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Original Article

Brain health PRO/Santé cerveau PRO: The development of a web-based program for dementia literacy and risk factor reduction

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ABSTRACT

Background: Online educational programs focused on ways to improve brain health could increase participant literacy, empowerment, and engagement in activities that support personal brain health, potentially reducing dementia risk.
Objectives: Our goal was to develop an evidence-based online educational program with a focus on risk and protective factors for dementia. Here we present the rationale and features of the program and include results from a pilot study that assessed usability and acceptability.
Design: This project is part of the Can-Thumbs UP (CTU) initiative. An Intervention Mapping Approach framework and co-construction approach was used to develop the online program. A pre-post pilot open label design was used to test the usability and acceptance of this at-home educational program.
Setting: The program and assessment for the pilot study were delivered fully remotely.
Participants: Twenty community-dwelling older adults (60–83 years of age, 65 % female) living in Canada who were at increased risk of dementia.
Program: The *Brain Health PRO/Santé Cerveau PRO* is a web-based 45-week program available in French and English. It provides general information and guidance on seven modifiable risk factors for dementia: physical activity, nutrition, cognitively stimulating activities, sleep, social and psychological health, vascular health, and vision/hearing. After completing a brief intake questionnaire, users are provided with an individualized risk profile to personalize priorities and goals. During the course of the program, users receive feedback on lifestyle changes. For this pilot study, participants completed a 15-week version of the program.
Measurements: This pilot study reports measures of usability (System Usability Scale), acceptance (Technology Acceptance Model-2) as well as risk profiles at intake based on self-reported questionnaires.
Results: Two logic models were developed to identify the determinants of risk for dementia and how these could be targeted by the program. A review of dementia risk and protective factors and online educational programs for older adults, as well as co-creation activities with experts, stakeholders, and citizen advisors, were used to identify the determinants, target, format, and content of the program. The pilot study reports excellent usability and acceptance with scores of 80.4/100 and 93.5/120 respectively.
Conclusion: Intervention mapping and co-construction approaches facilitated the design of a program that effectively balances the delivery of scientific content with the specific constraints, needs and abilities of older adults.
Trial registration: NCT05347966.

1. Introduction

Neurocognitive disorders affect 10–15 % of people over the age of 65 and are considered one of the greatest health challenges of this century. Cognitive difficulties associated with neurocognitive disorders, dementia and Alzheimer's disease (AD) have a major impact on the ability of older adults to live independently and to participate fully in society. An increasing number of studies have identified modifiable risk factors that contribute to the risk of cognitive decline and dementia [1–3]. Offering prevention programs focusing on risk factors has been proposed as a major component of non-pharmacological intervention strategies targeting cognition. In particular, educational programs targeting modifiable risk factors for cognitive decline and dementia are potentially critical tools to inform older adults about brain health and to educate and empower them [4]. Addressing modifiable risk factors may have a major impact on the number of dementia cases worldwide given that 45 % of attributable risk of dementia is related to these risk factors [1–3]. A recent study showed that in Canada, where this study took place, the attributable risk increases to 49 % [5].

Face-to-face or supervised programs targeting modifiable risk factors [6–8] have been developed and reported to have a positive effect on cognition in older adults at risk for dementia [9]. However, providing supervised or face-to-face interventions is costly and logistically challenging. The use of new digital technologies can address some of these access challenges. Web-based programs facilitate scalability and improve access to specialized scientific knowledge by reducing the impact of geographic, mobility and time constraints. Moreover, the conditions for a web-based approach to brain health have recently improved, as older adults have increased their use of technology in response to mandated physical distancing and isolation during the COVID-19 pandemic [10]. However, it is essential to evaluate technology-based programs and adapt them to align with the needs and capabilities of older adults. Failure to do so runs the risk of reducing uptake, satisfaction and adherence [11]. For instance, studies have shown that technical constraints (e.g., ease of use, ease of navigation) and aspects of content (e.g., difficult to understand, not interesting, not science-based) represent barriers to the use of web-based prevention programs by older adults [4,11,12]. Surprisingly, few studies of dementia risk reduction interventions have included user's assessment in their outcomes and still fewer have relied on co-design to construct their intervention [4,11].

In response to this gap, a team of Canadian researchers developed *Brain Health PRO/Santé Cerveau PRO*, a user-friendly web-based educational risk reduction program tailored to Canadians and based on scientific evidence, using a collaborative co-creation research process [13,14] combined with the Intervention Mapping Approach (IMA). The IMA is a step-based framework that guides the construction, validation and dissemination of theory- and evidence-based health promotion programs [15]. The framework also guides program adoption, implementation and sustainability. Our process based on the IMA involved: 1. Establishing a detailed understanding of the brain health problem, the population at risk and the behavioral and environmental determinants based on the scientific literature and input from community-dwelling older adults; 2. Specifying intervention program targets and goals for change; 3. Translating this information into practical intervention strategies and content in a coherent program; 4. Testing the efficacy of the program; and 5. Developing implementation strategies to facilitate adoption, implementation, and maintenance in community settings.

Focusing on Steps 1–3 of the IMA framework, this paper provides an overview of the design process, the logic model of the factors and determinants of cognitive health (logic model of the problem), the logic model of change, and the main content and features of the resulting co-designed *Brain Health PRO/Santé Cerveau PRO*. Logic models, which are broadly used in health promotion, are defined as frameworks that illustrate the expected cause-and-effect relationships associated with a particular health problem, and with the proposed intervention (logic model of change) [16]. A secondary objective is to describe the program's usability and acceptance based on a 3-month pilot study. Steps 4–5 are currently under investigation and will be reported separately.

The program is part of the Brain Health Support Program Study of the Canadian Therapeutic Platform Trial for Multidomain Interventions to Prevent Dementia: (CAN-THUMBS UP) [17].

2. Methods

2.1. Design process

Completion of steps 1–3 of the IMA took approximately 3 years of development time. The first six months involved defining the problem, the general approach and identifying members of the Brain Health PRO expert group and the Citizen Advisory Group (CAG). The next six months were used to identify the targets of the program and the objectives for change based on Step 1 and the literature (Step 2). This was done partly in parallel with Step 1. The following 12–15 months involved program design and content construction (Step 3). The last 6 months involved pre-piloting elements of the prototype and completing a 3-month pilot to test usability and acceptance (Step 3). Plans for efficacy and a pilot for implementation assessment (Steps 4–5) were conducted concurrently to the program construction. A co-design approach was used in constructing the program by engaging potential users during the entire development process.

The CTU Co-Principal Investigators (S.B., H.C., H.F., H.N. and M.M.O) proposed the initial idea and outlined the general objectives of the program. The first author (S.B.) proposed a general layout, program content, personalization and other functionalities which were then discussed and adapted by the Brain Health PRO Expert group and the CAG. The Brain Health PRO Expert Group consisted of 33 people (25 researchers/clinicians, four CAG members and the knowledge mobilization expert) and was led by SB. The group met every other week to discuss and take decisions on the content, functionalities and modalities, to receive guidelines and recommendations by the knowledge mobilization expert (II), the techno pedagogical firm and the CAG. The CAG consisted of nine older adults living in Ontario, Quebec, and New Brunswick (3 men, 6 women; age range = 64–80 for seven of the nine members who completed demographic questionnaire). Members of the CAG were recruited from the networks of researchers. It was co-chaired by L.M. and E.H (see D'Amico et al. [18] for a full description and evaluation of the CAG), with N.A. serving as the liaison researcher. The membership was determined to reflect the intended end-users whose first language was English or French. The CAG met as needed and participated in the Brain Health PRO Expert Group meetings. Persons in the CAG were positioned as research collaborators who were involved in all aspects of program creation and development. They participated in the decisions and discussion that took place within the Brain Health PRO Expert Group meetings. They critically reviewed program material, and collaborated in the decision-making process regarding the program.

The Brain Health PRO Expert Group was in charge of developing the content of the program. A *topic leader* was designated for each topic (eight leaders across the eight topic modules), and *topic experts* were identified and tasked with content development and drafting the topic chapters, often calling on other colleagues within the Canadian Consortium on Neurodegeneration in Aging (CCNA), external colleagues, or upper-level trainees. Topic authors were provided with guidelines regarding ways to adapt content to the general public. The drafted chapters were reviewed by the CAG who focused on clarity and interest for older users and were revised by the topic experts accordingly. A knowledge transfer expert (I.I) was also available to topic experts if needed. Scripts for narration and written text in the chapters were verified by a linguist, the CAG and the main author. Once a chapter was finalized, it was translated to a storyline proposal by an instructional designer team with expertise in techno pedagogy. Storyboards were created containing the narration script, slide content, animation details and interactive activities. Upon final acceptance by the authors of a chapter, a final version was prepared and narrated by a voice actor. The instructional designer team integrated all components into the interactive online program.

Before initiating the pilot study, a one-session beta test was conducted virtually with eight older adults from Ontario, New-Brunswick and Quebec to provide feedback on usability and make adjustments prior to launching the pilot study. Feedback was requested on the homepage, registration process, dashboard, questionnaires, speedometers used to show level of risks, prioritization, goal set-up, navigation to access chapters, notebooks, automated mails and help section.

2.2. Brain health PRO/Santé cerveau PRO pilot study

2.2.1. Pilot study design

A mixed methods pilot study was conducted to assess usability and acceptance of the *Brain Health PRO/Santé Cerveau PRO* using a shorter 3-month version of the program (a maximum of 50 chapters). In this shorter version, of the program participants received the first 3-month contents and completed usability, acceptance and lifestyle questionnaires. Usability refers to the ease of use of technology based on a person's perception of its effectiveness, efficiency, and resulting satisfaction [19–21]; acceptance refers to the willingness to use a tool [22,23] and includes a pragmatic evaluation of its perceived usefulness, ease of use and intention to use [24]. The pilot was conducted between Nov 2021 and April 2022. This study was conducted in compliance with the International Conference on Harmonization of Good Clinical Practice and all applicable regulatory requirements. It was reviewed and approved by the following research ethics committees/boards: Clinical Trials Ontario (#3497), University of British Columbia (#H20–02817), University of Victoria (#BC20–0580) and Horizon Health Network (#2022–3096). The results reported in this paper focus on the quantitative data that was collected. The pilot study also included qualitative semi-structured focus groups and feasibility of conducting fully remote evaluations which will be the object of a separate publication [25].

2.2.2. Participants

A total of 20 English-speaking adults aged 60 to 85 years were recruited for the pilot study. Participants were eligible if they were at increased risk of dementia based on the presence of a first-degree family history of dementia, a history of hypertension or hypercholesterolemia, body mass index > 30, or physical inactivity (active is defined as engaging in at least 20- 30 min of physical activity causing sweating and breathlessness, at least 2 times a week). Participants were enrolled if they were cognitively intact (CI), cognitively intact with subjective cognitive impairment (CI + SCI), or met criteria for mild cognitive impairment (MCI). They were excluded if they had received a previous clinical diagnosis of dementia, had a stage score ≥1 on the Clinical Dementia Rating (CDR; telephone/video conference administration) or <13 on the Montreal Cognitive Assessment (MoCA; video conference administration. They were also excluded if they reported insufficient vision or hearing for remote clinical or neuropsychological assessment or technical limitations that prevented their participation in the program (e.g.: not having a computer, not having access to the internet; not having the ability to send and receive emails) (see Feldman et al. [17] for more details on inclusion/exclusion criteria).

Screening and Baseline visits were conducted remotely using a videoconference platform and eligibility was verified by site investigators prior to enrolling participants. Study participants were assigned an identification number (Project Study Center ID (PSCID)) which was used to store their data in the Longitudinal Online Research and Imaging System 120 (LORIS), a web-based database system. Data collected by the program were de-identified and linked to the PSCID. De-identified data linked to LORIS PSCID were uploaded (csv.format), processed, and included in the CTU dataset for long-term maintenance and secure storage on LORIS servers.

2.2.3. Measures

Program adherence was measured by examining interruption of the program, total number of available chapters viewed and number of

chapters viewed per topic. Questionnaires measuring program usability and acceptance were embedded within the online *Brain Health PRO/Santé Cerveau PRO* platform and were completed at the end of the 3-month pilot trial.

Usability was assessed using the 10-item System Usability Scale [21]. Participants were asked to rate their agreement with statements on a 4-point Likert scale (from strongly agree to strongly disagree), which included both positively and negatively worded statements. The wording of the questions must be aligned with the specific technology being evaluated. Thus, the items were worded in reference to the *Brain Health PRO/Santé Cerveau PRO* program. Additionally, the questions were organized to group positively and negatively phrased questions together. This was done to help reduce confusion and errors among older adults because our prior experience using the original mixed order indicated that switching between positive and negative responses was challenging for them, resulting in increased errors. An overall score was obtained by summing the scores and multiplying the total by 2.5 to yield a value ranging from 0 to 100. Scores above 68 indicate satisfactory usability, while scores above 80 signify excellent usability. Following Davis [24], we included an additional question to measure usage behavior by asking how often they used the program. Response options included: Less than once per month (scored 0), About once per week (scored 1), 1–3 times per week (scored 2), and 4–7 times per week (scored 3).

Acceptance was measured using a 20-item questionnaire based on the Extended Technology Acceptance Model (TAM2) [23]. To facilitate comparability with the model and with studies also relying on the TAM, the constructs and items were designed in similar terms as proposed in Venkatesh and Davis (2000). The TAM2 model purports to measure different dimensions of acceptance. Similar to the SUS, the questions in the TAM2 must be tailored to fit the specific technology being evaluated and its context of use. While the TAM2 model was initially developed to assess technology acceptance in workplace settings, it has been used broadly to assess technologies in the fields of health and education (see [26] and [27] for review). Therefore, the items were selected and rephrased to refer to the *Brain Health PRO/Santé Cerveau PRO* program, taking into account the goals of a program focusing on lifestyle changes. The items measured intention to use and four major constructs considered critical determinants of intention to use: perceived usefulness, perceived ease of use, output quality and results demonstrability [23]. We used alpha Cronbach measures to assess internal consistency overall and in relation to the four main constructs. We made the wording of the questions consistent in terms of direction, as using different wording (positive and negative) had previously confused participants. This change was shown to have no impact on the magnitude or structure of response ratings [24]. Participants were asked to rate their agreement with statements on a Likert scale from 0 - strongly disagree - to 6 - strongly agree. Total possible scores ranged from 0 and 120 with higher scores indicating greater acceptance of the web-based program.

Brain Health PRO/Santé Cerveau PRO also includes questionnaires to measure the level of dementia risk for each of the seven topics (nutrition, physical activity, cognitive engagement, social and psychological health, sleep, vascular health, vision and hearing) as well as dementia literacy [28], self-efficacy [29], and attitudes toward dementia [30]. Results from these will be presented here at baseline.

3. Results

3.1. Design process of the brain health PRO/Santé cerveau PRO

Identification of the problem and needs assessment (IMA Step 1): Fig. 1 shows the logic model of the problem outlining the relationship between determinants and outcomes. This is used to visualize how personal and environmental determinants contribute to increased risk, enabling the identification of the problem, the analysis of related personal and environmental influences, and the recognition of both proximal and distal causes [16]. This framework is essential for the intervention as it clarifies how it is anticipated to affect specific determinants and ultimately lead to lifestyle change.

Central to the program are seven modifiable risk factors on which the intervention focuses: physical activity, nutrition, cognitive engagement, sleep, social and psychological health, vascular health, and vision and hearing. Five of these factors were selected based on meta-analyses that provided evidence from observational and intervention-based studies linking them to dementia [1–3]. Although two of the domains, nutrition and sleep, were supported with relatively less epidemiological evidence [1–3], they were included because of their well-accepted mechanistic link to cognition [31–35]. All selected factors were considered as potentially modifiable at the individual level and with existing guidelines to facilitate risk modification and goal attainment. The program also included a chapter providing general information on cognition, the brain and neurodegenerative diseases. As shown in the logic model, the literature suggests that these risk factors impact cognition and can increase the likelihood of cognitive decline or dementia, which in turn leads to a reduction in quality of life. Identification of the seven risk factors was based on the literature and were identified as core components of the program.

Identifying the determinants of risk factors is just as crucial as identifying the risk factors themselves. Determinants provide insight into why individuals engage in certain behaviors and influence their level of risk. Consequently, they are underlying factors that the intervention must address. Fig. 1 identifies the major determinants targeted by *Brain Health PRO/Santé Cerveau PRO* including both personal (e.g., lack of knowledge about risks and ways to improve them, low motivation, and low self-efficacy) and environmental determinants (e.g., unfavorable environment or limited financial resources). Determinants were identified from the literature and from discussion during meetings of the Brain Health PRO Expert Group, which included researchers, the knowledge mobilisation expert and members of the CAG.

Program target and goals for change (IMA Step 2): Fig. 2 shows the logic model for change underlying the development of *Brain Health PRO/Santé Cerveau PRO*. The logic model for change clarifies how different components of the intervention are linked to the personal and environmental determinants identified in the logic model of the problem shown in Fig. 1. The model also identifies the relation between the problem identified, the features of the program, the program target and the outcomes measured [16]. Features of the program were first identified from the literature and were reviewed and discussed during meetings of the Brain Health Expert Group, which included researchers, the knowledge mobilisation expert and members of the CAG.

The program was designed as an educational platform tailored for older adults at risk for cognitive decline. This was done in response to the expressed need for information and guidance on brain health [4,11]. Indeed, older adults are demanding empirically supported information and guidelines regarding ways to maintain and improve their cognition [1,2]. Research suggests that older adults may benefit from online educational courses on dementia risk reduction [4] and evidence suggests that online educational interventions may improve dementia risk profiles in middle-aged adults [36,37].

To address determinants of risk factors, *Brain Health PRO/Santé Cerveau PRO* was designed to provide comprehensive information about cognition, the brain, and neurocognitive disorders (i.e., enhance knowledge), alongside practical solutions, tips, and guidance on lifestyle changes that can reduce the risk of cognitive decline with age (i.e., provide tools for change). The program also addresses personal and environmental barriers or challenges (e.g., self-efficacy, motivation, stigma, accessible resources, cost issues, stressful environment), offering strategies and alternative solutions to overcome potential barriers. The literature on aging and health underscores the importance of promoting older adults' ownership of their cognitive health and empowering them, an approach that has been integrated into the program's content and language. Additionally, the program was designed to be inclusive, reflecting the diversity of Canadian older adults in terms of ethnicity, sex,

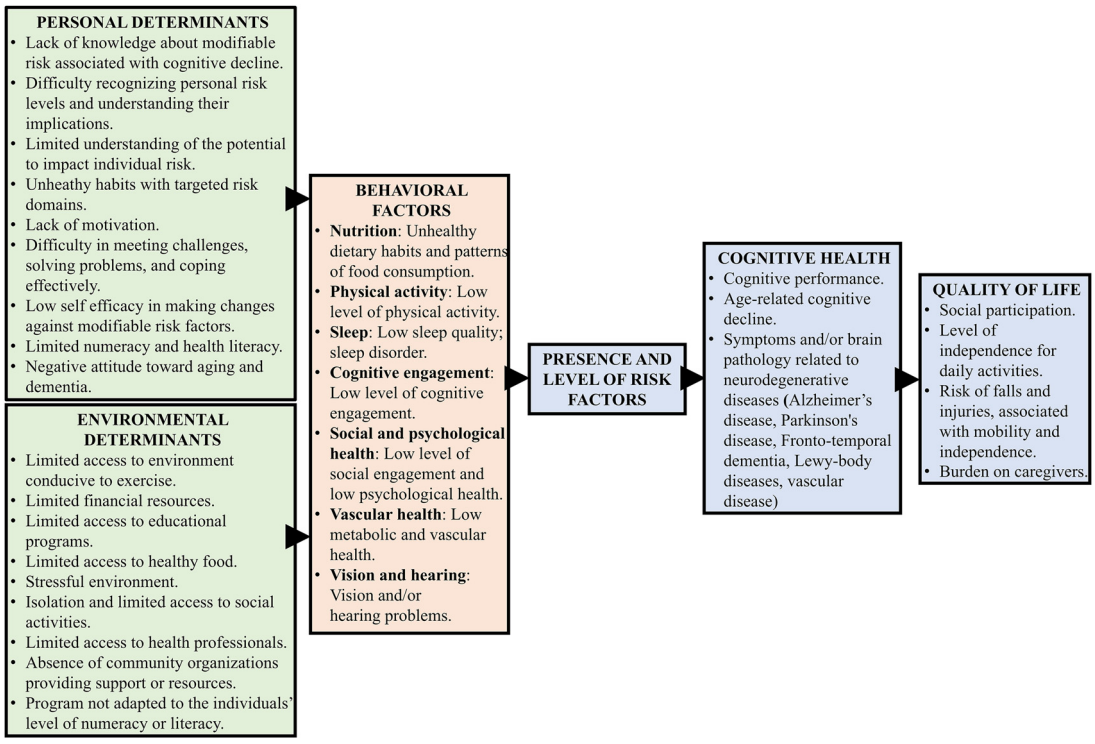

Fig. 1. Step 1 of intervention mapping: Logic model of factors and determinants of cognitive health.

Note. This figure shows the logic model that illustrates how personal, environmental, and behavioral determinants influence risk, cognitive health and quality of life. The orange box represents the risk domains identified as the focus of *Brain Health PRO/Santé Cerveau PRO*. The green boxes represent personal and environmental determinants that influence these specific risk domains. The blue boxes represent variables that are modified by these specific risk factors: the general level of risk, cognitive health, and quality of life.

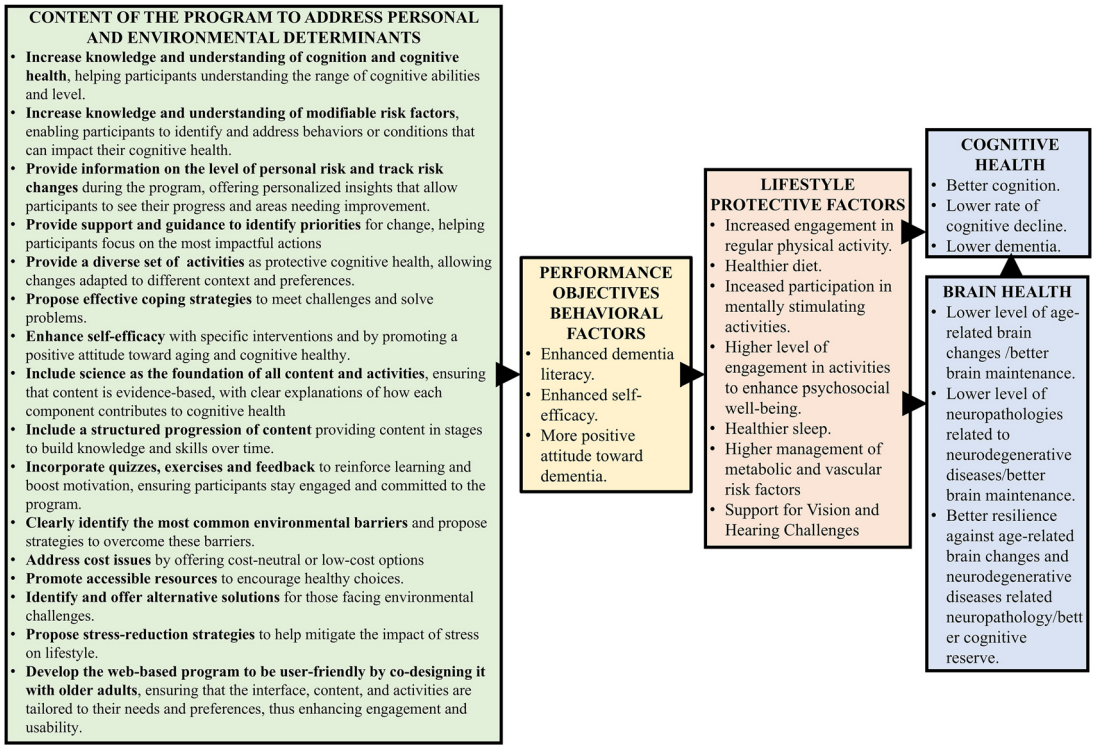

Fig. 2. Step 2 of intervention mapping: Logic model of change.

Note. This figure shows the logic model of change underlying the program content and format of the program. The green box shows the specifics of the content and format designed to address personal and environmental determinants. The orange box shows how this should impact the lifestyle domains that have been selected as the focus of the program. The yellow box represents the mediating objective behavioral factors. The blue boxes show how this should change cognitive and brain health.

gender, and sexual orientation. This inclusivity was woven into the infographics, examples, and wording used throughout the program.

As an educational program, our primary goal is to increase knowledge about dementia and about modifiable risk factors. However, the program is also designed to support self-efficacy and improve attitudes toward dementia, which are considered important ingredients for positive change. While level of risk and cognition were not a primary outcomes in this study, reducing risk factors was expected in response to enhanced dementia risk literacy and this was expected to positively impact cognition [38].

Description of the program format and content (IMA Step 3): *Brain Health PRO/Santé Cerveau PRO* is an interactive program developed for computers and tablets (Fig. 3). The platform is available in English and French to be accessible to the two main linguistic communities in Canada. It was developed with Javascript and the content presented using storyline. The *Brain Health PRO/Santé Cerveau PRO* website is hosted on a secure server.

After registration, users first view an orientation chapter that introduces the program, and provides a general overview of the program layout, contents and program expectations. Users are then presented with general information on cognition, dementia and the impact of modifiable risk factors. They are then asked to complete lifestyle questionnaires which identify the risk for each domain, and identify risk reduction priorities. The program is delivered progressively, with four new chapters released each week. At the beginning of each week, users receive a personalized email informing them that four new chapters are available. The e-mails remind them to connect to the platform, as new content is available or questionnaires need to be completed. The *Program Dashboard* (Fig. 3a) allows users to easily access the different functionalities of the program (e.g., chapters to complete, favorite chapters, prioritized topics). The *Home Page* provides information on the user's progress through the program, points and rewards collected through interactive activities, and goals. The *Profile Page* shows the current and past (if applicable) lifestyle risk profile. It also contains the list of all available chapters, a list of favorites and the notebook (see below).

3.1.1. Educational content

The program contains 181 chapters, organized into eight content topics, one general information topic on cognition, the brain and neurodegenerative diseases, and one topic for each of the seven modifiable risk factors. Each topic comprises between 16 and 24 short chapters. Content related to sex and gender differences is integrated throughout. Individual chapters are about 10-minutes long and provide information on a particular aspect of the topic. Topic experts created each chapter (see the list of authors for all chapters in supplementary material), which was reviewed and approved by the CAG using a standardized feedback form. When substantial revisions were required, chapters were re-reviewed by the CAG and, if needed, by the expert in knowledge translation. The content in each chapter is presented in the form of a multimedia storyline with narration, written material, images and animation. All narration was recorded in a professional recording studio to ensure the highest possible quality, which was deemed essential to optimize the auditory perception for older adults. Closed captioning of the narration is also available if needed. The content was revised by the CAG as mentioned below.

3.1.2. Selection of narrator

The narrator is a professional bilingual male actor who was able to narrate in French and English. Because the narrator accompanies program users throughout the program, narrator selection was conducted by a subgroup of researchers and members of the CAG. The selection committee evaluated a pool of potential narrators based on energy, clarity, ease of auditory perception, and rhythm of narration excerpts. Gender of the narrator and bilingualism were two points of discussion by the committee. The committee selected the male voice actor based on voice quality and fluency in both English and French. Selecting one narrator for both English and French versions was thought to help standardize the program.

3.1.3. Interactive activities, risk profile and personalization

The literature and feedback from the CAG indicated that interactivity, ease of manipulation and personalization were key aspects to increase pleasure and engagement with the program. The program had to be enjoyable, interactive, personalized as much as possible and easy to understand. To address these needs, each chapter contains animations and at least one *interactive activity*. Types of interactive activities include: clickable icons that provide additional information; clickable flashcards that reveal information; matching activities, in which the user drags and drops the correct items into a target; and multiple-choice quizzes with feedback. A digital notebook is available for the user to take notes and keep track of information related to their goals and objectives. The *notebook* may be viewed on the screen while viewing chapter content. Alternatively, users can download the notebook as a PDF file and fill it in electronically outside of the platform or by hand.

A *personal lifestyle risk profile* is generated for each of the seven topics based on responses to the lifestyle risk questionnaires completed at program intake and every 11 weeks until the end of the program. Brief lifestyle questionnaires were developed by each topic leader and topic experts to represent individual risk for each of the seven modifiable risk factor domains. The scoring method and risk range for each factor was based on current literature. After completing the questionnaires, the user's risk is computed for each modifiable risk factor. A visual representation of each risk factor is displayed as a colored speedometer on the user's Profile Page (Fig. 3b). An arrow indicates the score obtained for each domain and where it stands in terms of the level of risk (green zone: not a risk; yellow zone: medium risk; red zone: high risk).

After completing risk assessment, users receive their risk profile and are asked to select three topics to prioritize over the next eleven weeks. Users must choose at least two priority areas from those that were classified as 'medium' or 'high' risk when they completed the questionnaires determining their risk profile. The third priority could either be a domain at risk or a domain that the user is not at risk for but might be interested in viewing. Prioritizing specific topics unlock additional content related to those choices. It was determined that users would still receive some content on non-prioritized topics. This decision was made because the CAG noted that many topics contained valuable information for older adults, even if they are not directly related to their identified priorities. As an additional personalization feature, users have the opportunity to set personal goals for each priority topic while completing the program. Personal goals can be written in the notebook and are visible on the user's dashboard. At the end of an eleven-week period, the user may click a yes/no box to indicate whether the goal was met. A new lifestyle risk report profile is generated for each questionnaire completed each 11-week period. It remains available on the Profile Page, providing a summary of the user's lifestyle risk profile based on the speedometer and goals.

The inclusion of lifestyle risk questionnaires and updated speedometers every 11 weeks was based on recommendations from the CAG, which emphasized the need to receive feedback on lifestyle improvements during the program. Feedback every 11 weeks with updates to the user's risk profile allows users to monitor their progress towards reducing dementia risk and to adjust personalized priorities and goals accordingly.

3.1.4. Other elements to support adherence

Elements of gamification were included to support adherence to the program as adherence was identified as a main challenge by the CAG and from the literature. Users are rewarded with virtual prizes for their progression in the program and for their adherence. The dashboard tracks user progression throughout the chapters. Because technical problems were identified as a major potential source of frustration and withdrawal, users are given access to a *Help Section* where they can write to

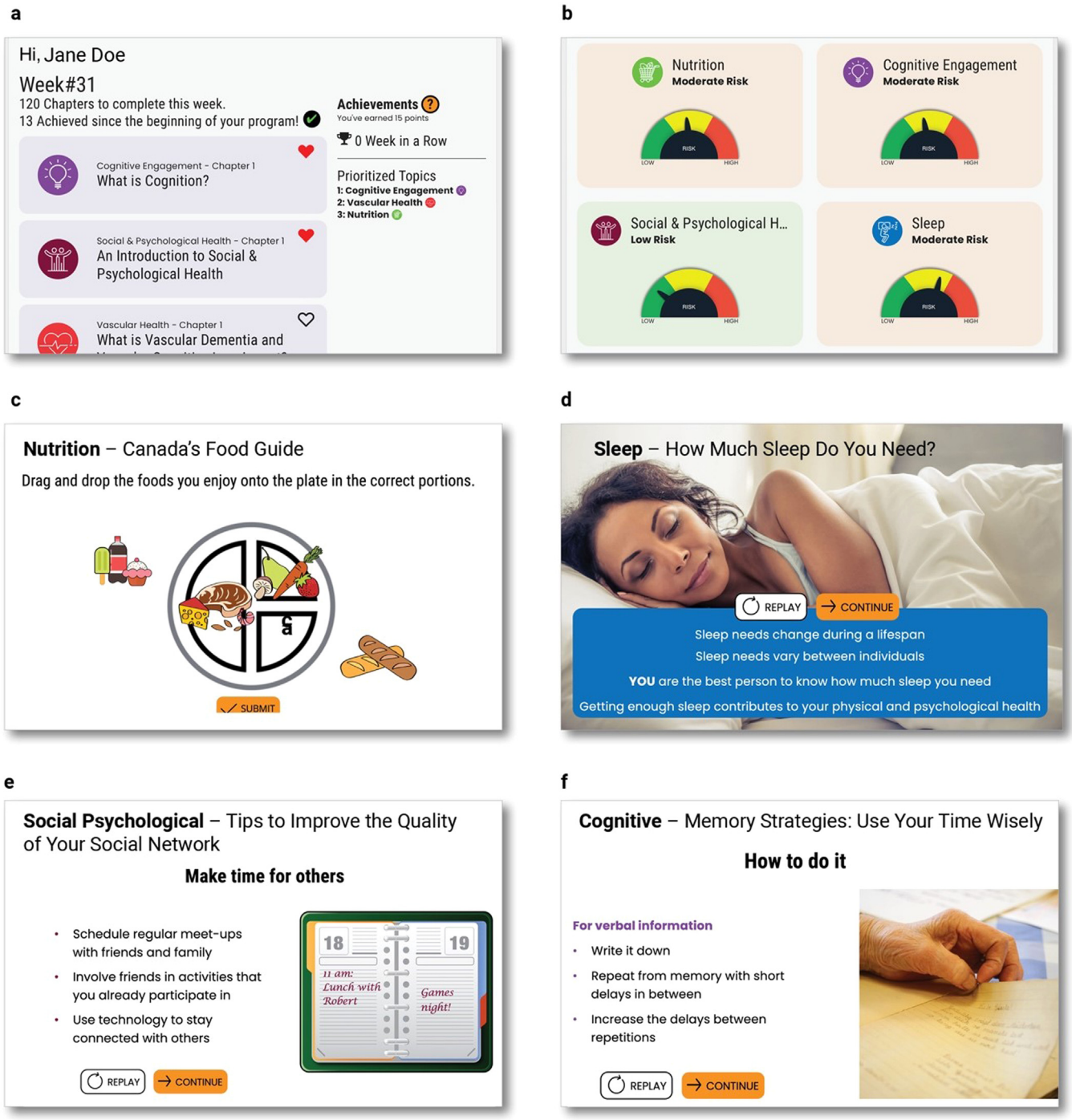

Fig. 3. Screenshots of *Brain Health PRO/Santé Cerveau PRO*. a) Dashboard showing some of the functionalities of the program (prioritized topics, completed chapters, gamification). b) Example of a speedometer indicating the individual's risk level for four of the modifiable risk factors. c) Example of a chapter page within the nutrition topic. This is a game to make the person aware of the quality of his/her diet. d) Example of a chapter page within the sleep topic. It provides information on inter-individual differences regarding the amount of sleep a person needs. e) Example of a chapter page within the psychological and social health topic: It gives tips on how to improve the quality of the person's social network. f) Example of a chapter page within the cognitive engagement topic: It gives instruction on how to use a strategy designed to improve memory recall.

get assistance and support with technical issues encountered with the program. When a user does not access *Brain Health PRO/Santé Cerveau PRO* for a week, they receive an encouraging email to prompt them to continue the program. If they remain inactive for two weeks, or are absent for three weeks, reminders are sent again on a weekly basis. Upon coming back, they can access unattended chapters, allowing users to seamlessly resume their engagement with the program.

3.2. *Results of* Brain Health PRO/Santé Cerveau PRO *pilot study*

Participants: As shown in Table 1, the majority of the sample was female, with an average of 16.75 years of education, a mean age of 70 years (SD = 5.79) and cognitive impairment status classified as unimpaired on the CDR. See Table 1 for baseline cognitive scores, affect, and baseline scores on dementia literacy, self-efficacy and attitude toward

Table 1
Participants' characteristics and baseline scores.

Domain/Measures	Frequency or mean score (range)
Demographics	
Sex F/M	13/7
Years of schooling	16.75 (12–22)
Age (years)	70 (60–83)
Cognition	
CDR 0/0.5	18/2
MoCA (range)	26.05 (23–30)
Logical Memory Immediate (range)	12.65 (8–17)
Logical Memory Delayed (range)	10.90 (4–17)
Baseline Determinants of Health	
Attitudes Towards Dementia (Max: 180)	118.95 (86–141)
Dementia Literacy (Max: 30)	24.4 (17–28)
Self- Efficacy (Max: 40)	34.40 (27–39)
Risk Entry Criteria	
First degree family history of dementia	11/20*
Hypertension	9/20*
Hypercholesterolemia	11/20*
BMI	4/18*
Physical inactivity	8/20*

Note. 2 participants did not answer the question on BMI; * # of participants meeting that criteria/2.

dementia as well as the number of participants who met each risk entry inclusion criteria.

Program adherence: No participants interrupted the program. They watched between 30 and 50 chapters and the overall average number of chapters consulted was 43.24 out of the 50 available chapters (SD = 5.82; 86.8 %), with a good balance between the different topics (General information: 6.95/8, SD = 1.36; physical activity: 5.38/6, SD = 0.74; nutrition: 5.24/6, SD = 0.99; cognitive engagement: 5.62/6, SD = 0.86; sleep: 5.62/6, SD = 0.67; social and psychological health: 4.71/6, SD = 1.06; vascular health: 4.90/6, SD = 0.99; and vision and hearing: 4.81/6, SD = 1.12).

***Brain Health PRO/Santé Cerveau PRO* Lifestyle Risk Assessment:** Table 2 shows the average score obtained on the *Brain Health PRO/Santé Cerveau PRO* lifestyle risk questionnaires and the number of participants who were considered at risk for each domain based on the questionnaire. As shown in Table 2, most participants reported relatively low risk for physical activity, cognitive engagement, and social and psychological health. Moderate risk was most notable for nutrition and vascular health. The number of participants that selected each topic as a priority and examples of goals selected by the participants for each topic are shown in Table 3.

Usability and Acceptance: In general, the program demonstrated excellent perceived usability, with an overall score of 80.38/100 (SD = 16.1; 95 % CI: 72.84–87.91). The mean item score was 3.22 (SD = 0.64; 95 % CI: 2.91–3.52) out of a maximum of 4. As shown in Fig. 4a, the mean scores for individual items were all positive. The highest scores were found for items related to user-friendliness (i.e., it does not require technical assistance, Mean = 3.55, SD = 0.82; 95 % CI: 3.16–3.94; it does not require to learn a lot of things before using it, Mean = 3.5, SD = 0.76; 95 % CI: 3.14–3.86; it is not cumbersome or awkward to use, Mean = 3.45, SD = 0.75; 95 % CI: 3.09–3.81). Although its average rating on the Likert scale remains on the positive side, relatively lower usability was noted for desire to use the website frequently (Mean = 2.75, SD = 0.71; 95 % CI: 2.41–3.09).

Regarding the frequency of the program usage, the mean score was 1.45 (SD = 0.75) which is halfway between *About once per week* (score of 1) and *1–3 times per week* (score of 2). Sixty percent of participants reported using the program about once per week, 30 percent reported using it 1–3 times per week, and ten percent reported using it 4–7 times per week.

A mean total score of 93.5/120 (SD = 15.05; 95 % CI: 86.46–100.54) was obtained on the TAM-2 which suggests a high level of acceptance for the *Brain Health PRO/Santé Cerveau PRO* program. The mean item score for the acceptance questionnaire was 4.68 (SD = 0.75; 95 % CI: 4.32–5.03) out of a possible total score of 6. Thus, on average participants reported that they somewhat to moderately agreed with the items reflecting acceptance. As shown in Fig. 4b, individual items were all judged as positive. The highest scores were found for items asking about: 1) Program platform and content, specifically, whether the health information was easy to understand (Mean = 5.55, SD = 0.76; 95 % CI: 5.19–5.91) or whether the website was easy to interact with (Mean = 5.2, SD= 1.01; 95 % CI: 4.73–5.67) and operate (Mean= 5.2, SD = 1.2; 95 % CI: 4.64–5.76); 2) Knowledge gained, specifically, whether the program helped them improve their knowledge related to health (Mean = 5.1, SD = 0.97; 95 % CI: 4.65–5.55) or better understand their health (Mean = 5.10, SD = 0.97; 95 % CI: 4.65–5.55); 3) Motivation to take care of their brain health (Mean = 5.05, SD = 1.15 95 % CI: 4.51-5.58); and 4) Recommendation, such that participants would recommend the program to friends or relatives (Mean = 5.05, SD = 1.05; 95 % CI: 4.56–5.54). Three items received somewhat lower scores compared to the others, although their average ratings on the Likert scale remain on the positive side. These included whether the achievements system in the program was motivating (Mean = 3.6, SD = 1.35; 95 % CI: 2.97–4.23), whether the program helped the participant to complete tasks of everyday life (Mean = 3.3, SD = 1.42; 95 % CI: 2.64–3.96) or helped them to better accomplish some tasks (Mean = 3.65, SD = 1.57; 95 % CI: 2.92–4.38). The reliability analysis indicated good to excellent internal consistency for all measured constructs. Perceived Usefulness (α = 0.83, 7 items), Perceived Ease of Use (α = 0.88, 4 items), and Result Demonstrability (α = 0.81, 7 items) all demonstrated good reliability levels (above 0.80). The Global scale showed excellent reliability (α = 0.91, 20 items), confirming strong internal consistency across all items.

4. Discussion

Web-based delivery has the potential to radically change the way lifestyle interventions are provided and accessed and can be a powerful means of scaling up dementia risk reduction programs across the population [4,12]. This paper provides a detailed description of the design process of *Brain Health PRO/Santé Cerveau PRO*, its main features and an initial program assessment in a pilot sample of 20 older adults.

Guided by the IMA framework and enriched by a co-design approach, this paper presents the first three steps of our IMA approach, which entailed establishing a detailed understanding of the problem, specifying the program target, and translating these into a coherent program. Relying on intervention mapping ensures that theory and scientific evidence are systematically incorporated in the creation of the program and in the selection of the most appropriate strategies. This framework was further enriched by the co-design approach with citizen advisors. The co-creation approach provides solutions to the two main gaps identified in the literature with regards to interventions for older adults: the need to create programs aligned with capacities and demands of users, and the need to identify facilitators and barriers to foster successful implementation by community partners [4,11].

The pilot data indicate excellent usability and acceptance of the *Brain Health PRO/Santé Cerveau PRO*. All elements were rated positively. Although still above a "neutral" rating, somewhat lower scores were obtained for areas related to help in achieving tasks in daily life which are more difficult to address with online platforms and may require the incorporation of some face-to-face intervention, an approach that we are currently developing in a subgroup of participants. The gamification that was used to motivate users also obtained somewhat lower scores.

The pre-pilot beta test group with older adults, the partnership with citizen advisors within an integrated knowledge translation approach and the series of cycles that characterized the development process likely contributed to the perceived usability and acceptance of the web-based program [39,40]. For instance, the pre-pilot beta test group was useful to identify features that would enhance ease of use. Many charac-

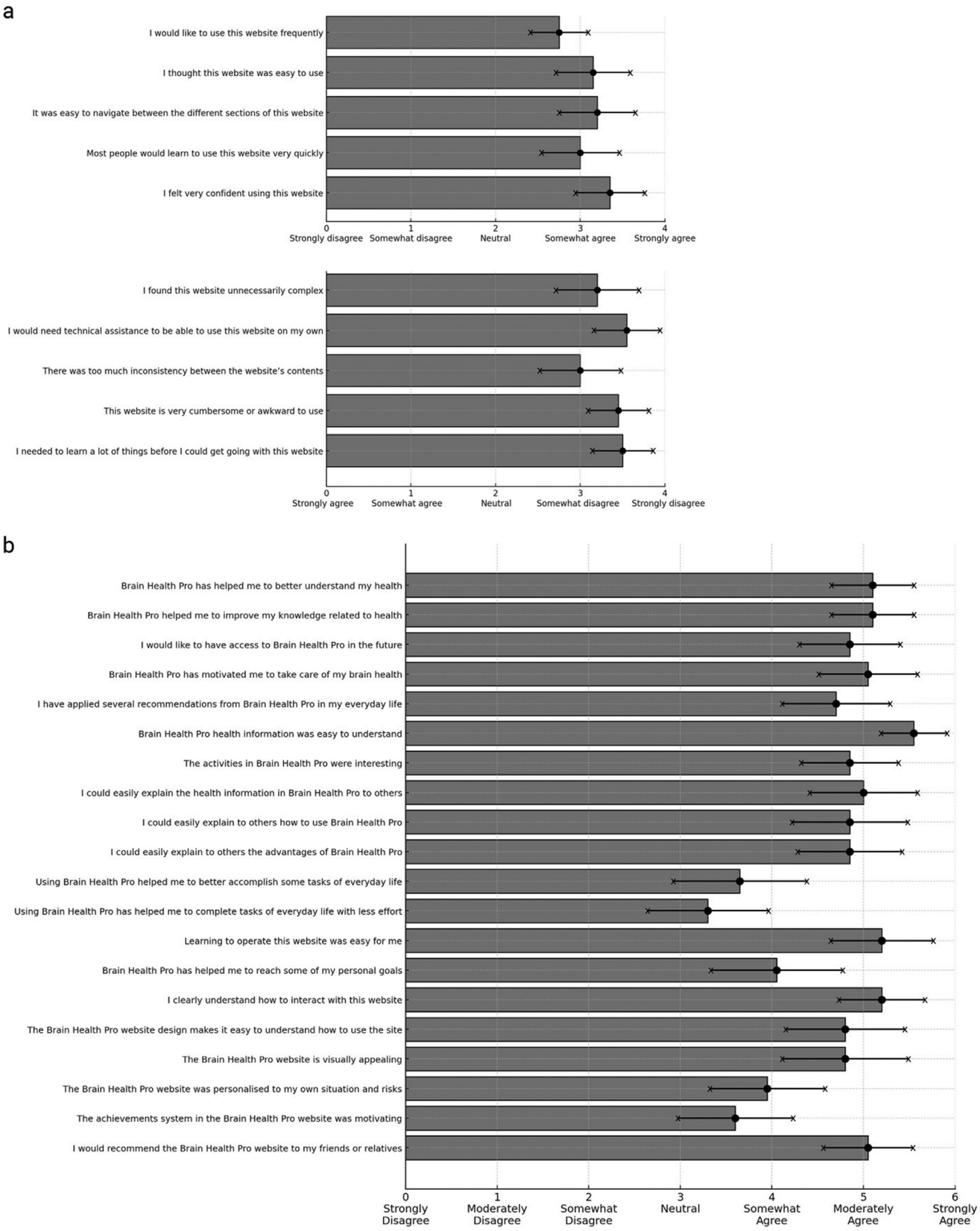

Fig. 4. Mean scores for individual items of a) the usability questionnaire; and b) the acceptance questionnaire. The horizontal bars indicate the 95 % confidence intervals.

Table 2
Participants' risk scores and number of participants per risk level.

	Mean Score (Range)	Low	Moderate	High
Physical activity risk score (*medium and high risk is below 1.75*)	4.49 (1.25 – 9)	18	1	1
Nutrition risk score (*medium and high risk is below 14*)	12.10 (3 – 18)	10	8	2
Cognitive engagement risk score (*medium and high risk is below 15*)	18.45 (9 – 24)	18	2	0
Sleep risk score (*medium and high risk is below 16*)	11 (4 – 11) *17.05 (8 – 20)	0 (15*)	19 (4)*	1 (1)*
Social and psychological health risk score (*medium and high risk is above 15*)	8.35 (1 – 24)	18	2	0
Vascular health risk score (*medium and high risk is below 7*)	7 (2 – 8)	11	9	0
Vision and hearing risk score (*medium and high risk is above 8*)	4.1 (1 – 18)	17	2	1

* The pilot study enabled the identification and correction of an error in the program's computation for the risk score of the sleep domain. Accordingly, the table presents the initial sleep and risk scores provided to participants at intake and the data following the [*] presents corrected scores that should have been computed.

Table 3
Participants who selected each topic as a priority and examples of personal goals.

Topic	Participant Selecting the Topic as a priority (Frequency)	Examples of Personal Goals
Physical activity	7	• Add 30 mins of bike riding 5 days/week. • Ride to beach & do beach cleanups at noon.
Cognitive engagement	16	• Do crossword puzzles and Jumble daily, as well as daily book reading.
Nutrition	12	• Eat fruit/vegetables at each meal. • Practice mindful eating at least once per day.
Sleep	16	• Go to bed at 10 pm every night. • Meditate instead of watching TV or checking the phone.
Social and Psychological health	2	• Keep a record for 1 month and commit to calling/seeing (speaking) with people 5 timesweek.
Vascular Health	3	• Get lab tests done and follow up with doctor on results related to vascular health. • Have regular yearly check-ups.
Vision & Hearing	1	• Focus on listening to understand. • Engage others in conversation.

teristics of the program emerged directly from the CAG's contribution, including enhancements to the readability of the content, increase in the number of interactive activities and the provision of regular feedback through lifestyle questionnaires and the speedometer. These aspects of our approach likely enhanced user acceptance and willingness to engage with the program.

Personalization was also identified as a critical component by citizen advisors and many elements of personalization were included when designing the program. First, key personal and environmental determinants of risk were incorporated in the logic model of the problem and in the logic model of change. These factors were considered in the development of the program content by identifying them and including practical tips to address them. In addition, the computation and graphical presentation of each person's risk on a color-coded speedometer allows direct individualized information and feedback in a familiar format to shape the users' experience and engagement with the program. Repeated assessment of risk over the course of the program also allows users to visualize their progress and goals achievement.

The preliminary risk profiles of the pilot participants were unevenly distributed, which may have been due to different risk assessment thresholds across the seven risk factors or due to the risk status of the participants, which may not be representative of community dwelling older adults in Canada. Interestingly, the topics that were more frequently selected by participants were not necessarily aligned with their risk profile, indicating that participants selected priorities based on preferences or interest. For example, the topic cognitive engagement was selected by 16 participants even though 18 scored within the low-risk

range. The freedom to select topics irrespective of risk profile may provide participants with a sense of agency. However, it is also important to ensure that users are considering their risk profile when making topic selections and are not avoiding topics of risk.

Some limitations must be considered. First, the use of a web-based program requires that users are technically literate, have access to a digital device and the internet, and are comfortable with technology. Second, the CAG and pilot sample included a self-selected group of highly educated, white, and motivated older adults. Accordingly, additional research is being conducted in a more diverse sample. The questionnaires had to be adapted to the technology used and the particularities of the population, and although the TAM-2 showed high internal consistency, it merits further validity studies. Finally, the pilot study relied on a small sample size, as the primary goal was to provide a preliminary assessment of usability and acceptability to determine whether the large efficacy study could proceed with the program as designed. However, the data reported should be interpreted with caution, considering the limitations in sample size and diversity. This highlights the importance of ongoing data collection on user experience when designing and refining technological innovations, particularly among older adults. Continuing to collect usability and acceptability data in the larger sample, which is likely to include a more diverse range of participants, will be essential. Since cohorts differ in their profiles—whether related to their level of education, familiarity with technology, level of numeracy, health literacy, or self-efficacy—ongoing data collection ensures that the tool can be continuously refined and adapted through an iterative process of improvement.

In summary, this study employed co-creation, participatory research, an integrated knowledge translation approach and implementation mapping to design a brain health program that is fully grounded in the scientific literature while being engaging and easy to use for the intended audience. We developed logic models to identify the determinants. This helped clarify the pathway through which *Brain Health PRO/Santé Cerveau PRO* contributes to reduce the level of risk for dementia, ensuring that all relevant elements are incorporated into the program to promote lifestyle changes, enhance brain and cognitive health, and ultimately improve quality of life. The pilot data suggest that *Brain Health PRO/Santé Cerveau PRO* is well received by community-dwelling older adults. Given the positive outcome of the pilot, the next steps include a large efficacy trial to test the impact of the program on dementia literacy, as well as an implementation study to examine how it can be used and promoted in the community.

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SB reports grant funding to CCNA from CIHR and ASC that supported this study. Outside of this study, she also reports consulting fees and participation on an advisory board for Lucilab and an unpaid role of scientific advisor for the Quebec Federation of Alzheimer's Societies.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Sylvie Belleville reports a relationship with Lucilab that includes: board membership and consulting or advisory. The authors have copyright on the written content of Brain Health PRO. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tjpad.2025.100134.

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