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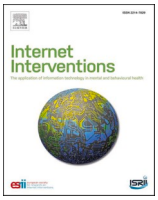

# Design considerations for a multiple sclerosis fatigue mobile app MS Energize: A pragmatic iterative approach using usability testing and resonance checks

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ABSTRACT

Multiple sclerosis (MS) is a chronic neurological condition affecting around 2.2 million people worldwide. The illness includes a range of symptoms, with fatigue considered to be one of the most disabling. This paper describes how a pragmatic and iterative approach, supported by usability and resonance testing, was used to build a minimum viable product of MS Energize—or MS Energise in UK English regions. MS Energise is a mobile application focused on self-management of fatigue for people with MS. The iterative approach included various stages of testing, during which user feedback including comments about interface, navigation and content, was sought to inform incremental app development and continual improvement. Usability testing was conducted with 11 people with longstanding multiple sclerosis in New Zealand and the United Kingdom, and focused on particular sections of the app as well as the accessibility of the app to users with MS. Two participants contributed to further resonance testing post-release to ensure the app was perceived as relevant and useful to the user. The usability testing and resonance testing phases suggested that user experience of MS Energise was mostly positive. Participants provided a number of suggestions for improvements to aspects of content and design; some of which we implemented during our app development process. Findings will also contribute to future planning and design iteration to enhance the user experience. The next step is further improvement of MS Energise prior to a trial of its clinical and cost effectiveness.

## 1. Introduction

### 1.1. Background to MS fatigue

Multiple sclerosis (MS) is a long-term condition of the central nervous system (CNS), characterised by demyelination and inflammation in the CNS, which causes a wide range of symptoms. Fatigue is reported as a significant symptom by 65–97% of people with MS, and by 50–60% as the most disabling (Weiland et al., 2015). MS fatigue differs from fatigue experienced by people who do not have MS, in that it is persistent in nature, yet can vary from person to person and fluctuate over time. Onset of fatigue is often sudden and overwhelming and not linked to any specific activity (Blikman et al., 2017; Krupp et al., 2010). Its pathophysiology is complex and not completely understood making it difficult to manage (Amato and Portaccio, 2012; Krupp et al., 2010; Rottoli et al., 2017).

### 1.2. Cognitive behavioural therapy interventions for MS fatigue

Cognitive behavioural therapy (CBT) is a time-limited, self-directed,

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structured talking therapy that has been successfully used in a wide range of mental and physical health conditions. According to the cognitive behavioural model our thoughts, emotions, behaviours and physical responses are all inter-connected. CBT aims to support people to identify and change unhelpful behaviours and thinking styles. Van Kessel and Moss-Morris proposed a cognitive behavioural model of MS-fatigue suggesting that "biology, cognition, emotion and behaviour influence one another", contributing to the outcome of an ongoing cyclical experience of fatigue (van Kessel and Moss-Morris, 2006).

Face-to-face CBT approaches for fatigue management in MS have been developed, trialled and found effective both when delivered by clinical psychologists in a one-to-one format (van Kessel et al., 2008) and by allied health professionals and MS nurses in a group format (P. W. Thomas et al., 2014; S. Thomas et al., 2013). Web-based delivery formats have also shown promise in pilot studies both with psychologist-delivered telephone support (Moss-Morris et al., 2012) and with psychologist-delivered email support (van Kessel et al., 2016).

Despite the promising findings of CBT approaches for fatigue management, they are relatively costly, often require travel and some form of therapist support and are not widely available. Cost-effective approaches that radically alter the service delivery approach are required allowing greater accessibility and flexibility.

### 1.3. Adaptation to mobile app format

Mobile apps are increasingly being used to package self-guided or behavioural interventions in a variety of health conditions (Dennison et al., 2013). Several systematic reviews have found some evidence of improved outcomes in self-management of long term health conditions such as diabetes mellitus (Whitehead and Seaton, 2016; Wu et al., 2019). Key advantages of mobile technologies include the ability to provide an individual with guidance to modify health behaviours, support self-management and provide relevant information when it is most needed (Free et al., 2013). Smartphones are portable, convenient to use, tend to be a constant accessory, and use of apps is usually unobtrusive (Dennison et al., 2013). Evidence suggests that people with neurological conditions are able to use mobile health technology with no special training (Babbage, 2014). Surveys that have been conducted among people with MS indicate that this population are very familiar with technology and are regular users with the majority owning a mobile device (Haase et al., 2013; Marrie et al., 2019; van Kessel et al., 2017). Simblett et al. have identified mHealth technology design considerations for people with MS. These include i. Variations in physical ability and MS symptoms; ii. Provision of information and feedback to enable active self-management; iii. Perceived costs of using mHealth technology balanced against perceived utility and iv. Practical issues in the design of mHealth technology that bring about a sense of choice and control (Simblett et al., 2019).

The acceptability of mHealth technology, including the use of mobile applications, alongside the limited access to face-to-face CBT interventions, provided the impetus to examine whether we could develop a mobile app (MS Energise,[1] https://msenergize.com/) to enable people with MS to self-manage fatigue. The current paper is focused on design considerations for the development of MS Energise, the mobile app for MS fatigue management.

## 2. Materials & methods

### 2.1. Objectives

The objectives of this paper are to (1) illustrate the use of a pragmatic and iterative approach supported by usability testing, to build a minimum viable product; (2) describe how "resonance checks" post-release were used to ensure the app was perceived as relevant and useful to the user; and (3) show how these data will contribute to future planning and design iteration.

### 2.2. Initial design and content considerations

A pragmatic and iterative approach was taken to the development of the MS Energise fatigue management app. The first phase of app development focused on content and design considerations. The original app content was developed by members of the research team with experience and expertise in CBT and the delivery of fatigue-management programmes (KvK, PK, ST, PT). Other members of the research team (AS, DB) reviewed current literature on the development of mobile health apps and factors that may influence their uptake and success, while exploring MS-specific issues that needed to be taken into consideration in the app design and development process. The software was developed by one of the research team members (DB) in collaboration with an independent mobile app design and development team (MEA, https://we-are-mea.com/).

The starting point for the app content was guided in part by the FACETS trial treatment manual (S. Thomas et al., 2010), but also integrated general CBT principles applied to MS fatigue. The aim was to support the user to develop individualised strategies to manage their fatigue in a way that fit their personal context. App content included general information about MS fatigue, factors that may influence MS fatigue and a section on planning for the future. Each of the seven main modules contained 2–4 subsections, within which were levels of topic-relevant education ('Learn'), an interactive task to engage with ('Interact') and an opportunity to apply what was learned by developing an action plan ('Apply'). The app also provided visual summaries for users and encouragement on their progress and achievements. The design directed users to complete the modules in a specific order via unlocking of content upon completion of topics, to reduce the likelihood of user overload and also ensure that introductory information was discovered first. On the home page each of the seven modules was represented by an icon surrounded by a circle outline. Progress through modules was indicated by the circle outlines ('progress circles') gradually changing from grey to orange. This design feature was incorporated based on earlier user feedback highlighting the importance of visualisation as a motivator. Upon completion of a module the outline became fully orange and all content for that module remained unlocked enabling the user to return to any topics they wished to review.

### 2.3. Usability testing and resonance checks

At all stages of testing, user feedback including comments about interface, navigation and content, was sought to inform incremental app development and continual improvement. This iterative approach was used to build a minimum viable app. Particular sections of the app were reviewed during usability testing and a beta version was used in later resonance checks.

#### 2.3.1. Participants

Participants from two countries, United Kingdom (UK) and New Zealand (NZ), were recruited through prior contact from a recently completed national survey in NZ and other projects at our research centres, where participants had indicated they were willing to be contacted again, or through local branches of the MS Society in NZ and the UK. Participants were people with a diagnosis of MS and who self-reported experiencing fatigue. Eleven people (nine in the UK; two in NZ) were recruited to take part in usability testing and all attended their testing session. Each usability testing session lasted between one and one and a half hours. For the resonance checking, two participants were available and attended, and one of these had also participated in the

[1] Note: MS Energise is the recognised UK spelling, while MS Energize is US spelling. The website uses US spelling while we use the UK spelling in this paper.

usability testing.

Participants were seven women and five men, most of whom had lived with multiple sclerosis for many years—see Table 1. (Note in Table 1, and throughout this manuscript, pseudonyms are used to refer to participants.) Participants ranged in age from 40 to 54 years, three were of New Zealand European descent, and nine were white British. Five participants were previously known to the researchers as they had taken part in earlier studies or other research projects at the university, while seven participants were not previously known.

The research team's professional backgrounds included psychology, pharmacy/public health, physiotherapy and health science.

#### 2.3.2. Materials & equipment

MS Energise was developed as a native iOS app. Usability testing was carried out on iPhone 6S phones provided by the research team.

Participants were video- and audio-recorded during the usability testing to capture their comments, facial expressions and reactions, and audio-recorded during the resonance checks. Additionally, during usability testing, the team used a Mr. Tappy™ camera kit, an adjustable rig which supports a webcam to capture users' hand movements when interacting with the app (https://www.mrtappy.com/).

#### 2.3.3. Procedure for usability testing and resonance checks

Ethical approval was obtained through the Auckland University of Technology Ethics Committee (14/326) and the Bournemouth University Ethics Committee (ID 10106). Usability testing took place in NZ and the UK throughout the development process in University settings (NZ) and at a local MS Society premises (UK). The usability tests required participants to complete three test scenarios, with step-by-step instructions, while they were audio and video-recorded. Identical test scenarios were used for participants in NZ and in the UK; for example to try to locate the Sleep Diary tool in the app and to complete a sleep record (see scenarios Appendix A). A 'think-aloud' protocol was used during this testing (Eccles and Arsal, 2017; Ericsson and Simon, 1980; Nielsen, 2012).

During the usability testing sessions one or two researchers were in the room observing the participants as they worked through the test scenarios. The researchers did not comment on the process or provide prompts once the testing was underway, unless a participant encountered a major error or problem which they could not solve themselves and which prevented them from proceeding. After working through the test scenarios, participants were asked to complete the System Usability Scale (Brooke, 1996) to assess their perceptions of the usability of the app alongside questions about their first impressions and whether the test prototype worked as they would have expected or not.

Small scale field trials were also undertaken and have been previously published (Babbage et al., 2019). Following field and usability-testing stages, eight NZ participants were invited to attend a 'resonance checking' session to further explore user experience issues.

**Table 1**
Participants' demographics from usability and resonance testing.

| Pseudonym | Gender | Age | Years living with MS | Stage of testing |
|---|---|---|---|---|
| Kathy | Female | 46 | 17 | Resonance checks |
| Trish | Female | 48 | 15 | Usability |
| Felicity | Female | 56 | 16 | Usability; resonance checks |
| Ken | Male | 40 | 6 | Usability |
| Kate | Female | 40 | 5 | Usability |
| Susan | Female | 51 | 15 | Usability |
| Samantha | Female | 45 | 5 | Usability |
| Stewart | Male | 45 | 16 | Usability |
| Chris | Male | 43 | 12 | Usability |
| Kerry | Male | 54 | 5 | Usability |
| Tony | Male | 45 | 9 | Usability |
| Audrey | Female | 54 | 10 | Usability |

Resonance checking or testing, is often employed during the concept design stage of development (Liikkanen and Reavey, 2015), but at this point in our project, we were interested to know which aspects of the app resonated with the users, if any. Resonance checks were facilitated by two researchers with professional backgrounds in physiotherapy and psychology. The first part of the resonance check was a card sorting activity using screenshots of the app. This activity (Fig. 1 screenshots) was used to start a conversation about components of the app, including which aspects were considered the most valuable, which were potential problem areas and specific areas of the app that could be improved.

The second part of the session explored possible solutions to previously identified issues in the app by focusing on three key areas – content, progress and structure of the app.

### 2.4. Data analyses

Descriptive analysis (Sandelowski, 2000) was used to analyse the data from the usability testing and resonance checks and provide a summary of participants' reactions and feedback to using MS Energise.

The video recordings from the usability testing were viewed and participant feedback was integrated into a project management software programme, Flow™ (https://www.getflow.com/) to ensure it was captured and the changes were integrated into the app. Tasks arising from feedback were classified according to whether a change was required as soon as possible or whether more testing was justified.

## 3. Results

From the outset, usability testing focused on the accessibility of the app to users with MS. Loss of dexterity and visual symptoms are commonly experienced by people with MS (Balcer et al., 2015; Ghandi Dezfuli et al., 2015). Therefore aspects of design such as font size, layout, colour use, movement between screens (swiping versus scrolling) and use of tools such as calendars and quizzes were the focus of early usability testing sessions.

Initial usability testing revealed that users found the cognitive load of written content challenging. As a result, video content, animations and illustrations were introduced to replace written content where possible. Videos of people with MS, who shared their personal experiences of coping with fatigue, were integrated into learning sections alongside a series of videos featuring a consultant neurologist who described some of the possible neurological and physical reasons for MS fatigue and ways of managing it. Illustrations and animations provided audio-visual learning opportunities, while quizzes and questionnaires were included as a way to maintain engagement and provide opportunities for users to check or apply their knowledge.

Analysis from the usability testing and resonance checking data identified a number of topics related to app navigation design, underlying structure, exiting screens, fine motor control demands, content and linear progression.

Participants' quotations reported here are followed by their pseudonym.

### 3.1. Design: navigation and tools

The main menu and sub-sections in the app were designed to provide an overview of the content, of progress through the content and to enable rapid navigation to any previous part of the app a user wished to revisit. During usability testing we observed that several testers were not clear about how to progress and needed guidance and prompting, which led to re-evaluation of the app's navigation strategy.

#### 3.1.1. Learn–Interact–Apply (LIA) structure (aka relationship between content and tools)

As described previously, a specific structure underpins the MS Energise app: new content to learn (Learn abbreviated to L), a way to

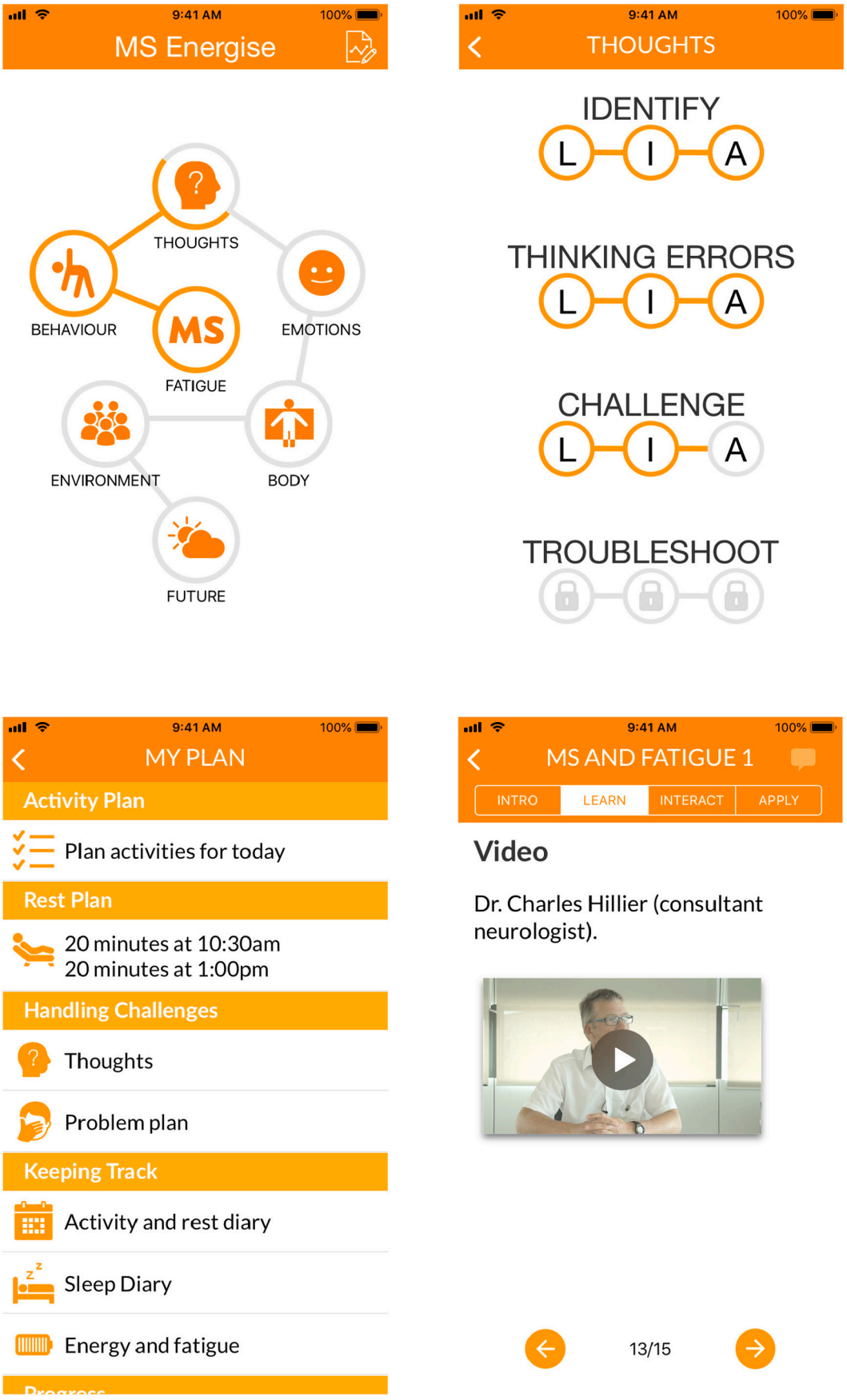
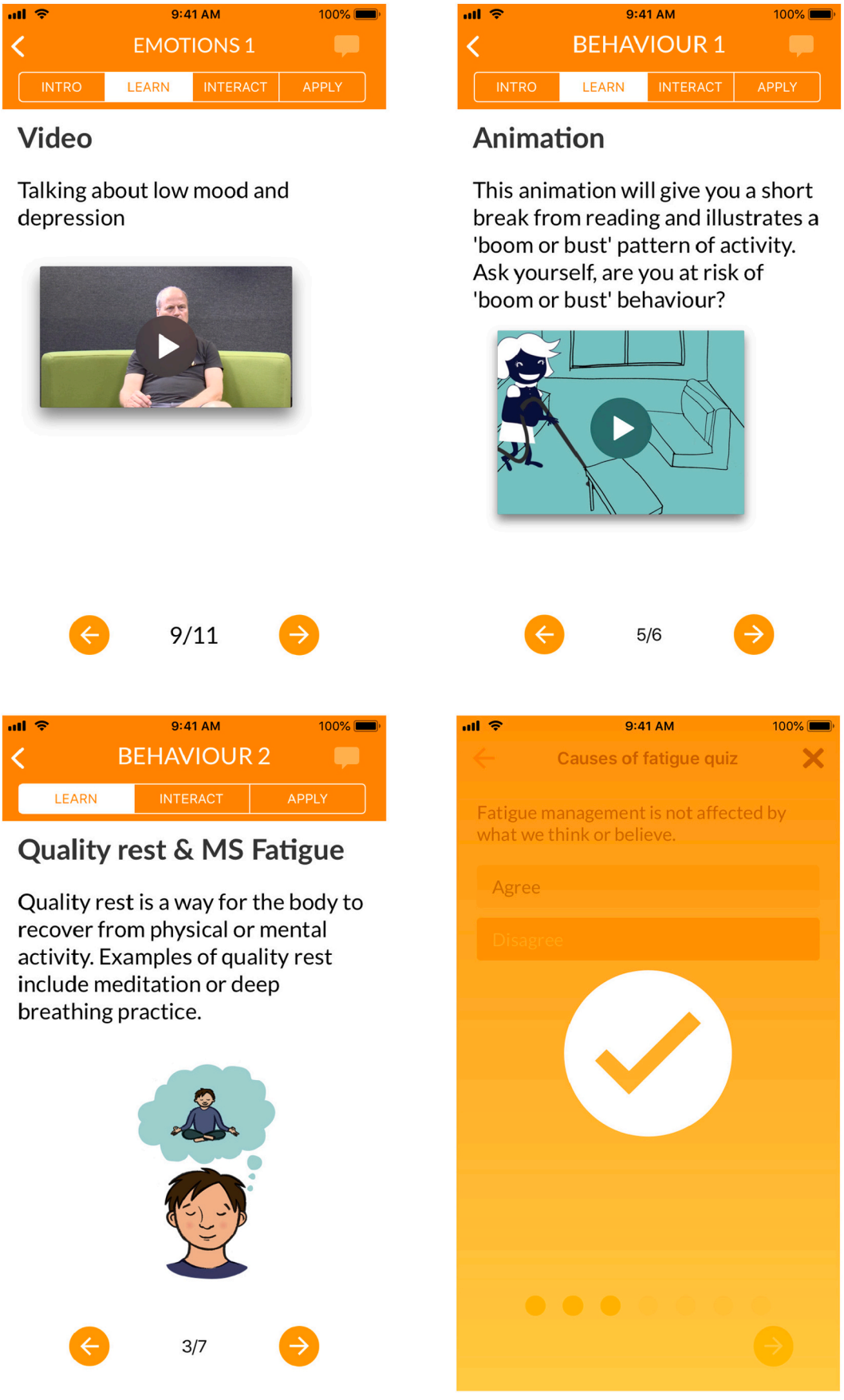



**Fig. 1.** MS Energize screenshots.

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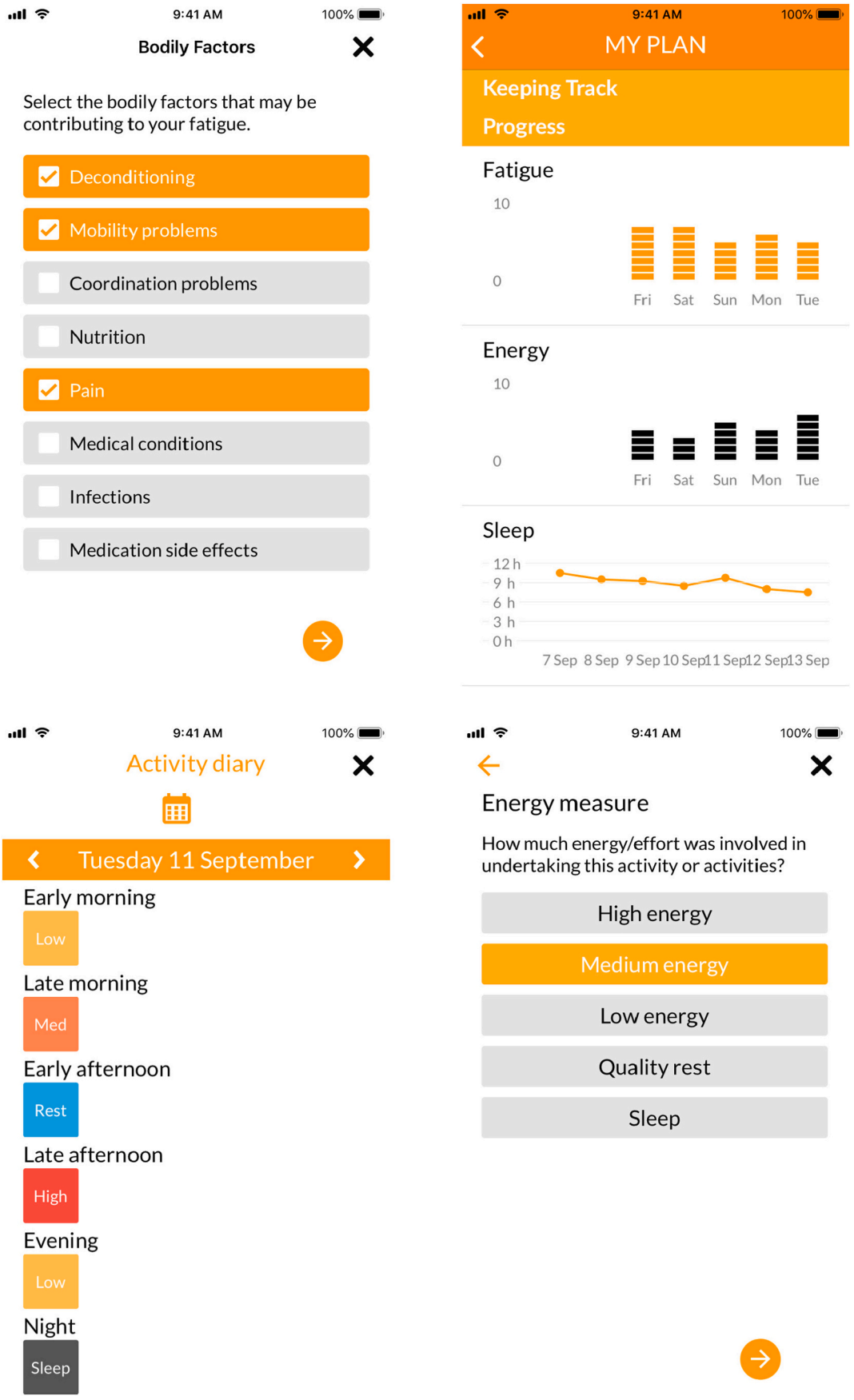


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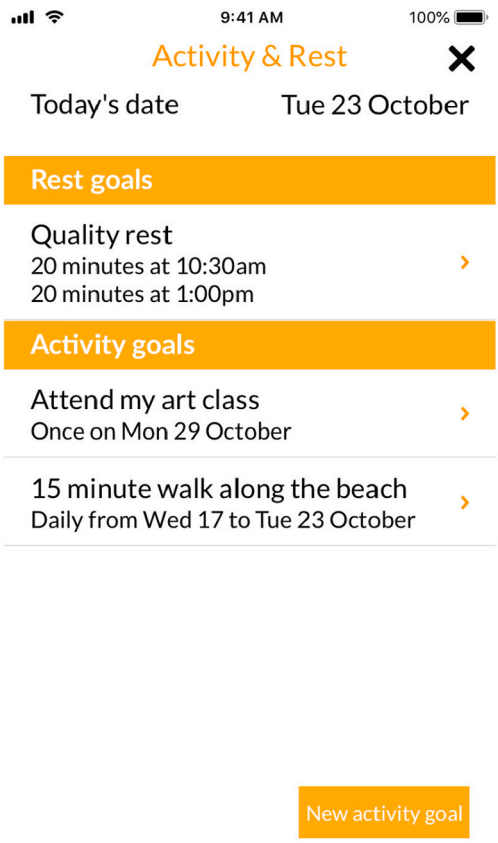


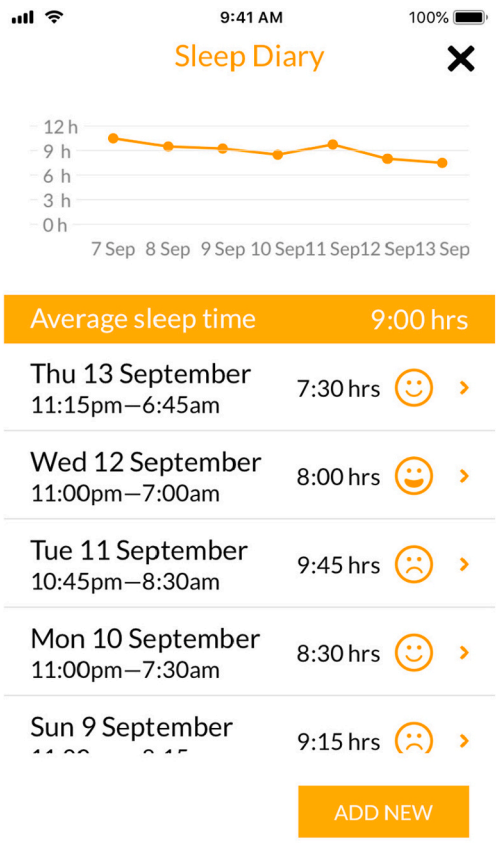


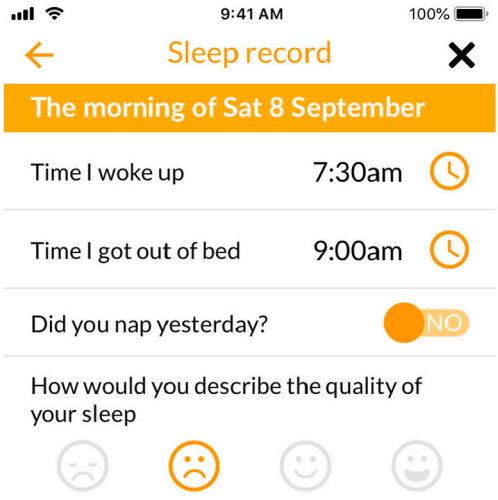


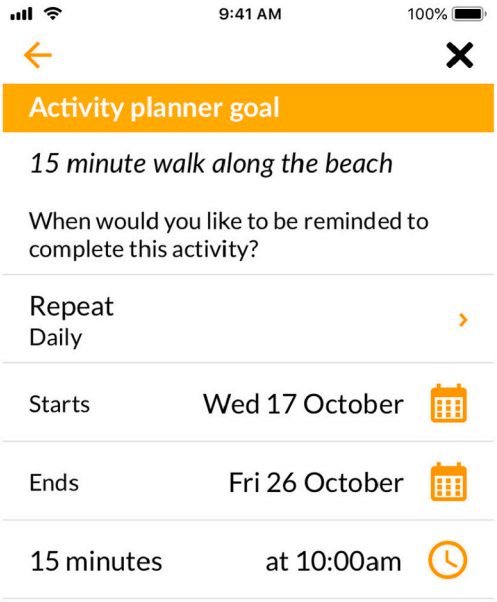


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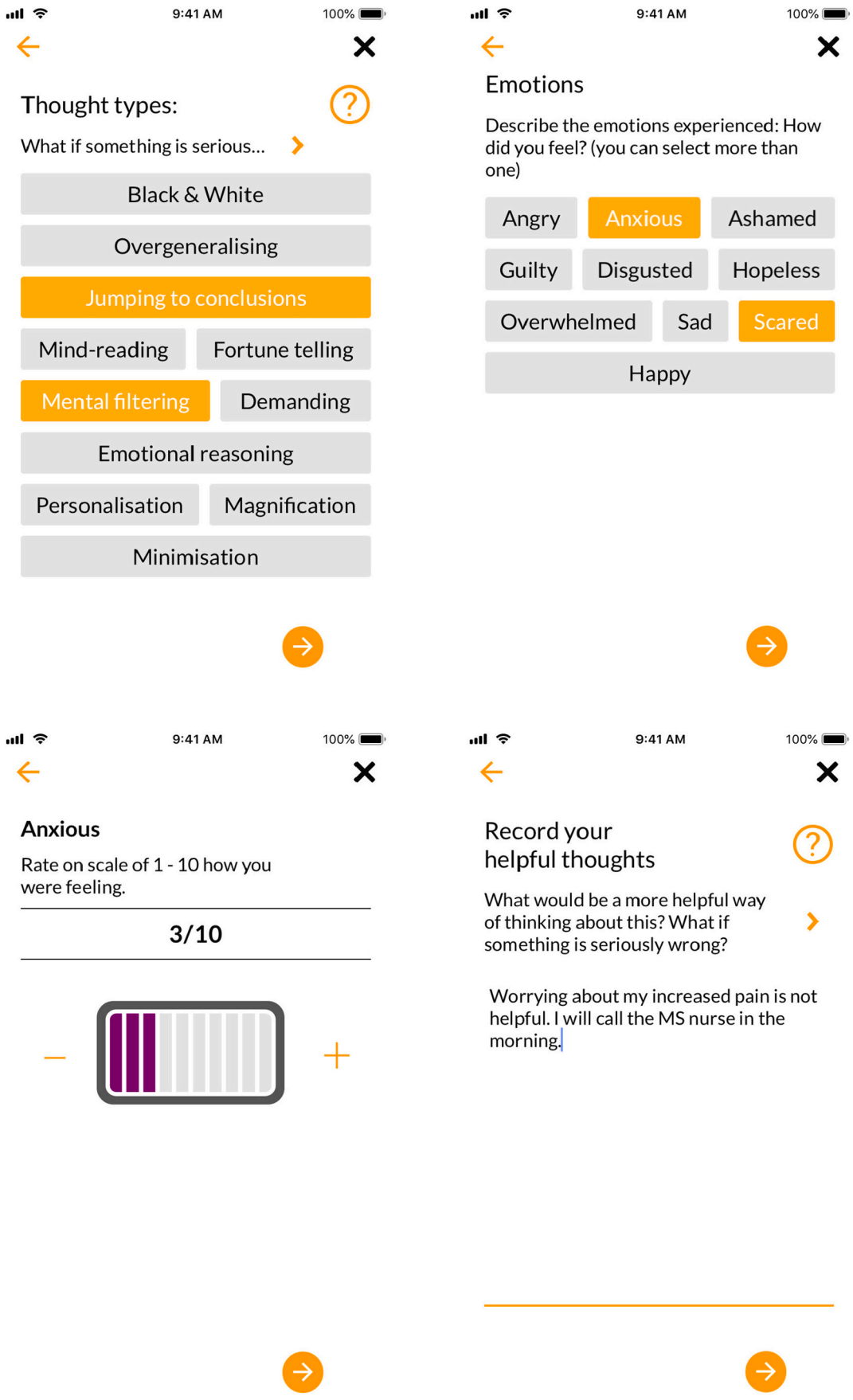


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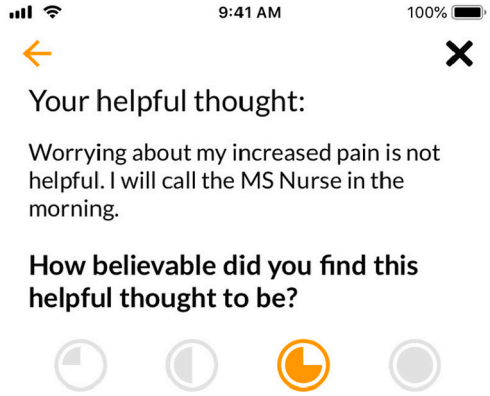


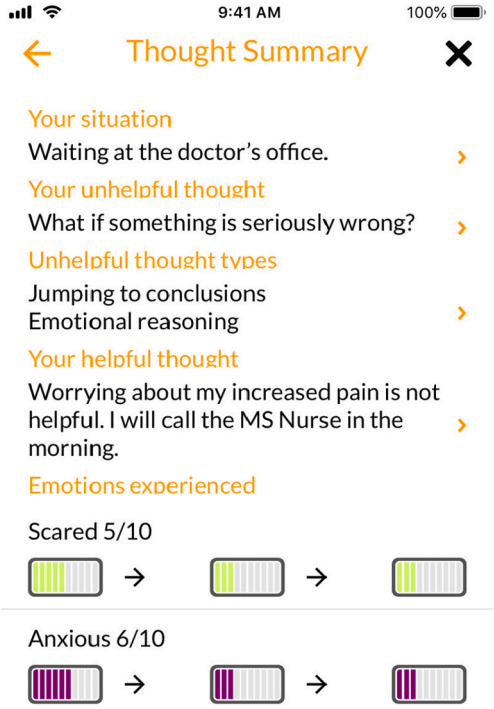


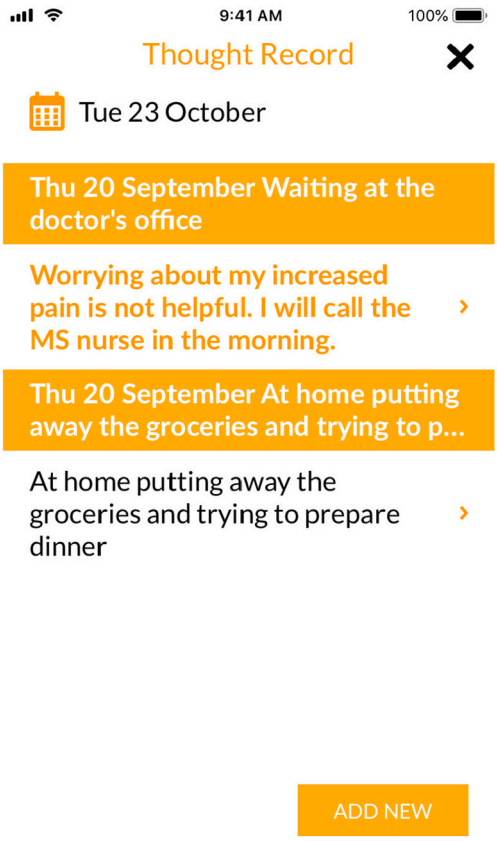


**Fig. 1.** (*continued*).

interact with that content to assist learning (Interact abbreviated to I), a tool to apply it to daily life (Apply abbreviated to A). Each module comprises two or more levels of information presented in the same structure. Navigation indicators along the top of the screen permit and display movement between the levels—see Fig. 1 second screenshot.

In the resonance checks, the two participants reflected they were aware of the structure when using the app but did not think they had used the navigation indicators intentionally to move between levels as they found it difficult to remember what the letters (L-I-A) represented.

"*And I've forgotten what the LIA even stands for again.*"

Felicity

They suggested the use of icons, rather than words, to label the Learn-Interact-Apply structure.

"*And I think you need little pictures instead of the learn, interact or apply. You could have a little, like, academic cap for the first one and 'interact,' I don't know what your picture will be, but to make it – yeah.*"

Kathy

#### 3.1.2. Exiting from tools

We found that users were unclear how to exit a quiz or a video they had watched. Inconsistent use of back or forward arrows and 'X' (close) symbols for navigation in the app was confusing. Testers in both the UK and NZ were unsure of the distinction between these symbols. The right-pointing arrows within a quiz took the user to the next question but at the end of the quiz, testers were unclear whether to tap an arrow or tap the 'X' symbol (as we intended), to close the quiz.

"*I guess I've come to the end…I guess a prompt of saying you've finished, completed, because I sort of find myself getting a bit agitated having to keep on pressing… that's my slow brain response and then I cross it to move on…*"

Trish

### 3.2. Minimising fine-motor control demands

#### 3.2.1. Minimise or eliminate scrolling

It was our objective to minimise or eliminate scrolling of content in the app, given the fine motor control demands this places on users. We found it was a challenge to do this while still supporting 'Dynamic Type', a key accessibility feature on the iOS platform. Dynamic Type allows users to select the size they would prefer text to be displayed—where possible—in both the operating system and in apps that have implemented the feature. This was clearly an important feature for people with MS. However, typically app developers enable this feature by allowing content areas to expand with the increased text size and for the content to be scrolled by the user where the text exceeds the size of the viewport (the content display area). To address the potentially conflicting requirements of the need for increased text size and to reduce scrolling, we opted to paginate content where it exceeded the current viewport. Thus, a user with a larger text size would have more pages to swipe through to read the full content of a level within the app, but would not have to scroll individual pages.

Although we favoured paginating content and swiping over scrolling based on literature recommendations (Ruzic and Sanford, 2017), none of our testers indicated that scrolling was particularly difficult for them. Nevertheless, user opinions on scrolling are illustrated in this resonance checking discussion.

Researcher: "One of the things we had was these arrow buttons instead. … we tried to eliminate scrolling as much as possible…normally the way you handle font [size] change is you just make something scroll and someone has to scroll it. Instead we wrapped it to another page…"

Kathy: "Yeah, that's better for me than scrolling"

Felicity: "Yeah, it's better for me as well"

Most of the movement between pages was designed to be achieved by swiping. However, some pages displayed longer content that we did not feel we could paginate—such as screenshot examples with explanatory text, e.g. instructions of how to use the diaries. In these cases, our testing found it wasn't obvious to users that they needed to scroll down to see the rest of the page and many users did not do so. Some users found that if they increased the font size for accessibility, the page numbering and the layout were affected, introducing blank pages in some places. The quizzes and diaries did not respond to an increase font size using the accessibility settings. These issues need to be addressed in the next versions.

#### 3.2.2. Date picker

Users again reported confusion between using arrows and the 'Done' button and found the 'Done' button difficult to see. We initially used a native iOS date and time picker in the thought diary. Testing results suggested that the native iOS date-picker might be difficult for people with dexterity issues to use as it relies on scrolling. Testers did not find tools for changing the date, saving the date and progressing to the next screen intuitive to use.

"*My initial reaction was to swipe on the month and see, that makes sense, that swipes* [*Day*], *this one you press on* [*Month*]…. *So then if you press Done that makes it done but if you press the arrow it keeps going on the numbers, so I don't know why you need the arrow and the swipe…*"

Felicity

In the Activity and Rest Plans (which required selecting times to rest each day) it was unclear to at least one tester that they needed to select times and they found it difficult to press 'Done'. As a result of testing, we reduced the number of buttons, clarified content, and limited scrolling in the next iteration. An alternative date picker was employed, guided by the desire to eliminate scrolling.

### 3.3. Content

#### 3.3.1. Content overload

User feedback suggested that while the app content was useful there was too much text.

"*I thought there was quite a lot of words, to be honest…But I just felt I was reading a lot. And reading tires me out quite a bit.*"

Felicity

One user pointed out that including an instruction to watch a video, or a description of what the video would illustrate, was unnecessary as it should be self-explanatory.

"*You don't need to read that you're getting a break from reading.*"

Kathy

Although repetition was intentionally used to clarify text content (such as explaining or expanding on a heading), this was not helpful in practice and instead consumed valuable time and energy.

The two participants who took part in the resonance checks, considered text-to-speech audio a desirable future addition that they would use and were already using on other apps.

#### 3.3.2. Illustrations

Custom illustrations were interspersed throughout the app modules. In each phase of usability testing, users indicated that they appreciated the illustrations which were seen to complement the text and provide a break from reading.

"*I think it's nice. It brightens up the app a bit insofar as it's a feel good factor. You've got something to look at as well. I think that's fine.*"

Felicity

#### 3.3.3. Videos

The videos were mostly well-received. Users liked the personal and relevant content.

"*Yeah, an actual other person who's dealing with the same stuff you are is nice, yeah.*"

Kathy

Videos provided a good balance between delivering credibility (medical) and applicability (lived experience) within the learning sections, and increased the accessibility of the app for people with visual difficulties who find large amounts of text difficult. Further suggestions for videos included adding a tutorial video on how to use the app diaries and an option to review or comment on videos.

"*I'm just thinking in terms of having like a list of where you could go and maybe see the videos and you can, and a place where you can review the videos that you've seen or something.*"

Tony

#### 3.3.4. Animations

Brief animations in the app were used to illustrate scenarios (such as having trouble sleeping or feeling overloaded in busy environments) and included sounds to represent aspects of the scenarios such as yawning to represent tiredness. Animations were met with mixed user feedback. While some users were neutral about them, others did not like them.

"*Honestly, I showed it to friends, going, 'Oh, my god. Look what they think of people with MS! Watch this! They think we're all like, you know…'*"

Kathy

They were seen as useful in terms of a break from text but comments on the animations themselves were variously, "stick-like", "didn't like the noises", "made no sense to me".

#### 3.3.5. Quizzes

Throughout the usability testing stages, content was arranged with information first, followed by a quiz or other tool to use, related to the content. Although the resonance check participants were not enthusiastic about having to take a quiz, both saw value in restructuring the module so that it started with a quiz and was then followed by information content.

"*And I think if you had the quiz at the beginning, I would more likely – personally would more likely take the quiz because I wouldn't be so exhausted after reading two pages of content.*"

Felicity

"*That sounds good to me actually, yeah, because if you've already read it, you've already read it. If you want to read it again, then you can. But spending time going through it is just spending time, you know, just using up more of my time.*"

Kathy

Further comments indicated that displaying a single correct answer to a quiz question may not fit with the lived experiences of some people with MS due to the wide range of potential symptoms that occur within that population.

"*so when there's such a variable in MS symptoms and conditions and everything else, then maybe there isn't only one answer, correct answer? Because like we won't ever have the same symptoms.*"

Felicity

Users pointed out that due to their many years of living with MS they could anticipate the correct answers in some of the quizzes, making quizzes perhaps more valuable to those newly diagnosed. As currently designed, the app requires interaction with the quiz to complete the progress circles at the beginning of each module. Being able to choose to choose to skip a quiz was an appealing option.

### 3.4. Linear progression

During resonance checks, neither participant had strong feelings about the directed progression model and did not experience any difficulties with it.

"*It didn't bother me. I don't know if I see pros, but it didn't bother me that I had to do one at a time.*"

Kathy

When asked if they would like the ability to begin the app at any point, both participants felt that with something new, they preferred a directed approach.

"*– that's quite easy. Yeah, you just do what you're told. It's like much easier just to, 'Okay, they're saying that this is the best way round, so that's the way I'll go.'*"

Felicity

The sequential nature of the app was overall seen as a positive feature for providing direction and guidance to use the app in a meaningful way.

### 3.5. Interaction with app

The resonance check participants offered the idea that in future the app could potentially initiate interaction and send them a positive, personal message at various points.

"*It's the phone interacting with me, 'I remember you've got MS and something you could…', I don't know, like send you a cheerful little reminder to 'do something good today' or during the Summer say, 'Make sure you keep cool', or…*"

Kathy

## 4. Discussion

The usability testing and resonance checks suggested that user experience of MS Energise was mostly positive. Participants provided a number of suggestions for improvements to aspects of content and design; some of which we implemented during our iterative testing process.

MS Energise is arranged so that users progress through seven topics in a pre-specified sequence. Users appreciated this directed approach to support their progression through the content in the most logical and meaningful way. While offering users choice and control is important (Simblett et al., 2019), Yardley et al. (2015) note that offering too much choice can feel overwhelming. It has been found that having a pre-specified order for a digital intervention can lead to increased engagement with content (Crutzen et al., 2012; McClure et al., 2013).

The importance of considering condition-specific requirements (such as dexterity issues, severe fatigue, visual impairments etc.) when designing apps for long term conditions has been highlighted in the

literature (Giunti et al., 2018a; Griffin and Kehoe, 2018; Simblett et al., 2019; Winberg et al., 2017). In MS Energise we tried to reduce fine motor demands by minimising the need for scrolling. Resonance checks suggested that text-to-speech would be a desirable addition.

While there are fatigue management apps for other conditions such as cancer (Spahrkäs et al., 2020), to our knowledge there is currently only one other mobile app ('More Stamina') that focuses on fatigue management in MS (Giunti et al., 2018b). 'More Stamina' is a task organisation tool that incorporates energy management and energy profiling, using the concept of "stamina credits", to minimise the impact of fatigue in users' day-to-day lives. Unlike MS Energise it does not include a cognitive behavioural component. More Stamina is at a pilot testing stage. In its initial development phase users identified similar usability issues to ones we have described in the context of MS Energise in terms of greater clarity needed about how to exit some screens (in the case of MS Energise how to exit videos) and a need to include shortcuts for more advanced users (in the case of MS Energise enabling users to 'skip' the quiz).

In the context of developing a cognitive behavioural mobile app to manage HIV fatigue (Barroso et al., 2020) participants reported that they felt that that the textual content needed interspersing with pictures and diagrams Similarly, participants in the current study reported that there was too much text in early versions of the MS Energise app. Too much content could lead to a sense of feeling overwhelmed and not in control (Simblett et al., 2019; Winberg et al., 2019) which itself is fatiguing. To address this feedback we replaced some of the written content with videos, animations and illustrations. The videos and illustrations were well-received by end users. However, the animations drew a mixed response. This highlights the importance of user-centred design and testing (McCurdie et al., 2012; Peiris et al., 2018).

Planned refinements to the app based on usability feedback include incorporating text-to-speech capability, moving quizzes to the beginning of modules and offering a 'skip' function, and revisiting the way we present the learn-interact-apply structure (possibly using icons rather than letters) to make it more intuitive. Changes will be tested and optimised via further iterations of usability testing which will include health care professionals and carers as well as people with MS. Involving all possible end users makes it more likely that an app will be implementable and adopted (Craven et al., 2014; Peiris et al., 2018). Peiris et al. (2018), note the risk of over-engineering solutions and neglecting user requirements if users are not involved throughout the stages of app development.

As we do not currently know if MS Energise is effective in managing fatigue the next step will be to evaluate this. The gold standard for testing complex interventions has traditionally been the randomised controlled trial (RCT). One of the methodological challenges in the field of digital health interventions is how to evaluate them when the field moves at such a swift pace. RCTs are time- and resource-intensive meaning a technology could be superseded or become obsolete before the end of a trial. In the field of mHealth, the iterative development process (with new releases and bug fixes) and personalisation of apps are not readily accommodated within the traditional RCT model whereby a rigid protocol is typically followed to assess a static intervention (Mohr et al., 2017; Murray et al., 2016; Pham et al., 2016). Thus traditional RCTs may often be an impractical evaluation approach for digital health interventions. Mohr et al. (2018), and Wilson et al. (2018) suggest we need to consider more agile and efficient approaches to mHealth development and evaluation lifecycles. Alternative frameworks and evaluation methods have been proposed that allow iterative changes to be made (West and Michie, 2016). Hybrid trial designs that combine evaluation of effectiveness and implementation potentially speed up the translation of research findings into real-world practice and increase the likelihood of successful uptake and adoption (Mohr et al., 2017). We will consider alternative, more agile methodological approaches when designing and planning future optimisation, evaluation and implementation phases of MS Energise.

### 4.1. Strengths and limitations

The MS Energise app draws upon previous fatigue management interventions that have been developed by the authors and which have been shown to be effective. Delivery of fatigue management using an app rather than face-to-face means that fatigue management could be available to a broader population (e.g. those in countries where fatigue management is not provided, those with work or other commitments, or health problems that make it difficult to attend in person).

Usability testing included 11 users across two countries; this was an adequate number given five users are considered optimal for usability testing (Nielsen, 2000), although more users means greater confidence (Faulkner, 2003). At the same time the number of users in the current study may not have been enough given the recommendation that mHealth technology design need to consider a range of variations in physical ability and MS symptoms (Simblett et al., 2019). Nielsen also highlights that the more difficulties users have, the more participants you need (Nielsen, 2000). Resonance checks were completed by two participants only, which limits our findings and highlights the need for further resonance checks, including in the UK.

Most of the participants in this study had many years of living with MS, and there was an absence of participants who were newly diagnosed. Further usability testing and resonance checks need to include such participants particularly since the app may be most useful for this group of people (Babbage et al., 2019).

## 5. Conclusions

People with multiple sclerosis who experience significant fatigue are able to use a mobile app (MS Energise, https://msenergize.com/) aimed at self-managing fatigue. This paper described how a pragmatic and iterative approach, supported by usability and resonance testing, was used to build a minimum viable product of MS Energise. The usability testing and resonance checks suggested that user experience of MS Energise was mostly positive, and participants provided a number of suggestions for improvements to aspects of content and design; some of which were implemented immediately following feedback from usability testers enabling iterative optimisation. Further optimisation of the app is recommended involving health care professionals and carers as well as people with MS, prior to larger-scale evaluation.

## Declaration of competing interest

The software package that is the focus of this paper has been released through the iOS app store. Kersten, Van Kessel and Babbage are the inventors of the product. Both Auckland University of Technology and Bournemouth University may receive royalty payments associated with sales of the software.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.invent.2021.100371.

## References


Amato, M.P., Portaccio, E., 2012. Management options in multiple sclerosis-associated fatigue. Expert. Opin. Pharmacother. 13 (2), 207–216. https://doi.org/10.1517/14656566.2012.647767.

Babbage, D.R., 2014. Mobile computing technology in rehabilitation services. In: Pachana, N.A., Laidlaw, K. (Eds.), The Oxford Handbook of Clinical Geropsychology: International Perspectives (pp. 937–955). Oxford University Press.

Babbage, D.R., van Kessel, K., Drown, J., Thomas, S., Sezier, A., Thomas, P., Kersten, P., 2019. MS Energize: field trial of an app for self-management of fatigue for people with multiple sclerosis. Internet Interv. 18, 100291. https://doi.org/10.1016/j.invent.2019.100291.

Balcer, L.J., Miller, D.H., Reingold, S.C., Cohen, J.A., 2015. Vision and vision-related outcome measures in multiple sclerosis. Brain 138 (1), 11–27. https://doi.org/10.1093/brain/awu335.

Barroso, J., Madisetti, M., Mueller, M., 2020. A feasibility study to develop and test a cognitive behavioral stress management mobile health application for HIV-related fatigue. J. Pain Symptom Manag. 59 (2), 242–253. https://doi.org/10.1016/j.jpainsymman.2019.09.009.

Blikman, L.J., van Meeteren, J., Twisk, J.W., de Laat, F.A., de Groot, V., Beckerman, H., Stam, H.J., Bussmann, J.B., 2017. Effectiveness of energy conservation management on fatigue and participation in multiple sclerosis: a randomized controlled trial. Mult. Scler. J. 23 (11), 1527–1541. https://doi.org/10.1177/1352458517702751.

Brooke, J., 1996. SUS: a "quick and dirty" usability scale. In: Jordan, P., Thomas, B., Weerdmeester, B., McClelland, I. (Eds.), Usability Evaluation in Industry (pp. 189–194). Taylor & Francis.

Craven, M.P., Lang, A.R., Martin, J.L., 2014. Developing mHealth apps with researchers: multi-stakeholder design considerations. In: Marcus, A. (Ed.), Design, User Experience, and Usability. User Experience Design for Everyday Life Applications and Services (vol. 8519, pp. 15–24). Springer International Publishing. https://doi.org/10.1007/978-3-319-07635-5_2.

Crutzen, R., Cyr, D., de Vries, N.K., 2012. The role of user control in adherence to and knowledge gained from a website: randomized comparison between a tunneled version and a freedom-of-choice version. J. Med. Internet Res. 14 (2) https://doi.org/10.2196/jmir.1922.

Dennison, L., Morrison, L., Conway, G., Yardley, L., 2013. Opportunities and challenges for smartphone applications in supporting health behavior change: qualitative study. J. Med. Internet Res. 15 (4), e86 https://doi.org/10.2196/jmir.2583.

Eccles, D.W., Arsal, G., 2017. The think aloud method: what is it and how do I use it? Qualitative Research in Sport. Exercise and Health 9 (4), 514–531. https://doi.org/10.1080/2159676X.2017.1331501.

Ericsson, K.A., Simon, H.A., 1980. Verbal reports as data. Psychol. Rev. 87 (3), 215–251.

Faulkner, L., 2003. Beyond the five-user assumption: benefits of increased sample sizes in usability testing. Behav. Res. Methods Instrum. Comput. 35 (3), 379–383. https://doi.org/10.3758/BF03195514.

Free, C., Phillips, G., Galli, L., Watson, L., Felix, L., Edwards, P., Patel, V., Haines, A., 2013. The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review. PLoS Med. 10 (1) https://doi.org/10.1371/journal.pmed.1001362.

Ghandi Dezfuli, M., Akbarfahimi, M., Nabavi, S.M., Hassani Mehraban, A., Jafarzadehpur, E., 2015. Can hand dexterity predict the disability status of patients with multiple sclerosis? Med. J. Islam Repub. Iran 29, 255.

Giunti, G., Kool, J., Romero, O.R., Zubiete, E.D., 2018a. Exploring the specific needs of persons with multiple sclerosis for mHealth solutions for physical activity: mixed-methods study. JMIR MHealth and UHealth 6 (2), e37. https://doi.org/10.2196/mhealth.8996.

Giunti, G., Mylonopoulou, V., Romero, O.R., 2018b. More stamina, a gamified mHealth solution for persons with multiple sclerosis: research through design. JMIR MHealth and UHealth 6 (3), e51. https://doi.org/10.2196/mhealth.9437.

Griffin, N., Kehoe, M., 2018. A questionnaire study to explore the views of people with multiple sclerosis of using smartphone technology for health care purposes. Disabil. Rehabil. 40 (12), 1434–1442. https://doi.org/10.1080/09638288.2017.1300332.

Haase, R., Schultheiss, T., Kempcke, R., Thomas, K., Ziemssen, T., 2013. Modern communication technology skills of patients with multiple sclerosis. Mult. Scler. J. 19 (9), 1240–1241. https://doi.org/10.1177/1352458512471882.

Krupp, L.B., Serafin, D.J., Christodoulou, C., 2010. Multiple sclerosis-associated fatigue. Expert. Rev. Neurother. 10 (9), 1437–1447. https://doi.org/10.1586/ern.10.99.

Liikkanen, L.A., Reavey, H., 2015. Resonance testing: an industry approach for experiential concept evaluation. Int. J. Prod. Dev. 20 (4), 265. https://doi.org/10.1504/IJPD.2015.071396.

Marrie, R.A., Leung, S., Tyry, T., Cutter, G.R., Fox, R., Salter, A., 2019. Use of eHealth and mHealth technology by persons with multiple sclerosis. Multiple Sclerosis and Related Disorders 27, 13–19. https://doi.org/10.1016/j.msard.2018.09.036.

McClure, J.B., Shortreed, S.M., Bogart, A., Derry, H., Riggs, K., St John, J., Nair, V., An, L., 2013. The effect of program design on engagement with an internet-based smoking intervention: randomized factorial trial. J. Med. Internet Res. 15 (3), e69 https://doi.org/10.2196/jmir.2508.

McCurdie, T., Taneva, S., Casselman, M., Yeung, M., McDaniel, C., Ho, W., Cafazzo, J., 2012. mHealth consumer apps: the case for user-centered design. Biomedical Instrumentation & Technology 46 (s2), 49–56. https://doi.org/10.2345/0899-8205-46.s2.49.

Mohr, D.C., Lyon, A.R., Lattie, E.G., Reddy, M., Schueller, S.M., 2017. Accelerating digital mental Health research from early design and creation to successful implementation and sustainment. J. Med. Internet Res. 19 (5) https://doi.org/10.2196/jmir.7725.

Mohr, D.C., Riper, H., Schueller, S.M., 2018. A solution-focused research approach to achieve an implementable revolution in digital mental health. JAMA Psychiatry 75 (2), 113–114. https://doi.org/10.1001/jamapsychiatry.2017.3838.

Moss-Morris, R., McCrone, P., Yardley, L., van Kessel, K., Wills, G., Dennison, L., 2012. A pilot randomised controlled trial of an Internet-based cognitive behavioural therapy self-management programme (MS Invigor8) for multiple sclerosis fatigue. Behav. Res. Ther. 50 (6), 415–421. https://doi.org/10.1016/j.brat.2012.03.001.

Murray, E., Hekler, E.B., Andersson, G., Collins, L.M., Doherty, A., Hollis, C., Rivera, D.E., West, R., Wyatt, J.C., 2016. Evaluating digital health interventions: key questions and approaches. Am. J. Prev. Med. 51 (5), 843–851. https://doi.org/10.1016/j.amepre.2016.06.008.

Nielsen, J., 2000. Why You Only Need to Test With 5 Users. Nielsen Norman Group. https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/.

Nielsen, J. (2012, January 15). Thinking Aloud: The #1 Usability Tool. Nielsen Norman Group. https://www.nngroup.com/articles/thinking-aloud-the-1-usability-tool/.

Peiris, D., Miranda, J.J., Mohr, D.C., 2018. Going beyond killer apps: building a better mHealth evidence base. BMJ Glob. Health 3 (1). https://doi.org/10.1136/bmjgh-2017-000676.

Pham, Q., Wiljer, D., Cafazzo, J.A., 2016. Beyond the randomized controlled trial: a review of alternatives in mHealth clinical trial methods. JMIR MHealth and UHealth 4 (3), e107. https://doi.org/10.2196/mhealth.5720.

Rottoli, M., Gioia, S.L., Frigeni, B., Barcella, V., 2017. Pathophysiology, assessment and management of multiple sclerosis fatigue: an update. Expert. Rev. Neurother. 17 (4), 373–379. https://doi.org/10.1080/14737175.2017.1247695.

Ruzic, L., Sanford, J.A., 2017. Usability of mobile consumer applications for individuals aging with multiple sclerosis. In: Antona, M., Stephanidis, C. (Eds.), Universal Access in Human–Computer Interaction. Design and Development Approaches and Methods (pp. 258–276). Springer International Publishing. https://doi.org/10.1007/978-3-319-58706-6_21.

Sandelowski, M., 2000. Whatever happened to qualitative description? Research in Nursing & Health 23 (4), 334–340. https://doi.org/10.1002/1098-240X(200008)23:4<334::AID-NUR9>3.0.CO;2-G.

Simblett, S. K., Evans, J., Greer, B., Curtis, H., Matcham, F., Radaelli, M., Mulero, P., Arévalo, M. J., Polhemus, A., Ferrao, J., Gamble, P., Comi, G., Wykes, T., & RADAR-CNS consortium. (2019). Engaging across dimensions of diversity: a cross-national perspective on mHealth tools for managing relapsing remitting and progressive multiple sclerosis. Multiple Sclerosis and Related Disorders, 32, 123–132. doi: https://doi.org/10.1016/j.msard.2019.04.020.

Spahrkäs, S.S., Looijmans, A., Sanderman, R., Hagedoorn, M., 2020. Beating cancer-related fatigue with the untire mobile app: protocol for a waiting list randomized controlled trial. JMIR Research Protocols 9 (2), e15969. https://doi.org/10.2196/15969.

Thomas, S., Thomas, P.W., Nock, A., Slingsby, V., Galvin, K., Baker, R., Moffat, N., Hillier, C., 2010. Development and preliminary evaluation of a cognitive behavioural approach to fatigue management in people with multiple sclerosis. Patient Educ. Couns. 78 (2), 240–249. https://doi.org/10.1016/j.pec.2009.07.001.

Thomas, S., Thomas, P.W., Kersten, P., Jones, R., Green, C., Nock, A., Slingsby, V., Smith, A.D., Baker, R., Galvin, K.T., Hillier, C., 2013. A pragmatic parallel arm multi-centre randomised controlled trial to assess the effectiveness and cost-effectiveness of a group-based fatigue management programme (FACETS) for people with multiple sclerosis. J. Neurol. Neurosurg. Psychiatry 84 (10), 1092–1099. https://doi.org/10.1136/jnnp-2012-303816.

Thomas, P.W., Thomas, S., Kersten, P., Jones, R., Slingsby, V., Nock, A., Davies Smith, A., Baker, R., Galvin, K.T., Hillier, C., 2014. One year follow-up of a pragmatic multi-centre randomised controlled trial of a group-based fatigue management programme (FACETS) for people with multiple sclerosis. BMC Neurol. 14 (1), 109. https://doi.org/10.1186/1471-2377-14-109.

van Kessel, K., Moss-Morris, R., 2006. Understanding multiple sclerosis fatigue: a synthesis of biological and psychological factors. J. Psychosom. Res. 61 (5), 583–585. https://doi.org/10.1016/j.jpsychores.2006.03.006.

van Kessel, K., Moss-Morris, R., Willoughby, E., Chalder, T., Johnson, M.H., Robinson, E., 2008. A randomized controlled trial of cognitive behavior therapy for multiple sclerosis fatigue: Psychosomatic Medicine 70 (2), 205–213. https://doi.org/10.1097/PSY.0b013e3181643065.

van Kessel, K., Wouldes, T., Moss-Morris, R., 2016. A New Zealand pilot randomized controlled trial of a web-based interactive self-management programme (MSInvigor8) with and without email support for the treatment of multiple sclerosis fatigue. Clin. Rehabil. 30 (5), 454–462. https://doi.org/10.1177/0269215515584800.

van Kessel, K., Babbage, D.R., Reay, N., Miner-Williams, W.M., Kersten, P., 2017. Mobile technology use by people experiencing multiple sclerosis fatigue: survey methodology. JMIR MHealth and UHealth 5 (2), e6. https://doi.org/10.2196/mhealth.6192.

Weiland, T.J., Jelinek, G.A., Marck, C.H., Hadgkiss, E.J., van der Meer, D.M., Pereira, N. G., Taylor, K.L., 2015. Clinically significant fatigue: prevalence and associated factors in an international sample of adults with multiple sclerosis recruited via the internet. PLoS One 10 (2), e0115541. https://doi.org/10.1371/journal.pone.0115541.

West, R., Michie, S., 2016. A Guide to Development and Evaluation of Digital Behaviour Change Interventions in Healthcare. Silverback Publishing. https://www.silverbackpublishing.org/products/cbc-monograph-1.

Whitehead, L., Seaton, P., 2016. The effectiveness of self-management mobile phone and tablet apps in long-term condition management: a systematic review. J. Med. Internet Res. 18 (5) https://doi.org/10.2196/jmir.4883.

Wilson, K., Bell, C., Wilson, L., Witteman, H., 2018. Agile research to complement agile development: a proposal for an mHealth research lifecycle. Npj Digital Medicine 1 (1), 1–6. https://doi.org/10.1038/s41746-018-0053-1.

Winberg, C., Kylberg, M., Pettersson, C., Harnett, T., Hedvall, P.-O., Mattsson, T., Månsson Lexell, E., 2017. The use of apps for health in persons with multiple sclerosis, Parkinson's disease and stroke—barriers and facilitators. Studies in Health Technology and Informatics 242, 638–641.

Winberg, C., Kylberg, M., Pettersson, C., Harnett, T., Hedvall, P.-O., Mattsson, T., & Lexell, E. M. (2019). Feeling controlled or being in control? Apps for self-management among older people with neurological disability. Disability and Rehabilitation: Assistive Technology, 0(0), 1–6. doi: https://doi.org/10.1080/17483107.2019.1685017.

Wu, X., Guo, X., Zhang, Z., 2019. The efficacy of mobile phone apps for lifestyle modification in diabetes: systematic review and meta-analysis. JMIR MHealth and UHealth 7 (1), e12297. https://doi.org/10.2196/12297.

Yardley, L., Morrison, L., Bradbury, K., Muller, I., 2015. The person-based approach to intervention development: application to digital health-related behavior change interventions. J. Med. Internet Res. 17 (1), e30 https://doi.org/10.2196/jmir.4055.