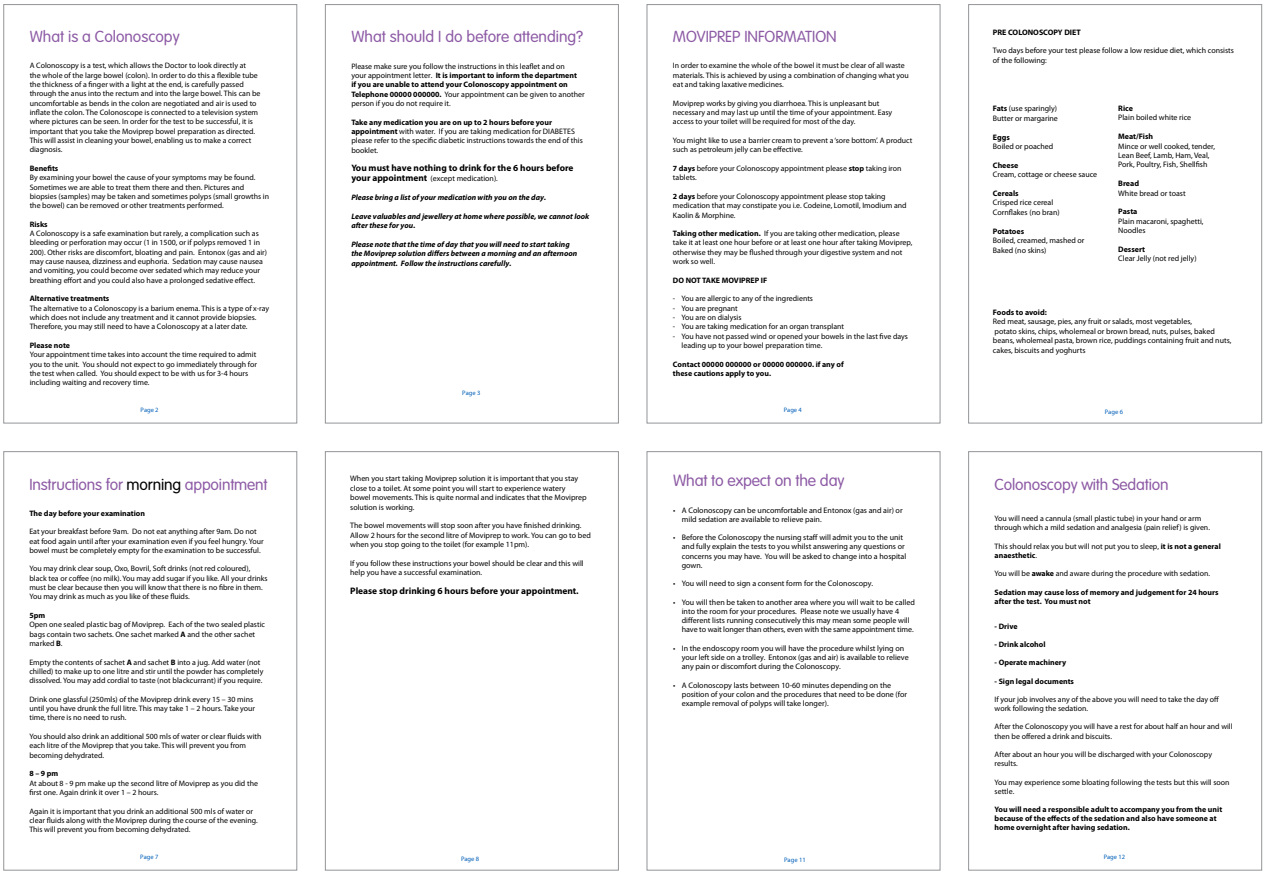


Figure 1 Existing booklet (some pages).

the 'diet list'. In terms of opinion about the design of the booklet, both designs received mostly positive feedback, but Design A received more positive feedback (76%) than Design B (53%). Overall, feedback for Design A was as follows: 1) Infographics and Illustrations – clear, easy to read, accessible, stand out, friendly, pleasant, modem, approachable, descriptive; 2) Color palette and color coding – friendly, nice, appropriated, secure, relaxed, fresh; 3) Detachable schedule – helpful, clever, clear, nice, appropriate size. The booklet (Figure 2.1 and 2.2) and schedule (Figure 3) were developed fully and also taking into account suggestions given by participants that included: 'have a bit more color than only one color'; 'would like to see more infographics'; 'more illustration or icons for key points'.

3.2 Motion graphics development, testing and iteration

As discussed above, a motion graphics video was one of the most selected companion outputs for the booklet. In addition, research has shown motion graphics to be beneficial towards effective learning (Wiana et al., 2018), engagement with audiences and recall of information (Petterson, 2015).

Figure 2.1 Redesigned booklet (some pages).

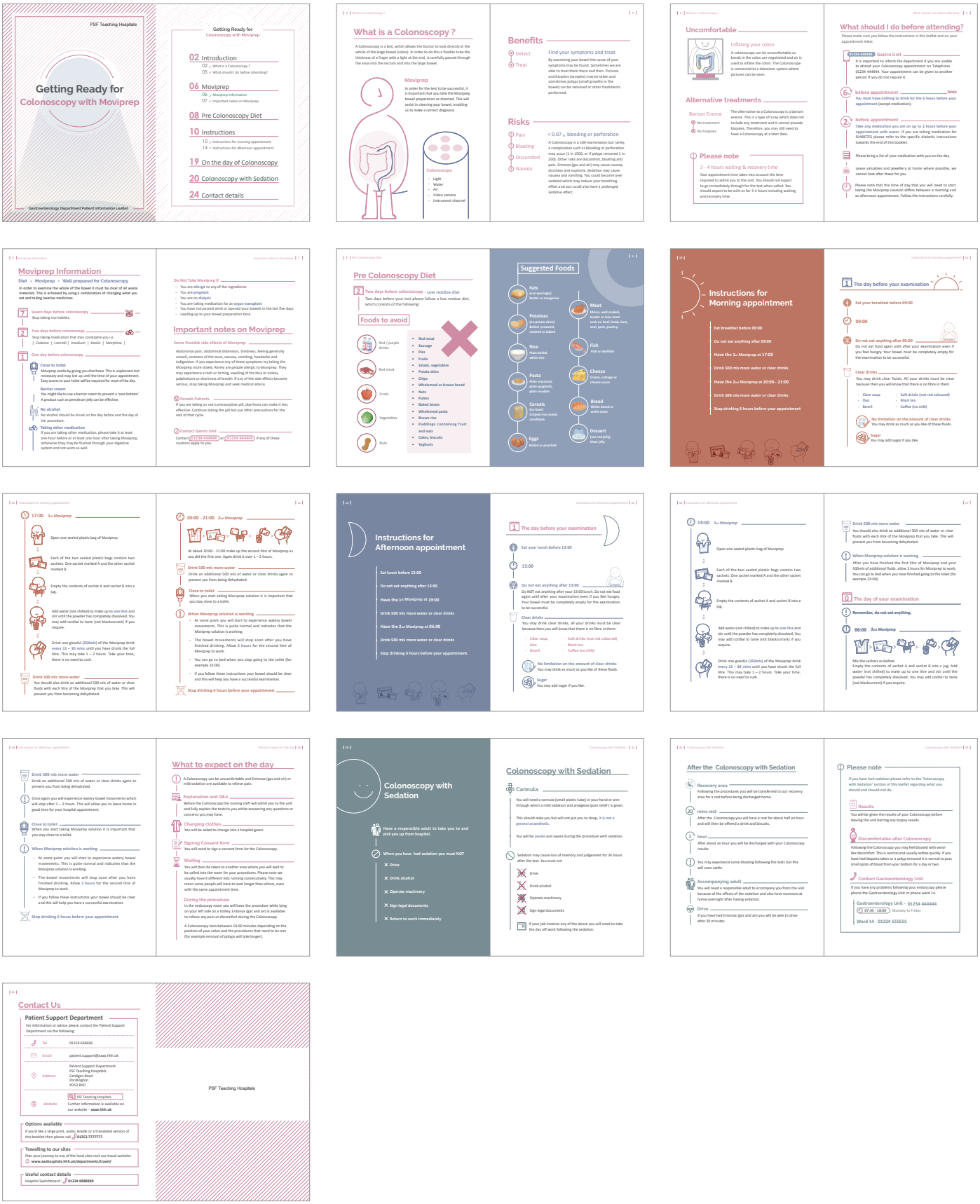


Figure 2.2 Redesigned booklet (all pages).

Figure 3 Detachable Schedule

In terms of design, the patient-support motion graphics was an alternative and/or companion version of the booklet. Therefore, the motion graphics followed the design style and color palette of the new booklet. Creating a second output from an output that had been already tested saved time, i.e. less iterations; and gave the research team better insight regarding the design. For example, insight on: what information needed to be communicated more effectively than in the original booklet; what worked well in the new booklet and should be kept; and what was problematic and should be avoided. In terms of problems, things to be avoided were: lack of clarity regarding foods allowed and foods prohibited; lack of clarity on how exactly to take Moviprep purgative solution; etc. The motion graphics design was also based on systematic literature reviews on information and motion graphics design.

There were several stages of design development and iteration where representatives of the target audience, as well as information design experts, were asked to watch the motion graphics and provide feedback. Results were as follows: Layout – improve organization of information; Transitions – make transitions smoother; Video length – reduce length to no more than 4 or 5, otherwise it is too tiresome; Video pace – speed up the pace to make video more dynamic and shorter; Action – give movement to some objects to make video more active; Key words – make key words bigger; Sound effects – adjust to make sure sound effects fit with what is shown on the screen and do not over use; Voice-over – redo to make more engaging; Voice-over script – explain

particular information more clearly, such as prohibited and allowed foods and how to take purgative solution; Background music – change to a more balanced tone, i.e. not to cheerful, but not too serious either; Content and respective illustrations – adjust the content for clarity, i.e. add more specific information on diet list, such as 'white bread' and not just 'bread', emphasize 'no potato skins'; clarify medicines using plain English, such as using the word 'iron' instead of 'Fe', etc. Four participants were then tested using the same template of questions as the one to be used for the experimental testing in order to fine tune the final design further. The final design of the motion graphics is shown through static frames in Figure 4.

Figure 4 Screenshots of the motion graphics

3.3 App development, testing and iteration

A patient-support App was also developed and the opportunity was taken to create a different design, which once again followed different stages of design, testing and iteration.

In a first stage, in addition to systematic literature review, a survey of medical Apps was conducted to identify the main interface, features, and design style to be used. Four color palettes and two design styles were identified. This was followed by usability testing with seven participants: 5 male and 2 female; 4 over and 3 below 50 years old, with an average age of 43.7. The majority of participants chose bright blue as the best color palette because: "the background makes things stand out"; "it is clean, bold and professional"; "full of energy'" As for the design style, both styles were chosen by 3 participants each, and the seventh participant was happy with both. All in all, the main features participants believed an App should have included: clean, easy to use, cheerful, user-friendly, calm and with illustrations. On the other hand, too light/soft or too bright should be avoided.

A low fidelity version of the App was then developed that included: a 'calendar page' with a clickable calendar and corresponding instructions for that day; the 'learn page' with frequently asked questions and respective answer, as well as articles and videos; the 'contact page' with the telephone number and email of the hospital; the 'my page', which was a profile for the user. A usability test was conducted with 5 participants: 3 female and 2 male; 4 English native-speakers and 1 non-native English speaker; 3 below and 2 over 50 years old, with an average age of 42.2 years old. Improvements identified at this stage included "uncompleted content" and "little visualization".

In stage 4, a high fidelity and final prototype was developed. A logo and a sign-up page were added and, as the homepage is the calendar page, more instructions were added to help the user. This included: '7 to 3 days before the colonoscopy' that when clicked displayed instructions on medication and what to do before attending on the day of the exam; '2 days before' that when clicked displayed food (low residue diet) and new medication information; 'day before' that when clicked displayed food information (clear liquid diet) and instructions on how to prepare for the exam and have the Moviprep solution; 'the colonoscopy day' that when clicked displayed information on what to expect on the day of the exam and, again, a reminder of what to do before attending. More visualizations were added with captions to enhance comprehension, especially for how to prepare and have the Moviprep solution. This is what Wolf et al. (2011) describe as tasked-center solution to show step by step instructions. The final design of the App is shown in Figure 5.1, 5.2, 5.3.

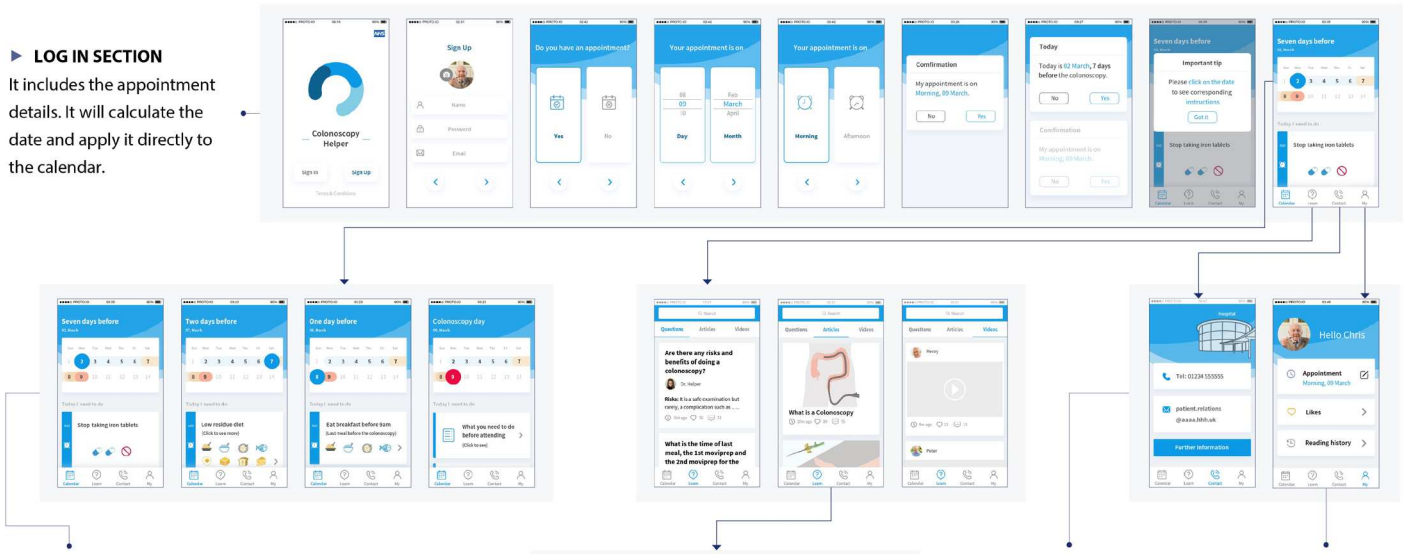


Figure 5.1 Screenshots of the App with explanatory text for the main features.

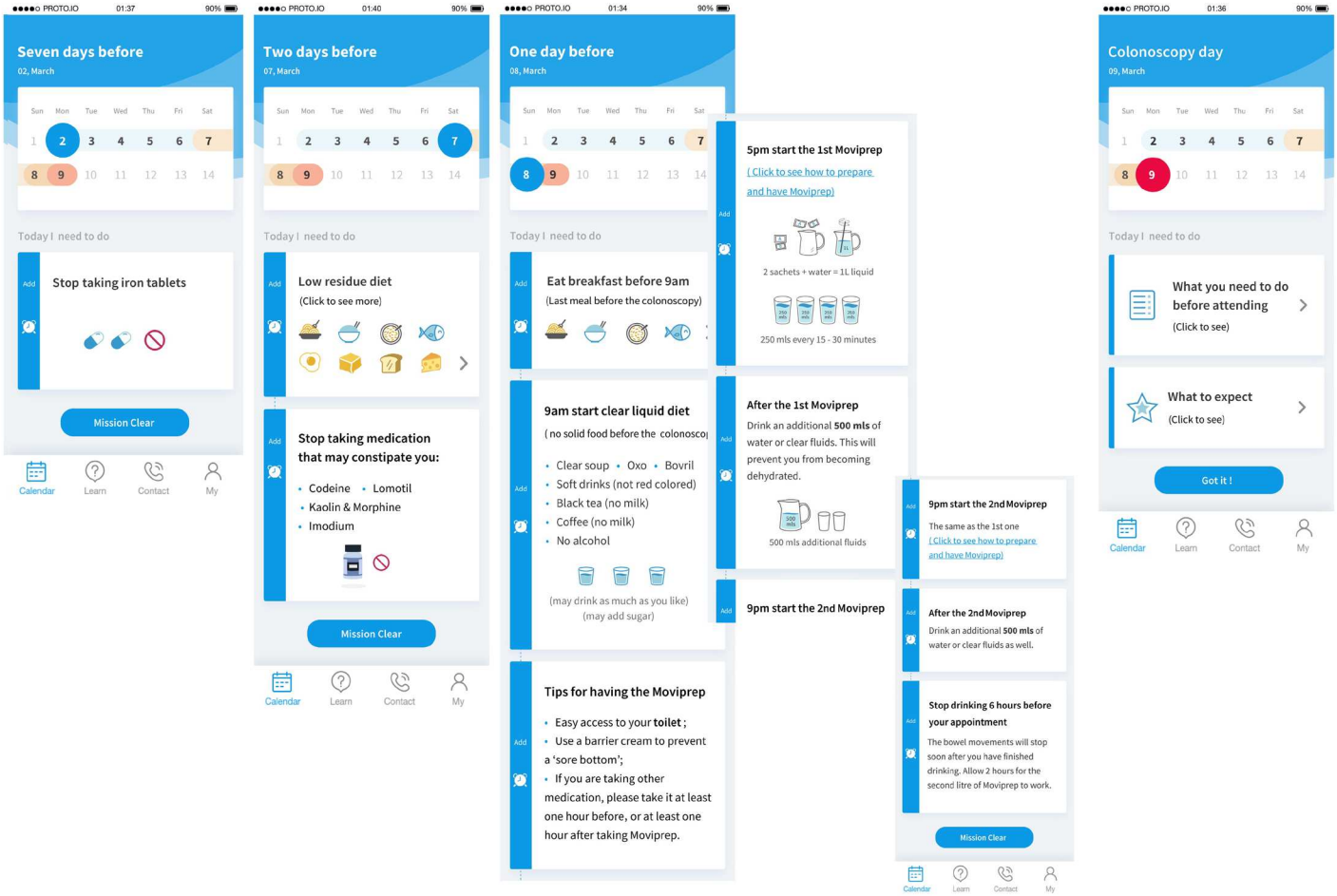


Figure 5.2 Screenshots of the App – Calendar pages

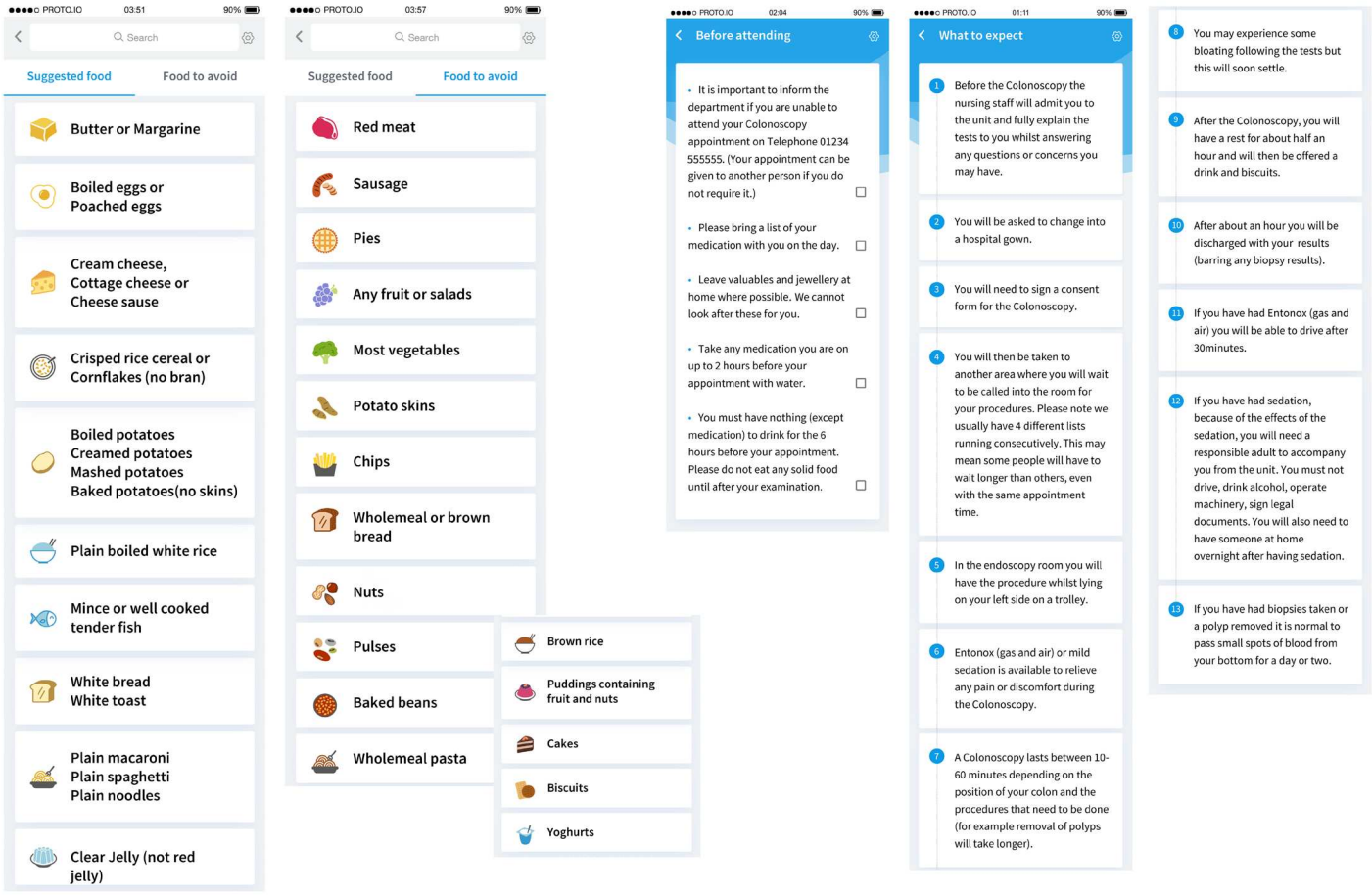


Figure 5.3 Screenshots of the App with 'Diet', 'Before attending' and 'What to expect' pages.

4 Evaluation and validation

4.1 Booklet

A first stage of experimental testing was conducted to test participant performance (measured by the time to find information and comprehension accuracy of the information found) and to collect participants' opinion on the design of the patient-support bowel preparation booklet for colonoscopy screening. For that, two separate groups were tested: Group 1 – exposed to the existing booklet (that we will refer to as 'Old Booklet Design'); and Group 2 – exposed to the new booklet (referred to as 'New Booklet Design').

4.1.1 Participants

A sample of 60 participants completed the experimental testing. Participants were equally divided into 2 groups of 30 participants each. Participants had not undergone a colonoscopy before nor had knowledge of how to prepare for a colonoscopy (e.g. if caring for a family member who had to do a colonoscopy). Participants details were as follows.

Group 1 (Old Booklet Design) consisted of 20 females and 10 males; 13 below 50 years old and 17 above 50 years old; all living in the UK but 17 were British and 13 non-British; 19 native English speakers and 11 non-native English speakers; 25 were educated at Undergraduate and Postgraduate level and 5 at Secondary School and Further Education level.

Group 2 (New Booklet Design) consisted of a very similar set of participants: 19 females and 11 males; 15 below 50 years old and 15 above 50 years old; all living in the UK but 18 were British and 12 non-British; 19 native English speakers and 11 non-native English speakers; 25 were educated at Undergraduate and Postgraduate level and 5 at Secondary School and Further Education level.

4.1.2 Procedure and materials

All 60 participants were tested individually and given a task to complete, which asked them to find specific information in the booklet to answer questions about bowel preparation for colonoscopy including: what happens on the day of the colonoscopy; what to do before attending; what diet to follow during preparation for the colonoscopy; guidelines on how to take the purgative medicine preparation; guidance on sedation, etc.

Participants were then asked their opinion about the design of the booklet. First participants had to rate the design for the following criteria, and explain why: a) Easy to find information, b) Easy to understand information; c) Makes information memorable; d) Makes information engaging; e) Makes information trustworthy. Participants were also asked to choose 3 words from a table with eight positive words and 8 negative words (selected from the Microsoft Desirability Toolkit; Moran, 2018) to describe their opinion about how the information is designed in the booklet, and another 3 words to describe how they felt while and after searching for the information in the booklet.

4.2 Motion graphics

A second stage of experimental testing was conducted, this time to test participant performance (measured by time to find information and comprehension accuracy of the information found) and collect participants' opinion on the design of a patient-support motion graphics video focusing on bowel preparation for colonoscopy screening.

Two separate groups were tested and exposed to the new motion graphics: Group 3 (Motion Graphics Gen X) – tested an older generation of adult participants aged 25 or older; and Group 4 (Motion Graphics Gen Z) – a younger generation of adult participants aged between 21 and 25. The reason for testing two different generations was to ascertain whether the claim that younger audiences are more used to motion, are more attracted to it, and perceive it more easily and naturally (Strizver, 2014), is supported in the context of preparing for a medical exam. Or whether motion graphics is superior to static graphics (Höffler and Leutner 2007) independently of the audience using it.

4.2.1 Participants

Another sample of 60 participants completed the second experimental testing. Participants were equally divided into 2 groups of 30 participants each. As before, participants had not undergone a colonoscopy before nor had knowledge of how to prepare for a colonoscopy. Participants details were as follows.

Group 3 (Motion Graphics Gen X) consisted of: 23 females and 7 males; all participants were above 25 years old, of which 18 were above 50 years old; all living in the UK but 15 were British and 15 non-British; 18 native English speakers and 12 non-native English speakers; 19 were educated at Undergraduate and Postgraduate level and 11 at Secondary School and Further Education level.

Group 4 (Motion Graphics Gen Z) consisted of: 24 females and 6 males; all participants were young adults between 21 and 24 years old; all living in the UK but 10 were British and 20 non-British; 12 native English speakers and 18 non-native English speakers; all were educated at Undergraduate or Postgraduate level.

4.2.2 Procedure and materials

Participants were asked the find the exact same information as for the booklet, but this time by watching carefully the motion graphics video 'Colonoscopy Preparation'. As participants had to watch the video online, the test was set online using Google forms. Participants were also allowed to watch the video more than once and go back to it while answering the questions if needed (as with the booklet, where they were also allowed to go back and forth as needed).

In terms of opinion, participants were also asked to rate the design but this time for criteria that related to a motion graphics output, which is different from a booklet, and explain why: a) Clear; b) Easy to follow; c) Engaging; d) Animation style is appropriate for the content of the video and the target audience; e) Color palette appropriate for the theme of the video; f) Text is legible and easy to read.

Participants were also asked to choose 3 words to describe their opinion about the design of the motion graphics video, and another 3 words to describe how they felt after watching the motion graphics video.

4.3 App

A third stage of experimental testing was conducted to test participant performance (measured by time and comprehension accuracy again) and obtain feedback on the design of an App to assist bowel preparation for colonoscopy screening.

4.3.1 Participants

A fifth group pf 30 participants was exposed to the App – Group 5 (App Design). Participant details were as follows: 13 females and 17 males; 21 below 50 years old

and 9 above 50 years old; all living in the UK but 19 were British and 11 non-British; 19 native English speakers and 11 non-native English speakers; 21 were educated at Undergraduate and Postgraduate level and 9 at Secondary School and Further Education level.

4.3.2 Procedure and materials

The same procedure followed for the booklet was followed for the App: face to face testing; same performance task but using a mobile phone accessing an App this time; same opinion questions, just replacing the word 'Booklet' with the word 'App'.

5 Results

In order to validate the effectiveness of the new design outputs in communicating bowel preparation instructions to colonoscopy patients, experimental testing was conducted. An Independent Two Samples t-test was used to compare performance for completing the given tasks between the following groups as presented in Table 3: G1 – Existing Booklet Design; G2 – New Booklet Design; G3 – Motion Graphics Generation X; G4 – Motion Graphics Generation Z; G5 – App.

	PARTICIPANT DETAILS												
		GENDER		1st LANGUAGE		AGE					EDUCATION		
	N	Female	Male	English	Other	18-24	25-50	18-50	50+	Average	Sec	FE	HE
G1 . Existing Booklet Design	30	20	10	19	11	-	-	13	17	49	3	2	25
G2 . New Booklet Design	30	19	11	19	11	-	-	15	15	47.6	3	2	25
G3 . Motion Graphics Gen X	30	23	7	18	12	-	12	-	18	50.3	8	3	19
G4 . Motion Graphics Gen Z	30	24	6	12	18	30	-	-	-	22.6	0	0	30
G5 . App	30	13	17	19	11	-	-	21	9	43	2	6	21

Table 3 Participant details for all five groups

5.1 Comprehension accuracy (performance)

Performance was measured by comprehension accuracy (i.e. the number of correct answers). Results for all groups are presented in Table 4 and Figure

6 and show that the information found and written down by participants was significantly more accurate with:

- The New Booklet Design than with the Existing Booklet Design.
- The New Booklet Design than with the App.
- The Motion Graphics than with the Existing Booklet Design.
- The Motion Graphics than with the New Booklet Design.
- The Motion Graphics than with the App.

	Comprehension accuracy					
	n	**M**	**SD**	**t**	***p***	
Existing Booklet Design	30	24.90	2.604	-5.336	p = .000	**p < .001**
New Booklet Design		27.83	1.510			
Existing Booklet Design	30	24.90	2.604	-7.223	p = .000	**p < .001**
Motion Graphics Gen X		28.53	0.900			
Existing Booklet Design	30	24.90	2.604	-7.155	p = .000	**p < .001**
Motion Graphics Gen Z		28.47	0.819			
Existing Booklet Design	30	24.90	2.604	-0.970	p = .336	NS
App		25.80	4.366			
New Booklet Design	30	27.83	1.510	-2.181	p = .033	**p < .05**
Motion Graphics Gen X		28.53	0.900			
New Booklet Design	30	27.83	1.510	-2.019	p = .048	**p < .05**
Motion Graphics Gen Z		28.47	0.819			
New Booklet Design	30	27.83	1.510	2.411	p = .019	**p < .05**
App		25.80	4.366			
Motion Graphics Gen X	30	28.53	0.900	0.300	p = .765	NS
Motion Graphics Gen Z		28.47	0.819			
Motion Graphics Gen X	30	28.53	0.900	3.358	p = .001	**p < .01**
App		25.80	4.366			
Motion Graphics Gen Z	30	28.47	0.819	3.288	p = .002	**p < .01**
App		25.80	4.366			

Table 4 Mean comprehension accuracy (number of correct answers): comparison between all five groups.

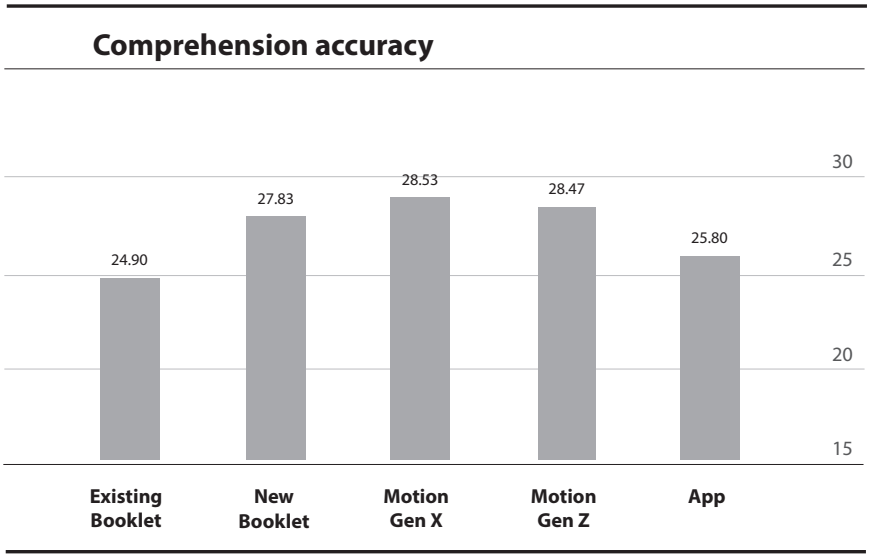


Figure 6 Mean comprehension accuracy (number of correct answers) for all five groups

This shows evidence for the superiority of a Booklet developed following research-based information design principles and user-centred research methods, in communicating bowel preparation information effectively. This superiority is even higher with a Motion Graphics following the same principles and methods.

The results also show that the Motion Graphics is as effective in communicating information to a younger information (Gen Z) as it is to an older generation (Gen X). However, participants did not perform as well with the App, i.e. the App was not significantly better than any of the other outputs (although it was slightly better than the Existing Booklet Design, but not significantly better).

5.2 Time (performance)

Performance was also measured by time (i.e. time taken to find the information and write the answers down). Results for the existing booklet design, the new booklet design, and for the App, are presented in Table 5 and Figure 7. Time was not measured for the motion graphics as the test was conducted online and time could not be recorded using Google forms. Results for time also show that participants performed better, i.e. spent significantly less time to find information, with the New Booklet Design than with the Existing Booklet Design and the App.

	Time					
	n	**M**	**SD**	**t**	***p***	
Existing Booklet Design	30	1440.57	385.699	4.083	p = .000	**p < .001**
New Booklet Design		1088.03	273.655			
Existing Booklet Design	30	1440.57	385.699	0.808	p = .422	NS
App		1351.53	464.125			
New Booklet Design	30	1088.03	273.655	-2.679	p = .010	**p < .05**
App		1351.53	464.125			

Table 5 Mean time (time in seconds taken to find and write the information down): comparison between three groups.

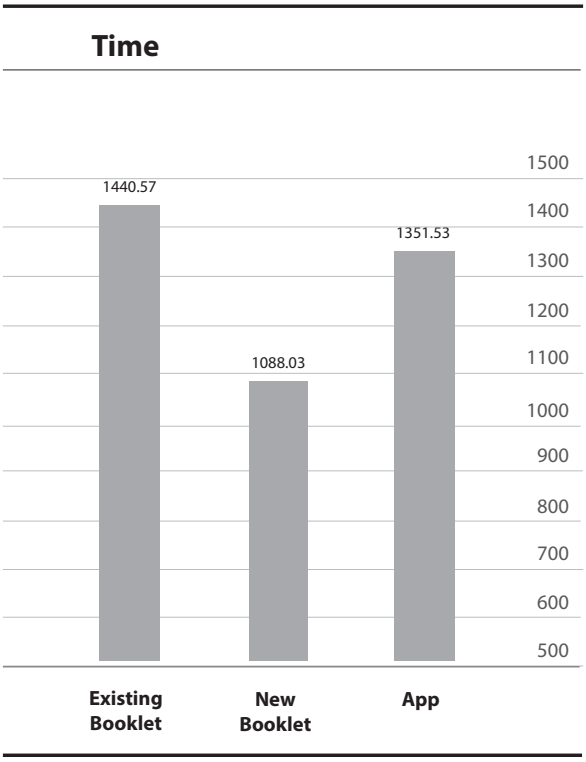


Figure 7 Mean time for three groups

5.3 Opinion

At the end of each experiment, participants were asked their opinion about the design of the output they used. Results are shown in Figure 8. Although for the Existing Booklet Design (Chart 1) participants' opinion was very mixed, for the New Booklet Design (Chart 2) the vast majority of participants agreed that the information was: Easy to find (87%); Easy to understand (97%); Memorable (70%); Engaging (83%); and Trustworthy (90%). The same superiority for the New Booklet Design is found when comparing the two booklets (Chart 3), where information was: Easier to find (92%); Easier to understand (92%); More professional (92%); and More engaging (79%). Comments made by participants include: "the use of large text for headings and key points, and the use of color and bold for emphasis, make it easy to find the information"; "the contents page is very useful and can help find most information"; "very good to have the information divided in different sections, as well as in a sequential order"; "diagrams and step by step instructions help understand what to do"; "the use of icons and illustrations makes the information easy to understand, as well as engaging and memorable"; "information is set out clearly and it is not overwhelming". There were also useful comments made by participants that were helpful for future design improvements and development, such as: "have page number at the bottom, as it is more intuitive"; "table of contents is very useful but should be even more detailed"; "add numbers to the section with instructions for the morning appointment, to show the order of steps"; "if possible, have less information on each page".

The vast majority also agreed that the Motion Graphics was: Clear (Gen X = 93%; Gen Z = 93%); Easy to follow (Gen X = 73%; Gen Z = 87%); Engaging (Gen X = 77%; Gen Z = 77%); Moreover, that the design style (Gen X = 80%; Gen Z = 90%); color palette (Gen X = 77%; Gen Z = 87%); and typography (Gen X = 94%; Gen Z = 94%); were appropriate. Participants' comments include: "the motion graphics is helpful, easy to follow, clear and informative"; "the illustration style is good and the color palette is calming"; "there is attention to detail and the overall feel is of something professional and well made"; "it puts people at ease before doing a colonoscopy"; "more engaging than average NHS documents". Some participants also mentioned that, in addition to the motion graphics, they still expect to receive medical information in a more traditional way such as the new design booklet. There were not many suggestions for design improvements, apart from an isolated case mentioning that the colour palette could be more neutral, i.e. use less pink.

Regarding the App, it is very interesting to find out that, despite participants not performing significantly better with the App, their opinion was very positive, with the vast majority of participants agreeing that the information using the App was: Easy to find (80%); Easy to understand (93%); Memorable (77%); Engaging

(83%); and Trustworthy (80%). Participants commented that: "the information was well designed and structured"; "the calendar that can be clicked to get specific information before the appointment was a good feature"; "the design is simple and clean"; "good use of bold to emphasise key information"; "it looks professional and has a good mix of texts, pictures and videos"; "good to have a

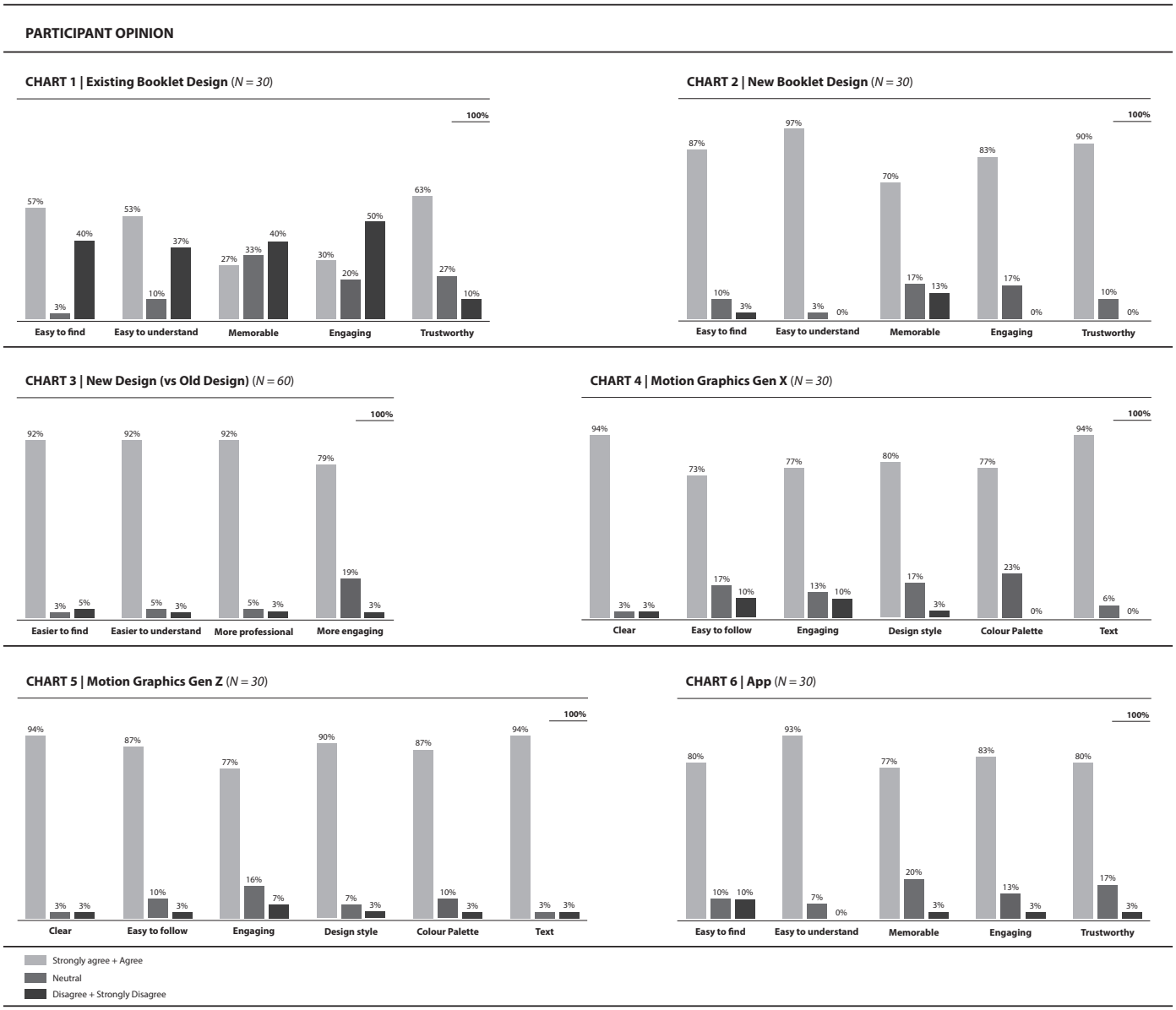


Figure 8 Participant opinion for all groups

Q&A of things patients want to know but might not feel comfortable asking". However, quite a few participants mentioned that some information is very easy to find, while other information is hard to find. Moreover, some participants did not realize they could press on the different dates to access the information. Suggestions included: "adding a timeline and more pictures, as there is still too much text"; "having a main menu listing all the information"; "moving some information to other sections"; "having instructions prior to using the App". Some participants also mentioned they did not have experience using Apps and that younger people would find the information more easily using Apps.

When asked to choose 3 words to describe their opinion about how the information is designed in the booklet, and another 3 words to describe how they felt while and after searching for the information in the respective output, the results were as shown in Figure 9. In summary, in contrast to the Existing Booklet Design, the most chosen words for the New Booklet Design and Motion Graphics were positive words. The same applies to the Detachable Schedule that was designed as an additional component to the Booklet, giving a step-by-step procedure for bowel preparation at a glance.

As for the App design the most chosen words were also positive, with the word 'confused' being selected by 23% of participants (the 5th most selected word in parallel with the positive words 'valued' and 'impressed'). This seems to show some evidence to explain why participants did not perform significantly better with the App.

Figure 9 Participant choice of three words to describe their opinion and feelings about the design of each output – top five chosen words and number of times chosen.

6 Discussion and conclusion

Colorectal cancer is one of the most commonly occurring cancers in the world (the third in men and the second in women), but very treatable if found early (Cancer Research UK, 2019; World Cancer Research Fund, 2019). Colonoscopy has been found to be the most sensitive procedure to detect colorectal cancer. However, colonoscopy success depends on the quality of bowel preparation and there are at least 25% of cases of poor bowel preparation in colonoscopy screening (Harewood et al., 2003; Rex et al., 2006; Romero and Mahadeva, 2013; Sidhu et al., 2011). The responsibility to accurately prepare the bowel for colonoscopy screening falls mainly on patients (Smith, 2012), and although patients are usually provided with an instructions booklet, its design does not meet patient needs. In addition to unattractive booklets, which are text dense and have poor visual clarity and hierarchy, there is an overall lack of visualization despite its benefits in supporting user comprehension of health information. Research has shown evidence: for the superiority of combining text with visualization (e.g. Spiegel et al., 2011); for the role of pictures in improving health communication (see Houts et al., 2006 for a through review of research papers); for the role of pictures in helping patients with low literacy skills" (Houts et al., 2006).

It is not possible to accurately predict the influence of visualization on patient comprehension for every health communication (i.e. health communications for different purposes and in different formats, i.e. static, motion and interactive). Therefore, Houts et al. (2006) advise to conduct systematic evaluation of the impact of visualization on patient performance, and this is what this study aimed to do. That is, to design and test the effectiveness (ease of finding information and comprehension) of a bowel preparation booklet for colonoscopy, of a motion graphics, and of an App. To that end, a user-centered multiple-methods approach was followed in three sequential stages that mirror the design process: 1) Identification of problems and needs – survey of booklets, focus group, online questionnaire; 2) Design development – usability testing and iteration;

3) Evaluation and validation – experimental comparison between 5 groups and 4 different outputs.

Results showed the superiority of information combining text and visualization, over text dense information. This was true in both static (redesigned booklet) and motion formats (motion graphics video). The superiority of motion formats was also found for both younger (Gen Y) and older generations (Gen X). The motion graphics in particular was very useful in tackling some communication issues that cannot be addressed with print-based information without turning the booklet into a very long and exhausting piece of information. With the combination of written, visualized and spoken information, the motion graphics enabled explanation in more detailed step-by-step instructions, as well as illustration of exactly what was required in a much shorter period of time than reading several pages of text. For example: How exactly should the purgative medicine be prepared and taken?; Which foods exactly can or cannot be consumed, and how many?, etc. Research has shown that "spoken information can, with the help of pictures, be recalled to a high degree by people with low literacy skills" (Houts et al., 2006, p. 188). Furthermore, combining written, visualized and spoken information effectively, as it is the case of the motion graphics created for this study, is especially important if we want to create inclusive design solutions that are also suitable for visual impaired, senior, non-native speakers and low literacy patients.

The same superiority should be found with interactive Apps. However, although in our study there was a slight advantage using an App with visualized information over a text dense booklet, such advantage was not significant. This non-significance might have been due to various factors. For example, the App was quite novel in its approach, as it included tailored information and various interactive tasks (e.g. clickable calendar with bespoke instructions for specific days and times during preparation). In future research, further usability tests might be needed when developing novel approaches to ensure that all factors have been considered, tested and refined. Another factor to consider is the following. When conducting performance testing for statistical analysis and validation, participants could also be given a demo task or be allowed a few minutes to freely interact with the App. This would allow participants to get familiar with the interaction and navigation process and avoid these clouding the results. During the performance test, at times participants found it difficult to use a digital platform and felt lost while using the App due to lack of experience, independently of age, gender, educational level, etc. One other factor that might have contributed to the results was the inclusion of less visualized information, when compared to the booklet and motion graphics.

It is also recognized that designing Apps to guide and empower patients to manage their health is challenging (Honka et al., 2011), as it will be instructing

patients on how to follow complex instructions on their own without regular support from medical staff and in a moment of great anxiety. However, the capabilities of mobile devices and Apps are many (Patrick et al., 2008): from intervention, to guidance, persuasion, and behaviour change. Moreover, an App used with a mobile device also shows benefits in assisting patients while preparing the bowel for colonoscopy screening (MDedge, 2013). For example, patient-support Apps allow patients to check information at suitable times and anywhere; to make a quick phone call to get medical support if needed; as well as access text and visualized information at the same time as audios and videos (Heynsbergh, 2019).

In conclusion, this study has shown alternatives to face-to-face support, as the latter can be time consuming, costly and it is not always accessible to patients. On the one hand, the effective combination of text and visualized information (following research-based design principles and applying user-centred research methods) can help colonoscopy patients find information more easily and improve comprehension of complex information for bowel preparation for screening. On the other hand, having at patients' disposal various multimedia outputs (booklet – print and pdf, motion graphics and Apps) will make bowel preparation instructions more inclusive and more accessible to a larger audience. The more effective and inclusive health information is, the easier it should be for patients to manage their health. Consequently, it could increase uptake and compliance, improve quality of bowel preparation, reduce anxiety in patients, increase colonoscopy completion and accuracy of diagnosis, as well as reduce colonoscopy time, patient pain and discomfort, and costs associated with longer and failed colonoscopies.

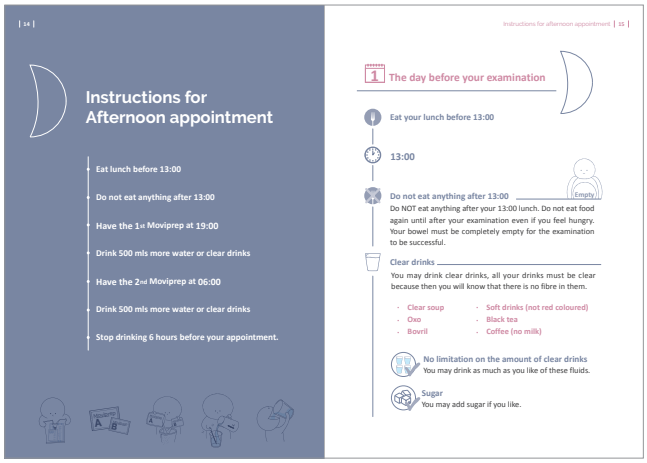
7 Practical implications and guidelines

This final section provides a list of easy-to-apply guidelines with visual examples (Table 6) that are informed by our research and findings, by literature review, and by our expertise in information and instructional design. These guidelines will be a useful tool for healthcare professionals, health communication experts, and graphic and information designers developing bowel preparation instructions and any other medical instructions of a similar nature or with a similar purpose. Cultural differences should be considered, however, as they may play a role in acceptability of visual/graphic material. Nevertheless, this is a novel approach in academic journals, but a worthwhile contribution to knowledge in the field of design and healthcare, and of great importance to enable research to have direct applicability to real life contexts.

Guidelines | 1

General

- To communicate to a large audience (including low literacy and non-native patients) use accessible, simple, direct and positive words supported by simple, clear and universal visualizations (icons, illustrations, symbols).
- Keep the design consistent throughout: typefaces; type size for headings, sub-headings, captions, and main text; color palette; column length; margins, position of elements (page number, running head, etc.); illustrations and icons style; etc.
- Use a friendly and calm design tone: soft colors, but with enough contrast to avoid com-promising legibility of text and images; round and soft shapes and edges, as sharp objects are perceived as associated with fear and anxiety; realistic illustrations but with a positive and a friendly style.
- Balance the proportion between text and images. While visualized information is beneficial, not all text content can or should be visualized. Visualize information when there is a need to: provide step-by-step instructions; call attention to a particular issue; identify particular actions patients have to take; show dos and don'ts; remind patients; etc.



Emphasis

- Prioritize and emphasize essential content.
- Key points are important to help patients understand and recall what information is not to be neglected. Adding a pictogram to help recall is also beneficial, such as '+' for benefits, and '–' for risks; or 'X' for prohibited.
- Use bold type, size and color to create a clear hierarchy, as well as emphasize information.

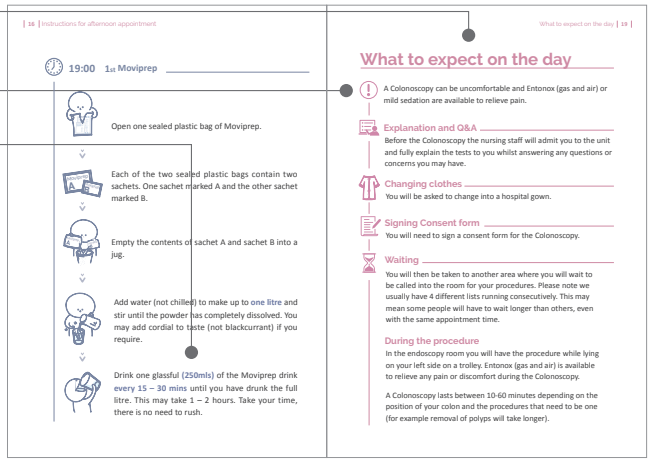
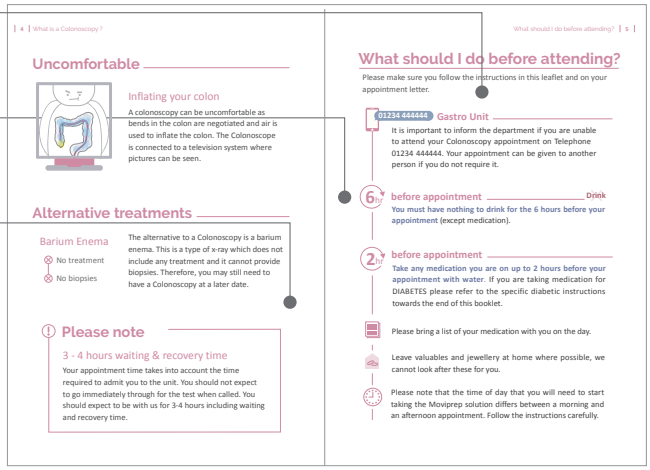


Table 6.1 Practical implications and guidelines

Guidelines | 2

Layout

- Break long text into different chunks and/or replace some text with visualized information (illustrations, infographics, tables, diagrams)
- Group and organise content into logical sections and in a chronological order when applicable, to help patients clearly understand and remember what they need to achieve day-by-day and step-by-step.
- Use lines and color to group sections that relate to each other.
- Use invisible guides to make sure information looks tidy and consistent on every page.
- Use sufficient negative/white space and margins to avoid cluttering the page and allow the reader to rest their eyes.



Typefaces and color

- Restrict the number of typefaces to 2 maximum, and instead use variations of the same font family (e.g. bold, regular, light), as well as size to create hierarchy between headings and emphasize certain text.
- Use a line length between 60 and 75 characters for most of the main text; a type size of 11pt or 12pt; an interlinear space of around 15pt (1.5 in Word documents); use sans serif fonts, which are preferred by patients.
- Favor the use of black or dark grey for the main text.
- If using white text on a coloured background, make sure to use a thicker weight to maintain legibility (e.g. regular text on a white background should be semi-bold for white text on a coloured background).
- Restrict the color palette to 2 or 3 colors maximum (including the main text), unless color coding is needed to distinguish various elements.
- Avoid using red in healthcare communications, as this gives a negative sense and is also associated with blood and harm. Red can be used, however, to alert patients of things that cannot be done.
- Avoid using brown for instructions linked to the bowel.
- Use color and lines to connect sections of information.

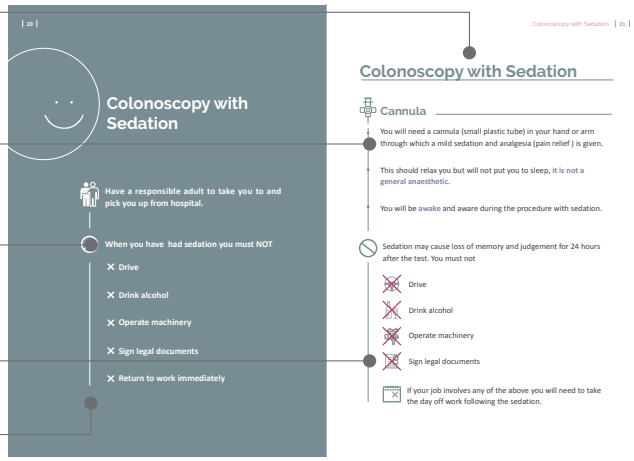
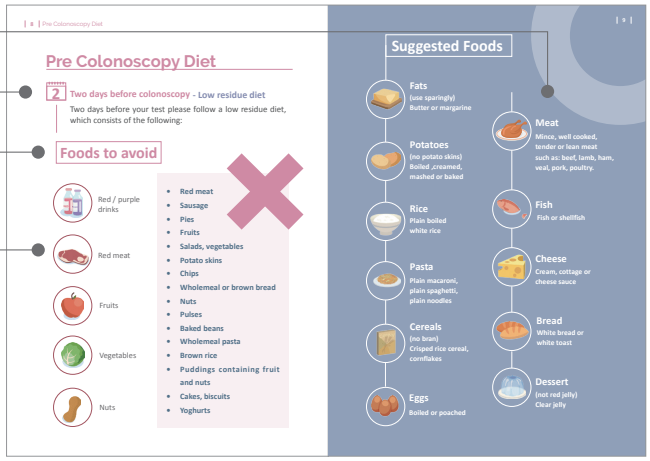


Table 6.2 Practical implications and guidelines (continued)

Guidelines | 3

Visualization

- Include visualized information in every health information that requires patients to follow step-by-step instructions, differentiate between what can and cannot be done, etc.
- Use pictograms/illustrations to identify specific information such as: time, length of time, number of days, etc.
- Use pictograms/illustrations to represent the content of specific information that needs to be recalled at a later time.
- Use pictograms/illustrations that are simple, universal and as realistic as possible, so that they can be identified quickly and accurately. This is particularly important with food, as failing to consume the right foods will compromise the quality of the bowel preparation.
- In addition to helping to understand and recall information, the effective use of visualization also makes information more engaging.



Clarity

- Distinguish chapters (i.e. main sections) and provide a summary page of what will be in that section.
- Differentiate between morning and afternoon appointment, as preparing for the wrong time will be a big contributor to inadequate bowel preparation and/or failed colonoscopies.
- Clarify complex and unknown procedures by using step-by-step explanations and pictograms/illustrations that are simple, clear, and with sufficient detail. This is particularly the case of how to mix and when to take the purgative medicine.
- Always avoid vague and unclear and instructions.

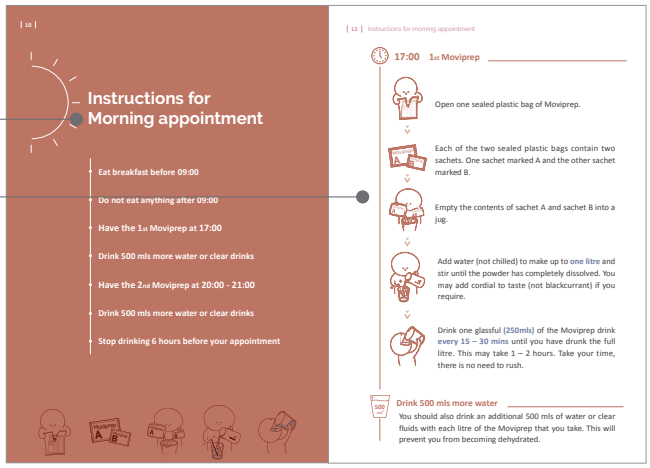
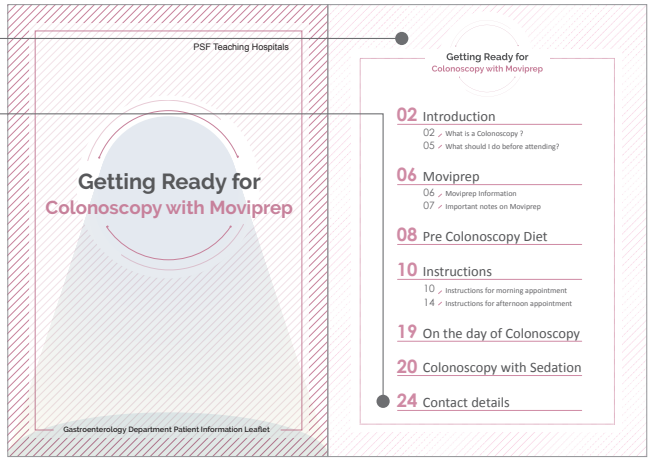


Table 6.3 Practical implications and guidelines (continued)

Guidelines | 4

At a glance information

- Include a table of contents to identify main sections at a glance, signpost more important information, and allow patients to find information quicker (the latter is particularly important during bowel preparation when only certain information is needed on specific days and times).
- Organize information in the booklet on a sequential basis.
- Avoid booklets that are excessively long and might put patients off from reading. Instead, condense the booklet to a reasonable size and avoid blank pages, as these only make booklets longer.



Contact information

- Include contact information in various places where patients might need to be alerted to contact the colonoscopy unit if needed, such as problems with preparation, side effects, etc.
- Avoid including contact details just at the end of the booklet, but still make sure to have all contacts on a page and clearly identified.

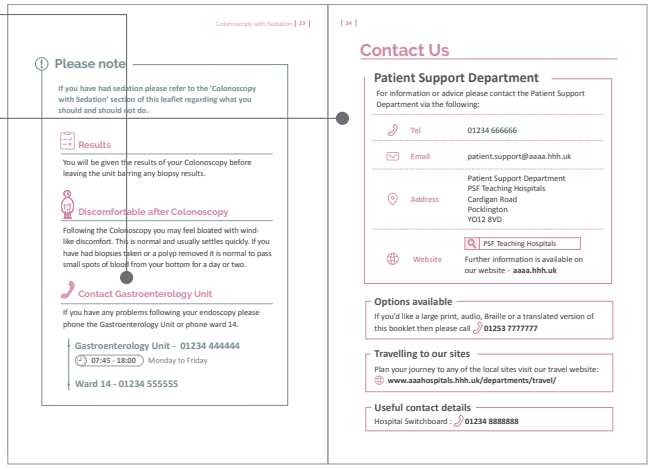


Table 6.4 Practical implications and guidelines (continued)

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