

Title Informing the development of a mobile application for the physical activity guidelines in multiple sclerosis: a qualitative, pluralistic approach

Item Type	Article (Accepted Version)
UoW Affiliated Authors	Richardson, Emma
Full Citation	Neal, W. N., Richardson, Emma and Motl, R. W. (2022) Informing the development of a mobile application for the physical activity guidelines in multiple sclerosis: a qualitative, pluralistic approach. <i>Disability and Rehabilitation: Assistive Technology</i> , 19 (4). pp. 1161-1169. ISSN 1748-3107
DOI/ISBN/ISSN	https://doi.org/10.1080/17483107.2022.2153937
Journal/Publisher	Taylor & Francis Group <i>Disability and Rehabilitation: Assistive Technology</i>
Rights/Publisher Set Statement	This is an Accepted Manuscript of an article published by Taylor & Francis in <i>Disability and Rehabilitation: Assistive Technology</i> on 9 December 2022, available at: https://doi.org/10.1080/17483107.2022.2153937 This is an Accepted Manuscript version of the following article, accepted for publication in <i>Disability and Rehabilitation: Assistive Technology</i> (Neal, W. N., Richardson, Emma and Motl, R. W. (2022) Informing the development of a mobile application for the physical activity guidelines in multiple sclerosis: a qualitative, pluralistic approach, 19 (4). pp. 1161-1169). It is deposited under the terms of the Creative Commons Attribution-NonCommercial License (http://creativecommons.org/licenses/by-nc/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited. Made available after a 12 month embargo from publication as per: https://authorservices.taylorandfrancis.com/research-impact/sharing-versions-of-journal-articles/
License	CC BY NC 4.0
Link	https://www.tandfonline.com/doi/full/10.1080/17483107.2022.2153937

Informing the Development of a Mobile Application for the Physical Activity Guidelines among Adults with Multiple Sclerosis: A Qualitative, Pluralistic Approach

Authors: Whitney N. Neal, MA¹, Emma V. Richardson, PhD², Robert W. Motl, PhD³

¹Department of Health Behavior, University of Alabama at Birmingham, Birmingham, USA

²School of Sport and Exercise, University of Worcester, Worcester, UK

³Department of Kinesiology and Nutrition, University of Illinois Chicago, Chicago, USA

Corresponding Author:

Whitney N. Neal

Department of Health Behavior

University of Alabama at Birmingham

1665 University Boulevard

Birmingham, AL 35233, USA

Email: wnneal@uab.edu

Phone: 205-996-0825

Keywords: exercise, health promotion, telehealth, qualitative inquiry

23 **Practice Points**

- 24 • mHealth technologies could be an empowering and inclusive method of supporting long
25 term physical activity uptake among persons with multiple sclerosis (MS).
- 26 • Knowledge is currently lacking regarding how mHealth technologies, such as mobile apps,
27 can facilitate uptake of Physical Activity Guidelines for Adults with MS (PAGs).
- 28 • People with MS desired an app grounded in a solid scientific foundation, but then translated
29 into simple, accessible, personalized physical activity guidelines that focused on safely
30 achieving activity goals.
- 31 • Motivational, functional, and personalization strategies should be included in the
32 development of an app based on the PAGs.

33

34

Abstract

Background. The uptake of Physical Activity Guidelines (PAGs) for adults with multiple sclerosis (MS) may be facilitated through mHealth solutions such as a mobile app. To date, there is limited information regarding preferred features of an app for people with MS. We explored desired features for an app that supports physical activity behavior among persons with MS.

Methods. Using a pluralistic analytical approach, we examined qualitative data from 40 people with MS through two different lenses to explore (i) what persons with MS wanted in an app based on the PAGs and (ii) how the PAG-based app should facilitate behavior change. The data were subjected to deductive, content analysis to identify populous mentions of desired PAG-based app elements. We then used inductive, semantic reflexive thematic analysis to further explore the opinions and evaluations of participants.

Results. Participants perceived features such as activity tracking, incentives for completing milestones, and customization as both triggers for doing PA and supporting engagement with the app. Participants expressed a desire for a personalized PA prescription based on mobility and fitness level, expert feedback based on data entered in the app, and an exercise library with a range of evidence-based content. Participants insisted the app be backed by a solid scientific foundation and that accessibility of personal data be controlled by the user.

Conclusions: We propose developing a simple, trustworthy, and evidence-based app that focuses on helping persons with MS safely reach the PAGs.

Multiple sclerosis (MS) is a chronic, immune-mediated, demyelinating condition of the central nervous system (CNS) with prevalence estimates of nearly 1 million adults in the U.S. and 2.5 million adults worldwide¹. This condition typically follows one of two clinical courses. Relapsing remitting MS (RRMS), the most common clinical course of MS, is characterized by clearly defined relapses of new or increasing neurologic symptoms followed by periods of partial or complete remission of symptoms. Progressive MS (PMS) is less common and is characterized by progressive worsening of neurological function over time. The condition typically involves inflammation within the CNS, resulting in diffuse CNS damage. Both courses of MS can cause walking and cognitive dysfunction, fatigue, depression, and pain, and reduced quality of life².

As part of a comprehensive, holistic care approach, physical activity (PA) can have a therapeutic impact by improving function, symptoms, and quality of life among people with MS^{2,3}; however, the majority of people with MS do not engage in sufficient amounts of PA for accruing the benefits⁴. The Canadian Physical Activity Guidelines for Adults with Multiple Sclerosis (PAGs) prescribe the appropriate dose of PA for people with MS to improve quality of life outcomes, and recommend 30+ minutes of moderate intensity aerobic activity twice weekly and strength training for major muscle groups twice weekly for adults ages 18-64 years with mild-to-moderate disability⁵; nonetheless, PA levels have remained markedly low in people with MS even after the publication of these guidelines. This may be attributed to a gap between the development of scientific knowledge and translation to the real world. That is, despite there being some evidence supporting the feasibility and benefits of the PAGs in MS⁶⁻⁸, there are few avenues for the broad dissemination, knowledge translation, or implementation of these guidelines among persons with MS. This critique is supported by a recent qualitative study that

examined perceptions and awareness of the PAGs for PA engagement among persons with MS in the US⁹. The PAGs were viewed as a good introduction to structured PA, but there was confusion about the intended audience for the PAGs (i.e., only Canadians), and that the guidelines lacked the necessary details to put a PA program into practice. To improve uptake of the PAGs, persons with MS suggested that the guidelines should convey the importance of being physically active, offer a wide array of symptom-specific exercises¹⁰, and use a variety of mutually reinforcing dissemination and implementation strategies, such as print and online platforms⁹.

Arguably, utilizing online platforms to facilitate physical activity among persons with chronic illness (particularly those who are immune-compromised) has become even more essential during the COVID-19 era¹¹. There is increasing focus on the application of telehealth solutions to facilitate PA behavior change due to advantages such as ubiquity, cost-effectiveness, and ease of access¹². However, a systematic review of existing PA telehealth interventions in people with MS reported low-quality evidence for a beneficial effect of these interventions on reducing fatigue, improving balance, and increasing quality of life¹³. It is important to note that these studies utilized internet-based technologies that required access to a website and or video conferencing software instead of a mobile app. Mobile health (mHealth), the use of wireless technology to deliver health services and information in mobile communication devices such as tablets, wearable monitoring devices, and smartphones, may be a more applicable mode of PA promotion as it is easily accessible to persons with MS at a time most convenient to them. Compared to other PA intervention modalities that require a desktop computer or laptop and internet connection to access a website, smartphones have a more portable size, can use built-in sensors or be paired with external sensors for continuous activity monitoring and feedback,

and despite having a smaller screen size than desktop computers or laptops, allow for creating rich app experiences to the user¹⁴. At present, the use of mobile apps has the potential to provide engaging real-time coaching experiences for motivating users to increase PA behavior through features such as measuring daily PA and providing feedback, guidance, and incentives to generate awareness on current behavior and stimulate users to achieve and maintain an active lifestyle¹⁴.

As yet, the development of an MS-specific PA app is a relatively novel approach to explore regarding cost-effective solutions to encourage, support, and empower persons with MS in their activity behavior^{12,15} and an opportunity to create a dissemination strategy informed and inspired by persons with MS. To increase the likelihood of an app based on the PAGs being appropriate, meaningful, and beneficial to adults with MS, it is essential to understand their contextual needs and preferences as end users of the technology to inform system design. Qualitative inquiries can be a valuable tool in the early stages of the user-centered design process to provide insight into complex and multifaceted experiences of individuals. Therefore, the current study ascertained what persons with MS desired from an app to support PA behavior, utilizing a qualitative, pluralistic approach to explore both what persons with MS wanted regarding content of a PAG-based app and how they wanted this content to be facilitated. This qualitative inquiry provides an empirical foundation for understanding the unique needs and perceptions of persons with MS for mHealth solutions to support PA behavior.

Methods

Philosophical assumptions

The current study followed a qualitative design that was guided by an interpretivist paradigm (i.e., ontological relativism and epistemological constructionism). Ontological relativism asserts that reality is a malleable, fluid experience and that standards of truth, knowledge, and morality depend on one's culture, society, and past histories¹⁶. Epistemological constructionism maintains that individuals create or construct personal understandings of knowledge through the interaction of their existing 'truths' and the social and cultural environments in which they live. Researchers become a part of this knowledge construction when conducting qualitative interviews¹⁷.

Participants

This research was part of a larger study examining approaches for increasing the uptake of the PAGs in MS, and we have previously reported on the sampling procedures⁹. Briefly, consistent with recommendations on quota-based sampling in qualitative research^{18,19}, we targeted recruitment of seven or more persons per geographical region of the U.S. (e.g., Southeast, Southwest, Midwest, West, and Northeast) by mailing flyers containing study information to an extensive list of persons who previously contacted us requesting information about studies from our lab. The 40 participants enrolled in the study were largely female (n=30) and the mean age was 58.6 (SD=9.3) years. Participants had been diagnosed with MS for a mean of 18.0 (SD=10.1) years and represented 27 different states in the United States. The study inclusion criteria were (i) age over 18 years, (ii) confirmed diagnosis of MS, (iii) and Multiple Sclerosis Neuropsychological Screening Questionnaire (MSNQ) score ≤ 27 ²⁰. The descriptive data on the overall sample of 40 participants are in **Table S1**.

Data collection

The original research was conducted in 2019 and explored potential approaches for increasing uptake of the PAGs⁹. The current research explored desired features regarding a PAG-based app and strategies to facilitate behavior change. The first author initiated the research and collected and analyzed data. The second author served as a “critical friend” and provided support, advice, and feedback throughout the research process²¹. We received Institutional Review Board approval before the study began, and all participants provided verbal consent before the interviews were audio recorded. Names were removed from all transcripts and changed to participant ID numbers to maintain confidentiality.

Data analysis and rigor

We adopted a pluralistic analytical approach to explore both what persons with MS wanted regarding content of a PAG-based app and strategies to support PA behavior. Analytical pluralism involves the application of two or more qualitative analytical methods to explore multiple aspects of a phenomenon and enhance complexity and depth of interpretation within a data set²². This approach allows researchers to extract as much meaning as possible from the data²³, and to construct holistic, multi-layered understandings that are deeper than one method of analysis alone²³. Pluralistic data analysis has further been effectively used to craft a more complex understanding of the lived experiences of aging with MS²⁴. To that end, two methods of data analysis were applied in a sequential method to the same data set to explore not only what persons with MS wanted regarding content of an app, but also *how* they wanted this content to be facilitated. The data were first subjected to content analysis (CA) to identify populous

mentions of desired app features based on the PAGs. A reflexive thematic analysis (RTA) was then used to provide details, context, and depth to the CA. In doing so, instead of focusing on either the 'reality' of the participants' accounts or quantifying mentions of app components, the analysis was an attempt to examine both what and how to create an app to support physical activity behavior; thus extending the understandings that would be derived from one method alone²⁵. All data were coded by the first author and organized using NVivo 12.

To ensure rigor and trustworthiness throughout the research process, we adopted a relativist approach. In line with this approach, we chose the evaluative markers worthy topic, transparency, and substantive contribution from the ongoing list for quality and rigor first proposed by Smith and Caddick²⁶. We highlighted the worthiness of our topic through the justification in the introduction regarding why an examination of desired PAG-based app features is currently needed by people with MS. We maintained transparency by completing an audit trail whereby the first author used the second and third authors as critical friends throughout the analytical process. We strived for our work to make a substantive contribution by conceptualizing the development of a PAG-based app within theoretical frameworks when applicable, providing recommendations for practice and future research, and highlighting how the use of a pluralistic analysis can be used to illuminate the meaning of an experience not well understood. Our significant contribution to the literature is reported in the results, discussion, and conclusion sections.

Content analysis

The data were first subjected to deductive, CA to identify recurrent mentions of app components. CA is a qualitative research method for describing and identifying common themes

in collected data. Using the three-phase guide put forth by Elo and Kyngäs²⁷, CA started with the preparation phase wherein researchers selected the unit of analysis (e.g., a word or theme). During this phase, the theoretically-informed categories ‘engagement’, ‘information management’, ‘functionality’, and ‘ease of use’ were identified as general themes that participants would likely address when discussing desired app features based on previous research²⁸⁻³¹. These categories further united common elements described by participants that would provide meaningful guidance in the creation of a PAG-based app. The ‘engagement’ and ‘functionality’ categories cover consumer interaction with the app and guidance provided by the app developers, respectively, and are aligned with the Mobile Application Rating Scale (MARS)³¹. ‘Ease of use’ is aligned with the Technology Acceptance Model (TAM) and includes concepts such as automation, convenience, and health literacy suitable to cater a range of users³⁰. The ‘information management’ category describes reliability, data security, and quality and quantity of data and is aligned with the Health Information Technology Acceptance Model (HITAM)²⁹. The first author then initiated the analytic process (phase 2), reviewing the data for content and coding based on correspondence with the pre-determined categories. Abstraction, a method used in CA to formulate general descriptions and interpretations of categories into a logical framework, guided the creation of sub-themes using content-characteristic words and provided a rich description of the phenomenon (i.e., desired app components) (**Figure S1**). In phase 3, results were synthesized for identifying the most relevant themes in the data by noting the frequency of the themes that were described by participants, thereby providing further context of app preferences among people with MS.

Reflexive Thematic Analysis

We then applied inductive, semantic RTA to explore how persons with MS desired a PAG-based app to function for personal, relevant, and engaging experiences. This further reflected our epistemological stance that knowledge is created mutually by participants and researchers. Using this approach, themes were constructed from participant testimonies (inductive analysis) and opinions were identified plainly in the data without applying a further layer of interpretation (semantic analysis). This method was chosen to reflect data content that best represented meaning as communicated by participants³². To ensure rigor, the first author utilized the six-stage thematic analysis guide for conducting inductive TA³². Already immersed in the data (stage 1), the first author proceeded to stage 2, applying content-characteristic codes to the data to generate a list of initial ideas for each participant, with miscellaneous responses interpreted inductively into new codes as necessary. In phase 3, potential themes were identified by sorting and collating the list of codes related to perceptions of a PAG-based app. Phase 4 involved the review of potential themes by the research team and discussion of whether themes were sufficiently supported with examples from the transcripts. In step 5, themes were named and defined in a way that explained data content, whilst step 6 yielded a report, which is the focus of the Results and Discussion section.

Results and Discussion

The demographics for participants in the app group are provided along with the overall sample in **Table S1**. Six themes related to motivational, functional, and personalization strategies to be used in an app based on the PAGs were identified through CA: (1) activity tracking and reminders, (2) positive reinforcement, (3) customization, (4) personalized PA prescription, (5) PA guidance and virtual resources, and (6) activity monitoring and support. Participants perceived

features such as activity tracking, incentives for completing milestones, and customization as both triggers for doing PA and support for engagement with the app. They expressed a desire for a personalized PA prescription based on mobility and fitness level, expert feedback based on data entered in the app, and an exercise library with an array of evidence-based content. Using RTA, we identified four desires stated by participants to facilitate this content into a usable, motivational app: (1) increase motivation to sustain usage, (2) include evidence-based content, (3) provide expert feedback, and (4) allow personal data management. The findings of the analyzed data are presented in **Tables S2** and **S3**; the table of associated CA themes includes a selection of quotes as data supporting our presentation. The results and discussion are presented together below to immediately conceptualize findings within the wider literature, focusing on the RTA themes.

Increase motivation to sustain usage

This theme underpins participants' desire for a PAG-based app to have features that would facilitate motivation and prolonged engagement in physical activity. For example, participants suggested proactive features such as reminders or triggers to engage in PA:

If it's something that they could hold in the palm of their hand and it sends them a reminder or their phone chirps and says, "Quick, do 20 burpees," which I could ever do a burpee again but something like that, that might be good for people to look at your program and keep them focused on it rather than start it and stop it. (Participant 38)

246 And it's a good reminder...to help you remember to do this twice a week or do this three
247 times a week whatever, a reminder, that's always helpful to get a reminder. (Participant
248 31)

249 Participants often associated inclusion of interactive features such as activity tracking and
250 incentives for achieving milestones to an increase in user engagement: "Some way of tracking
251 and also I know Fitbit does this, that they essentially have, you can set a goal and then if you
252 achieve that goal it says, hey, congratulations, you've met your goal for today" (Participant 34).

253 Features that enable users to draw their attention to how their PA progresses and to any
254 discrepancies between PA behavior and goals may increase app engagement and subsequent PA
255 levels. Indeed, in a similar study examining experiences of people with MS regarding digital self-
256 monitoring, participants were more likely to act on self-monitoring data¹⁵, highlighting the crucial
257 role of action planning features in PA apps to facilitate goal attainment. Moreover, proactive
258 features (i.e., reminders, context-aware prompts, and tailored PA plans and suggestions)
259 constitute one of the main gaps of commercial PA apps, suggesting that these features should be
260 core components in a PA app for adults with MS.

261 Participants also reported the need for autonomy and expected motivation to continue
262 using a PAG-based app to increase when users have an active role in the regulation of their
263 behavior. Self-regulation can be viewed through the lens of social cognitive theory (SCT), which
264 specifies mechanisms through which the factors that determine behavior work and how they
265 may be translated into practice³³. App features that incorporate SCT-based constructs to support
266 the self-regulation of behavior to achieve exercise goals (i.e., goal setting, self-monitoring, and

feedback) may allow users to self-organize their experiences and their behavior and therefore, foster experiences of autonomy^{12,15,34}.

Include evidence-based content

This RTA theme communicates perspectives regarding the information needs of people with MS. A shared view among participants was that the app should only include information backed by a solid scientific foundation. Incorporating information on the benefits of PA and new MS research involving exercise were also vital components for a PAG-based app, “Because I think we all know how exercise can help us, because a lot of times you’ll just hear, you know, you need to exercise and it can help with your fatigue and it’ll tell you what it can help with, but they don’t tell you what to do” (Participant 14). Participants believed that including evidence-based content unique to persons with MS would increase app usage and emphasized the need for a prescribing tool that would help them plan their PA, including details on what exercises to do. The variability of MS symptoms and how these inform PA levels was an important factor in the need for a personalized exercise program based on the PAGs:

And it’s a good idea...having it broken down between RRMS, secondary PMS and primary PMS, but even then you could subset it, depending on the individual. Because some people, they can’t walk, but their upper body strength is great, depending on the manifestation of their MS. Other people, it’s the other way around. They can walk, but they don’t have the upper body strength. (Participant 4)

In the context of this study, participants’ awareness of the physical and psychological benefits of PA was highlighted as a source of motivation to be physically active, but they desired an evidence-based PA program with symptom-specific exercises to help them reach the PAGs.

Preferences for a wide array of symptom-specific PA suggestions has been reported in previous literature examining the preferred sources for obtaining PA information by people with MS¹⁰. Further, mHealth PA interventions that are personalized to an individuals' needs and motivations are potentially more effective at maintaining adherence³⁵. In persons living with MS, the damage within the CNS results in the heterogenous expression of symptoms including fatigue, pain, walking dysfunction, bladder and bowel dysfunction, and cognitive impairment³⁶, so a strategy that may work for one person may not work for another. Thus, factors such as type of MS, mobility level, and physical fitness should be considered when designing an app for persons with MS^{10,12,37}. Providing information on a variety of exercises stratified by mobility level^{10,37,38} and recommendations for further modification of the movements if the given standards are too difficult may increase user engagement, which can contribute to overcome the general low PA levels of persons with MS.

Provide expert feedback

This RTA theme highlights participants' attitudes toward remote monitoring and feedback based on user data. Some expressed a reluctance of online information not presented by experts in MS and exercise: "I wouldn't go on the internet and just google, "What is the best exercise for MS?" I think I would try to seek out experts, like your study or through the MS Society" (Participant 22). Feedback from an expert in MS and exercise regarding progress towards reaching the PAGs appeared to be important to those interviewed, especially when beginning the exercise program: "They would need to have a person to direct them into, you know, what to do, how to record it, you know, how to progress. Or, you know, progress or possibly let up on" (Participant 4). Such feedback could consist of additional insights and advice based on personal

311 data. For example, Participant 21 suggested providing feedback on resistance training, “...to know
312 when to increase the weight and those types of specifics that would be really helpful. From a
313 trainer would probably know that or a physical therapist”. Participants had varied opinions on
314 how best to provide this feedback, suggesting formats such as a phone call, text message, or
315 automated in-app message from an expert in MS:

316 I mean, it doesn't have to be somebody's eyeballs on the screen, because that could be
317 incredibly tedious for whoever's having to do the review...You know, it could be, “We've
318 noticed that you haven't done X in three weeks, do you want to talk about it? If so, call
319 this number”, or it can be something automated. (Participant 25)

320 The desire for feedback based on personal PA data and variability in opinions regarding the
321 format of feedback provided can be conceptualized within the wider literature. It is almost
322 impossible to imagine a PA intervention that does not employ some form of feedback as a
323 technique to increase motivation, but the ways of doing so are diverse in terms of timing,
324 content, and representation. Apps that aim to support PA in daily life report a more diversified
325 use of feedback representation, including graphical displays, spoken dialogue, and haptic
326 feedback¹⁴. The chosen representation for interacting with the user seems to be mostly based on
327 the target audience and expected use of the app. For example, apps that are focused on recording
328 PA in real time typically employ either spoken dialogue or haptic feedback, as users are too
329 preoccupied with performing the exercise to use the visual display of a smartphone¹⁴.
330 Alternatively, it has been suggested that the most effective technologies are those that come
331 close to the “gold standard” of one-on-one, face-to-face counseling with an expert³⁹. That is, the

use of an avatar to simulate interactions with a real PA trainer and provide personal feedback and guidance may be more effective at achieving desired health outcomes.

Allow personal data management

This RTA theme gathers insights from participants on system requirements related to the use of data collected from the app. One major deterrent to downloading an app based on the PAGs was allowing third party access of personal information. Participants insisted that access to personal information and data be controlled by the user, "...I'm more concerned about privacy and... I don't want anything on my phone that's going to phone-home. I don't want apps talking to some server, God knows where..." (Participant 25). Research suggests that better system credibility may increase the persuasive capability of PA-promoting apps⁴⁰. In line with this, personal data should be optional and transparent to help ensure that users trust the app. Technology trustworthiness may further be increased by informing users that the app was created in conjunction with healthcare and exercise professionals and that there are other individuals like them using it.

Conclusion

There is a paucity of research on MS-specific needs for mHealth-based solutions for PA, particularly an app for increasing PA behavior. This study applied a pluralistic analytical approach to identify what persons with MS want in an app based on the PAGs. Four themes were identified through RTA that can guide the development of a future PAG-based app: (1) increase motivation to sustain usage, (2) include evidence-based content, (3) provide expert feedback, and (4) allow personal data management. This aligned with design considerations for a PAG-based app such

as: (1) activity tracking and reminders, (2) positive reinforcement, (3) customization, (4) personalized PA program, (5) activity monitoring and support, and (6) exercise guidance and virtual resources. Such insights should inform the development an app for promoting PA designed to integrate persons with MS as the primary user base.

Our results align nicely with previous research on apps for PA in MS. One study identified MS-specific needs for a PA-based app including activity tracking, incentives for completing tasks and objectives, customizable goal setting, optional sociability, and a game-like attitude¹². Another study examined the needs and preferences of people with MS regarding further development and implementation of an existing MS-specific self-monitoring app¹⁵. The themes identified included personalization, providing guidance, and integration into clinical treatment plans. Our findings are consistent with results from those studies. Our use of a pluralistic analytical approach expands on those findings by providing an additional level of detail regarding perceptions of an app based on the PAGs for MS and further underscore the importance of protecting user information from third parties and providing feedback on progress towards meeting the PAGs.

Recommendations for Research and Practice

Our results suggest that the key behavioral components of a PA app for MS align with SCT and may inform the development and implementation of a PAG-based app for people with MS. For example, providing more practical evidence of the importance of exercise for overall health within the app may increase outcome expectations and subsequent PA levels of adults with MS. Integration of SCT components, particularly the threefold stepwise implementation model, into the app could allow for better tailoring of materials and guidance by ensuring the information

provided is appropriate to the individual's level of change⁴¹. We further provide key recommendations and considerations regarding user experience, information management, and engagement, along with strategies for integrating behavior change methods, in **Table S4** and discuss below.

As previous research on the attitudes of people MS and health care providers towards apps for measuring PA likewise identified customization as a facilitator to uptake of PA tracking apps^{12,15}, the inclusion of customization elements such as goals, frequency of exercise, timing and type of activity cues, and type of activity or exercise equipment are vital in the construction of the PAG-based app. Incorporating basic gamification elements (i.e., point system for in-app activity and rewards for completing exercise sessions)⁴², has also emerged as a popular strategy for influencing health behaviors. Previous research further supports a correlation between the use of health behavior theory and gamification in commercial health and fitness apps, suggesting that gamification may be an effective strategy for changing health behaviors^{35,43}.

Accessibility and ease of use were held in high regard to usage of a PAG-based app; participants were clear that the app should be simple and intuitive to use. To ensure the materials address a range of users, the materials should be presented in interactive formats including dialogue, videos, pictures, and written descriptions. Designers of a PAG-based app should also consider other MS-specific limitations, such as reduced fine motor skills or blurry vision, to increase uptake.

Limitations

This study is not without limitations. First, though one benefit of a secondary review on the same data set is that it allows researchers to shed light on a topic without added burden to

study participants, transcripts were based on individual responses to questions regarding awareness of the PAGs and approaches for increasing uptake, not desired features of an app based on the PAGs. As less than half of participants (n=16) from the original interviews were included in the secondary analysis, the sample size was not large enough to be representative of a larger population of adults with MS. The nature of the secondary analysis further precluded us from asking follow-up questions, seeking clarification, or eliciting feedback for comparison from participants (n=24) who did not express interest in a PAG-based app. Our findings may further be limited by the fact that three-fourths of these participants were moderately active according to the GLTEQ, so their awareness of the benefits of PA maybe positively biased. As less-active adults with MS may have different needs and preferences regarding a PAG-based app, future research should analyze such differences and generalize to a more diverse sample of adults with MS, considering age, mobility level, educational level, digital literacy, and race/ethnicity.

To conclude, this study identifies several design considerations for an app based on the PAGs for MS. The results suggest a simple, guiding, trustworthy, and evidence-based app that focuses on helping persons with MS safely reach and maintain the recommended PAGs. The elements identified should be considered in future design processes for an app that may increase the uptake of the PAGs by persons with MS.

414 References

- 415 1. Browne P, Chandraratna D, Angood C, et al. Atlas of Multiple Sclerosis 2013: A growing
416 global problem with widespread inequity. *Neurology*. 2014;83(11):1022-4.
417 doi:10.1212/WNL.0000000000000768
- 418 2. Motl RW, Pilutti LA. The benefits of exercise training in multiple sclerosis. *Nat Rev*
419 *Neurol*. 2012;8(9):487.
- 420 3. Motl RW, Sandroff BM, Kwakkel G, et al. Exercise in patients with multiple sclerosis.
421 *Lancet Neurol*. 2017;10(16):848-856. doi:10.1016/S1474-4422(17)30281-8
- 422 4. Kinnett-Hopkins D, Learmonth Y, Hubbard E, et al. The interpretation of physical activity,
423 exercise, and sedentary behaviours by persons with multiple sclerosis. *Disabil Rehabil*.
424 2019;41(2):166-171.
- 425 5. Latimer-Cheung AE, Martin Ginis KA, Hicks AL, et al. Development of evidence-informed
426 physical activity guidelines for adults with multiple sclerosis. *Arch Phys Med Rehabil*.
427 2013;94(9):1829-1836.e7. doi:10.1016/J.APMR.2013.05.015
- 428 6. Adamson BC, Learmonth YC, Kinnett-Hopkins D, Bohri M, Motl RW. Feasibility study
429 design and methods for Project GEMS: Guidelines for Exercise in Multiple Sclerosis. *Contemp*
430 *Clin Trials*. 2016;47:32-39. doi:10.1016/j.cct.2015.12.002
- 431 7. Learmonth YC, Adamson BC, Kinnett-Hopkins D, Bohri M, Motl RW. Results of a
432 feasibility randomised controlled study of the guidelines for exercise in multiple sclerosis
433 project. *Contemp Clin Trials*. 2017;54:84-97. doi:10.1016/J.CCT.2016.11.012

- 434 8. Canning KL, Hicks AL. Benefits of adhering to the Canadian physical activity guidelines
435 for adults with multiple sclerosis beyond aerobic fitness and strength. *Int J MS Care*.
436 2020;22(1):15-21.
- 437 9. Neal WN, Richardson E, Motl RW. "How Come You Sent Me the Canadian One?"
438 Application and Uptake of the Canadian Physical Activity Guidelines for Adults With Multiple
439 Sclerosis in the United States. *Adapt Phys Activ Q*. Apr 9 2021;38(3):413-434.
440 doi:10.1123/apaq.2020-0136
- 441 10. Sweet SN, Perrier M-J, Podzyhun C, Latimer-Cheung AE. Identifying physical activity
442 information needs and preferred methods of delivery of people with multiple sclerosis. *Disabil*
443 *Rehabil*. 2013;35(24):2056-2063.
- 444 11. Motl R, Ehde D, Shinto L, Fernhall B, LaRocca N, Zackowski K. Health Behaviors,
445 Wellness, and Multiple Sclerosis Amid COVID-19. *Arch Phys Med Rehabil*. Oct
446 2020;101(10):1839-1841. doi:10.1016/j.apmr.2020.06.001
- 447 12. Giunti G, Kool J, Rivera Romero O, Dorronzoro Zubieta E. Exploring the Specific Needs of
448 Persons with Multiple Sclerosis for mHealth Solutions for Physical Activity: Mixed-Methods
449 Study. *JMIR Mhealth Uhealth*. Feb 9 2018;6(2):e37. doi:10.2196/mhealth.8996
- 450 13. Khan F, Amatya B, Kesselring J, Galea M. Telerehabilitation for persons with multiple
451 sclerosis. *Cochrane Database Syst Rev*. Apr 9 2015;2015(4):Cd010508.
452 doi:10.1002/14651858.CD010508.pub2
- 453 14. Jones VM, Hermens HJ. Tailoring real-time physical activity coaching systems: a
454 literature survey and model. *User modeling and user-adapted interaction*. 2014;24(5):351-392.

- 455 15. Wendrich K, van Oirschot P, Martens MB, Heerings M, Jongen PJ, Krabbenborg L.
456 Toward Digital Self-monitoring of Multiple Sclerosis: Investigating First Experiences, Needs, and
457 Wishes of People with MS. *Int J MS Care*. Nov-Dec 2019;21(6):282-291. doi:10.7224/1537-
458 2073.2018-083
- 459 16. Papathomas A. From Cardinal to Marginal... and Back? *Routledge Handbook of*
460 *Qualitative Research in Sport and Exercise*. Routledge; 2016:37-48.
- 461 17. Burr V. *Social constructionism*. 3rd ed. Routledge; 2015.
- 462 18. Kuzel AJ. Sampling in qualitative inquiry. *Doing Qualitative Research*. Sage Publications,
463 Inc; 1992:31-44. *Research methods for primary care, Vol. 3*.
- 464 19. Robinson OC. Sampling in interview-based qualitative research: A theoretical and
465 practical guide. *Qual Res Psychol*. 2014;11(1):25-41.
- 466 20. Benedict RH, Cox D, Thompson LL, Foley F, Weinstock-Guttman B, Munschauer F.
467 Reliable screening for neuropsychological impairment in multiple sclerosis. *Mult Scler*. Dec
468 2004;10(6):675-8. doi:10.1191/1352458504ms1098oa
- 469 21. Sparkes AC, Smith B. *Qualitative research methods in sport, exercise and health: From*
470 *process to product*. 1st ed. Routledge; 2013:288.
- 471 22. Clarke NJ, Willis MEH, Barnes JS, et al. Analytical Pluralism in Qualitative Research: A
472 Meta-Study. *Qualitative Research in Psychology*. 2015/04/03 2015;12(2):182-201.
473 doi:10.1080/14780887.2014.948980
- 474 23. Simons L, Lathlean J, Squire C. Shifting the focus: sequential methods of analysis with
475 qualitative data. *Qual Health Res*. Jan 2008;18(1):120-32. doi:10.1177/1049732307310264

- 476 24. Richardson EV, Motl RW. "Kicking and Screaming" or "Gracefully Conceding": Creative
477 Nonfiction Stories of Aging With Multiple Sclerosis. *Qual Health Res*. Aug 2021;31(10):1861-
478 1874. doi:10.1177/10497323211009864
- 479 25. Simons L, Lathlean J, Squire C. Shifting the Focus: Sequential Methods of Analysis With
480 Qualitative Data. *Qualitative Health Research*. 2008;18(1):120-132.
481 doi:10.1177/1049732307310264
- 482 26. Smith B, Caddick N. Qualitative methods in sport: A concise overview for guiding social
483 scientific sport research. *Asia Pacific Journal of Sport and Social Science*. 2012;1(1):60-73.
- 484 27. Elo S, Kyngäs H. The qualitative content analysis process. *J Adv Nurs*. Apr
485 2008;62(1):107-15. doi:10.1111/j.1365-2648.2007.04569.x
- 486 28. Anderson K, Burford O, Emmerton L. Mobile Health Apps to Facilitate Self-Care: A
487 Qualitative Study of User Experiences. *PLoS One*. 2016;11(5):e0156164.
488 doi:10.1371/journal.pone.0156164
- 489 29. Kim J, Park HA. Development of a health information technology acceptance model
490 using consumers' health behavior intention. *J Med Internet Res*. Oct 1 2012;14(5):e133.
491 doi:10.2196/jmir.2143
- 492 30. Hu PJ, Chau PYK, Sheng ORL, Tam KY. Examining the Technology Acceptance Model
493 Using Physician Acceptance of Telemedicine Technology. *Journal of Management Information*
494 *Systems*. 1999/09/01 1999;16(2):91-112. doi:10.1080/07421222.1999.11518247
- 495 31. Stoyanov SR, Hides L, Kavanagh DJ, Zelenko O, Tjondronegoro D, Mani M. Mobile app
496 rating scale: a new tool for assessing the quality of health mobile apps. *JMIR Mhealth Uhealth*.
497 Mar 11 2015;3(1):e27. doi:10.2196/mhealth.3422

- 498 32. Clarke V, Braun V, Weate P. Using thematic analysis in sport and exercise research. In:
499 Smith B, Sparkes AC, eds. *Routledge Handbook of Qualitative Research in Sport and Exercise*.
500 Taylor & Francis; 2016:191-205.
- 501 33. Bandura A. Health promotion by social cognitive means. *Health Educ Behav*.
502 2004;31(2):143-164.
- 503 34. Baretta D, Perski O, Steca P. Exploring Users' Experiences of the Uptake and Adoption of
504 Physical Activity Apps: Longitudinal Qualitative Study. *JMIR Mhealth Uhealth*. Feb 8
505 2019;7(2):e11636. doi:10.2196/11636
- 506 35. Monteiro-Guerra F, Rivera-Romero O, Fernandez-Luque L, Caulfield B. Personalization in
507 Real-Time Physical Activity Coaching Using Mobile Applications: A Scoping Review. *IEEE Journal*
508 *of Biomedical and Health Informatics*. 2020;24(6):1738-1751. doi:10.1109/JBHI.2019.2947243
- 509 36. Motl RW. Physical activity and irreversible disability in multiple sclerosis. *Exercise and*
510 *sport sciences reviews*. 2010;38(4):186-191.
- 511 37. Remy C, Valet M, Stoquart G, et al. Telecommunication and rehabilitation for patients
512 with multiple sclerosis: access and willingness to use. A cross-sectional study. *Eur J Phys Rehabil*
513 *Med*. Aug 2020;56(4):403-411. doi:10.23736/s1973-9087.20.06061-x
- 514 38. Casey B, Hayes S, Browne C, Coote S. What do people with MS want from a web-based
515 resource to encourage increased physical activity behaviour? *Disabil Rehabil*. Aug
516 2016;38(16):1557-66. doi:10.3109/09638288.2015.1106601
- 517 39. Bickmore TW, Mauer D, Brown T. Context Awareness in a Handheld Exercise Agent.
518 *Pervasive and mobile computing*. 2009;5(3):226-235. doi:10.1016/j.pmcj.2008.05.004

- 519 40. Matthews J, Win KT, Oinas-Kukkonen H, Freeman M. Persuasive Technology in Mobile
520 Applications Promoting Physical Activity: a Systematic Review. *J Med Syst.* Mar 2016;40(3):72.
521 doi:10.1007/s10916-015-0425-x
- 522 41. Fifolt M, Richardson EV, Barstow E, Motl RW. Exercise behaviors of persons with
523 multiple sclerosis through the stepwise implementation lens of social cognitive theory. *Disabil*
524 *Rehabil.* Dec 4 2018:1-9. doi:10.1080/09638288.2018.1514077
- 525 42. Deterding S, Dixon D, Khaled R, Nacke L. From game design elements to gamefulness:
526 defining "gamification". presented at: Proceedings of the 15th International Academic
527 MindTrek Conference: Envisioning Future Media Environments; 2011; Tampere, Finland.
528 <https://doi.org/10.1145/2181037.2181040>
- 529 43. Lister C, West JH, Cannon B, Sax T, Brodegard D. Just a Fad? Gamification in Health and
530 Fitness Apps. *JMIR Serious Games.* 2014/08/04 2014;2(2):e9. doi:10.2196/games.3413
531
532

Table 1. Descriptive characteristics of the overall sample and those who mentioned the desire for a PAG-based application.

Variable	Original Sample (N=40)	Mentioned App (n=16)
Age (years (SD))	58.6 (9.3)	56.8 (9.1)
Gender (n (%) F/M)	30 (75) F/ 10 (25) M	11 (68.8) F/ 5 (31.2) M
Race (n (%))		
Caucasian	36 (96)	16 (100)
Non-Caucasian	4 (4)	0 (0)
MS Type (n (%))		
RRMS	23 (57.5)	11 (68.75)
PMS	7 (17.5)	3 (18.75)
SPMS	10 (25.0)	2 (12.5)
Disease Duration (years (SD))	18.0 (10.1)	15.7 (8.6)
PDDS (IQR)	3.60 (0.0-7.0)	3.06 (0.0-7.0)
PA Level (n (%))		
Active (GLTEQ $\geq$ 24)	29 (72.5)	12 (75.0)
Inactive (GLTEQ < 24)	11 (27.5)	4 (25.0)

Note. PAG = Canadian Physical Activity Guidelines for Adults with Multiple Sclerosis; MS = multiple sclerosis; PDDS = Patient-Determined Disease Steps; PA = physical activity

Table 2. Content analysis themes regarding an application for supporting the Physical Activity Guidelines for MS.

Theme	Components	Quotes
Activity tracking and reminders (n=5)	- Allow users to log exercise-related information - Reminders to stay active	Well, I'll be honest with you, if there was an app that actually made you put in there what you did, how long you did it for, something like that, that would help. (Participant 2)
Positive reinforcement (n=6)	In-app rewards and encouraging messages	- And again, the app every time they open that up, it'd say for an MS patient, "Remember, it's not your muscles, it's your nerves." (Participant 31) - And say, "I completed two of my four activities for this week. So, I'm 50% done." type of thing. (Participant 3)
Customization (n=6)	- Flexibility in completing exercise sessions - Specify use of an assistive device, exercise equipment used	- I mean, the 30 minutes a day, a lot of people, especially now if they're still working...will say they can't find time to do 30 minutes a day twice a week. So somewhere, to break it up, because they could break it up in some way, shape, or form (Participant 6) - It's harder for a person to use a walker and walk, it's harder to walk with a cane. But you do get, that is moderate intensity for an individual...So I don't know if you're talking with people, give them credit for doing walking a shorter distance with their cane, or with their walker. That's a suggestion. (Participant 12)
Personalized PA program (n=16)	- Tailored to mobility and/or fitness level - Automated adjustments to exercises based on progress	I think that's what a lot of us, people with MS, we don't really have a plan, a customized individual plan. That would be really interesting if they could see that. (Participant 21)

	Guidance on progressing to meeting PAGs	
PA guidance and virtual resources (n=8)	- MS-specific exercises and instructions on proper technique - Guidance on appropriate and alternative exercise equipment - Access to live exercise classes	- I would actually like to see links to classes that'll be held that I can click on, and join the class remotely...Or, also maybe new classes that are coming local to my area that I might be interested in taking for physical activity. (Participant 3) - I like a picture and a description of what to do. Like I took my home program sheets that the PT gave me, and I laminated them and cut them and put them on a little ring so I can flip through them and see them every day. (Participant 14) - So, you've got to have access [to the] internet, TV, YouTube, Netflix videos, whatever exercise video you're going to do to get up to that aerobic level twice a week. (Participant 17)
Activity monitoring and support (n=5)	Feedback and guidance based on app data provided in the user's preferred format	It would be real helpful if there was like a weekly check-in for the people that are part of the program. You know, just whatever, a 10-minute call in number once a week, or whatever. Just say, "Hey, how you doing?" (Participant 3)

540

541

Table 3. Thematic analysis themes and subthemes regarding an application for supporting the Physical Activity Guidelines for MS.

Theme	Components
Increase motivation to sustain usage	• Proactive features such as reminders and suggestions as triggers to be more physically active
Include evidence-based content	• Information backed by a solid scientific foundation • Information on the benefits of exercise • Include new information on MS exercise research
Provide expert feedback	• Incorporate monitoring of participant's progress in meeting the PAGs
Allow personal data management	• Data privacy important • User control of personal data

Note. PAGs = Canadian Physical Activity Guidelines for Adults with Multiple Sclerosis; MS = multiple sclerosis

548 **Table 4. Key recommendations for the design and development of an application based on the**
 549 **Physical Activity Guidelines for MS.**

Engagement Features

Tailored exercise prescription

- Provide personalized exercise prescription stratified by user mobility and activity level and include questions to gauge users' current levels and adapt the program accordingly.
- Include guidance on gradually working up to meeting the PAGs with detailed activities and demonstrations of proper techniques based on physical limitations.
- Dynamically adjust the exercise prescription when needed based on user's mobility level, progress, symptoms (e.g., mood, fatigue, pain), and perceived difficulty.

Customization

- Tailor app to specific goals, needs, and preferences of the person with MS.
- In communications, include the name of the person with MS to convey that the communication is designed specifically for them.
- Allow for a certain degree of customization of features such as goals, frequency of aerobic and resistance exercise (and the ability to reschedule), timing and type of activity cues (reminders or notifications), use of an assistive device, and type of activity or exercise equipment.
- Present activity and progress based on user preferences (i.e., user may like to see steps and duration but not distance).

Positive reinforcement

- Include basic gamification elements – for instance, a point system for activity within the app, rewards for completing exercise sessions, and encouraging messages when opening the app – to provide a fun and engaging experience.
- Gamification elements should be carefully designed to ensure the feature does not seem childish or overly competitive and either include an option to opt out or have a secondary role in the app.

Information Management Features

Evidence-based education

- Include SCT and evidence-based modules with topics such as knowledge of the benefits of exercise in MS, tools for managing day-to-day activities, and the core determinants of SCT presented in interactive ways that include dialogue, text, video, and graphics.
- For modules related to SCT, consider including topics such as strategies for increasing self-efficacy, identifying outcome expectations, the benefits of self-monitoring, common MS-specific barriers to physical activity and strategies to overcome them, and identifying facilitators to exercise.
- Adjust type and frequency of communication based on the user's level of change according to the stepwise implementation model. For example, providing more practical evidence of the importance of exercise for overall health in the module about the benefits of exercise in MS may increase the self-efficacy and subsequent physical activity levels of Level 2 persons with MS.

Exercise library

- Include exercises stratified by mobility and activity levels offered in a variety of formats including videos, pictures, and written descriptions.
- Provide guidance on using various exercise equipment (e.g., free weights, household items) appropriate for people with MS.
- Provide information on local resources related to physical activity including parks, facilities, and programs, based on the user's location.

Privacy

- Provide clear and easy-to-understand information on data security and privacy methods used.
- Include transparent and customizable data sharing (e.g., with researchers, physical therapists, neurologists, and other healthcare providers)

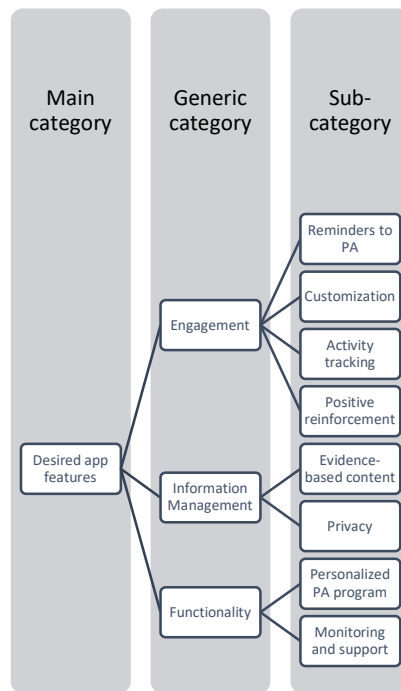
Functionality Features

Data visualization

- Include a simple and intuitive app interface along with instructions on how to use the app, explanations on interface specifics (e.g., explanation of what a graph represents), and specific action instructions (e.g., "Type the number of steps you took below").
- Monitor and present visual information on current activity (e.g., steps, distance, duration, and sets/repetitions), progress towards reaching the PAGs, and progress through time (e.g., weekly, monthly, and yearly historical data) using straightforward and visual forms (i.e., graphs, progress bars).
- Provide interpretation of progress (e.g., weekly, monthly) relevant to the person with MS's goals and health concerns, highlighting the health benefits of sustained engagement in physical activity.

Note. PAGs = Canadian Physical Activity Guidelines for Adults with Multiple Sclerosis; MS = multiple sclerosis; SCT = social cognitive theory

553 **Figure 1. Example of the abstraction process.**



554