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Protocol for an intergenerational randomized controlled trial to enhance physical activity in older adults at risk for Alzheimer's disease

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Declaration of competing interest

The authors 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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Abstract

Background: Physical inactivity is one of the most important modifiable risk factors for Alzheimer's disease in North America. Despite this, most older adults are physically inactive. It is currently unknown how to successfully motivate physical activity behavior in older adults at risk for Alzheimer's disease, and this knowledge is crucial for early and effective disease prevention. Prior research has shown that intergenerational social engagement and prosocial behaviours can enhance the health and well-being of older adults.

Objectives: This manuscript describes the design of a randomized controlled trial that will test the efficacy of a behavioral intervention to enhance physical activity in older adults at risk for Alzheimer's disease.

Design/setting: This is a single-blinded, two-arm stratified randomized controlled trial that incorporates a hybrid efficacy and implementation design. Participants are randomized to an intervention or control condition in a 1:1 ratio and are stratified by a multimodal Alzheimer's disease risk score. All study visits are conducted remotely through videoconferencing.

Participants: The study aims to recruit 60 older adults with a first-degree family history of Alzheimer's disease from the PREVENT-AD cohort and 30 younger adults who are paired with older adults in the intervention condition.

Intervention: Older participants in the intervention group will be paired with younger study partners and receive positive, daily messages over four weeks using a novel technology platform. The daily messages combine intergenerational social engagement (growing a virtual garden with a younger study partner) and prosocial goals (donations to charity after reaching step count goals).

Measurements: The primary outcome is change in step count compared to baseline measured using a wrist-worn triaxial accelerometer. Secondary outcomes include time spent physically active, mood, generativity, loneliness, and cognition. Target mechanisms (social support and

generativity) of physical activity engagement will be examined. Ease of use, acceptability, and feasibility of the technology as well as barriers and facilitators of participation will be assessed.

Conclusions: This research will advance our understanding of mechanisms and individual differences underlying successful physical activity engagement in older adults who are at risk for Alzheimer's disease. This knowledge will contribute to strategies for promoting health behaviours that can prevent the risk of Alzheimer's disease.

Keywords

Alzheimer's disease; clinical trial; behavioral intervention; physical activity; intergenerational

1. Introduction

Alzheimer's disease (AD) is a neurodegenerative disease characterized by cognitive, emotional, and behavioral impairments [1]. The prevalence of mild cognitive impairment and dementia in older adults over the age of 65 is estimated to affect nearly 1 in 3 individuals [2]. Globally, the number of dementia cases is expected to more than double by 2050, largely because of population growth and aging [3]. The projected increase in dementia cases poses significant health, social, and economic challenges for individuals with AD, their caregivers, families, healthcare systems, and society at large [4]. Moreover, there are currently no curative treatments for AD dementia [5].

Given the current limitations of AD treatment, it is essential to focus on effective primary prevention strategies. Up to 50 % of AD cases may be attributed to potentially modifiable risk factors and even a 10 % reduction in these risk factors could potentially reduce the number of global AD cases by an estimated 1.1 million [6]. Physical inactivity is one of the most attributable modifiable risk factors for AD in North America [6]. Among different types of exercise, aerobic physical activity has been found to be particularly effective in delaying the onset of AD and promoting cognitive function in older adults [7]. Aerobic exercise contributes to several brain changes such as increasing cerebral blood flow and promoting vasodilation and oxygenation to the brain, which contributes to its protective effects on brain health and cognition [7]. Numerous randomized controlled trials have demonstrated that increased aerobic physical activity can improve various cognitive functions and reduce AD pathology, such as cortical atrophy and hippocampal volume loss [8,9]. Specifically, walking has been shown to be protective against AD-related cognitive decline, with higher daily step counts being associated with a lower risk of dementia onset [10]. Furthermore, walking is typically an accessible and low-cost activity for older adults that has physical and mental benefits, including enhanced mobility, social engagement, and health-related quality of life [11].

Initiating healthy behaviors is challenging for older adults but is crucial for improving and maintaining their health and well-being [12,13]. Knowledge of older adults' motivational processes can offer valuable insight into strategies that can aid in engagement and adherence to health behaviors [12,13]. It is known that socioemotional values (e.g., prosocial behaviors, interpersonal relationships) tend to increase with age relative to self-serving values [12]. Socioemotional Selectivity Theory (SST), a motivational lifespan theory, suggests that older

adults perceive their time horizons as being limited, and therefore prioritize socioemotional goals over information acquisition [12,14,15]. Interventions that incorporate socioemotional goals and stimuli to encourage physical activity engagement might be effective for older adults, and especially effective for those with a heightened risk for AD. Cognitively unimpaired older adults with elevated amyloid burden have shown heightened orientation towards socioemotional processes, including emotional reactivity and empathy [16,17]. Moreover, older adults with elevated amyloid burden [16] and *APOE4* genotype [18] have enhanced connectivity of the salience network, a brain network implicated in socioemotional processing [19]. Socioemotional processing also appears to be preserved or enhanced in early stages of AD [20].

Prior research suggests that older adults are oriented towards socioemotional stimuli and goals. Further, the "positivity effect" describes an age-related preference and selective processing of positive over negative information compared to younger adults [12,14]. Studies have shown that positively framed information, such as emphasizing the health benefits of walking, can increase physical activity in older adults to a greater degree than younger adults [21]. In addition, personalized health messaging has been shown to increase physical activity more effectively than generic messaging [22,23]. Moreover, intergenerational social engagement has been shown to enhance health behaviors in older adults: For example, a prior intervention where older adults volunteered to help children with academic subjects resulted in improved physical strength, walking speed, and cognitive function in older participants relative to older adults who participated in other volunteer work, with greater gains seen in those at higher risk for cognitive impairment [24,25]. One possible reason for this benefit is the pro-social goal orientation observed with aging [12]. Enhancing self-transcendence, a developmental shift in focus from oneself toward the well-being of others, has also been associated with higher physical activity levels [26] as well as heightened activity in the ventromedial prefrontal cortex, a brain region involved in socioemotional processing that is relatively preserved with age and AD [27]. Lastly, prosocial goals might be particularly motivating in older adults with an increased risk of AD. Older adults exhibit a ’prosocial goal shift,’ showing higher empathy and social trust than younger adults [12]. Prior behavioral studies have demonstrated that charitable incentives effectively promote physical activity in older adults, with greater increases in step count when donations were made to charity rather than when incentives were personal [28]. Taken together, this evidence suggests that an intervention combining socioemotional motivation (i.e., including [1] positive, personalized health messaging, [2] intergenerational engagement, [3] self-transcendence, and [4] prosocial goals) may be particularly effective at encouraging physical activity in at-risk older adults.

While there is evidence that social motivation might enhance older adults’ physical activity, the mechanisms underlying the efficacy of social interventions remain unclear. Potential mechanisms of action include enhancements in generativity and social support. Generativity is the desire to contribute to the well-being of younger generations and actions directed towards increasing their well-being [29]. One randomized controlled trial where older adults volunteered to help children with academic subjects demonstrated increased generative desire and achievement following the intervention relative to controls who engaged in other volunteer work that was sustained after 24 months [29] as well as increased physical activity

levels [30,31]. Another study found that affectionate social support mediated the relationship between generativity and purpose in life in older adults at risk for AD, suggesting that intergenerational interventions incorporating enhanced love, affection, and appreciation from others might be particularly effective at enhancing older adults' motivation [32]. Another putative target mechanism of behavior change is social support, which plays a vital role in active aging [33]. Physical activity motivation and engagement have been found to be positively associated with emotional support in adults [34-36]. In one prior study, older adults who engaged with one another using a virtual platform significantly increased their step count compared to the control group, and this effect was mediated by social support [37].

1.1. Objectives and hypotheses

Given that physical activity is a key modifiable late-life risk factor for dementia [6], and the beneficial influence of social motivation on decision-making and behavior in older adulthood, this study will test the efficacy of intergenerational social motivation on physical activity engagement in at-risk older adults. This study represents a Stage I intervention within the context of the NIH Stage Model for Behavioral Intervention Development [38]. The specific objectives of this study are to (1) investigate the efficacy of a novel, remotely administered intergenerational social motivation intervention for increasing physical activity engagement in older adults at risk for AD, (2) determine the extent to which putative target mechanisms, including generativity and social support, mediate the effect of the intervention on physical activity behavior change, (3) investigate the influence of the intervention on secondary outcomes including amount of time spent physically active, mood, generativity, loneliness, and cognition, and (4) evaluate the ease of implementing this technology-based intervention in everyday life of at-risk older adults. We hypothesized that (1) older adults who are paired with an intergenerational study partner and receive daily, socially-framed messages will increase their step count more than participants in an active control condition, (2) enhanced sociomotivational processes (generativity, social support) will mediate the effect of the intervention on physical activity engagement, and (3) older adults in the intervention group will show greater improvements in secondary outcomes (amount of time spent physically active, mood, generativity, loneliness, and cognition) compared to those in the control group.

2. Methods

2.1. Participants

This study will recruit a subsample of 60 cognitively unimpaired older adults from the Pre-Symptomatic Evaluation of Experimental or Novel Treatments for Alzheimer's Disease (PREVENT-AD) longitudinal cohort at McGill University [39] and 30 intergenerational study partners who will be paired with each older adult in the intervention condition. The sample size was calculated based on a prior intergenerational program in inactive older adults [30] that showed a significant difference in the number of minutes spent physically active between the intervention and control groups at follow-up with an effect size of $d = 0.8$. The calculation was performed based on a two-sample t-test model with 85 % power and a two-sided alpha of 0.05. The PREVENT-AD cohort consists of individuals aged

55 years and older who are cognitively unimpaired at enrollment and have a first-degree family history of AD. The cohort has been followed longitudinally since 2011 with serial neuropsychological, PET and MRI neuroimaging, genetic, and serological and CSF fluid biomarkers.

2.2. Recruitment

To recruit older adult participants, the research team will reach out to individuals from the PREVENT-AD cohort through phone calls and emails, offering them the opportunity to participate in this optional sub-study. Based on evidence derived from Socioemotional Selectivity Theory showing that older adults prioritize emotionally gratifying interactions with close family and friends rather than new social partners [19,40] and evidence demonstrating that intergenerational familial relationships promote greater purpose and well-being for at-risk older adults [32,41], older adults assigned to the intervention group will be preferentially paired with an intergenerational study partner who is a younger family member (aged 14 to 40) (e.g., grandchild, niece, nephew). In cases where an older adult does not have a younger family member available to participate, they will be paired with a younger adult (aged 18 to 40) recruited from the community. Recruitment of young adults from the community will involve posting flyers around the McGill University campus and advertising on McGill University's Department of Psychology SONA participant pool.

2.3. Intergenerational social motivation condition

The intervention pairs older and younger participants as dyads using a novel technology-based platform for four weeks. The timeline of four-week intervention is based on prior, similar physical activity interventions in older adults that have shown significant increases in step count over four weeks relative to controls [21,37]. Older adults wear wrist-worn accelerometers to measure their physical activity before beginning the intervention for one week, and then throughout the four-week intervention period. The intervention and technology platform incorporates four elements of social motivation that have shown promise in promoting physical activity in older adults: (1) intergenerational social engagement [24,25,30,31], (2) positive and personalized social feedback [21,23], (3) self-transcendence [26,42], and (4) prosocial goal attainment [16,43-45]. Intervention participants receive a daily text message or email containing a personalized link that directs them to a web application, designed and developed in-house, called *Our Family Garden*. The *Our Family Garden* application uses Django, an open-source Python web framework designed for creating web applications accessible on desktop and smartphones [46]. The application allows older adults to view their step count from the previous day and observe the progressive growth and bloom of a flower in a virtual family garden shared with their intergenerational study partner.

Every morning, the application prompts the participant to engage in a self-transcendence task where they spend one minute thinking about warm wishes towards a loved one [26]. The warm wish prompt alternates daily, including phrases such as "May you be well," "May you be happy," and "May you be safe". Next, they receive a positive, personalized message written to them by their intergenerational study partner. A bank of personalized messages is written by the study partner prior to the intervention onset to ensure that the older adult's

participation is unaffected should their study partner drop out. These personalized messages express a positive quality about the older adult (i.e., reasons why the younger adult is proud of them, qualities that they admire about them, etc.). Older adults and study partners view the same daily messages so that the study partner can follow the older adult's progress in reaching physical activity goals.

Throughout the intervention, main participants grow a different flower every 4 days in their virtual family garden. The flower grows by 25 % increments each day, and blooms on the fourth day, notifying participants that the older adult achieved their daily step count goal. Thus, they are able to visualize their progress towards donating to the Alzheimer Society of Montreal as a prosocial reward for increasing step count. On days when the participant does not meet their goal, the progress of the flower remains unchanged. Once the older participant achieves their step count goal for 4 days, participants receive a notification that a donation was made to the Alzheimer Society of Montreal. Subsequently, a new step count goal is calculated by adding the participant's average step count from the previous four days to a chosen step count increase (i.e., the average step count from the previous 4 days plus 100, 200, or 300 additional steps, depending on the personalized target set by a given participant). Step count goals are low and lenient and chosen by the primary participant prior to the intervention onset.

2.4. Active control condition

Older adults in the active control group have an identical study timeline and visit schedule as those in the intervention group. Similar to participants in the intervention, control participants wear the accelerometer for 28 days continuously and log their sleep and wear times in a daily journal each night. In contrast to participants in the active arm, those randomized to the control condition do not access the technology platform and are not paired with an intergenerational study partner.

2.5. Physical activity monitoring

Physical activity will be measured objectively in both the intervention and control group participants using a GT9X Link accelerometer worn on participants' non-dominant wrist (ActiGraph LLC, Pensacola, FL). Accelerometers are worn continuously during the four-week and baseline periods and are only removed for bathing, swimming, and charging the device. The primary outcome captured by the accelerometer is step count, and a secondary outcome will be total physical activity (i.e., time spent in light, moderate, and vigorous physical activity) [47]. To facilitate compliance, there is a conference call prior to the baseline week for all participants and again before the intervention or control period. During the intervention period, participants are sent reminders to wear their device and upload their data. If data are not uploaded for 2 consecutive days, an experimenter contacts the participant by phone and email to ensure there are no technical issues. Physical activity information is transmitted to *Our Family Garden* using the Centrepoint encrypted software package from ActiGraph. The Centrepoint data hub securely communicates the data captured by ActiGraph monitors to provide feedback to participants regarding their daily physical activity.

2.6. Cognitive and behavioral assessments

All older adult participants will complete remotely administered questionnaires and computerized cognitive tests during remotely administered videoconference visits with the research team to enhance access for participants in rural regions. Cognitive and behavioral assessments are considered secondary outcome measures, allowing us to examine the degree to which the intervention results in changes in domains other than physical activity, such as cognition and mood. Intergenerational study partners complete a shorter battery of questionnaires during the remote visits, as well as computerized cognitive assessments at baseline. The battery of assessments included as secondary outcomes is shown in Table 2.

2.7. Study design

This study was approved by the McGill Research Ethics Board and was deemed to be "minimal risk". This study is a remotely administered behavioral intervention conducted as a hybrid type 1 efficacy and implementation design [40]. This design involves testing the effects of the randomized controlled trial on outcomes while gathering data on its implementation, with the aim of informing subsequent real-world implementation efforts [40]. The study timeline for older adults is depicted in Fig. 1. Initially, all participants undergo a verbal screening over the phone to assess their eligibility based on the inclusion and exclusion criteria. The inclusion and exclusion criteria for older adults and intergenerational study partners are presented in Table 1.

If deemed eligible, a consent visit is scheduled between the participant and the researcher using a secure videoconferencing platform. During this visit, the researcher provides a detailed explanation of the study, addresses any participant inquiries, and obtains informed consent in accordance with the Declaration of Helsinki. Study partners between the ages of 14 and 17 complete an alternate consent form that requires a signature from their parent or legal guardian. Participants who agree to participate sign the informed consent document electronically in the REDCap platform.

At baseline, older adult participants wear a wrist-worn ActiGraph GT9X Link accelerometer on their non-dominant wrist for seven days to measure baseline physical activity. At the start of the 4-week intervention, intervention participants receive instructions to access daily messages, set personalized step goals (increasing by 100–300 steps every four days), and continue wearing the accelerometer for 28 days while engaging with the Our Family Garden social messaging app via email or Smartphone. Both groups complete a daily diary kept at their bedside, where they record the time they fell asleep the night prior, the time they woke up, and any times where they removed the accelerometer device (e.g., to swim, charge the device, or shower). Additional assessments occur at both the baseline and post-intervention phases during encrypted videoconferenced visits with the research team (Visits 1-5 in Fig. 1). Virtual visits with the research team are spaced approximately one week apart.

The study will incorporate implementation science techniques to better understand factors that affected participants' routine use of the technology platform in real-world settings [51]. After the intervention, all participants complete a questionnaire and provide open-ended feedback on the feasibility, ease of use, and acceptability of the technology. Moreover,

we will collect open-ended feedback on barriers and facilitators that affected older adult participants' success in implementing the intervention and maintaining its use over time. A participatory approach will be incorporated, wherein volunteer participants will elaborate on their experiences with the intervention, including any issues they encountered and how it affected their daily use of the technology and feedback on how we can refine and maximize the design of the technology to meet older adults' needs.

Intergenerational study partners follow a streamlined but similar duration to the older adult participants, as illustrated in Fig. 2. Study partners provide informed consent and undergo a condensed version of the pre- and post-intervention neuropsychological and behavioral assessments during encrypted videoconferenced visits with the research team. After the consent visit, study partners engage in an encrypted videoconferenced call with the older adult participant and a member of the research team. The purpose of this visit is to allow the older adult to share information about their interests, experience and knowledge with the younger adult. The younger study partner facilitates the conversation and is provided in advance with a set of questions to guide the discussion, enabling them to get to know the older adult on a personal level. This interaction serves as the foundation for the younger study partner to create personalized messages for the *Our Family Garden* application. Following the conversation, the older adult logs off the videoconferenced call, and the younger study partner generates the 30 personalized messages. Rationale for personalized positive messages is based on prior research showing that this type of messaging can enhance physical activity [21] and that positive affect is predictive of physical activity engagement in older adults [20,52]. These messages express 10 reasons why the study partner is proud of the older adult, 10 aspects of the older adult that they admire, and 10 positive qualities or memories they associate with the older adult. It is important to note that study partners do not wear an accelerometer to track their physical activity. However, they receive feedback that is mirrored to the older adult's feedback.

2.8. Randomization and blinding

After informed consent is obtained, half of the participants will be randomized to the social motivation condition (intervention group) and the other half will be randomized to the control condition (1:1). A multimodal AD risk score based on older participants' already acquired AD biomarker, health and cognitive data from PREVENT-AD will be used as strata for randomization to ensure equal assignment of high-risk participants to the intervention and active control groups. For participant classification into the higher risk group, an individual's score is taken from a two-tier system of variables shown in Table 3. For Tier 1 variables, any positive result classifies the participant in the higher risk for AD. Any combination of at least two Tier 2 variables also classifies the participant into the higher risk group. Participants that are not classified into the higher risk group either because they had negative results to all Tier 1 risk variables or because they had a positive score to only one Tier 2 risk variable, will be randomized into the lower risk group. The participants in each risk group will be randomized to either the intervention group or active control (ratio of 1:1). The stratified randomization scheme uses a permuted block method with random blocks and will be managed by Harvard Catalyst.

All participants are blinded to their treatment condition during the study and will not be informed of their treatment arm. During the informed consent process, older adults are informed that they may participate in the study with an intergenerational study partner. However, they are not told that the intergenerational partner is part of the intervention arm or provided with any details on how the two study arms differ. Similarly, intergenerational study partners are not informed that their role is specific to the intervention arm. To ensure blinding, participants are not made aware of their assigned treatment arm until the debriefing session at the final study visit. All research assistants involved in data collection will remain unblinded to treatment conditions given that certain study materials and assessments differ between intervention and control participants (e.g., a tutorial on how to use the *Our Family Garden* application, questionnaires assessing the participant's relationship with the study partner). Bias from an unblinded study team will be minimized by using objectively measured, reliable outcome measures (i.e., accelerometry data and well-validated questionnaires and computerized cognitive assessments). Any assessments requiring human scoring (e.g., physical assessments) will be performed by two separate evaluators who will be blinded to the participant's treatment condition and reach interrater reliability of ≥ 85 %. Moreover, researchers involved in data cleaning and analysis will remain blinded by using numerical codes for the participant's condition.

2.9. Statistical analyses

To examine the hypothesis that the intervention group will experience greater increases in physical activity compared to the control group, changes in physical activity (step count [primary outcome], and, minutes in light + moderate + vigorous physical activity [secondary outcome; [47]] across the five time points will be analyzed using linear mixed effects models. In the analysis, curvilinear changes over the time points will also be considered by including quadratic effect terms in the models. The linear mixed effects models will incorporate both random intercepts and slopes to capture subject-specific variations in physical activity patterns over time. A fixed effect for the group x time interaction will be included to assess the differential effect of the intervention between the two groups. Analyses of covariance (ANCOVA) and linear mixed models will be used to examine change in secondary outcomes (e.g., physical fitness, mood, sleep) between two timepoints (pre- and post-intervention). In all models, sex, age, APOE4 status, and years of education will be included as covariates. Dedicated analyses will also be performed for each sex separately. Initially, all valid data will be included in the models. Subsequently, per protocol analyses will be conducted, which involve excluding cases with less than four valid days of ActiGraph data or more than two days of non-compliance with the daily message intervention. This approach ensures a more rigorous evaluation of the intervention's impact on behavior change by focusing on participants who have sufficiently adhered to the study's protocol.

To examine the hypotheses regarding the mediating roles of generativity and social support in the relationship between the intervention and physical activity engagement, longitudinal mediation models will be employed, as outlined in the Science of Behaviour Change framework [53]. In separate models, group assignment will serve as the independent variable, with change in behavioral variables included as mediators, and change in physical

activity measures included as the dependent variables. Change in physical activity will be defined using the following equation: (mean physical activity during intervention – mean baseline physical activity) / mean physical activity during intervention x 100. Additionally, as outlined by the Operating Conditions Framework [54], analyses will be performed to assess how AD biomarkers, behavioral features (e.g., cognition, self-efficacy, self-regulation), demographic characteristics (e.g., sex, education level, socioeconomic status), and intervention context (e.g., neighborhood walkability, intra- vs. extrafamilial study partner) moderate the relationship between the intervention and changes in physical activity.

To assess the ease of integrating the *Our Family Garden* technology into the lives of at-risk older adults, we will use frequency distributions, means, and standard deviations to evaluate adherence, the proportion of days and amount of time where daily tasks within the application were completed, as well as participants' ratings on ease of use, acceptability, and feasibility. Additionally, open-ended feedback on the barriers and facilitators of using the technology and improvements for subsequent versions of the technology will be analyzed through qualitative thematic analysis to identify common patterns of feedback expressed by the participants.

2.10. Data management and confidentiality

To reduce the risk of breach of confidentiality we developed a Data Safety and Monitoring Plan that also includes a protocol for adverse event reporting and incidental findings. De-identified participant data is stored on REDCap, a password protected and encrypted platform. All participant demographic information will be registered monthly on the National Institute on Aging's Clinical Research Operations and Management System (CROMS). A Safety Officer assigned to the study will review all adverse event reports and will meet biannually with the investigators to review progress of recruitment and retention of participants, compliance with the protocol, and operating procedures. We will ensure participant confidentiality by using PREVENT-AD's coding for all participants' data according to their numbering system and separating these data from the informed consent. All informed consent documents and data files pertaining to subject data information will be kept in encrypted, password-protected files on an encrypted, password-protected flash drive that only researchers involved in the project will have access to. Data that are saved electronically are protected by the REDCap firewalls. All electronic data will be backed up onto an external hard drive monthly, and the external hard drive will be stored in a locked office at the Montreal Neurological Institute. Paper copies of data will be destroyed 7 years after study completion.

3. Discussion

This research aims to evaluate the efficacy of a remote behavioral intervention that harnesses intergenerational social motivation to enhance physical activity in older adults at risk for AD. The intervention incorporates four components of social motivation that have demonstrated potential in promoting the health and well-being of older adults: intergenerational social engagement, positive and personalized social feedback, self-

transcendence, and prosocial goal orientation. Notably, the remote nature of the intervention, requiring only a few minutes of technology engagement per day, offers advantages and flexibility compared to previous intergenerational interventions requiring extensive time commitments and in-person interaction [29].

This research addresses critical knowledge gaps surrounding the target mechanisms of how physical activity interventions work and individual differences in older adults who are most likely to benefit from the intervention. Applying the Science of Behaviour Change experimental medicine framework [53], and the Operating Conditions Framework [54], the study aims to identify the factors that enhance the intervention's efficacy. This new knowledge will inform the design of future interventions to targeting modifiable mechanisms involved in promoting behavior change in at-risk older adults as well as community-based programs for increasing physical activity. Furthermore, this study aims to identify individuals who are most likely to benefit from the intervention based on already acquired biomarker data within the context of a longitudinal cohort, allowing for the identification of intervention responders and modulation of intervention response with increasing AD risk. Ultimately, the goal of this research is to promote brain resilience in at-risk aging populations by preserving cognitive functioning and enhancing overall quality of life. By understanding the efficacy, mechanisms, and individual differences underlying our novel intergenerational intervention, this study aims to promote healthy aging using a personalized approach to engagement in lifestyle behaviors that promote dementia prevention. Finally, the study will incorporate implementation science techniques [51] by assessing the feasibility, ease of use, and acceptability of the technology, as well as identifying barriers and facilitators to participation. This information will help understand factors that influence the routine use of the technology in the everyday lives of at-risk older adults, with the aim of maximizing its real-world application.

Despite the promising insights gained from this study, it is not without limitations. First, given the multimodal nature of the intervention combining several components of social motivation, it will not be possible to determine what component has the greatest influence on behavior change. However, future work will aim to compare the components of social motivation on physical activity used in this study with a multi-arm clinical trial. Additionally, the intervention's short duration of four weeks limits our ability to assess its effectiveness in promoting long-term maintenance in physical activity gains. Another limitation of the current study is that older adult participants within the PREVENT-AD study are primarily Caucasian, Francophone, predominantly female, live in Quebec, Canada, and already volunteer in a cohort to prevent AD. Thus, the results obtained might be influenced by selection and recruitment bias. However, the influence of selection and recruitment bias will be examined by comparing the demographic characteristics of our sample with the larger PREVENT-AD cohort and Statistics Canada's 2021 Census of Quebec, allowing us to better characterize the generalizability of our findings.

In summary, this 4-week randomized controlled trial will examine the effect of a novel, multimodal, technology-based intergenerational social motivation intervention to increase physical activity in older adults at risk for AD. Our results aim to examine the efficacy of the intervention as well as identify how and for whom the intervention is most

effective using a combination of behavioral and biomarker data. This research aims to identify the neuropsychological factors impacting physical activity engagement in at-risk aging, uncovering mechanisms of behavior change and brain-based therapeutic targets for promoting well-being and dementia prevention.

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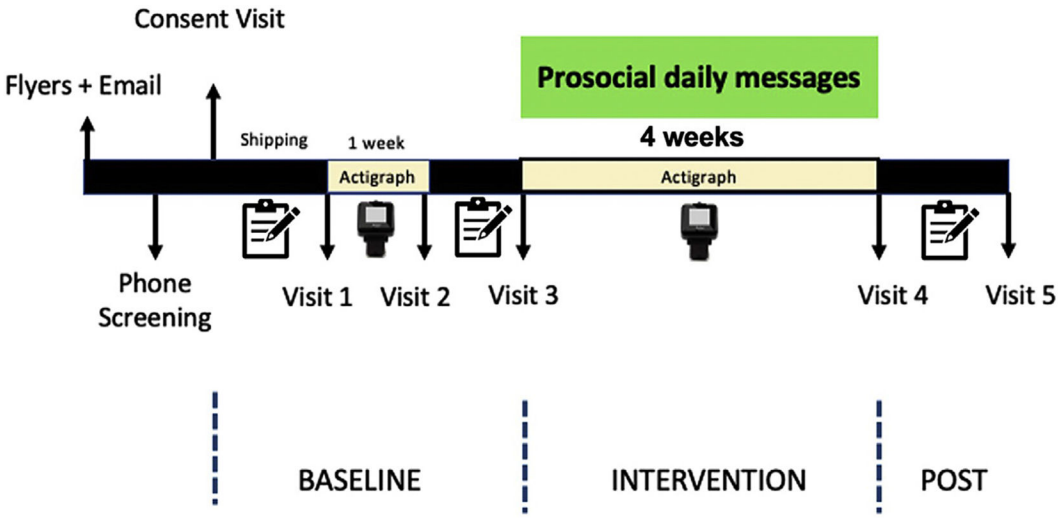

Fig. 1. Study timeline for primary older adult participants.

Note. Participants complete questionnaires in between Consent and Visit 1, Visit 1 and Visit 2, and Visit 4 and Visit 5 in the REDCap platform.

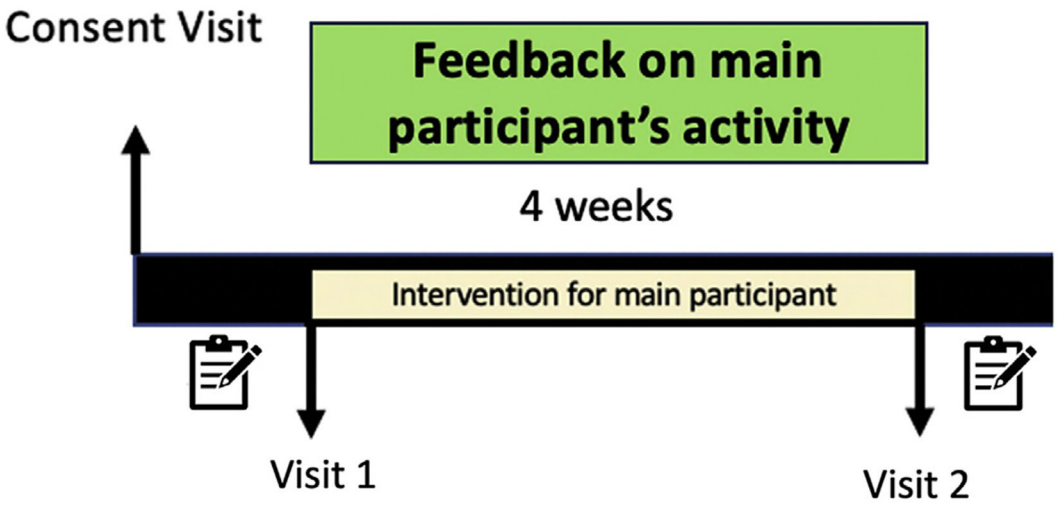

Fig. 2. Study timeline for intergenerational study partners.

Note. Intergenerational study partners complete questionnaires in between Consent and Visit 1 and after Visit 2 in the REDCap platform.

Table 1

Inclusion and exclusion criteria for primary older participants and intergenerational study partners.

Inclusion criteria	Exclusion criteria
Primary older participants • Men and women 60 years and above • Normal or corrected-to-normal vision based on the minimal 20/20 standard • Able to speak, read, and write English or French • Ambulatory without significant increase in pain with walking or the assistance of walking devices • Exercising less than the recommended 150 minutes of moderate-to-vigorous physical activity per week or sedentary for over 8 h per day, and responded “yes” to the question “Do you want to increase your physical activity?” • Regular access to a device with internet connection	Primary older participants • History of a psychiatric illness including schizophrenia or Attention Deficit Hyperactivity Disorder (ADHD). History of anxiety or depression accepted if stable on medication for at least 6 months • Current treatment for cancer – except non-melanoma skin cancer • Neurological condition (e.g., multiple sclerosis, Parkinson’s disease, and stroke) • Current alcohol or substance abuse • Current treatment for congestive heart failure, angina, uncontrolled arrhythmia, DVT or other unstable cardiovascular condition • Myocardial infarction, coronary artery bypass grafting, angioplasty or other cardiac event in the past six months.
Intergenerational study partners: • Identified as a relative, or, in the case a younger relative is unavailable, a younger adult recruited from the community • If intrafamilial, in contact with the primary participant more than once per 12 months at baseline • Able to speak, read, and write English or French	Intergenerational study partners: • Current alcohol or substance abuse • Any change in antipsychotic, stimulant, anti-depressant, anti-anxiety, other than for sleep, in the past 6 months • No regular access to a device with internet connection • Diagnosis of a neurological disease or unstable health condition

Table 2

Outcome measures completed by older adult participants.

Measure	Domain	Type	Description
Step count	Physical activity	Primary	This metric is gathered from the accelerometer devices and quantifies the average number of steps taken each day, from baseline to the end of the four-week period.
Time in total physical activity	Physical activity	Secondary	This metric is gathered from the accelerometer devices and quantifies change in the amount of time spent engaged in light, moderate, and vigorous physical activity each day, from baseline to the end of the four-week period.
Generativity Questionnaire † [29]	Generativity	Secondary	A questionnaire used for measuring generative desire and achievement. Consists of 13 items measured on a 6-point Likert scale.
Modified Differential Emotions Scale * [48]	Mood	Secondary	A questionnaire the measures the extent to which positive and negative emotions have been experienced in the past 24 h. Consists of 20 items measured on a 4-point Likert scale.
UCLA Loneliness Scale * [49]	Loneliness	Secondary	A questionnaire that measures participants' level of loneliness. Consists of 20 items measured on a 10-point Likert Scale.
TestMyBrain Digital Neuropsychology Toolkit † [50]			
Simple Reaction Time	Reaction time	Secondary	A computerized test that measures basic psychomotor response speed.
Choice Reaction Time	Reaction time, attention	Secondary	A computerized test that measures speed of response selection and attention.
Gradual Onset Continuous Performance	Attention, cognitive control	Secondary	A computerized test that measures sustained attention, response inhibition, and cognitive control.
Matrix Reasoning	Reasoning	Secondary	A computerized test that measures perceptual reasoning.
Digit Span (forward and backward)	Attention, working memory	Secondary	A computerized test that measures working memory and attention.
Visual Paired Associates	Episodic memory	Secondary	A computerized test that measures episodic memory.
Digit Symbol Matching	Processing speed	Secondary	A computerized test that measures processing speed.

Note. Outcome measures that are also completed by intergenerational study partners are indicated with* and those completed by study partners at baseline only are indicated with †.

Table 3

Variables used for classifying participants as “lower risk” or “higher risk” for Alzheimer’s disease.

Tier 1 Variables	Tier 2 Variables
• Amyloid tau index (ATI) ≤1 • p-tau in cerebrospinal fluid ≥ 60 pg/mL • β-Amyloid in PET ≥ 1.39 SUVR • Total tau in PET ≥ 1.3 SUVR • APOE-ε4/ε4 or ε4/ε3status	• Overall cognitive performance (i.e., Repeatable Battery for the Assessment of Neuropsychological Status [RBANS]) < 1 SD of age-adjusted normative value • Episodic memory (i.e., Rey Auditory Verbal Learning Test [RAVLT]) < 1 SD • Hippocampal volume on MRI < 1.5 SD • APOE ε4/ε2 status • Framingham Risk Score ≥ 18 points for women; ≥ 15 points for men • History of depression or consumption of psychotropic medication