EXAMINING THE REAL-WORLD EFFECTIVENESS OF COMBINED COGNITIVE AND PHYSICAL ACTIVITY INTERVENTIONS IN HEALTHY OLDER ADULTS: A SYSTEMATIC REVIEW AND CLINICAL TRIAL

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Abstract

Dementia risk reduction is one of seven aims of the World Health Organization's Dementia Plan (WHO, 2018). Specifically, risk reduction encompasses the development and delivery of interventions, and a greater emphasis on health promotion programs, with training aims to proactively manage modifiable risk factors. Recent research suggests that combined physical and cognitive activity interventions yield more significant treatment gains than single modality interventions. However, early research has focused upon determining efficacy of these interventions with regard to cognition, examining these interventions under optimal conditions on outcomes closely related to the trained task. As a result, two questions of generalizability remained unanswered: do these interventions impact outcomes related to everyday life, and can they be translated into accessible, community-based interventions? This research addresses these questions. In Study 1, I conducted a systematic review and meta-analysis evaluating the everyday impact of combined interventions. I found that combined interventions lead to improvements in quality of life relative to a mixed group of passive and active controls, but these improvements do not extend to domains of mood, activities of daily living, or self-efficacy. In Study 2, I designed and evaluated a replicable, community-based intervention to investigate the effectiveness of a combined approach in a real-world setting. Specifically, I added a physical activity component, facilitated by wearable activity trackers, to a well-established memory intervention. The combined intervention was determined to be feasible and acceptable to participants who demonstrated an increase in physical activity, a decrease in sedentary behavior, and an improvement in subject knowledge of memory and aging. Relative to the original program, the combined program did not yield additional benefits on quantitative measures of metamemory, objective memory, psychological well-being, or health and lifestyle. With respect

to the two types of generalizability addressed in this research, the findings indicate that combined interventions do impact everyday life and can be translated into accessible, community-based interventions. This research also underscores the importance of investigating patient-centered outcomes and conducting research with generalizability in mind to help with the translation from research to patient-centered care.

Dedication

This dissertation is dedicated to my best friend, Anthony.

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CHAPTER 1

General Introduction

Dementia is currently the second largest cause of disability for individuals 70 or older (World Health Organization, WHO, 2018). With an estimated 9.7 million new cases each year and a tripling in the total number of individuals experiencing dementia by 2050 (WHO, 2018), research surrounding cognitive aging (both healthy and pathological) has become a public health priority.

Aiming to improve this population health response, the Dementia Plan was introduced (WHO, 2018). Dementia risk reduction is one of seven action areas identified and encompasses the development, delivery, and promotion of interventions, increased understanding of linkage of dementia with other domains of neurocognitive disorder, and greater emphasis on health promotion programs. Such health promotion focuses on physical activity, healthy diets, mentally stimulating activities, and social engagement, with training aims to proactively manage modifiable risk factors. Indeed, modifiable risk factors are estimated to contribute to nearly one third of dementia cases (Barnes & Yaffe, 2011; Norton et al., 2014).

To address modifiable risk factors, early intervention in healthy older adults is paramount. In this dissertation, I provide a systematic review and meta-analysis as well as an empirical study to further understand one particular type of intervention, combined interventions involving a combination of physical and cognitive activity, in healthy older adults. The goal of this chapter is to provide an overview of the literature that I expand upon in subsequent chapters. To provide context for why these two intervention types are now being evaluated in unison, I first begin with a discussion of the components in isolation.

Overview of the Literature

Psychoeducation about dementia risk, techniques to enhance cognitive reserve, and resources to combat modifiable risk factors are critical elements of interventions in healthy older adults that are expected to mitigate future rates of dementia (Livingston et al., 2020; WHO, 2018). Cognitive interventions are one such type of early intervention program, often focusing on enhancing cognitive reserve. Cognitive reserve theory (Stern, 2002) posits that the brain has an adaptive capacity in its functioning and that certain factors, such as formal education, can serve to enhance the brain's ability to cope with pathological changes. The aim of studies using cognitive training with older adults is to restore or maintain cognitive abilities in the face of age-related declines (Malmberg Gavelin et al., 2020).

To date, many cognitive interventions have been successful in this endeavour, as evidenced by demonstrating improved performance on trained cognitive abilities (Bamidis et al., 2015; Rebok et al., 2014). Yet, there is limited evidence that cognitive training results in more generalizable cognitive improvements, as changes are most often seen in related tasks, and effects are less robust when examining distantly related or structurally dissimilar skills (Ball et al., 2002; Green & Bavelier, 2008; Harrison et al., 2013; Owen et al., 2010). For example, in one study, participants were randomized to one of four training groups: memory, reasoning, processing speed, or a no-contact control (Ball et al., 2002). Each group received training for their respective cognitive domain (e.g., problem solving and pattern detection for the reasoning group). Directly following the intervention, each group showed improvement on the task that had been trained but there was no generalization of treatment to untrained cognitive domains (e.g., the memory group showed no improvement on the reasoning test) or to everyday functioning (Ball et al., 2002). This lack of transfer across cognitive domains or to everyday functioning was consistent at post-test and at one- and two-year follow-ups. However, there was one exception. Participants in the processing speed group, who partook in a booster session at 11 months, did show transfer to activities of daily living and everyday speed at the one-year follow-up point, but these gains were lost at the two-year follow-up point. Although this study is one example, such a lack of “far transfer” (the term for broad generalization), has been noted consistently (Green & Bavelier, 2008; Tucker-Drob, 2011). This has prompted calls to ensure that cognition-oriented interventions yield more generalizable outcomes impacting functioning in daily activities, subjective cognitive concerns, and psychological well-being (Green & Bavelier, 2008; Harrison et al., 2016; Papp et al., 2009; Tucker-Drob, 2011).

Physical activity interventions have also been shown to mitigate age-related changes in cognition (Colcombe & Kramer, 2003; Philips, 2017) and brain health (Erickson et al., 2011; Leckie et al., 2014) in older adults. Physical activity interventions are hypothesized to yield positive effects through both direct and indirect mechanisms (Bherer, 2015). Direct evidence comes from studies showing exercise-induced changes in cerebral growth factors (Leckie et al., 2014) and structural brain changes (e.g., Erickson et al., 2011). Indirectly, physical activity is hypothesized to benefit cognition through optimized health such as improving health factors (e.g., stress, sleep, diet) and reducing chronic disease (Bherer, 2015). Research on physical activity interventions in older adults suggests that cognitive changes are most commonly seen in executive functioning (Colcombe & Kramer, 2003; Lautenschlager et al., 2008; Liu-Ambrose et al., 2010). However, the magnitude of these effects is sometimes small or inconsistent (Kelly et al., 2014; Smith et al., 2010).

In recent years, combined interventions that incorporate both cognitive and physical activity have gained increasing attention in the research literature. Recognizing that there are multiple contributors to brain health, combined interventions have the potential to address age-related changes on multiple fronts. Combined cognitive training and physical activity, for example, is posited to garner greater intervention benefit than either approach alone by capitalizing on physical activity-induced plasticity to enhance cognitive training-induced reorganization (Fabel et al., 2009; Fissler et al., 2013). This hypothesized synergy of the two component interventions has fuelled research enthusiasm, especially considering early research suggesting that combined approaches are more effective than unimodal approaches (e.g., Lauenroth et al., 2014). In fact, the efficacy of combined interventions on cognitive outcomes has been demonstrated in several systematic reviews and meta-analyses (Bruderer-Hofstetter et al, 2018; Law et al., 2014; Zhu et al., 2016).

Although research evaluating combined approaches is in a more nascent state, calls for greater generalizability seen in the cognitive intervention literature are equally applicable within this field. As mentioned, one such aspect of generalizability relates to the far-transfer of intervention outcomes, or whether they impact everyday life. This question is particularly important when considering that preserved functional abilities are a critical component in preserving an individual's autonomy (Burton et al., 2009) and that outcomes of daily life and psychological well-being are highly valued by the individuals participating in these interventions (Barrios et al., 2016; Harrison et al., 2016; Watson et al., 2019). Thus, everyday outcomes speak to the clinical significance of these types of interventions.

A second aspect of generalizability that warrants further exploration is the degree to which combined interventions can be implemented in real world settings with their intended populations. To date, much research on combined interventions has focused on study efficacy. Efficacy studies evaluate interventions under optimal conditions, typically involving homogenous samples, time-limited interventions, and levels of personnel support that are uncommon in community-based programs (Cicerone et al., 2000; Flay et al., 2005; Glasgow et al., 2003). Given that the efficacy of combined interventions has been well established, the next logical step is to determine their effectiveness when delivered in community-based settings.

In this dissertation, I address these two questions about the generalizability of combined interventions. In Chapter 2, I evaluate outcome generalizability by conducting a systematic review and meta-analysis of the everyday impact of combined interventions. Specifically, I examined outcomes impacting daily life such as measures of psychological well-being, quality of life, and activities of daily living. In Chapter 3, I conduct a single-arm trial evaluating the effectiveness of a combined intervention using an accessible and replicable, community-based program. For the latter study, I developed a combined intervention by integrating an established cognition-oriented treatment with a wearable activity tracker in a community setting with a sample of older adults. Collectively, my research aims to evaluate how well combined interventions translate to the real world with respect to both intervention outcomes and intervention settings.

CHAPTER 2

Introduction

In recent years there has been increasing recognition of the need to employ multimodal strategies in aging interventions designed to promote health and prevent dementia (Olanrewaju et al., 2015). Combined interventions, defined as those incorporating a physical and cognitive component, are one type of multimodal intervention. Critically, from a public health perspective, combined interventions address two modifiable, yet prominent, risk factors for dementia: lack of cognitive engagement and physical inactivity (Barnes & Yaffe, 2011; Livingston et al., 2020; Public Health Agency of Canada, 2019; World Health Organization, 2017).

Combined interventions have demonstrated efficacy in improving cognitive abilities among older adults, often countering age-related declines (Evans et al., 2009; Fabre et al., 2002; Hiyamizu et al., 2012; Oswald et al., 2006). These benefits have been noted in several cognitive domains such as global cognition, memory, and executive functioning. In some cases, benefits have been shown to be superior to changes elicited in single-domain interventions (Lauenroth et al., 2016), though this may be dependent on the nature of the intervention comparison (i.e., cognitive vs. physical activity; Zhu et al., 2016).

There is a large and growing literature evaluating the cognitive impact of combined interventions. Indeed, cognitive outcomes are requisite for the inclusion of studies in most meta-analyses and systematic reviews to date (Desjardins-Crépeau et al., 2016; Lauenroth et al., 2016; Law et al., 2014; Zhu et al., 2016). Building on this work, there is an opportunity to better understand the everyday impact of combined interventions. Everyday impact can be defined as outcomes beyond cognition that play a role in daily life, such as psychological well-being, quality of life, activities of daily living, and mood (see Chandler et al., 2016, for review).

Two previous reviews have examined select aspects of everyday impact (Bruderer-Hofstetter et al., 2018; Zhu et al., 2016) in addition to cognitive outcomes. In their review, Bruderer-Hofstetter and colleagues identified one study examining instrumental activities of daily living in healthy older adults and found no effect of the combined intervention (2018). In another review, Zhu and colleagues examined three studies and found that combined interventions did not yield significant improvement over controls on a summary measure of well-being that combined scores across measures of well-being, stress, anxiety, and depression (2016). Together, then, a total of four studies have contributed to evaluations of everyday outcomes in systematic reviews within the field to date.

The underrepresentation of outcomes involving daily life highlights an opportunity for an in-depth investigation of the generalizability of combined interventions to everyday life. This is an important question to ask, considering that cognitive change does not always equate to real-world impact (Kelly et al., 2014; McDaniel & Bugg, 2012). Evaluating primarily cognitive outcomes, then, paints a partial picture of a study's potential influence, and this picture can be enhanced with a more thorough examination of study outcomes.

Studies have shown that everyday outcomes (including quality of life and self-efficacy) are highly valued by both healthy older adults and individuals with memory impairment participating in cognitive interventions (Barrios et al., 2016; Watson et al., 2019). In addition, everyday outcomes are associated with independence (Burton et al., 2009). Thus, evaluating everyday outcomes will help us understand whether combined interventions impact outcomes of importance to participants themselves.

The Current Review

The objective of this review was to evaluate the everyday impact of combined physical and cognitive interventions in healthy older adults. We examined clinical trials that featured at least one control group to isolate treatment effects. We defined everyday impact as outcomes beyond cognition that play a role in daily life, such as psychological well-being, quality of life, activities of daily living, and mood (Chandler et al., 2016).

This review contributes to the research literature in its targeted evaluation of these outcomes via a rigorous search methodology, which notably included a methodical evaluation of the grey literature to address issues of publication bias, critical evaluation of study bias, and quantitative review of the included literature. Together, the current review provides a comprehensive examination of the existing evidence for generalizability of combined interventions in the everyday lives of older adults.

Methods

Design

This systematic review was conducted, and its results reported, in accordance with the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2019) and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009), respectively. The review was registered in the PROSPERO database prior to our initial search (CRD42020177998). This protocol can be accessed via https://www.crd.york.ac.uk/PROSPERO/.

Eligibility Criteria

Eligible studies were controlled clinical studies evaluating the everyday impact of combined interventions in healthy older adults. To address outcome reporting bias, a wide net was cast in our original systematic search to include all eligible interventions and did not specify types of everyday outcomes until a full article could be reviewed. Therefore, eligible studies identified via our systematic search protocol were those that: (a) involved a combination of cognitive and physical interventions; (b) included older adults with no known cognitive impairments; and (c) had at least one active and/or passive control group. There were no search restrictions pertaining to publication period. Studies were restricted to those published in English.

Search Strategy

A systematic literature search was conducted on May 6, 2020 and included all studies published up to that date. I searched the databases Medline, EMBASE, PsycInfo, and the Cochrane Register of Controlled Trials (CENTRAL). The search strategy was created upon consultation with, and checked for accuracy by, a subject librarian. This strategy included Medical Subject Headings and controlled vocabulary terms and keywords (see Appendix A). The search was updated on February 17, 2021.

Supplemental Searches

Recognizing that publication bias contributes to a skewed representation of positive results in the published literature (Torgerson, 2006), a series of supplemental searches were undertaken to maximize the scope of available research, regardless of the direction or significance of results. As described below, three types of supplemental search strategies were employed, including examining the grey literature, reviewing clinical trial registries, and exploring citation relationships.

Grey literature is defined as literature that has not been formally published, is limited in its distribution, or is not available through conventional channels (Auger, 1998), and its inclusion is a practical step to avoid publication bias (Hopewell et al., 2005). Examples of grey literature are conference abstracts, unpublished data, and dissertations. Grey literature was incorporated by indexing databases featuring grey literature (e.g., PsycInfo and CENTRAL) and by not constraining our search to full-text articles. Authors of conference abstracts that met criteria were contacted directly for more information.

Trial registries were examined to identify unpublished, recently completed, or ongoing trials to account for time-lag bias (Jones et al., 2014; Song et al., 2010). I hand-searched two clinical trial registries, Clinicaltrials.gov (http://clinicaltrials.gov/) and Current Controlled Trials, now the ISCTRCN registry (www.isrctn.com), on July 8, 2020, and updated the search on March 18, 2021. Search specifications included age (ages 65+ or seniors for clinicaltrials.gov and isrctn.com, respectively) and search terms "cognitive AND physical" under intervention type.

I also employed several methods of citation relationship searching, including hand searching reference lists of included studies, forward citation chasing (i.e., checking whether a study known to be relevant has been cited by any other articles; Cooper et al., 2017), and using the similar article feature in Pubmed. Articles identified through supplemental searches are represented by the additional sources box in the flow diagram (Figure 1).

Selection of Studies

All identified references from the systematic search and supplemental searches were imported into Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia; https://www.covidence.org/) for the screening process (Cochrane Effective Practice and Organization of Care, 2017). Two reviewers (CJD, KTS) worked independently and in parallel to screen all titles and abstracts to identify any studies that were clearly ineligible. At each stage, three response options were available (*Yes*, *Maybe*, and *No*). A study required two

Yes votes to pass to the next stage. In cases of discrepancy, articles were redirected by the software to an intermediary conflict stage and required consensus to progress to the next screening stage.

Full-text articles were obtained for all studies that passed screening and were assessed for eligibility by two reviewers (CJD, RH). At this stage, articles were excluded in the following order of priority: (a) not a controlled clinical study design; (b) study was ongoing; (c) not a healthy older adult population (or, if the sample was mixed, data were not separated for healthy older adults); (d) ineligible intervention (lacking cognitive AND physical intervention component); (e) no everyday outcome; (f) no active and/or waitlist control; or (g) duplicate sample without novel information. At each stage, the software flagged discrepancies for eligibility and for reasons for exclusion, which were then resolved by consensus. Interrater reliability was calculated for both title/abstract and full-text screening using Cohen's kappa and percentage agreement.

Risk of bias/quality of evidence assessment

Two reviewers (CJD, RH) independently assessed the quality of each study using the Effective Public Health Practice Project (EPHPP) tool (https://merst.ca/ephpp/). The EPHPP was used because, unlike the Cochrane Collaboration Risk of Bias tool, it features a scale that is designed to evaluate a range of study designs (i.e., beyond RCTs alone; Armijo-Olivo et al., 2012), thus expanding eligible studies and more thoroughly representing the extant literature. The EPHPP has demonstrated both content and construct validity (Thomas et al., 2004) as well as acceptable interrater reliability and test-retest reliability (Thomas et al., 2004). The likelihood of bias was judged on six methodological domains including participant selection, study design, confounders, masking, data collection methods, and withdrawals and drop-outs. Studies were given ratings for each component domain as well as a global summary. A standardized form was created and loaded into the review software where this rating took place. As with screening, discrepancies between the reviewers were redirected to an intermediary stage and resolved by consensus.

Data extraction and analysis

A data extraction form was developed *a priori* based on the Cochrane Effective Practice and Organization of Care data form (Cochrane Effective Practice and Organization of Care, 2017). Two reviewers (CD and RH) independently extracted data in duplicate. Independent data extraction has been shown to result in fewer errors than data extraction by a single author with verification by a second (Buscemi et al., 2006; Li et al., 2019). Data extraction contained the following elements: author details (e.g., sources of funding, institutions etc.), study design, population and settings, methods, participant details, intervention groups, outcomes, results, and study conclusions.

Using the review software, data extraction forms were automatically populated with data that were identical between reviewers. Discrepancies between extracted data were flagged and, upon consensus, were manually inputted into the consensus form. I then organized outcome data into meaningful categories with consensus from subject matter experts in the field of cognitive interventions.

Meta-analyses were conducted to summarize treatment effects by domain using Review Manager (Revman) software (version 5.4, the Cochrane Collaboration, 2020). I calculated and analysed standardized mean differences between intervention and control groups on our outcomes of interest. All analyses were conducted using random-effects models. Except for two studies that reported change scores, I used post-test scores (Andrieu et al., 2017; de Souto

Barreto et al., 2021) for all quantitative analyses. Although there are advantages to using change-from-baseline scores (including a less skewed distribution), post-test scores are recommended when outcomes are difficult to measure precisely or involve subjectivity and where measurement error may obfuscate true between-person variability (Higgins & Green, 2011). Considering the near exclusive use of self-report measures in the outcomes examined within the study, I elected to use post-test scores for our analyses.

Studies varied in the type of control groups used. Given the sample size, subgroup analyses were not feasible and thus I compared the performance of combined interventions to a mixed group featuring both passive and active control groups. In general, the combined group's performance was compared to the most passive control option available. For some studies (n = 4), this involved an active control (e.g., the provision of accelerometers or at-home strength workouts). For most (n = 8), this was a passive control (e.g., a waitlist group). Four studies reported both passive and active control groups. I chose to analyse the most passive control group given that previous reviews had shown null effects when evaluating everyday outcomes (e.g., Bruderer-Hofstetter et al., 2018; Zhu et al., 2016). Thus, a more liberal approach was utilized to determine intervention efficacy for these outcomes and could serve to guide future, targeted inquiries of relative efficacy as compared to single modality interventions.

In four cases, studies reported data for multiple outcomes that fit within one category of analysis. To avoid statistical overrepresentation of study samples, a single measure was selected or generated for each outcome, following methodology of a similiar review (Hudes et al., 2019). That is, in cases where studies provided data on subscales of an identical construct (n = 1), outcomes were pooled to calculate a single effect size for the study. If a study provided data for multiple measures capturing closely related constructs, a single measure was chosen on theoretical grounds (i.e., the measure most closely related to the target construct, $n = 3$).

Results

Included Studies

A flow diagram of study selection is presented in Figure 1. We identified 3439 studies through database searches. Of these, 300 articles were from PsycInfo, 1089 from Medline, 1632 from Embase, and 418 from CENTRAL. An additional 34 articles were found via supplemental searches. Following de-duplication, 2437 studies were screened for title and abstract. We deemed 2341 studies ineligible at this stage and examined 96 full-text studies. At the level of title/abstract screening, moderate agreement was obtained ($k = 0.55$, proportionate agreement = .96). Full-text screening achieved substantial agreement ($k = 0.66$, proportionate agreement = .91). The most common reason for ineligibility was study outcome; specifically, 30 of the 96 full-text articles reviewed were ineligible because they did not include an everyday outcome. Two additional studies met criteria for inclusion when the search was updated.

Altogether, 13 studies were included in the review, and 12 were included in the meta-analysis. This amounted to a total of 2757 participants across studies with sample sizes ranging from 30 to 1525 participants. Samples were predominantly female ($M = 67\%$). Except for two studies by the same first author, all studies were conducted in different countries (see Table 1 for summary characteristics of included studies).

Study Characteristics

Participant characteristics

The mean age of study populations ranged from about 63 to 80 years. Eight studies reported using cognitive screening at baseline to exclude persons suspected to have dementia, including the Mini Mental Status Examination or the Clinical Dementia Rating scale. The cognitive cut-offs used in these studies are detailed in Table 1. Education reporting was variable, with three studies reporting no information, five studies reporting number of participants per education level, and five studies reporting education mean in years. For these latter studies, education years ranged from about 5 years to 16 years. Studies recruited participants using various methods such as via physicians' databases, research pools, mass media, local organizations, and senior residence facilities.

Intervention characteristics

Ten of the interventions consisted of cognitive and physical components administered separately (see Table 2 for intervention characteristics). Three studies (Eggenberger et al., 2015; 2016; Gschwind et al., 2015) featured dual-task designs in which participants underwent simultaneous cognitive and physical training. Intervention length ranged from 8 weeks to 3 years. The most common intervention lengths were 12 weeks and 24 weeks. Five studies employed intervention components in addition to physical activity and cognitive engagement. This included nutritional counselling and/or supplementation, social activities such as board games, and musical stimulation.

Separate interventions. Studies that used separate physical and cognitive training (i.e., not dual-task) were distributed across exercise modalities: three studies featured aerobic training; three involved a muscular strength and/or balance component; and four had a combination of both types of exercises. Most (n = 7) studies featured group exercises at institutions. In contrast, three studies encouraged participants to increase their physical activity levels at home, providing resources but not overseeing the activity directly.

Studies' cognitive components were distinguished by mode of delivery, with four studies utilizing a computer-based platform to deliver cognitive training and six offering in-person cognitive training. Computerized training incorporated various tasks such as executive function training, auditory- or visual-based brain fitness programs, or multidomain cognitive training. In-person cognitive interventions featured training for several cognitive domains including memory skill training (e.g., mnemonic strategies), processing speed tasks, attention training, "brain training," and/or executive function abilities.

Simultaneous (dual task) interventions. Three studies incorporated dual-task designs in which cognitive and physical training were simultaneously applied (Eggenberger et al., 2015; 2016; Gschwind et al., 2015). In both studies by Eggenberger and colleagues, the combined condition involved a virtual reality dancing game that combined an attention-demanding task with a simultaneous motor coordination requirement. In the study by Gschwind and colleagues, participants completed balance exercises with simultaneous semantic and working memory games.

Control characteristics

Characteristics of control groups varied between studies and are detailed in Table 2. Studies were variable in the types of control groups utilized. Four studies featured both active and waitlist controls. Four had only passive (or waitlist) controls with two of these groups receiving educational materials or a placebo nutritional supplement. Five studies had only active control groups who received a physical or cognitive intervention in some format.

Outcome Measures and Intervention Effects

Descriptions of the measures used are provided in Table 3.

Mood: Symptoms of Depression and Anxiety

Depressive symptoms were the most common everyday outcome reported. Of the 13 included studies, seven contained a measure of depressive symptoms. All seven studies contributed to the meta-analysis evaluating depressive symptoms, with a combined sample size of 1306 participants. Results showed there were no significant differences in depressive symptoms at post-test in the combined condition compared to control conditions, $g = 0.11$, 95% CI [-0.25, 0.03], $Z = 1.50$, $p = 0.13$. A sensitivity analysis was conducted to evaluate the impact of two studies (Andrieu et al., 2017; De Souto Barreto et al., 2021) that reported change scores instead of post-test scores. The sensitivity analysis found no impact on statistical significance and only a minor change to the effect size, though confidence intervals were increased, $g = 0.12$, 95% CI [-0.39, 0.16], $Z = 0.84$, $p = 0.40$. Results of the meta-analysis for depressive symptoms are shown in Figure 2.

One study also provided outcome data on anxiety. In this study, there was a negligible, nonsignificant impact on anxiety symptoms (Shah et al., 2014).

Quality of Life

Seven studies contributed to the meta-analysis on quality of life, with a combined sample size of 705 participants. Results showed that compared to controls, combined interventions yielded a significant, small improvement on participants' quality of life, $g = 0.45$, 95% CI [0.19, 0.71], $Z = 3.35$, $p < .001$. Results of this meta-analysis are depicted in Figure 2.

Two studies reported multiple measures within this construct that fell under the domain of quality of life and well-being. For statistical reasons, only one outcome could be reported per study to avoid overrepresentation of the sample. The remaining two outcomes, subjective age and health, are described here. Oswald and colleagues found a small effect that was nonsignificant on a measure of overall health status (which was a composite of objective and subjective health ratings) when compared to passive controls (2006). Another study evaluated subjective age and found that the combined intervention group showed significant, very large decreases in their perceived subjective age when compared to waitlist controls (Leś et al., 2019).

Activities of Daily Living

Six studies contributed to the meta-analysis evaluating activities of daily living, with a combined sample size of 1234 participants. The results showed a nonsignificant, small effect, $g = 0.27$, 95% CI [-0.00, 0.55], $Z = 1.95$, $p = .05$, indicating no difference between combined intervention and control groups. These results are illustrated in Figure 2. A sensitivity analysis was also conducted with one study outlier removed (Pieramico et al., 2012). The overall effect remained nonsignificant, though the effect size decreased from small to negligible, $g = 0.10$, 95% CI [-0.02, 0.21], $Z = 1.67$, $p = .09$.

One study was not included in the meta-analysis for reasons of unavailable data. McDaniel and colleagues evaluated performance of a combined intervention on two tests designed to simulate everyday tasks (2014). One task, the Virtual Week task, evaluated everyday prospective memory in the context of daily living. Although there were no main effects for the presence and absence of cognitive and aerobic interventions, there were several significant interactions, indicating that the combined intervention group performed better than the other groups on measures of prospective memory. A Cooking Breakfast task was also administered which was a computerized laboratory simulation of a cooking task. For this task, the authors found no impact on primary outcomes but did report that the combined intervention group performed better on measures evaluating time, overall performance, and task difficulty (McDaniel et al., 2014).

Self-Efficacy and Coping

Six studies, with a combined sample size of 498 participants, contributed to the meta-analysis on self-efficacy and coping. Results showed no effect on these outcomes for the combined intervention group compared to controls, $g = 0.16$, 95% CI [-0.10, 0.42], $Z = 1.22$, $p = .22$. These results are illustrated in Figure 2.

Risk of Bias Assessment

The results of the risk of bias assessment are presented in Figure 3. Overall, 39% of the studies were rated *strong* ($n = 5$; representing lowest risk of bias), 15% were rated *moderate* ($n = 2$), and 46% of studies were rated *weak* ($n = 6$). The greatest limitations of included studies were in the domains of masking and selection process. Specifically, seven studies reported that assessors were masked to participants' conditions, and only two studies reported that the nature of the research question was concealed from participants. Regarding selection processes, most studies relied on convenience sampling via research pools, local organizations, or senior residences (see Table 1). Only one study (Oswald et al., 2006) reported that their sample was representative of the population at large.

Discussion

Faced with shifting demographics, cognitive aging interventions have long been a clinical and research priority. Interest in combined cognitive and physical interventions has increased markedly in recent years as evidenced by the number of reviews on the subject (Bruderer-Hofstetter et al., 2018; Gheysen et al., 2018; Malmberg Gavelin et al., 2021; Lauenroth et al., 2016; Law et al., 2014; Zhu et al., 2016). Given that previous research has focused primarily on cognitive outcomes, there is a current opportunity to better understand the everyday impact of these interventions.

I conducted a systematic review and meta-analysis, identifying 13 studies that examined the everyday impact of combined interventions in healthy older adults. This review examined several domains falling within the scope of everyday outcomes (Chandler et al., 2016), including mood, quality of life, activities of daily living, and self-efficacy. Due to an insufficient number of studies, the control comparison was heterogeneous in nature, consisting of both passive (e.g., waitlist) and active (e.g., single component only) control groups. Results of meta-analyses showed that combined physical and cognitive activity interventions are effective in improving quality of life as compared to controls. In contrast, combined interventions did not yield significant improvements in outcomes of depressive symptoms, activities of daily living, and self-efficacy compared to controls.

Mood, specifically depression, was the most common everyday impact assessed across the studies that we examined. The lack of significant differences in this outcome is surprising, given an earlier meta-analysis showing a positive impact of physical activity interventions on mood (Arent et al., 2000). However, this may be attributable to the fact that most studies used a screening measure for depression. Screening measures may be sufficiently sensitive to detect clinical levels of depressive symptomatology but are less likely to detect subtle changes in mood, especially if participants are not depressed at baseline. To circumvent this issue and more thoroughly investigate mood-related changes, authors of future studies may want to incorporate measures with demonstrated evidence for responsiveness to intervention (Mokkink et al., 2010), which may be achieved through the use of measures of mood that index both positive and negative affect or allow for a more dimensional characterization of mood than a cut-off for clinical diagnosis.

This meta-analysis did reveal that combined interventions, as compared to a heterogeneous group consisting of passive and active control groups, were effective in improving quality of life. An earlier review of combined interventions (Zhu et al., 2016) also examined psychological well-being but found no effect. The same three studies which were featured in this early review were also utilized in the current review. This dissonance in findings is likely attributable to the fact that that earlier study combined measures of well-being, stress, anxiety, and depression into a single category for the meta-analysis, whereas more data were available for the current analysis which facilitated a more specific approach. In addition, the current review provides an update including more studies that have since been conducted, thereby resulting in more data and a more representative depiction of the literature currently.

We did not find any significant differences in outcomes of activities of daily living or in self-efficacy. This is in accordance with findings from an earlier review identifying no effect of combined interventions on the one included study that examined iADLs (Bruderer-Hofstetter et al., 2018). Regarding self-efficacy, this outcome has not been explored previously in the combined intervention literature. However, physical activity alone has been shown to have significant, positive impacts on self-efficacy (Netz et al., 2005).

Inconsistencies of findings with respect to self-efficacy may be explained by intervention characteristics employed in the studies. Previous reviews have suggested that intervention characteristics such as the type of physical and cognitive intervention, as well as the intensity of the physical activity engaged in, have differential impacts on study results (Lauenroth et al., 2016; Northey et al., 2018; Zhu et al., 2016). Indeed, when it comes to improving cognitive abilities, the authors of one review found that the most efficacious studies were those incorporating both cardiovascular and strength training, with a cognitive component training either attention, executive function, or working memory, for at least 3 months (Lauenroth et al., 2016). Whether these intervention characteristics are equally desirable in improving everyday outcomes remains to be seen. Owing to sample size, intervention characteristics could not be explored with subgroup analyses in the meta-analyses. However, an exploratory and descriptive examination suggests that the intervention characteristics enhancing cognitive outcomes may not hold true for everyday outcomes. That is, regarding self-efficacy and activities of daily living, the two studies showing significant, positive results for the combined intervention (Mendoza-Ruvulcaba et al., 2015; Pieramico et al., 2012) varied in their treatment durations (8 and 24 weeks, respectively), their use of aerobic versus strength interventions (strength or aerobic, respectively), and the focus of the cognitive component (whether cognitive training or cognitive stimulation).

Research indicates that, according to older adults, the everyday impact of interventions is of primary importance (DiBenedetti et al., 2020; Watson et al., 2019), prompting calls to design interventions that look beyond traditional cognitive evaluations to also capture the changes impacting daily life (DiBenedetti et al., 2020; Harrison et al., 2016). A review of the literature revealed that many studies in this field did not look at outcomes beyond cognition. Lack of an everyday outcome was the primary reason for ineligibility in these analyses. For those studies that did include an everyday outcome, there was a great degree of clinical diversity in the outcomes assessed, including mood, activities of daily living, quality of life, and self-efficacy. The relative mismatch between the number of studies investigating combined interventions and the small subset evaluating generalizable outcomes underscores a need for more research investigating generalizability and transferability in the field (Law et al., 2014).

Together, the present findings reveal two areas of opportunity within the current literature, namely, greater investigation of everyday outcomes and greater consistency amongst the evaluated outcomes when they are examined. The development of consensus guidelines of everyday outcomes known to be susceptible to age-related changes and important to aging persons could address these two shortcomings. Such guidelines would ensure the regular evaluation of the generalizable impacts of cognitive aging interventions and serve as an initial step toward the goal of greater generalizability and transferability within this field. Further, the adoption of consensus guidelines would also allow for more consistency and comparability of outcomes across studies, facilitating quantitative evaluations to better evaluate efficacy and inform clinical recommendations. Naturally, the derivation of consensus guidelines requires the availability of a pool of measures that are psychometrically sound and routinely utilized. Per this review, the field may not be at this point currently, so this would be an avenue of future exploration.

This review establishes that when it comes to evaluating the everyday impact of combined interventions, more research is needed. On a theoretical level, I emphasize the importance of examining everyday outcomes, and doing so in a systematic way that facilitates comparability between studies. Incorporating everyday outcomes, which are prioritized by participants receiving these interventions (DiBenedetti et al., 2020; Watson et al., 2019), is a necessary step in the provision of person-centered care by creating interventions that match participants' expressed needs. For clinicians conducting these interventions, findings of this review reveal that combined interventions have a positive impact on participants' quality of life. Currently, the evidence suggests that combined interventions do not yield meaningful improvements in outcomes of depression, occupational and functional measures, and self-efficacy in comparison to controls. However, it is important to consider that the population of interest, healthy older adults, would be less likely to report high severity of issues in these domains so there would be less room for movement on the measurement scales (e.g., floor effects on depressive screening tools). It is also important to interpret these findings bearing in mind the heterogeneous nature of the control group, which consisted of both active and passive controls. Considering that exercise has been shown to improve mood (Penedo & Dahn, 2005), the lack of effect may be attributable to the incorporation of active control conditions in our comparison group.

There are methodological considerations in the current review that warrant addressing. Of the 13 studies included in this study, 6 were assessed as having high risk of bias using the EPHPP tool related to selection bias and masking. In terms of selection biases, many of the studies used convenience samples, recruiting primarily from research pools or local senior organizations. Two studies provided no information regarding recruitment methods. When convenience samples are distinct from the target population (e.g., participants in a research pool with proximity to a university versus older adults with opportunity to optimize management of modifiable risk factors for dementia), this can overestimate intervention effects and impact internal validity (Larzelere et al., 2004). For researchers, the use of convenience samples may be unavoidable for pragmatic reasons. One recommendation to limit the influence of selection bias is the use of specific statistical techniques when experimental design cannot be tailored (e.g., modelling for selection factors or controlling for pre-existing differences; Larzelere et al., 2004).

Masking was also a cause for high risk of bias ratings. To be conservative in estimates of bias, some studies were rated as high risk of bias in this domain because they did not report any masking procedures. Understandably, several articles disclosed that, due to the nature of the intervention, it was impossible to fully mask the experimental condition to the participant taking part in the intervention. However, there are alternative practices to be employed in situations and reporting practices when double-blinding is not feasible. For example, CONSORT guidelines suggest that in reporting the results of trials, authors not only disclose the type of masking practices utilized (e.g., single- or double-blinding) but also how the masking was achieved (Schulz et al., 2010). By offering a thorough description of masking procedures, this allows the reader to judge the risk of bias themselves, allowing studies that are otherwise strong methodologically to be evaluated as such (Schulz & Grimes, 2002). Even in open interventions where assignment is not concealed, efforts can be made to ensure that outcome assessors (particularly in cases where the outcomes are subjective) are masked to participant group (Day & Altman, 2000; Schulz & Grimes, 2002). Finally, in psychological interventions where participants are aware of the experimental manipulation, efforts can still be made to conceal the research question to help avoid response bias.

Strengths of this review include the efforts undertaken to conduct a comprehensive search of the research literature, particularly the inclusion of grey literature and the review of current trial registries. With these actions, the aim was to minimize the impact of publication bias and time-lag bias to accurately capture the existing evidence for our research question. However, by incorporating nonrandomized controlled trials, there is a limitation on the quality of evidence included, as randomized controlled trials are considered the gold-standard of intervention research. Another limitation of the current study was that the control comparison within the quantitative analyses was a combination of active and passive control groups. The heterogeneous nature of this comparison group was necessary due to the small number of studies available. Although we attempted to maximize homogeneity by selecting the most passive control condition across studies, for a subset of studies only active control groups were available. This is a limitation of the study in its current form as it impacts the interpretation of the meta-analytic results. Certainly, if combined interventions are not found to be efficacious as compared to active controls, that is a notably different take-away than a lack of effect when compared to a waitlist control group. It follows that one future direction of the current research, once a larger sample size of studies is available, is a sub-group analysis to decipher the relative impact of combined interventions when compared separately to passive and active control groups.

Conclusion

This is the first review to focus on the generalizable, everyday impact of combined interventions in healthy older adults. In this review, I examined outcomes in domains of mood, quality of life, activities of daily living, and self-efficacy. The meta-analysis revealed that combined interventions yield a small, positive effect on participants' quality of life compared to a mixed control comparison featuring both passive and active control groups. No effects were found on the other outcomes investigated. Results should be interpreted with due consideration of the limited number of studies available and moderate levels of bias risk. Future directions include the increased adoption of everyday outcomes in cognitive aging interventions to match participants' expressed needs and the use of consensus outcomes to reduce variability and increase comparability across studies.

Table 1

Characteristics of Included Studies

Study	Country	Design	Participants					
			Cognitive screening at recruitment	*N*	Age (mean years)	% Female	Education mean*	Recruitment
Andrieu et al. (2017)	France & Monaco	RCT	MMSE > 24 MMSE = 28	1525	75	65%	**	Patient databases and ads at conferences/local media
Desjardins-Crepeau et al. (2016)	Canada	RCT	MMSE = 29[1]	76	72[1]	70%	16[1]	Public advertisements and research subject pool
de Souto Barreto et al. (2021)	France	RCT	MMSE ≥ 24	120	74[1]	58%	***	Media campaigns or from an internal database
Eggenberger et al. (2015)	Switzerland	RCT	MMSE > 22 MMSE = 28[1]	71	79[1]	65%	n.i.	Newspapers, local organizations, residence facilities, & physicians
Eggenberger et al. (2016)	Switzerland	RCT	n.i.	33	75[1]	64%	14[1]	Newspapers, local organizations, residence facilities, & physicians
Gschwind et al. (2015)	Germany, Spain & Australia	RCT	Intact Mini-Cog	153	75	61%	11	Oral presentation, leaflets, & newspaper advertisements
Leś et al. (2019)	Poland	CCT	n.i.	61	80	100%	****	n.i.
McDaniel et al. (2014)	USA	RCT	CDR < 0.5	96	65[1]	64%	16[1]	Mass media, research subject pool & community efforts
Mendoza-Ruvalcaba et al. (2015)	Mexico	RCT	MMSE > 23	64	71[1]	89%	5[1]	Seniors' centers
Oswald et al. (2006)	Germany	CCT	n.i.	179	*	65%	*****	Local organizations, newspapers & presentations
Pieramico et al. (2012)	Italy	RCT	n.i.	30	60-75 years	50%	n.i.	n.i.

Shah et al. (2014)	Australia	CCT	MMSE > 24	222	68 years	69%	******	Research pools, private hospital, local media & public talks
Yu et al. (2020)	Hong Kong	RCT	n.i.	127	63 years	88%	n.i.	Community screening

[1]For studies presenting participant characteristics by group, weighted means were calculated.
Note. n.i. = no information; N refers to number of participants included in the analysis; RCT = randomized control trial; CCT = controlled clinical trial; MMSE = Mini Mental State Examination (Folstein et al., 1975); CDR = Clinical Dementia Rating (Morris, 1991); Mini-Cog (Borson et al., 2000)
Age is presented as mean years or as number of participants per age range; * 75-79 years (58.9%), 80-84 years (31.5%), 85-89(8.8%), 90-94 (0.8%)
Education presented as mean years or as number of participants per education level; ** no diploma or primary school certificate (n=334), secondary education (n = 511), high school diploma (n=218), university level (n=438);*** primary education (n = 3), secondary education (n=40), undergraduate or over (n=77); **** primary education (n=4), secondary education (n=47), vocational education (n=9), and higher education (n=1); ***** primary education (n=154, 41.1%), secondary school (n=147, 39.2%), university entrance (n=54, 14.4%), university graduates (n=20, 5.3%); ****** post-graduation (n=35)

Table 2

Intervention Characteristics of Included Studies

Study	Intervention characteristics		
	Group Description	Delivery Mode (Setting/Format)	Frequency/Duration/Length
Separate Interventions			
Andrieu et al. (2017)	**CPIsup[1]:** Cognitive training involved sessions on reasoning and memory. Physical training involved aerobic training (e.g., walking). **CPIplac:** Combined training with placebo supplements **Sup:** Took daily polyunsaturated fatty acid supplements **CG:** Took placebo capsules **Additional intervention components:** Nutritional supplementation and counselling	Mixed/Mixed	First two months, 12 sessions of 60 minutes cognitive and 45 minutes physical intervention. Then, five 30-minute sessions of physical activity per week for 3 years with 1-hour booster each month
Desjardins-Crepeau et al. (2016)	**PI:** Aerobic training (resistance and cardiovascular training with weights and treadmill, respectively). Also completed cognitive control (i.e., computer lessons) **CI:** Computerized visual dual task. This group also completed the physical control activity (low-intensity flexibility exercises) **CPI:** Participated in aerobic training and computerized visual dual task **CG:** Cognitive control was introductory lessons to computers. Physical control was low-intensity flexibility exercises	Institution/Group	Three 60-minute sessions per week (two physical, one cognitive) for 12 weeks
de Souto Barreto et al (2021)	**CPI:** Participants had access to a web multidomain platform. Exercise training involved strength and balance exercises directed by video and instruction for aerobic activity. Computerized cognitive training targeted executive functioning. **CG:** Participants were given an accelerometer (Fitbit) **Additional intervention components:** Participants in the intervention group had access to nutrition advice via 12 pre-recorded videos on the platform	Remote/Individual	Strength & balance exercises twice per week. Daily aerobic activity (lasting 6-30 minutes). Two 30-minute cognitive session per week. Intervention was 16 weeks.
Leś et al. (2019)	**PI:** Nordic walking (exercises aimed at improving aerobic capacity, joint stabilization, flexibility, increasing muscle strength and improving balance) **CPI:** Cognitive exercises targeting attention, working memory, visual memory, and executive functions, plus Nordic walking. **CG:** Remained on program waitlist but were able to continue participating in typical weekly activities organized by the day center	Institution/Group	Two 60-minute sessions per week for 12 weeks (for each component)
McDaniel et al. (2014)	**PI:** Aerobic training (either a stationary bike or treadmill with warmup and cool down exercises). Also completed the cognitive control (i.e., health education sessions)	Mixed/Mixed	Three 60-minute aerobic sessions per week for 24 weeks. Three cognitive

	CI: Cognitive training focusing on attentional control, prospective memory and recollection. Group also completed the physical control (i.e., at-home exercise program) **CPI:** Participated in both aerobic training and cognitive training. **CG:** Low-intensity home-exercise program with face-to-face health education sessions		sessions per week for the last 8 weeks
Mendoza-Ruvalcaba et al. (2015)	**CPI:** Group sessions involved physical activity (e.g., working on muscular strength, balance and mobility), 'reality orientation' (e.g., discussion of current events), and cognitive training (e.g., memory, attention and processing speed tasks) **CG:** Remained on program waitlist and did regular weekly activities organized by the senior center. **Additional intervention components:** Nutritional counselling	Institution/Group	Two 120-minute sessions per week for 8 weeks
Pieramico et al. (2012)	**CPI:** Group sessions involved brain training (e.g., puzzles and crosswords), and aerobic training (e.g., walking or dancing) **CG:** Waitlist control. **Additional intervention components:** Musical stimulation	Mixed/Mixed	Six 60-minute cognitive sessions and three 60-minute aerobic sessions per week for 24 weeks
Oswald et al. (2006)	**PI:** Training of balance, perceptual and motor coordination, and flexibility **CI1:** Cognitive training focusing on processing speed, attention and memory **CI2:** Psychoeducation aimed to help individuals cope with everyday life demands (e.g., falls prevention, compensatory tools) **CPI1:** Combination of the physical and cognitive training conditions **CPI2:** Combination of the physical and psychoeducation conditions **CG:** No treatment	Institution/Group	One 45-minute physical activity session and/or one 90-minute cognitive session per week for 30 sessions.
Shah et al. (2014)	**PI:** Resistance training for upper and lower body and walking. **CI:** Sessions of auditory-based Brain Fitness Program or visual-based Insight Program **CPI:** Both physical and cognitive interventions **CG:** No treatment. Continued with regular activities.	Remote/Individual	Five 40- to 60-minute physical activity sessions and/or five 60-minute cognitive sessions per week for 16 weeks
Yu et al. (2020)	**CPI:** Physical training was combination aerobic circuit and resistance training. Cognitive training was computer-assisted training via Branastic, which involved training in memory, attention, executive function, flexibility, and visuo-spatial ability. **CG:** Waitlist control **Additional intervention components:** Board games	Institution/Mixed	Two 60-minute exercise and two 30-minute cognitive sessions per week for 12 weeks
Simultaneous (Dual task) Interventions			
Eggenberger et al. (2015)	**PI:** Combination of aerobic, muscular strength, and balance exercises **CPI1:** Treadmill walking with simultaneous verbal memory training	Institution/Group	Two 60-minute sessions per week and 20 minutes balance for 24 weeks

	CPI2: Virtual reality video game dancing combining an attention-demanding cognitive action with a simultaneous motor coordination aspect		
Eggenberger et al. (2016)	**PI:** Consisted of conventional balance training and stretching **CPI:** Dance condition involved a dance exergame, combining attention demanding task with simultaneous motor coordination	Institution/Group	Three 30-minute sessions per week for 8 weeks
Gschwind et al. (2015)	**CPI:** Used the iStoppFalls program- an exergame platform. Exergames targeted balance while working on semantic and working memory on more advanced levels. Also completed strength exercises such as knee extensions and calf raises. **CG:** Received an educational booklet about falls prevention.	Remote/Individual	Three balance sessions (exergames) of 40 minutes each and three muscle strength exercises of 15-20 minutes each per week for 16 weeks.

Note. [1]CPIsup: combined with nutritional supplementation; CPIplac: combined with placebo; Sup: nutritional supplementation
CPI: Combined cognitive and physical intervention; PI: Physical intervention; CI: Cognitive intervention; CG: Control group

Table 3
Outcome Characteristics of Included Studies

Study	Outcome Characteristics	
	Outcome domain	Name, (external reference, if applicable), and description
Andrieu et al. (2017)	Mood	**Geriatric Depression Scale** (Yesavage et al., 1982): A 15-item self-report scale identifying depressive symptomatology in the elderly
	Activities of Daily Living	**Alzheimer's Disease Cooperative Study-Activities of Daily Living Prevention Instrument** (Galasko et al., 2006): A measure of activities of daily living and physical functioning (dependency) **Consequences in Everyday Life** (McNair & Kahn, 1983): A visual analogue scale assessing memory impairment in everyday life **Short Physical Performance Battery** (Guralnik et al., 2000): A physical performance measure predicting disability incidence
Desjardins-Crepeau et al. (2016)	Activities of Daily Living	**Physical Performance Test** (Reuben & Siu, 1990): An occupational measure assessing physical performance tasks simulating activities of daily living
de Souto Barreto et al. (2021)	Mood	**Geriatric Depression Scale** (Yesavage et al., 1982): A 15-item self-report scale identifying depressive symptomatology in the elderly
	QOL	**European Quality of Life 5 Dimensions** (Herdman et al., 2011): Questionnaire indexing health-related quality of life across five dimensions: mobility, self-care, daily activities, pain/discomfort, and anxiety/depression.
	Activities of Daily Living	**Short Physical Performance Battery** (Guralnik et al., 2000): A physical performance measure predicting disability incidence
Eggenberger et al. (2015)	Mood	**Geriatric Depression Scale- German version** (Gauggel & Birkner, 1999): German version of the Geriatric Depression Scale
	Self-Efficacy and Coping	**Falls Efficacy Scale International** (Yardley et al., 2005): An international scale evaluating concern of falling when performing activities of daily living without falling
Eggenberger et al. (2016)	Mood	Same as above
	Self-Efficacy and Coping	
Gschwind et al. (2015)	Mood	**Patient Health Questionnaire** (Kroenke et al., 2001): A nine item questionnaire for screening, diagnosing, monitoring and measuring the severity of depression
	QOL	**European Quality of Life 5 Dimensions** (Herdman et al., 2011): Questionnaire indexing health-related quality of life across five dimensions: mobility, self-care, daily activities, pain/discomfort, and anxiety/depression.
	Self-Efficacy and Coping	**Iconographical Falls Self Efficacy Scale** (Delbaere et al., 2010): Scale measuring participants' concerns about falling when participating in 10 daily activities

	Activities of Daily Living	**World Health Organization Disability Assessment Schedule (WHODAS) 2.0** (Üstün et al., 2010): Questionnaire assessing disability and functioning. Evaluates six domains of functioning including: cognition, mobility, self-care, getting along (interaction with other people), life activities (domestic responsibilities, leisure, work and school), and participation.
Leś et al. (2019)	QOL	**World Health Organization Quality of Life-Age** (Caballero et al., 2013): A measure evaluating quality of life in an aging population **Subjective Age**: Participants reported how old they felt
McDaniel et al. (2014)	Activities of Daily Living	**Cooking Breakfast task** (Craik & Bialystok, 2006): A computerized laboratory simulation of a cooking task **Virtual Week task** (Rendell & Craik, 2000): A computerized board game used to gauge everyday prospective remembering in the context of daily living
Mendoza-Ruvalcaba et al. (2015)	QOL	**Quality of Life Index** (Ferrans & Powers, 1992): A Spanish version of the quality of life index assessing general quality of life and its components (e.g., health and functioning, psychological/spiritual, socioeconomic, and family)
	Self-Efficacy and Coping	**Self-efficacy for physical activity:** Participants estimated the strength of their belief in their ability to perform regular physical activity **Self-efficacy for memory:** Participants estimated the strength of their belief in their ability to improve their memory abilities
Pieramico et al. (2012)	Activities of Daily Living	**Occupational Therapy Evaluation** (Fisher et al., 2007): A measure evaluating performances in activities of daily living activities related to motor and process skills
Oswald et al. (2006)	Mood	**Depression Scale** (Zung, 1965): A self-rated depression scale
	QOL	**Well-being** (Oswald & Fleischmann, 2002): A composite score of subjective aging, quality of life, and general well-being using the Neuropsychological Aging Inventory (Oswald & Fleischmann, 2006) **Health status:** A composite score of objective (a clinical assessment of organ functions and laboratory tests including blood count and cholesterol) and subjective health (self-rating of perceived health)
	Self-Efficacy and Coping	**Everyday competence:** Interviewer-rated measure of how participants cope with age-related problems
	Activities of Daily Living	**Independent living**: Participants were asked about their ability to complete activities of daily living with or without assistance. A composite score was devised between a participant's self-rating and the interviewers rating.
Shah et al. (2014)	Mood	**Hospital Anxiety & Depression Scale** (Zigmond & Snaith, 1983): Self-report scale assessing anxiety and depression. Depression effect listed above, anxiety below.
	QOL	**RAND-36 Health Survey** (Ware & Gandek, 1998): Short-form health survey examining physical and mental health for a measure of health-related quality of life.
	Self-Efficacy and Coping	**Memory Functioning Questionnaire** (Gilewski et al., 1990): Self-report measure of everyday memory functioning
Yu et al. (2020)	QOL	**Self-rated Health:** Participants were asked to self-rate their health on a scale of excellent, very good, good, fair, or poor **Life satisfaction**: Participants were asked to rate their satisfaction with life on a linear scale

Note. IL: Independent living, QOL: Quality of life, n.c. = not calculable (data not available)
For all effects above, except those assessing mood, positive effect values favor the combined intervention. For depression measures, negative values favor the combined intervention.

Figure 1

PRISMA Flow Diagram for the Study Selection Process

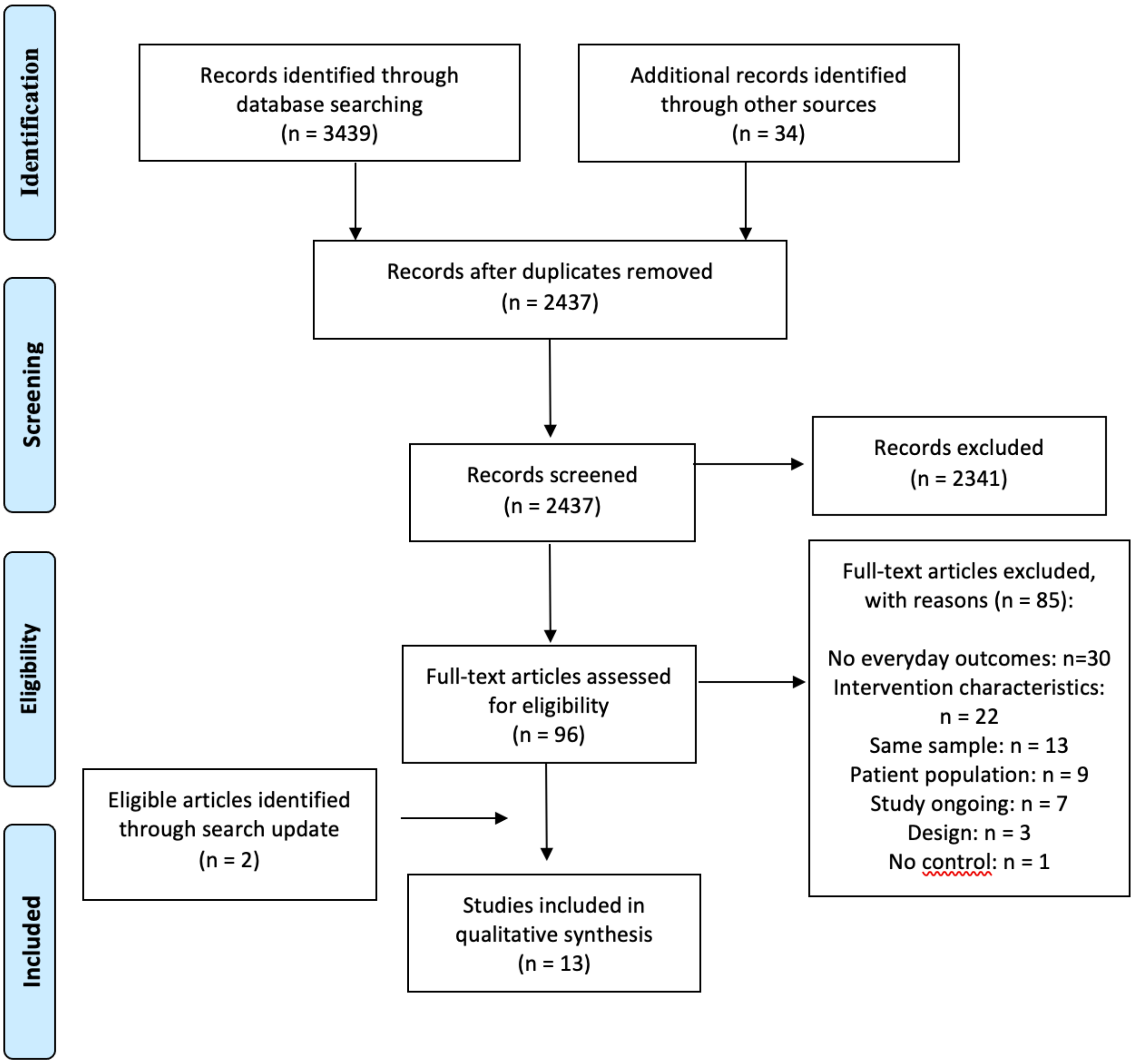


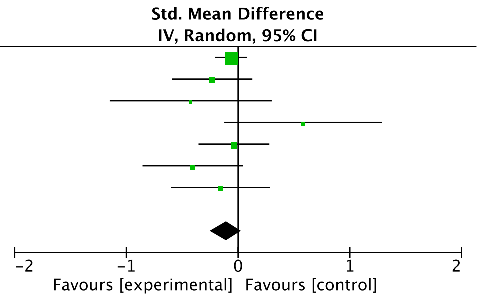
Figure 2

Meta-Analyses Results

Depression

Study or Subgroup	Weight	Std. Mean Difference IV, Random, 95% CI
Andrieu 2017	45.9%	−0.06 [−0.20, 0.08]
De Souto Barreto 2020	13.0%	−0.23 [−0.59, 0.13]
Eggenberger 2015	3.6%	−0.42 [−1.15, 0.30]
Eggenberger 2016	3.8%	0.58 [−0.12, 1.29]
Gschwind 2015	16.0%	−0.04 [−0.35, 0.28]
Oswald 2006	8.8%	−0.41 [−0.86, 0.04]
Shah 2014	8.9%	−0.16 [−0.60, 0.29]
Total (95% CI)	**100.0%**	**−0.11 [−0.25, 0.03]**

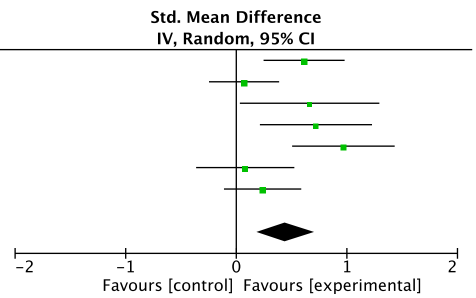
Heterogeneity: $Tau^2 = 0.01$; $Chi^2 = 7.11$, df = 6 (P = 0.31); $I^2 = 16\%$
Test for overall effect: Z = 1.50 (P = 0.13)



Quality of Life

Study or Subgroup	Weight	Std. Mean Difference IV, Random, 95% CI
De Souto Barreto 2020	16.1%	0.61 [0.25, 0.98]
Gschwind 2015	17.4%	0.07 [−0.25, 0.39]
Les 2019	9.9%	0.66 [0.03, 1.29]
Mendoza- Ruvulcaba 2015	12.5%	0.72 [0.21, 1.23]
Oswald 2006	13.5%	0.97 [0.50, 1.43]
Shah 2014	14.0%	0.08 [−0.36, 0.52]
Yu 2020	16.5%	0.24 [−0.11, 0.59]
Total (95% CI)	**100.0%**	**0.45 [0.19, 0.71]**

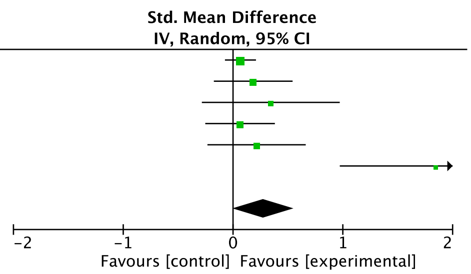
Heterogeneity: $Tau^2 = 0.08$; $Chi^2 = 16.24$, df = 6 (P = 0.01); $I^2 = 63\%$
Test for overall effect: Z = 3.35 (P = 0.0008)



Activities of Daily Living

Study or Subgroup	Weight	Std. Mean Difference IV, Random, 95% CI
Andrieu 2017	25.9%	0.07 [−0.07, 0.21]
De Souto Barreto 2020	18.9%	0.18 [−0.17, 0.54]
Desjardins-Crepeau 2016	11.4%	0.34 [−0.28, 0.97]
Gschwind 2015	20.3%	0.06 [−0.25, 0.38]
Oswald 2006	16.1%	0.21 [−0.23, 0.66]
Pieramico 2012	7.4%	1.85 [0.97, 2.72]
Total (95% CI)	**100.0%**	**0.27 [−0.00, 0.55]**

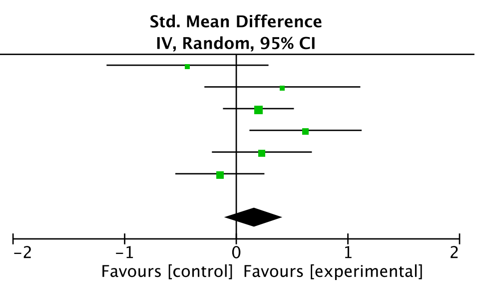
Heterogeneity: $Tau^2 = 0.07$; $Chi^2 = 16.40$, df = 5 (P = 0.006); $I^2 = 70\%$
Test for overall effect: Z = 1.95 (P = 0.05)



Self-Efficacy and Coping

Study or Subgroup	Weight	Std. Mean Difference IV, Random, 95% CI
Eggenberger 2015	9.7%	−0.44 [−1.16, 0.29]
Eggenberger 2016	10.2%	0.41 [−0.29, 1.11]
Gschwind 2015	25.1%	0.20 [−0.12, 0.52]
Mendoza- Ruvulcaba 2015	16.0%	0.62 [0.12, 1.12]
Oswald 2006	18.3%	0.23 [−0.22, 0.68]
Shah 2014	20.6%	−0.15 [−0.55, 0.25]
Total (95% CI)	**100.0%**	**0.16 [−0.10, 0.42]**

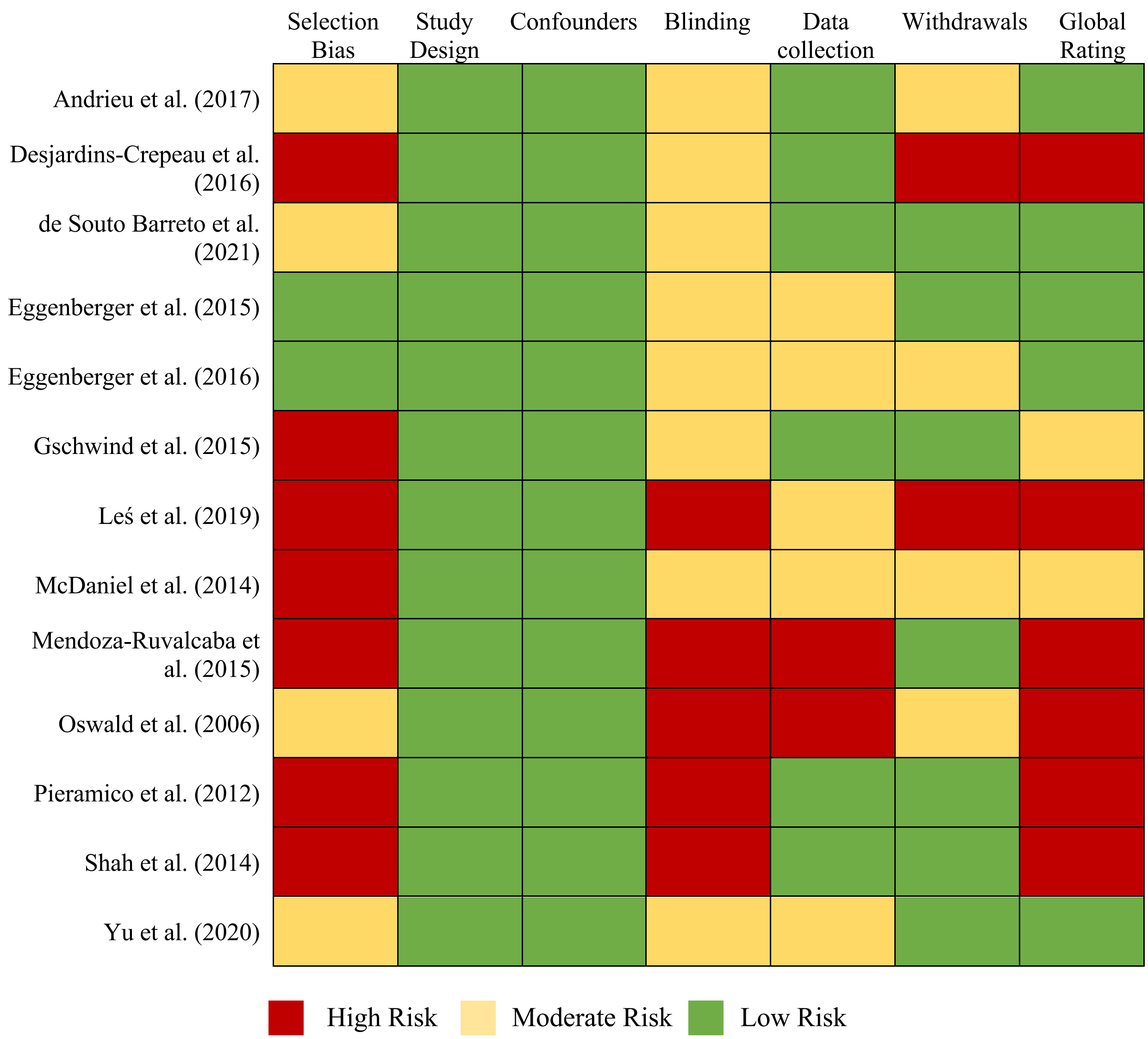
Heterogeneity: $Tau^2 = 0.04$; $Chi^2 = 8.75$, df = 5 (P = 0.12); $I^2 = 43\%$
Test for overall effect: Z = 1.22 (P = 0.22)



Note. Except for depression, positive effect sizes favour the combined intervention. Negative effect sizes indicate a decrease in depressive symptoms, favouring the combined intervention.

Figure 3

EPHPP Study Quality Ratings



CHAPTER 3

Introduction

Research investigating the efficacy of combined interventions has proliferated in recent years, as demonstrated by the number of reviews in the field (Bruderer-Hofstetter et al., 2018; Law et al., 2014; Malmberg Gavelin et al., 2021; Zhu et al., 2016). Such increased interest levels are certainly warranted, considering that combined interventions address multiple modifiable risk factors associated with cognitive impairment and dementia and are proposed to work synergistically, counteracting age-related changes within the brain (Phillips, 2017). Moreover, recent reviews indicate that combined interventions are effective in improving cognitive outcomes (Law et al., 2014), perhaps more so than unimodal approaches (Bruderer-Hofstetter et al., 2018; Malmberg Gavelin et al., 2021; Zhu et al., 2016).

In their meta-analysis (involving 20 studies and 2667 participants), Zhu and colleagues reported that combined interventions showed significantly greater effects on cognitive outcomes in healthy older adults than control groups participating in physical activity (2016). Yet, combined interventions were not more efficacious than cognitive interventions (Zhu et al., 2016). Later reviews (featuring 11 studies and 670 participants with normal cognition, and 30 studies and 2866 healthy older adults, respectively) indicated that combined interventions were superior to cognitive or physical training alone on outcomes of global cognition and physical outcomes (Bruderer-Hofstetter et al., 2018; Malmberg Gavelin et al., 2021). Finally, in the previous chapter we also found that combined interventions have positive impacts on everyday functioning. Specifically, when compared to both active and passive controls, combined interventions yield improvements in quality of life.

Notably, most of this research has focused on intervention efficacy, not effectiveness. Efficacy studies evaluate interventions delivered under optimal conditions, which are often highly constrained, time-limited interventions with homogenous samples (Cicerone et al., 2000; Flay et al., 2005). Effectiveness trials, by contrast, are studies conducted in real-world conditions and may involve clinical judgment and strategic modification in clinical settings (Cicerone et al., 2000; Flay et al., 2005). Efficacy and effectiveness studies also differ concerning the level of researcher control over study implementation, with the former utilizing strict standards to minimize potential confounding factors (Gottfredson et al., 2015). Often, particularly with research involving older adults, the minimization of confounds results in a research sample that is quite removed from the target population: younger and without comorbid health conditions otherwise ubiquitous in the demographic (Zulman et al., 2011). Although efficacy studies play a pivotal role in the development and evaluation of evidence-based interventions, a lack of the explicit acknowledgment of study parameters with which efficacy was shown (including the settings, population, time, intervention, and outcome) can lead to a false sense of generalizability and an overestimation of an intervention's potential (Gottfredson et al., 2015).

Given the preponderance of efficacy research, an evaluation of intervention effectiveness using real-world interventions is timely to ask critical questions of ecological validity and generalizability. That is, there is a need to evaluate whether combined interventions are effective in community-based settings using interventions that are accessible and replicable. The focus of this study is the development and evaluation of such an intervention.

Study Components

In their most recent statement, the Society of Prevention Research outlines standards for effectiveness research (Gottfredson et al., 2015). These standards include: (a) the replication of a previous efficacy trial; (b) intervention description; (c) generalizability; (d) population subgroups; (e) intervention tested; (f) outcomes measured; and (g) effectiveness claims. Within these standards, intervention description, generalizability, and outcomes measured, were of particular focus when choosing the study components for our combined intervention as they were areas of opportunity identified in the previous chapter through the systematic review.

Regarding intervention description, the standards of effectiveness research require that manuals or training and support be available so that the intervention can be replicated. To meet this standard, I selected components that were either manualized or for which we could provide clear details of study processes to enable replication. The standard of generalizability requires that the target population and settings be explained and representative of the population for future dissemination. Pertaining to generalizability, intervention components were selected that could readily be administered within community settings with healthy older adults. Finally, the last standard we focused on in this study was study outcomes for which the effectiveness standards require that intervention effects must be practically important. For this, I chose intervention components that have previously shown effects on outcomes of practical importance (both to the participant and with practical significance in terms of public health), conforming to the suggested standard of outcomes measured.

Cognitive Intervention

Unlike specific skills training, strategy-based cognitive interventions (Cavallini et al., 2010; Hastings & West, 2009) aim to enhance everyday memory abilities by teaching participants to use strategies for learning and remembering information. Such empirically supported strategies include techniques such as rehearsal, categorization, visual imagery, and association. Research indicates that such memory training can improve objective memory performance in cognitively normal older adults (Verhaeghen et al., 1992; Zehnder et al., 2009), but this is not always a consistent finding (Martin et al., 2011).

In addition to objective gains, memory-strategy training interventions have been shown to yield significant benefits in participant-reported outcomes such as quality of life, psychological well-being, and metamemory (Hudes et al., 2019). The term metamemory encompasses subjective factors impacting memory including personal knowledge, beliefs and perceptions of one's memory abilities (Valentijn et al., 2005). Gains in metamemory are themselves important moderators in everyday memory functioning (Valentijn et al., 2005).

The Memory and Aging Program®, a multidimensional behavioural memory intervention, has been shown to mitigate some of the personal and societal burdens of age-related changes. That is, participants of the Memory and Aging Program show increased confidence surrounding memory-related concerns (Vandermorris et al., 2017) and demonstrate a reduced intention to seek unnecessary medical care (Wiegand et al., 2013). The program is also associated with increased knowledge about memory (i.e., facts about memory and memory strategies) and greater implementation of memory strategies and healthy lifestyle behaviors (Troyer, 2001; Vandermorris et al., 2020; Wiegand et al., 2013). The program is multidimensional in its provision of education about memory and memory change, training in the use of memory strategies, and coaching for the adoption of healthy lifestyle behavior changes (Vandermorris et al., 2020; Wiegand et al., 2013).

The Memory and Aging Program is distinct from the types of cognitive training most often used in combined interventions. To begin, the program is more holistic in nature, relying less on specific skills training and instead using a mix of psychoeducation, memory strategy training, and subsequent practical application. This focus on more generalized skills and knowledge, as opposed to domain-specific skills, addresses a gap in the research literature. Outcomes of the Memory and Aging Program have also proven to be generalizable, impacting affect and everyday behaviors (Vandermorris et al., 2020; Wiegand et al., 2013). The Memory and Aging Program is also an apt choice as the cognition-oriented component in our combined intervention when one considers that combined interventions show more significant benefit in individuals without clinically determined neurocognitive deficits (Bamidis et al., 2015), the target demographic for this group intervention (Troyer et al., 2001).

Physical Activity Intervention

Physical activity robustly contributes to physical, cognitive, and mental health (Colcombe & Kramer, 2003; Hötting & Röder, 2013; Penedo & Dahn, 2005). However, only one in five adults participates in the recommended amount of daily physical activity (Center for Disease Control and Prevention, 2014). These rates are even lower in older adults as physical activity adherence decreases with age (Schoenborn et al., 2013). Poorer physical activity adherence in this demographic is significant given a host of research showing that exercise may work to preserve everyday cognitive function and maintain structural and functional brain health in older adults (Erickson et al., 2011; Voss et al., 2010). Thus, although the impact of exercise is well researched, there is a need for a greater understanding of how activity levels can be feasibly increased at the population level.

The incongruence between the benefits of activity and levels of adherence may be attributable to several barriers encountered by older adults (Schutzer & Graves, 2004). Surprisingly, lack of awareness of physical activity's benefits and a tendency to see it as leisure rather than health promotion is a frequent barrier (Chao et al., 2000; Hui & Morrow, 2001; Schutzer & Graves, 2004). Other barriers include fear of falling, lack of planning, perceived frailty, and lack of time (Booth et al., 2000; Krebs & Duncan, 2015; Schrack et al., 2016; Schutzer & Graves, 2004; Sullivan & Lachman, 2017).

Activity trackers, or fitness bands, may offer a solution to the problem of poor adherence to exercise recommendations (Sullivan & Lachman, 2017). They have beneficial impacts on activity levels (Cadmus-Bertram et al., 2015; Rowe-Roberts & Cercos, 2014), metrics of physical health (such as body mass index and heart rate; Rowe-Roberts & Cercos, 2014), and mental health (Kerr et al., 2008). Features such as rewards, feedback, and the ability to self-monitor serve to increase motivation and self-efficacy (Karapanos et al., 2016; Kurti & Dallery, 2013) and thus contribute to more enduring effects (McAuley & Blissmer, 2000; Neupert et al., 2009; Sullivan & Lachman, 2017). Indeed, feedback, self-monitoring, and goal setting (which are elements of activity trackers' use) are vital constituents in lifestyle behavioural change (Greaves et al., 2011; Michie et al., 2009).

Trackers can achieve similar benefits as large-scale physical activity interventions (Mansi et al., 2015). For example, in one study where employees were given the opportunity to purchase an activity tracker at a reduced rate, participants made significant positive changes, such as increasing their step count, managing weight, and reducing health risks (Rowe-Roberts & Cercos, 2014). Notably, participants achieved these changes even without formal intervention or goal setting. Similarly, another study showed that participants who self-monitored with an activity tracker only made significant gains in moderate to vigorous intensity activity over the course of 6 weeks, even without the provision of SMS prompts (Wang et al., 2015)

Despite the numerous benefits of activity trackers, their use is limited mainly to younger or middle-aged adults (Comstock, 2014), with only 3.3% of users over the age of 65 (Wurmser, 2019). However, there are several features of activity trackers that may make them particularly beneficial for older adults. Features such as prompts and stepwise goal-setting may minimize cognitive load in prospective memory, planning, and shifting, all of which are impacted by aging (Conn et al., 2003; Craik, 1994; Glass et al., 2000; Miyake et al., 2000). Trackers also address barriers to physical activity that older adults encounter. Chao and colleagues found that the time commitment of physical activity was often perceived as too great by older adults, especially when factoring in commuting time to an exercise facility (2000). By capturing walking and activities of daily living, trackers minimize this barrier by encouraging activities that older adults are more likely to engage in (Schrack et al., 2015). Overall, trackers have several features that may compensate for cognitive changes and address several identified barriers to physical activity in this demographic.

The Current Study

Combined interventions have been shown to be efficacious in conventional research settings. This empirical study aimed to devise a real-world combined intervention in a community setting and evaluate its effectiveness. To create a combined intervention, we used Fitbit activity trackers as an added physical component to the multidimensional Memory and Aging Program. The combined intervention was analyzed using mixed methodology, in which we triangulated data from qualitative and quantitative measures to evaluate feasibility and acceptability, program outcomes, and relative efficacy compared to current best standards of treatment.

Study Aims

This study aimed to devise and evaluate the effectiveness of a combined, community-based intervention. To evaluate the program, we investigated the feasibility of our intervention in a population of older adults with subjective memory concerns and examined its acceptability (i.e., whether it was "suitable, satisfying, or attractive" to participants, Bowen et al., 2009, p. 454). We were also interested in whether the combined intervention led to increased exercise among participants and whether participants gained knowledge about memory and aging or initiated other lifestyle changes. Finally, we investigated relative efficacy to see whether the benefits gained in this combined program were superior to the original program or waitlist comparison. From a public health perspective, it was prudent to investigate relative efficacy to determine whether the additional costs, financial or administrative, of a combined intervention are warranted, especially considering that combined approaches have frequently been touted as superior based on findings from efficacy studies.

Research Questions

There were three research questions of principal interest for this study:

Question 1: Feasibility & Acceptability. Is the combined program feasible to be implemented as designed and acceptable for participation according to older adults?

Question 2: Primary Program Outcomes. How did the combined program impact participants' activity levels, lifestyle behaviours, and knowledge about memory and aging?

Question 3: Relative Efficacy. How does the combined intervention perform compared to current treatment alternatives (the original program or a waitlist comparison) on outcomes of metamemory, psychological well-being, and health and wellness?

Hypotheses

Hypothesis 1. The combined program will be feasible to conduct as measured by acceptable rates of enrolment in the program, rates of attrition, and activity tracker adherence (days worn and the number of weeks in which participants met their goals) relative to similar programs in the extant literature. Participants will evaluate the program as acceptable based on qualitative feedback eliciting participants' reactions to the program, including program satisfaction, features that they liked or disliked, and whether they saw the combined intervention as cohesive.

Hypothesis 2. The combined program will be successful in achieving its two primary goals (a) promoting a more physically active lifestyle as measured by increased step counts, decreased sedentary behaviour, and qualitative feedback of lifestyle change, and (b) increasing knowledge about memory and aging and use of practical memory strategies to manage memory changes, as measured by a memory knowledge quiz and metamemory measures.

Hypothesis 3. Compared to the original Memory and Aging program and a passive, no-treatment comparison group, we hypothesize that participants in the combined intervention will show gains in domains of metamemory, measures of psychological well-being, and metrics of health and lifestyle behaviors. We hypothesize that gains for the combined intervention will be most prominent on measures of psychological well-being, considering the addition of physical activity in the combined intervention and reported positive associations between physical activity and psychological outcomes (Netz et al., 2005). We do not hypothesize changes in objective memory measures given the short nature of the intervention however, due to previous studies showing a positive impact on memory outcomes (Zhu et al., 2016), we evaluated objective memory as an exploratory analysis.

Methods

Participants

Community-dwelling, older adults who were registered for the Memory and Aging Program and had indicated an interest in research involvement were contacted and screened for eligibility for the study. Recruitment for the Memory and Aging Program consisted of physician referrals, word-of-mouth recommendations, and newspaper advertisements.

Inclusion and Exclusion Criteria

Participants were assessed for study eligibility via telephone. To be included, participants were required to be older than 50 years of age, available for all testing sessions, and eligible for participation in increased physical activity. To determine participants' readiness for engagement in exercise, they filled out the Physical Activity Readiness Questionnaire (PARQ+; Warburton et al., 2011). Participants who endorsed comorbid health conditions on the PARQ+ were required to obtain physician consent before starting the intervention to ensure medical clearance.

Our third research question, evaluating the relative efficacy of the combined intervention compared to current treatment alternatives, utilized participant data from a past randomized control trial (RCT; Vandermorris et al., 2020). To ensure comparability between samples, we restricted our sample for these relative efficacy analyses to those participants also meeting the eligibility criteria of the RCT. Exclusionary criteria included: (a) health conditions with significant effects on cognition, including a current or previous history of stroke, brain surgery, or diagnosed neurological disorder; (b) dependence in instrumental activities of daily living; (c) cognitive impairment, defined as performance below the cut-off for cognitive impairment on the Telephone Interview for Cognitive Status test (Brandt et al., 1988); and, (d) affective impairment, defined as performance below the cut-off for depression on the Geriatric Depression Scale, 5-item short form (Hoyl et al., 1999).

Study Procedure

Research Ethics Board Approval

This single-site trial took place at Baycrest Health Sciences, an academic geriatric medical center in Toronto, ON. The Research Ethics Boards approved all study procedures at Baycrest Health Sciences (Approval Number: 18-48) and York University (Certificate Number: e2019-257).

Data Collection Timeline

For the combined intervention, participants were recruited between January and October 2019. The program was offered five times throughout this period: starting in January, March, May, June, and October based on the typical schedule for the Memory and Aging Program established by the host institution. As mentioned, data to evaluate relative efficacy were collected in a previous RCT for which data collection took place between March 2014 and June 2015 (Vandermorris et al., 2020).

Study Design

Testing Sessions

The total study duration was 12 weeks extending from the baseline session to the follow-up assessment. There were three testing sessions in total. At each session, participants completed a battery of standardized measures (detailed below). The introductory session was the longest in duration as it also included the collection of informed consent, introduction of the activity tracker, and discussion of resources (detailed below). Once the cognitive intervention was complete (after 5 weeks), a post-test session occurred. Six weeks later, the follow-up testing session was conducted. A graphical depiction of this study timeline can be found in Figure 4. At the follow-up session, in addition to the standard testing battery, participants took part in a semistructured qualitative interview. Testing sessions ranged in length according to session number and individual differences but generally took about an hour and a half.

Introductory Session and Resources. The baseline session occurred in the week before the start of the Memory and Aging Program. During this session, research assistants aided participants in setting up their device accounts and demonstrating the use of their new activity trackers. In addition to this hands-on introduction, participants were given a 'Fitbit Wiki' which was a PDF document with illustrated step-by-step instructions reviewing the tracker's use (e.g., how to synchronize or charge the device). There were three formats of the Wiki--for Android devices, Apple devices, and computers--to ensure that visual illustrations were comprehensive and compatible with the technological platform participants were using.

Some research suggests that simply wearing a fitness band serves as a reminder to engage in greater activity levels (Thompson et al., 2014). Other research indicates that action planning and barrier identification are necessary to ensure effective use of trackers in this population (Robinson & Lachman, 2016). To target this, each participant was also provided with an informational booklet detailing recommended activity amounts and activity types (including modifications for individuals with mobility issues) created by the Ontario Brain Institute (2014). This booklet contained a resource to aid in problem-solving and goal-setting to help to address known physical activity barriers in older adults (Schutzer & Graves, 2004). The booklet also featured a section on action planning with implementation intentions where participants are asked to outline how and when their physical activity goals will be achieved. It also included barrier identification (e.g., anticipating obstacles such as poor weather) which is specifically helpful for inactive vulnerable adults (i.e., adults who are older or with lower socioeconomic status; Sullivan & Lachman, 2017). These additional resources were provided because action planning with implementation intentions is not a feature typically offered by common activity trackers themselves (Conroy et al., 2014; Mercer et al., 2016).

Cognition-Oriented Intervention

The cognition-oriented intervention, the Memory and Aging Program, and testing sessions were conducted in person at Baycrest Health Sciences, Toronto. This manualized intervention consists of five weekly 2-hour sessions (Troyer & Vandermorris, 2012). As mentioned, the program is multidimensional in nature, providing psychoeducation about memory and memory change, training in the use of memory strategies, and coaching for the adoption of healthy lifestyle behavior changes (Vandermorris et al., 2020; Wiegand et al., 2013.) Details regarding the development and evaluation of this program have been published previously (Troyer, 2001; Weigand et al., 2013; Vandermorris et al., 2020).

Physical Activity Component

Engagement in physical activity was done entirely remotely and independently. Participants engaged in physical activity on their own time in locations of their choosing that were readily accessible to them (e.g., local gyms, at home, parks, etc.). As part of the combined intervention, participants were given a FitBit Alta HR at the baseline session and asked to wear the device continuously for the duration of the study. Participants were to wear the activity tracker without making changes to their physical activity levels for the first week (between the baseline and initial cognitive intervention session) to establish a baseline. Participants were then encouraged to attain the recommended amount of daily physical activity as per the Canadian Society for Exercise and Physiology (Tremblay et al., 2011). For adults over the age of 50, the recommendation is for 150 minutes of moderate-vigorous intensity aerobic physical activity per week, in sessions of 10 minutes or more, as well as two sessions of muscle and bone strengthening per week. The society distinguishes between adults aged 18-64 and those aged 65 and over in their recommendations. For these two groups, the amount of recommended activity time is the same. However, the type of activity (e.g., cross-country skiing for younger adults vs. swimming for older adults) is different.

Weekly Check-Ins

The first week of activity tracker wear established an activity baseline for each participant. Beginning in the second week, research assistants contacted participants weekly either by email or phone to set new goals and to offer technical assistance if necessary. Participants were encouraged to make gradual changes (i.e., adding 10% to their average daily step count) towards a recommended step target for older adults (approximately 5000 steps; Tudor-Locke et al., 2011). For participants who exceeded this target at baseline, gradual changes of 10% per week were also encouraged. Targets were not to exceed 10,000 steps a day as this is more than sufficient to meet daily moderate activity recommendations, particularly for older adults (Tudor-Locke et al., 2011). Participant step count was monitored remotely by research assistants via the activity tracker dashboard (Fitbit.com). If participants did not meet their step goal for 4 out of 7 days, the goal remained the same for the following week and was not increased. This measured approach to goal setting ensured that participants experienced a sense of mastery in achieving their smaller goals to build momentum towards their larger goals (Sullivan & Lachman, 2017).

In addition to the communication detailed above, a research assistant was also available in person to provide technical support or study clarification at the Memory and Aging Program. This additional support was offered for the duration of the cognitive intervention (the first 5 weeks of the study) to ensure participants were comfortable using their devices and promptly addressing any difficulties.

Measures

Demographic Data and Descriptive Measures

Basic demographic data, including age, gender, and education, were obtained through self-report questionnaires completed during the telephone screening call. At this time, participants also provided information as to the nature and impact of their subjective memory concerns. During the initial testing session, participants filled out self-report questionnaires querying their comfort level with different aspects of technology and whether they had previous experience with Fitbits or other physical activity trackers.

Feasibility and Acceptability

With due consideration of the additional expectations of a combined intervention upon participants, we were interested in evaluating aspects of feasibility pertaining to demand, implementation, and acceptability of our intervention (Bowen et al., 2009; Wang et al., 2006). That is, we were interested in determining the level of interest in the program and rate of participation, and the extent to which the program could be successfully delivered in this context (Bowen et al., 2009; Wang et al., 2006). Within the current study, we operationalized this by examining quantitative metrics of recruitment, retention, and adherence to the intervention.

Recruitment was assessed by how many participants were ultimately enrolled versus how many individuals expressed interest in the intervention (Cullen, 2019; Male, 2020). Retention was evaluated by examining the number of participants who completed the study versus the originally enrolled number (Cullen, 2019; Male, 2020). In our determination of feasibility, we also evaluated intervention adherence levels and participant perceptions of acceptability akin to a previous study (de Souto Barreto et al., 2021). Adherence to the physical activity intervention was measured by the number of days participants wore their activity trackers for a minimum of 1000 steps (Hardcastle et al., 2020) and the number of weeks participants met their set goals. Acceptability was evaluated using feedback from qualitative interviews, which included participants' sentiments of satisfaction, features that they liked or did not like about the program, and suggestions for improvement.

Outcome Measures

A list of all outcome measures can be found in Table 4.

Primary Program Outcomes. The primary outcomes of interest for our within-groups analyses were participants' activity levels, sedentary behavior and knowledge about memory and aging.

Physical Activity Measures. Daily step counts obtained via the activity tracker dashboard were recorded and averaged weekly as an objective indicator of physical activity. We also examined tracker-recorded sedentary behaviour as physical activity and sedentary behaviour have been found to impact cognition and well-being independently via distinct mechanisms (Voss et al., 2014). Sedentary behavior was defined using the Fitbit, which calculated minutes where no movement was detected.

Memory Measures. A modified version of the Memory Knowledge Quiz (Troyer, 2001; Troyer & Vandermorris, 2012) was used to assess knowledge about memory processes, age-related changes, and memory strategies. Modifications involved a shorter length of questionnaire with the removal of questions pertaining to basic brain anatomy and stress hormones.

Relative Efficacy Outcomes. When assessing relative efficacy compared to no-treatment or best-treatment alternatives, we examined outcomes in several domains known to show changes in combined interventions, including objective memory, metacognition, psychological well-being, and health and lifestyle measures. In this study, we were also interested in examining whether this combined intervention yielded benefits in subjective memory performance, a predictor of functional status (Valentijn et al., 2005).

Metamemory Measures. The Multifactorial Memory Questionnaire (Troyer & Rich, 2002) was used to quantify self-perceived memory. This measure comprises three scales, evaluating subjective memory ability, memory strategy use, and satisfaction with memory performance. A previous modification (Vandermorris et al., 2020) of the Memory Strategy Toolbox (Troyer, 2001) was also used to quantify behaviour change in memory-dependent everyday situations.

Objective Memory Measures. In the surname learning task (based on Troyer et al., 2006), 12 surnames are presented visually (via a projector) at the rate of one name every 5 seconds. Written free recall was used to quantify objective performance on this memory task.

Psychological Well-being Measures. The Positive and Negative Affect Schedule (Watson et al., 1988) was employed to assess self-perceived psychological well-being. Self-perceived global self-efficacy was quantified using the Generalized Self-Efficacy Scale (Schwarzer & Jerusalem, 1995).

Health and Lifestyle Measures. The RAND 36-Item Short-Form Health Survey (Ware & Sherbourne, 1992) provides summary scores of physical and mental health, reflecting health-related quality of life (Ware & Gandek, 1998). Changes in healthy lifestyle behaviours were quantified using the Health Promoting Lifestyle Profile II (Walker et al., 1987).

Qualitative Feedback

Semistructured qualitative interviews were conducted to elicit feedback regarding program feasibility, acceptability, and primary program outcomes. We were also interested in learning about how participants interacted with the program. In addition, interview questions were tailored to assess changes in perception in the main content domains of the combined intervention (i.e., lifestyle and behaviour change, physical activity change, and knowledge about memory). This script was adapted as the interviews were conducted, employing a theoretical sampling approach (Francis et al., 2010). The semistructured script is included in Appendix B.

Preliminary qualitative analyses were conducted concurrently with data collection, and collection ended when data were deemed theoretically saturated (i.e., when no new information was gained from additional interviews). Previous research indicates that this point of saturation is typically encountered with a participant sample size of 15 (Francis et al., 2010; Guest et al., 2006). With ongoing analyses, our data were deemed saturated at a similar point, so qualitative data collection ceased after the fourth cohort was completed for a total of 18 participants.

Quantitative Analyses

Power Calculations

Previous evaluations of the Memory and Aging Program have found average effect sizes in the medium to large range (d = 0.6 to 0.7). A meta-analysis evaluating the impact of exercise found a medium effect (d = 0.5) for short interventions (lasting less than 3 months) on measures of cognition (Colcombe & Kramer, 2003). With a desired power of .9 and an anticipated moderate effect size (d = 0.5, given the length of our intervention), the target sample size for a repeated-measures ANOVA was 18 participants (as calculated using G*Power version 3.1; Faul et al., 2007).

Data Preparation

Data were explored visually and quantitatively to detect the presence of outliers and deviations from normality. Violations of sphericity were addressed using the Huynh-Feldt adjustment for degrees of freedom (Abdi, 2010; Huynh & Feldt, 1976). Statistical outliers were winsorized with the value modification method (Field, 2013; Kwak & Kim, 2017). Levene's test was used to evaluate homogeneity of variance. Variables not meeting this assumption were transformed with a square root transformation. Effect sizes were calculated using partial eta squared for higher-order interaction effects and using Cohens' *d* for pairwise contrasts. Interpretations of effect sizes were based on research by Fritz and colleagues (2012). Analyses were conducted using IBM SPSS Statistics 27 for MAC.

The data of two participants who dropped out of the combined intervention were not analyzed because the intervention was not completed and the reasons for withdrawal were unclear or compromised their eligibility (i.e., a participant diagnosed with dementia). With that in mind, there were no missing data for the primary outcomes of participants included in the analysis. Regarding the relative efficacy analyses, there were 192 missing values of the possible 4, 272 (4.5%, based on 89 participants, 16 measures, and 3 testing sessions). Most participants (n = 78, 88%) had no missing values.

Analyses were conducted to detect patterns of missing data related to baseline covariates (e.g., sex, Telephone Interview for Cognitive Status score, age, level of memory concerns) or group differences (Dziura et al., 2013). There were no statistically significant associations between baseline covariates and participants with missing data (all ps > .05) nor differences in reasons for participant withdrawal between groups. Effect sizes were negligible (d < 0.2) for covariates of sex, age, and memory concerns. There was a large effect size that was nonsignificant for education (d = 0.83) and a moderate effect size that was also nonsignificant for the telephone screener (d = 0.56), where participants with missing data had lower levels of education and lower scores on the telephone screener. To address missing data, I conducted a regression imputation (Kang, 2013) to impute missing values using the expectation-maximization algorithm in SPSS (Heymans & Eekhout, 2019).

Primary Program Outcomes

To evaluate primary program outcomes, repeated-measures ANOVAs were used to evaluate within-group changes at baseline, post-test, and follow-up. For the activity tracker data, the baseline was defined as the first full week of tracker use. For most participants, this was achieved by the first (n = 15, 68%) or second (n = 20, 90%) week of the Memory and Aging Program. The reason for this delay was that some participants were unable to have their physician consent forms completed in time, and the device was not released before the receipt of the consent form. Sensitivity analyses were conducted to compare differences in baseline scores if the baseline was interpreted as the first full week of use or using available data from Week 1 with mean imputations for missing data. The overall pattern of results did not change between these two methods.

Relative Efficacy Analyses

Group comparisons for the relative efficacy analyses were examined using mixed-model ANOVAs with the intervention groups (control, cognitive, and combined) as the between-subjects factor and the three assessment time points (baseline, post-test, and follow-up) as the within-subjects factor. Significant interactions were followed up with post hoc analyses of regression coefficients to determine the time point and which group pairings were driving the interaction effect. In examining regression coefficients, we analyzed how groups differed in response to the intervention (Field, 2013). Given that participants completing the combined intervention were self-selected and not randomized, baseline differences between the three groups could not be attributed to chance. Thus, comparisons of group means were not used.

Eta-squared effect sizes were calculated for all interactions, indexing the proportion of the dependent variable accounted for by the group by time interaction. Eta squared is an effect size estimate indexing the strength of an association, and these types of indices (which also include *r*) are more accurate for continuous data than group difference estimates (Ferguson, 2016). However, for all post-hoc and pairwise comparisons, Cohens' *d* was used as it is a more frequently reported effect size in psychology research (Schäfer & Schwarz, 2019) and lends itself to easier interpretation and clinical application. For the primary outcomes, this effect size indexed the standardized difference in scores between two time points (e.g., baseline and post-test, or baseline and follow-up). For the relative efficacy analysis, this indexed the standardized difference in mean change scores between two groups.

Qualitative Analyses

Audio recordings of interviews were transcribed verbatim into Microsoft Word format. Before analysis, the dataset (i.e., every individual interview) was reviewed several times by the primary investigator to facilitate familiarity and develop an overall sense of participants' experience in the program (Braun & Clarke, 2006). The transcribed text was then uploaded for analysis in NVivo 12 Software.

Transcripts were analyzed using qualitative content analyses (Graneheim & Lundman, 2004; Morgan, 1993; Vaismoradi et al., 2013). Qualitative content analysis is "a systematic coding and categorizing approach used to … determine trends and patterns of words used, their frequency, relationships, and the structures and discourses of communication" (Vaismoradi et al., 2013, p. 40). Qualitative content analysis incorporates the counting of codes to facilitate pattern detection and guide further interpretation of the data (Morgan, 1993). It uses a descriptive approach in its initial coding and the subsequent interpretation of quantitative counts of codes, employing relatively low levels of interpretation (Morgan, 1993; Vaismoradi et al., 2013). As a result, the frequency of codes that appear plays a prominent role in determining themes of significance and, as such, frequency of endorsement of themes and sub-themes are presented throughout the results section.

The data were analyzed recursively, with multiple steps of coding. The initial step involved the segmentation of the data into codes that represent separate but meaningful concepts (referred to as *nodes* in NVivo). At the next level, codes were organized into categories based on commonalities (Graneheim & Lundman, 2004). Once the data were coded and collated, a thematic focus was applied where lower order categories were organized into higher order themes. Themes and categories were evaluated based on two criteria: internal homogeneity and external heterogeneity (Patton, 1990) to ensure data cohered meaningfully with a clear distinction between them (Braun & Clarke, 2006).

Importantly, qualitative analyses and interpretation do not emerge without researcher influence and a series of methodological choices, which merit stating (Braun & Clarke, 2006). Data were analyzed inductively or using a bottom-up approach (Frith & Gleeson, 2004), with attention to semantic (not latent) themes, where themes were strongly associated with the original data (Braun & Clarke, 2006; Patton, 1990). As the primary investigator, I actively analyzed the dataset. As a doctoral student in Clinical Psychology, I believe in the merits of psychotherapy, psychoeducation, and lifestyle change. I also have a research background investigating lifestyle modification in cognitive aging, influencing my perspective on the utility and efficacy of such programs.

Mixed-Methods Triangulation

The merits of mixed methodology are increasingly recognized in health research for their ability to investigate complex phenomena (Tariq & Woodman, 2010), and this is of particular benefit to participants and other stakeholders in health intervention research (Almeida, 2018). In this study, qualitative and quantitative modes of inquiry facilitated the evaluation of *a priori* hypotheses informed by the literature while simultaneously affording an opportunity to explore new avenues of inquiry resulting from the collected data.

This mixed-methods study employed a concurrent triangulation design where qualitative and quantitative data were collected simultaneously (Almeida, 2018). This design equally weighs qualitative and quantitative data, considering them complementary perspectives in contrast to embedded designs that feature a primary inquiry mode (Almeida, 2018). An advantage of triangulation is its ability to validate and confirm findings within a single study from multiple perspectives (Tariq & Woodman, 2010). In this study, qualitative and quantitative data were analyzed separately and then merged at the level of interpretation and discussion.

Results

Participant Characteristics

Demographic information for the participants recruited for the current, combined intervention group is provided in Table 5. Similar data from previously recruited participants (Vandermorris et al., 2020) used for the current relative efficacy analyses are re-presented here for comparison. The three groups were not significantly different in age, education, or scores on a cognitive screening tool ($p > .05$) with small to medium effect sizes (d = .36 - .53).

Although subjective memory concerns were not required for participation in the study, participants in the combined intervention overwhelmingly endorsed having concerns about their memory (n = 21, 95%). Compared to data from previously recruited participants, the combined intervention showed a small effect size that was nonsignificant relative to the cognitive group (d = 0.49), and a significant, medium-sized effect relative to the waitlist control group, (d = 0.69), indicating greater prevalence of memory concerns at baseline.

Participant flow is detailed in the Consolidated Standards of Reporting Trials (CONSORT) flow chart in Figure 5. Two participants did not finish the study for reasons rendering them ineligible to participate or for reasons that could not be determined, so they were not included in the analyses. Study composition was heavily weighted towards the summer groups (January: n = 2; March: n = 1; May, n = 7; June: n = 8; October: n = 4).

Comfort with Technology and Device Use

Participants in the combined condition were asked at baseline to indicate their level of comfort using various forms of technology that they could encounter during the intervention. On a 5-point scale with 5 indicating that they were *Very Comfortable*, the group indicated a high level of comfort using computers (M = 3.9, SD = 1.3), the internet (M = 3.9, SD = 1.3), and smart phones (M = 3.9, SD = 1.5). Results from this questionnaire are further illustrated in Table 6.

To upload their data, participants were required to pair their devices with either a smart phone, tablet, or computer. The majority (n = 17, 77%) of participants elected to use their smart phones. A handful of participants opted to use tablets (n = 4, 18%), and one participant chose to interact with the tracker platform via the computer (5%). Two participants had used an activity tracker prior to the study (9%), though most were new to wearable technology (n = 20, 91%). Participants who already owned a wearable device were given a study Fitbit to ensure device models were consistent across the sample.

Feasibility and Acceptability

The first aim of the study was to evaluate the feasibility of the combined program as designed through triangulation of qualitative and quantitative measures examining rates of enrolment, attrition, and adherence, as well as feedback regarding liked and disliked aspects of the program and barriers to full participation.

Rates of Enrollment, Attrition, and Adherence

Between January 2019 and October 2019, 55 individuals gave consent to be contacted regarding the research study. Communication was established with 50 participants who were then screened for eligibility (91%). In total, of the 50 participants who were screened, 24 were enrolled, representing a recruitment rate of 48%.

Of the 24 participants enrolled in the study, one participant stopped attending the intervention before the post-test testing session when diagnosed with dementia. Another participant dropped out of the study prior to the follow-up session and contact was lost for several weeks. The participant later reached out following the study but did not provide a reason for withdrawing. In summary, of the 24 participants who were enrolled in the study, two dropped out, which represents a 4% attrition rate (96% retention rate) at post-test and an 8% attrition rate (92% retention rate) at follow-up.

The total duration of the exercise intervention was variable between participants as the devices were only given to participants once physician consent had been received. Once the participants received their tracker, physical activity levels were recorded for up to 10 full weeks, for a maximum of 70 days. Analyses were limited to the last full week of participation for two pragmatic reasons: (a) to have a comparable intervention length for as many participants as possible, and (b) because an average step score over the course of a week is less likely to be biased than a few days.

Adherence was measured using the number of days participants reached at least 1000 steps (Hardcastle et al., 2020) divided by the number of possible wear days for each participant. Upon receiving their trackers, participants had a 100% adherence rate. That is, each participant wore their device every day of the study, achieving at least 1000 steps, until the end of the 10th week. Fifteen participants began wearing their activity trackers the first week of the study (for a total possible duration of 70 days), five more participants received theirs by the second week (duration of 63 days), and the final two received their devices by the third week (with total possible durations of 56 and 58 days). The average duration of the exercise intervention for the group was 67 days or 9.6 weeks. Participants' levels of adherence to their weekly step goal targets varied markedly within the group. On average, the group met their weekly goals slightly more than half of the time (M = 57%, SD = 28%), and this ranged from 0% to 100%. The range and frequency of participants' weekly goal adherence is depicted in Figure 6.

Qualitative Feedback on Acceptability of the Combined Program

Relevant to the aims of the study was participants' evaluations of the program's acceptability (if it was "suitable, satisfying, or attractive," Bowen et al., 2009, p. 45). Eighteen participants completed semistructured interviews at the follow-up session to provide qualitative feedback, whereupon the data were deemed saturated, and collection of qualitative data ceased.

The three main themes identified were program acceptability, general program feedback, and nature of program engagement. A hierarchical representation of themes and subthemes relating to acceptability, and their frequency of endorsement can be found in Table 7. Given that we employed qualitative content analysis, frequency of endorsement played an important role in determining themes and their relative position within the thematic hierarchy. Within the tables, *n* refers to the number of participants endorsing a theme, not the number of codes. It is also important to note that, as the codes were organized hierarchically into higher-order themes, lower order categories are not mutually exclusive, so the frequency of endorsement may not align.

Program Acceptability. The main theme, program acceptability, was composed of four sub-themes including satisfaction with the program, perceptions of program cohesion, barriers encountered during the program, and suggestions for improvement.

Satisfaction with the Program. Participants expressed a high degree of satisfaction with and gratitude for the program in its current form, describing it as "enjoyable" (P3), "worthwhile" (P13), and "excellent" (P17). Six participants said that they would recommend the program, with two of those participants reporting that they had purchased an activity tracker for a friend or loved one because they wanted to encourage them or "help them experience the benefits [that they had had] during the program" (P4).

Perceptions of Program Cohesion. Considering that this combined intervention introduced an additional physical activity component to an already established cognitive intervention, whether the program was seen as complementary and cohesive was of primary importance. Eleven participants addressed this question of cohesion, with most (n = 8) reporting that the program worked well as a combined intervention. When asked whether the combined nature of the intervention made a difference, one participant responded:

> I think so. It's made me more positive about everything. I think the combination of doing a little more exercise with the memory program itself, I think. Because if you just have

> the memory program and they say do the exercise but there's nothing really to motivate you- I think that some people, maybe even me, I would probably say "oh, ok" and think that I was doing enough at the time. So I think that [the combined intervention] motivates you, that's for sure. I think they work in conjunction ... one reinforces the other (P1)

Another participant shared that, without the combination of the two intervention components, she thought her experience would have been different:

> Not nearly as good. I think that both components… going to a class was great with the listening and learning and doing all that stuff. I think that having the Fitbit component made me stop and think about more what we did in the class. (P11)

The previous quote introduced another theme of the combined intervention - that the daily rhythms of the exercise inspired more review and reflection of the cognitive component of the course (*n* = 4):

> So when we pole walk which we've been doing every morning now unless we have meetings, I reinforce. We discuss memory strategies you know… so you put your keys on the stairs… then make the connection you know that's the habit and that's the association (P13)

Many participants reported that the combined nature of the program inspired a more holistic perspective of health where physical activity was seen as an important contributor to cognitive health (*n* = 10). In one participant's words, "It gave me some encouragement to improve myself physically for exercise. Exercise is good for my diabetes, also for my brain too" (P8). Another participant explained:

> I'm not a person who separates into compartments. This was good for me in that it put it all together and that's how I think. So, it was easier for me to get along with that strategy and not compartmentalize everything because it's one whole body… So, your mind and your brain and your memory goes into the whole thing of the Fitbit, the exercise, the diet, everything that goes in with better memory. (P3)

In contrast, several participants (*n* = 3) stated that they did not perceive the combined intervention to be cohesive, seeing the two components as distinct or "very separate" (P9). These two individuals also did not endorse a more holistic perspective of health (*n* = 2).

Barriers Encountered During the Program. When asked about factors that impacted their ability to engage in exercise during the intervention, participants reported a range of barriers including health or illness, lack of time, and the weather. With respect to barriers that were encountered as part of the program, one participant reported having technical difficulties, specifically synchronizing her device. Another participant described forgetfulness as a barrier, "a couple times I forgot… I put it in the charger when I go for my shower to avoid the water, and a couple times I forgot to put it back on" (P10). Several participants indicated that they did not encounter any barriers, including two individuals who had endorsed barriers above, stating that obstacles encountered were often temporary and not insurmountable.

Suggestions for Improvement. When prompted, a few participants had suggestions for improving the program. One such suggestion was for greater integration of the physical activity component with the in-class component. For example, one participant expressed a desire to have the same group atmosphere for the physical activity as they had for the cognitive component, "have a session with the people who are part of the program to get feedback from them because we can also learn from each other" (P17). Another participant suggested that integrating the activity tracker into the class would help participants maximize their use. An additional suggestion was to incorporate and emphasize other forms of exercise in the program.

General Program Feedback. The second main theme, general program feedback, was composed of two sub-themes: positive aspects of the program and negative aspects of the program.

Positive Aspects of the Program. Most participants identified features of the program that they enjoyed. The accountability of the program was widely cited as a motivating factor, with participants describing the activity tracker and the research assistants as sources of accountability. In one participant's words, "[the program] motivated me more because it's not just me I have to answer to" (P1). Three participants shared that wearing the activity tracker made them more aware and conscious of their daily activity level, which was a change from before.

Similarly, participants enjoyed the automaticity of exercise- that the program's goal of daily exercise made it a habit (*n* = 3). Participants described this as "I don't have to write it down to remember. Now I have to go. It's a good thing" (P5) and "It kept me on the straight and narrow ... It means keep at it every day" (P6). These categories of accountability and automaticity are best summed up in the following participant's sentiment, "I just don't make excuse… I'm looking forward to it too. I get into the habit- I have to do it". (P8).

Another positive feature of the program was its flexibility. Across both components, participants reported a sense of confidence in adopting what worked for them regarding which types of memory strategies they used (*n* = 3), and how (*n* = 8) and how much (*n* =4) exercise they engaged in. Concerning the amount of exercise, several participants liked the flexibility that was built into the program with the ability to set their own goals and have several nonexercise days per week as well (*n* = 4). Eight participants cited the flexibility to get their steps in whatever manner of exercise they chose to be a selling point of the program, as it gave them choice and freedom to tailor the program to their own needs. Two of these participants mentioned that safety or health concerns had previously prevented them from engaging in exercise and shared how they had navigated these concerns within the study. The flexibility to exercise when they wanted, without being constrained by time and place as in conventional exercise classes, was a commonly named positive feature of the intervention and is captured in the following statement:

> If you know the day is going to be very hot, go for a walk [in the morning]. The morning is beautiful… The gym is closed at that time and you don't know that ... Holidays they

> are closed. This frees you. The weather is bad outside - so if you want to [exercise], I have steps all over the place in my house… [the Fitbit] keeps you independent, you know? And I appreciate that (P10)

Participants also expressed an appreciation for the resources that were provided through the program, particularly the heavy research grounding, as it provided credence and confidence. This applied to their lifestyle change, "It's given me a way to say [the importance of activity] is not just coming from me, we heard it from the experts sort of thing, right? So that made a big difference also" (P11), and adoption of memory strategies:

> I have tools that I can use. You know, I'm not just using things that I've learned over the years. These are specific tools that other people have researched and have obviously been successful … So, that I think is a biggie for me. You know, the fact that I have the authority as it is to use the SHARP strategies and to know that they will work for me (P4)

Given that step counts were provided daily, participants (n = 4) reported enjoying a sense of progress as the intervention continued. Through the weekly check-ins, there was also a sense of support and encouragement for participants. One participant shared, "I got supported because I knew I was going to hear from [the RA] and she would make a cute comment or something. So, you know I think that that was a big part. Feeling supported in it" (P11).

Perhaps the most loved feature, in terms of the enthusiasm with which it was reported, was that the program enabled participants to put what they were learning into practice and experience the benefits. The sentiment that it's "not new that I learned, but it's new that I'm applying" (P2) was a consistent theme. One participant shared:

> I'm really appreciative and happy that this research, [the addition of] exercise and the Fitbit… you know it intellectually, but now I've experienced it so that will be a continuous motivator for me… Just that importance of being more active (P13)

Likewise, another individual shared that the accountability of the program helped ensure that she experienced first-hand something she knew in concept, "In my own head I need to prove that [exercise] made a difference. Even though I knew that it would, I wanted to prove it to myself."

(P11). Another participant echoed this sentiment, suggesting that the combined intervention made her aware of the benefits of exercise that she otherwise would not have known:

> I do enjoy it you know because as I say, I was never even aware. This [program] has improved my exercise, my mentality, and socializing… But, as I say if I don't come here, I don't have this [Fitbit], I will be the same thing as before (P8)

The activity tracker itself was also recognized as a positive feature of the intervention because it provided readily accessible information (n = 9). For some, the ready record of their activity helped to fuel a sense of satisfaction and accomplishment (n = 6). Other participants described the record as useful in tracking their activity levels to ensure they were meeting their goals (n = 3).

Negative Aspects of the Program. Participants also discussed negative aspects of the intervention, with feedback about the program specifically and also about aspects of the activity tracker that they disliked. One participant spoke to both components. As was discussed in the suggestions for improvement, two participants felt that the program could have been more integrated with the incorporation of the physical activity component into the class itself. Both participants thought they would have gained more from the intervention if there was more of a didactic introduction at the beginning of the program. One participant shared that, towards the end of the intervention, the step goals were beginning to be stressful for her and that "There were some days I said I just can't do it, and then I would feel guilty" (P11). Two participants voiced disappointment that their typical format of exercise was incompatible with the model of tracker used and thus did not count toward their activity goals. For one participant, "I was disappointed that it didn't – that I didn't get a model that kept track of - now I'm not swimming too much because of this" (P12).

Several participants voiced frustration or discontent with the activity tracker itself. Three participants did not like the aesthetic of the device model they received. Another frustration that was voiced was the perceived inaccuracy of the step counts (n = 4). For those participating in the study as a couple, different step counts after taking walks together was a particular point of irritation (n = 3).

Nature of Program Engagement. There was a fair amount of flexibility within the program regarding how participants engaged in exercise and how they used their activity trackers.

Activity Tracker Use Details. Although participants were required to use the device application to synchronize their devices, further interaction with the platform afforded additional opportunities to set goals and track progress. Several participants stated that they did not interact with the application beyond uploading their data, indicating that they relied solely on the wrist-based feedback from the device (n = 3). Six participants reported daily use of the application, including two participants who also kept written records.

Despite step counts being the only feature discussed within the program, many reported using additional features of the activity tracker including the heart rate monitor (n = 5), movement reminders (n = 1), monitoring sleep patterns (n = 5), and water intake (n = 1). For most participants, the activity tracker was seen as a tool for the larger research study and was motivating (n = 16). However, two participants reported that the tracker made little impact on their activity. They each reported high levels of activity prior to joining the program and saw the tracker as extraneous to the larger goal of becoming more active.

How Participants Got Their Steps. With an agreed-upon step goal, the program was designed to offer flexibility to enable participants to gain their steps in their most preferred manner. Most participants reported a conscientious effort to increase the amount that they walked. All participants shared that they made small changes to their daily activity (*n* = 14). For one participant, "Even today, I walked a little bit more. I didn't park in the area, I said 'You know, I'll walk. I'll park up there and just walk' " (P1). Other participants reported making intentional choices to take the stairs, walk around their home on bad weather days, to get off the bus one stop earlier, and choosing to complete errands they would otherwise have delegated to others. Most participants (*n* = 9) chose to do a combination of planned walks and daily changes, as described here:

> We did a lot of "okay, let's go, let's move, let's get up and go for a walk after dinner" … but I have made myself go on the subway more and walk and I have parked the car further away, very conscientiously parked the car further away to do things when I park in a parking lot now or on the street somewhere. (P11)

Primary Program Outcomes

Descriptive statistics and effect sizes for primary outcomes are shown in Table 8.

There was a large, significant effect of time on daily step count, $F(2, 42) = 5.14$, $p = .010$, $\eta^2 = .20$, indicating that the group increased their physical activity over the course of the intervention. Post-hoc analyses showed that this interaction was driven by medium, significant changes between baseline and post-test, $F(1, 21) = 4.60$, $p = .044$, $d = 0.46$, and a small effect size that was nonsignificant between post-test and follow-up, $F(1, 21) = 2.26$, $p = .148$, $d = 0.32$. To index the overall impact of the combined intervention, we also examined differences between baseline and follow-up scores. In total, participants increased their average daily steps by 1463 steps or by 27% of their baseline rate at the follow-up assessment, which was a medium effect, $F(1, 21) = 7.13$, $p = .014$, $d = 0.57$.

There was a medium-sized effect of time on sedentary behavior that was nonsignificant, $F(1.62, 34.06) = 3.20$, $p = .063$, $\eta^2 = .13$, when adjusted for sphericity. Given that the combined intervention was ongoing at post-test, despite the nonsignificance across the three time points, we also evaluated differences in sedentary behavior between baseline and follow-up to index intervention impact. We found a numerical decrease in sedentary behavior that was small in size and not statistically significant, $F(1,21) = 3.46$, $p = .077$, $d = 0.40$. On average, participants spent 93 fewer sedentary minutes per day at follow-up when compared to baseline, or nearly 10% less sedentary time daily.

Across the three time points, we also saw a large effect of time on memory knowledge quiz scores, $F(2, 42) = 34.89$, $p < .001$, $\eta^2 = .62$. This effect was driven by very large changes in test scores between baseline and post-test, $F(1,21) = 48.58$, $p < .001$, $d = 1.49$. In fact, scores decreased slightly, though nonsignificantly, between post-test and follow-up, $F(1,21) = 2.92$, $p = .102$, $d = 0.36$. Overall, between baseline and follow-up, there was a significant, large effect of time on memory knowledge quiz scores, $F(1, 21) = 29.66$, $p < .001$, $d = 1.16$, suggesting that participants made large gains in subject matter knowledge of cognitive aging, memory processes, and available memory strategies.

Qualitative Feedback of Program Outcomes

Qualitative interviews allowed for a more exploratory evaluation of the intervention's impact on participants' daily lives. Analyses of the interviews identified several themes that had not been directly anticipated and thus not queried through standardized measures. In fact, several participants expressed feelings of satisfaction that they would have the opportunity to verbally convey the impact of the intervention through the interview as they felt the standardized measures had not captured their experiences ($n = 4$). Participants' reports of program outcomes were overwhelmingly positive with all participants reporting healthy behavioral changes as well as changes in psychological, memory, or subjective health outcomes.

Regarding program outcomes, five main themes were identified from the qualitative feedback: behavior change, psychological well-being, impact on memory, subjective health, and sustainability and continuity. The hierarchical structure of these themes and subthemes, as well as their frequency of endorsement, are depicted in Table 9.

Behavior Change. All participants who were interviewed described behavior changes resulting from program participation. This involved lifestyle changes and the adoption of memory strategies in their day-to-day lives.

Lifestyle Changes. The most common behavior change reported was the implementation of increased physical activity, attesting to program effectiveness in one of its primary goals and validating, through triangulation, results obtained through the objective activity tracker metrics. For some participants, this increase in activity was relative to low levels of exercise prior to the study, "I was never a walker so [the program] did push me to walk a little bit and towards the end I was better than at the beginning" (P17). For others, a conscientious effort was made to improve upon previous levels of activity, "I was exercising before, but I think I'm doing a little bit more because I got to get those extra steps" (P1). For some, this involved trying new exercise forms or classes, as one participant described below:

> As far as the exercise goes- I'd be the last to say it out loud to my husband or to my family, I felt great doing it. (laughs) And because of that, I've now joined three other classes. I'm taking two aerobics classes on land and an aquatics one and they're both very heavy duty. So, I'm three times a week doing an hour each time in those classes. (P11)

Some participants noted that the program instilled a new sense of the importance of physical activity and initiated intentional healthier choices over sedentary behaviors (n = 5). One participant shared, “I didn’t walk very much before. I would watch more TV which I don’t bother with very much right now” (P11), while for another:

> This walking is extra for me because sometimes I did not go out at all. Now I do and I will continue after this too. Because I would probably just sit home before I did not join the research group. I would sit home more because it’s not easy for me to walk (P5)

In the quest to increase their activity, participants reported coming across new opportunities that they would otherwise not have engaged in. Stemming from the program, several participants were motivated to engage in other organized activities, enrolling in gardening committees, bridge classes, and other community courses. Other participants described meeting new people as they navigated their neighbourhoods over the course of the program, establishing social support in their lifestyle change. Two participants described engaging more with their families in activities they had previously forgone. For some this involved new relationships, as described below:

> I walked down the halls a little bit because there was another lady on my floor that was doing the same thing. She said, “Oh look, it’s raining outside.” So, I said “Well I was thinking of walking at least a few times around the block.” She said, “No, no. Walk with me, we’ll go up and down and around.” So I did that a little bit (P18)

When asked how increasing her activity levels impacted her, one participant explicitly identified that the physical activity fostered social engagement, which helped her feel less lonely:

> [increasing my activity] impacted me twice. Both ways. First, I got to physically do the exercise and I can socialize with other people… Before that I only sit at home watching TV and everything, right? And I don’t go out that much because everybody working. Or sometimes I don’t feel like nobody asked you to. So, you feel very lonely for yourself, right? And you feel I guess a little bit depressed. But right now you go to – oh I have to go to exercise you know three times a week. Even though you know in the exercise itself you won’t get very close friends but you can have a social life. For the people because

> they all do the same go to – socialize. So, I recognize your face-You recognize my face. We just little bit chat before the exercise, a little bit chat after the exercise. There's talking. (P8)

A few participants noted that, as they became more active, they started exploring their community. Sometimes this induced reminiscence and promoted a sense of gratitude, "Seeing the small things… Because you're walking in your neighbourhood, you see the things that are changing… You appreciate what you see and enjoy it" (P10). Another participant shared,

> One of the things that I am doing to get more walking in – I will, you know, I take public transportation these days, I will get off at the stop before my home. And walk a stop. And uh it actually has its payoff. Because I'm getting to know the community better. Yeah, I found that quite interesting. One day I got off a little further back and I discovered there was a farmer's market on Saturdays and I thought hmm. Maybe I should come one Saturday morning and see what's here. (P4)

Memory Strategy Use. In addition to integrating more physical activity in their lifestyle, participants reported that they were adopting the memory strategies into their day-to-day routines. For example,

> [to help remember people's names] I do that a lot … focusing and saying it, you know, going over it and spreading out the time and trying to retrieve it. I do a lot of the strategies. I do the habits. I did a lot with the habits about remembering what I needed and where to put my stuff and to do that. Things like that I knew but I just didn't do it. (P11)

Psychological Well-being. Positive changes to psychological well-being was another main theme stemming from participation in the program.

Agency and Independence. Some participants described a newfound sense of agency in the process of aging, reporting that they had "a greater sense of control" (P16) and that it "was an important thing just to realize that there's ways to help" (P9). One participant described feeling more physically capable than she had in a long time which encouraged her to expand her limits;

> I think I got the courage to try things that I hadn't. So, there were exercise classes in my building before, and I looked at the people doing them I would watch it. And I thought I

> can't do that you know? I had knee surgery in both knees. I can't kneel, I can't this, I can't that, I'm too heavy, I can't do those things… And then I end up not only signing up for one but signing up for three. I was doing the walking a lot, and distances and amount of time I did that I thought I would never be able to do it… And when I was doing the walking outside every day I sort of added another block or whatever uh area to see or to do. So, I think I got the confidence to try something else. And it was a new water aerobics class. (P11)

Similarly, another participant shared:

> It's made me aware of what I can do that I thought I couldn't do- So it's pushed me past the finish line that I thought that I had before. And that finish line is now extended which is really good. (P9)

An increased sense of independence was also described. The combined nature of the program appeared particularly impactful in this regard as participants shared that it was what they learned through both aspects of the program that led them to feel more equipped. For one participant, she was venturing out in her community more because she felt more confident in her physical capacity to navigate the excursion and her ability to remember places she wanted to visit:

> I've become more independent too in terms of – like I was afraid to go out because I didn't know where I was going. Or how I would get to wherever. Um so I'm less nervous about going out somewhere uh by myself… Just knowing now that I can walk with that walker and remembering where those stores are, where things are on the street that I need to get… So, I'm using my memory, but I'm also enjoying where I'm going when I get there. (P3)

Impact on Mood. Changes in mood was another subtheme identified as a psychological outcome. This included sentiments of increased confidence, stemming from feelings of physical capability (n = 2) or due to feelings of normalization about their memory struggles (n = 3), "I feel more confident ... I feel more confident in what I'm saying. I feel more confident in knowing that a lot of people my age are going through this." (P11)

For some, the program helped them feel more positive, "I feel that I'm happier… I just feel more like getting out and doing, you know, things. I think it's helped me a lot when I feel better because I followed [what I had learned from the group]" (P18). A small subset of participants also shared that the program had improved their mental health (n = 2). For example, one participant said:

> Like I would walk before, and I enjoyed it. But there was this little friend here (laughs) helped me to . . . you know increase even more than what I have been. And it made me feel capable you know and got me out of the blues. (P6)

Change in Perspective. The final subtheme with regard to psychological outcomes was a change in perspective. According to participants endorsing this category, the program had had an impact on their outlook moving forward, with an overwhelming sentiment being to "accept where I am but do what I can". This increased self-acceptance was often fueled by group discussion within the cognitive component, where participants benefited from the normalization of their memory difficulties:

> I'm more sure of myself in some areas and in other areas not so much. Um for one thing, I felt very open in the class that I could talk about it. And that encouraged me to do the same thing with my friends. Because before that I was kind of hiding it a bit and I've decided not to hide it. (P6)

When asked how the addition of physical activity impacted her experience of the program, one participant shared:

> It's made me realize that I've got some life left in me. Yeah. And I'm going to make good use of it… even though if I'm going to be having problems with my memory- that's only one portion of me. I can do many other things without feeling badly about myself. Just to get out there and try to help people. And doing that, I'm helping myself also.

Another participant shared his biggest take-away from the program:

> I would say so much 'more'… More aware of who I am, what I am, how much I remember, how much I don't. How I need to improve physically to be able to get through another year and I think a better mental attitude as well (P3)

Fuelled by this change in perspective, several participants also reported feeling more hopeful about the future.

Impact on Memory. This intervention was provided to individuals who overwhelmingly endorsed subjective memory concerns, so evaluating its impact on memory was paramount. Nearly all participants commented on the intervention's impact on their memory in terms of function or perceptions of memory (n = 16).

Feelings about One's Memory. Overwhelmingly, participants reported that the greatest impact of the intervention was on how they felt about their memory with unanimous consensus that they felt better about their memory. Several participants shared that prior experiences with loved ones who had dementia had driven them to enroll in the group (n = 5). For a small subset of these individuals, sentiments of fear decreased during the intervention (n = 2). One participant who enrolled with her husband described this change:

> I think it really helped him emotionally. I can see because he was terrified… I don't think he has dementia. I think it's a part of aging. So now it's easier for me to say, "Remember, we talked about this and it's a part of aging. What can we do about it to make it easier for you?" (P11)

The driving factor in this improved perception was the normalization of memory struggles within the group. Participants described this as "I realized in the group that I wasn't all by myself. Yeah, that other people were going through it at the same time, and they seemed to be conquering it" (P6) and "there were other people that are in the same boat!" (P15). When asked how the program had impacted how she felt about her memory, one participant shared:

> It's reassured me that um my inability to remember words, which is probably my main concern right now. It's reassured me that that's not so terrible. That it's a normal part of aging, which I knew, but this reinforced it. Um I really enjoyed the discussions that we had, the challenges of the little tasks that we were given… I'm far less concerned than I was before I started this whole process… Partly from the workshops, and partly from trying to implement some of the things that I learned in the workshops. Um I would say those are the two main sources because when I forget something before, my lady friends' comments would make me think "Hmm, how bad is this?" Now I realize well it's part of aging. It's ok. (P2)

Only two participants suggested that they felt better about their memory owing to increased physical activity and engagement, suggesting that the sense of normalization derived from the group discussion was the primary factor generating this outcome, not the addition of physical activity.

Subjective Health. A handful of participants provided information about their perceptions of subjective health. Of those endorsing this category, most reported feeling healthier following the intervention. Participants also described feeling more "energized," "happier with my body" and "less tired".

Sustainability and Continuity. With all participants endorsing behavioral changes during the intervention, the final theme identified related to concepts of sustainability and continuity. That is, what were participants' intentions following the program? All participants endorsed a desire to maintain their behavior changes into the future, with many indicating that they planned to continue using their activity trackers. For some, the tracker had been adopted as a motivating tool, "Yeah, I'm into [wearing the tracker] now. Like, I've got a goal and I need this to help me do that goal… I won't know my steps without it" (P9).

Two participants suggested they would continue wearing the tracker but in a less rigorous manner owing to its aesthetic (one participant missed wearing his watches) and sentiments of pressure (one participant who reported feeling pressured by the daily step goals towards the end of the intervention). Finally, two participants who had previously reported that the tracker made little impact on their activity levels as they were motivated to engage in activity without them, stated that they did not intend to keep using the device, "I mean, if you want, I would give it back to you and I wouldn't miss it at all" (P2).

Relative Efficacy Analysis

Descriptive statistics for the relative efficacy analyses are shown in Table 10. Within the table, data collected from the current, combined intervention participants are displayed alongside data from previously recruited (Vandermorris et al., 2020) participants for comparison.

Memory Measures (Metamemory and Objective Memory)

All three subscales of the Multifactorial Memory Questionnaire showed significant group by time interactions. There was a medium significant group by time interaction for the Satisfaction subscale with a correction for sphericity, $F(3.29, 141.39) = 6.44$, $p < .001$, $\eta^2 = .13$. This interaction is illustrated in Figure 7. Post-hoc contrasts for the Satisfaction subscale indicated that these interactions were driven by changes between baseline and post-test. The combined and cognitive groups showed large, significant improvement over the control group, combined: $F(1,53) = 8.42$, $p = .005$, $d = 0.80$; cognitive: $F(1,65) = 13.94$, $p < .001$, $d = 0.91$. It is notable that there were large, significant differences between the groups at baseline, $F(2, 86) = 5.25$, $p = .007$, $\eta^2 = .90$, with the control group remaining stable over the course of the intervention whilst the other two groups improved. These baseline differences likely fuelled this interaction. There was no difference between combined and cognitive groups between baseline and post-test ($p > .05$, $d < 0.2$.)

There was a medium, significant group by time interaction for the Ability subscale, $F(4,172) = 2.97$, $p = .021$, $\eta^2 = .07$. This interaction is depicted graphically in Figure 8. Post hoc slope contrasts revealed that this was driven by changes between baseline and post-test. The combined group showed significant, medium improvements over controls, $F(1, 53) = 5.23$, $p = .026$, $d = 0.63$. The cognitive group had a small effect that was nonsignificant, indicating minor improvements over controls, $F(1, 65) = 1.66$, $p = .203$, $d = 0.31$. There was also a small effect that was nonsignificant for the combined group over the cognitive group, $F(1, 54) = 1.69$, $p = .199$, $d = 0.36$.

There was a medium, significant group by time interaction for the Strategy subscale of the MMQ which was corrected for sphericity $F(3.79, 162.96) = 5.90$, $p < .001$, $\eta^2 = .12$. This interaction is illustrated in Figure 9. Post hoc contrasts showed that the combined group had large, significant improvements over the control group between baseline and post-test, $F(1, 53) = 12.09$, $p = .001$, $d = 0.96$. The cognitive group showed significant, large improvements over the control group between baseline and post-test, $F(1,65) = 15.25$, $p < .001$, $d = 0.96$. However, both the combined, $F(1,53) = 9.57$, $p = .003$, $d = 0.85$, and cognitive, $F(1,65) = 5.41$, $p = .023$, $d = -0.57$, groups declined from post-test to follow-up as compared to controls. There were no significant interactions between the combined and cognitive groups between these time points ($p > .05$) though there was a small effect size that was nonsignificant between the groups indicating that this decrease in scores was more precipitous for the combined intervention ($d = 0.26$).

A medium, significant interaction of time and group was also found for memory strategy use as measured by the Memory Strategy Toolbox, $F(4, 172) = 4.34$, $p = .002$, $\eta^2 = .09$. This interaction is illustrated in Figure 10. Post-hoc contrasts revealed that the combined intervention showed a medium, significant effect over controls, $F(1, 53) = 7.58$, $p = .008$, $d = .76$, and the cognitive intervention showed a medium significant effect, $F(1, 65) = 6.87$, $p = .011$, $d = 0.64$, as compared to controls between baseline and post-test. There were no differences between combined and cognitive intervention groups between either time points ($p > .05$, $d < 0.2$).

For the objective memory measure using the Surnames Task, the variances were unequal between groups at the post-test session, $F(2, 76) = 3.83$, $p = .026$. Scores were transformed using a square root transformation across all three time points to correct for heteroscedasticity. There was no interaction of group and time for the surname recall test, $F(4, 172) = .33$, $p = .856$, $\eta^2 < .01$, indicating no changes in memory recall between groups.

Psychological Well-being

Groups did not differ on any of the administered psychological outcomes. Specifically, there were small effect sizes that were nonsignificant for the interaction of group and time for the Positive Affect subscale, adjusted for sphericity, $F(3.86, 165.84) = .67$, $p = .610$, $\eta^2 = .02$, and for the Negative Affect subscale, $F(4, 170) = .64$, $p = .634$, $\eta^2 = .03$, of the Positive and Negative Affect Schedule. There was also a small effect that was nonsignificant for the interaction of group and time on the Generalized Self-Efficacy Scale, $F(4, 172) = .61$, $p = .66$, $\eta^2 = .01$.

Health and Lifestyle

There was no interaction of group and time for the RAND-36 Health Survey, with a correction for sphericity, $F(3.75, 161.34) = .51$, $p = .719$, $\eta^2 = .01$, indicating no differences in health-related quality of life between groups. There was a medium effect size for the interaction of group and time for the Health Promoting Lifestyle Profile II index, adjusting for sphericity, $F(3.54, 152.21) = 3.69$, $p = .009$, $\eta^2 = .08$, which measures changes in lifestyle behavior. This interaction is illustrated in Figure 11. Post-hoc contrasts revealed that this was driven by group differences between baseline and post-test. The combined group showed significant improvement compared to controls with a medium effect size, $F(1,53) = 5.44$, $p = .024$, $d = 0.64$. The cognitive group also showed significant improvements over controls, again with a medium effect size, $F(1,65) = 7.72$, $p = .007$, $d = 0.68$. There were no differences between intervention groups ($p > .05$, $d < 0.2$).

Given the significant group by time interaction for the summary score on the Health Promoting Lifestyle Profile II index, a subscale analysis was conducted. There was a medium-sized effect with a significant group by time interaction for the Health Responsibility subscale, $F(4, 172) = 3.81$, $p = .005$, $\eta^2 = .08$. Post hoc contrasts showed that the combined group had negligible, nonsignificant improvements over the control group between baseline and post-test, $F(1, 53) = .005$, $p = .944$, $d = 0.02$. The cognitive group showed significant, medium effect sizes indicating improvements over the control group between baseline and post-test, $F(1,65) = 8.34$, $p = .005$, $d = 0.71$, and significant increases with a medium effect size over the combined intervention group, $F(1,54) = 6.24$, $p = .016$, $d = 0.68$. There was also a significant interaction on the Stress Management subscale with a medium effect size, $F(4, 172) = 3.03$, $p = .019$, $\eta^2 = .07$. Contrasts revealed that these changes occurred between baseline and follow-up, as the two time points in between (baseline and post-test, and post-test and follow-up) were insignificant. Between baseline and follow-up, the combined group showed a medium effect size that was nonsignificant relative to controls, $F(1, 53) = 3.47$, $p = .068$, $d = 0.51$. The cognitive group showed a significant, large improvement relative to controls, $F(1,65) = 11.62$, $p = .001$, $d = 0.83$, and nonsignificant increases with a small effect size over the combined intervention group, $F(1,54) = 1.50$, $p = .227$, $d = 0.34$. The four other subscales were found to be nonsignificant with small effect sizes ($\eta^2 = .02 - .04$)

Discussion

In this study, we evaluated the effectiveness of a combined, community-based intervention using program components that are accessible and replicable. We sought to (a) determine whether the intervention was feasible and acceptable as designed, (b) determine whether it was effective in eliciting primary program outcomes of activity levels and knowledge about memory and aging, and (c) evaluate the relative efficacy of this intervention compared to current best practices.

Using a mixed-methods design, the study was both confirmatory and exploratory. The study was confirmatory in its aim to replicate findings from previous efficacy studies and exploratory in its aim to determine effectiveness in a real-world environment. An additional aim was to evaluate the use of wearable technology in a population of older adults who endorsed subjective memory concerns. Notably, this is the first study to evaluate the effectiveness of a community-based combined intervention using mixed methods. The qualitative inquiry incorporated in this study afforded an exploratory approach to ascertain additional, non-hypothesis-driven impacts of the intervention and to determine intervention elements and outcomes that were of value to participants themselves, applying a patient-centered approach (Jayadevappa, 2017).

Feasibility and Acceptability

The intervention was found to be feasible, as demonstrated by enrolment, attrition, and adherence rates. Concerning enrolment, about half of participants who gave consent to be contacted for the study were enrolled. This rate is lower than an earlier study of the Memory and Aging Program however that group had different recruitment strategies (Vandermorris et al., 2020). Importantly, this rate of recruitment is higher than comparable combined interventions (Bott et al., 2018; De Souto Barreto, 2021), including those with patient populations with subjective concerns (Barnes et al., 2013), and in studies using wearable trackers (Thompson et al., 2014; Wijsman et al., 2013) in populations of older adults. There was a high retention rate at

6-week follow-up, which is largely consistent with previous studies (Bott et al., 2018; De Souto Barreto et al., 2021; Thompson et al., 2014; Vandermorris et al., 2020; Wijsman et al., 2013).

Participants were conscientious regarding the consistency of Fitbit wear, with all individuals wearing their devices daily from the time the device was received. This high level of adherence aligns with an earlier study evaluating a wearable-based physical activity intervention in a sample of inactive, postmenopausal women (Cadmus-Bertram et al., 2015). In that study, the women wore their devices approximately 95% of total intervention days.

Adherence was also evaluated using the number of weeks participants met their step goals. Within the current study, weekly step goals were met about half of the time. Although less than originally anticipated, this rate of exercise compliance is higher than two recently published combined interventions where 60% and 53% of participants completed at least half of the available exercise sessions, respectively (Coley et al., 2019, de Souto Barreto et al., 2021). Together, these results suggest that the intervention was well-received and well-tolerated by participants, thereby establishing this community-based model as a feasible option for older adults with subjective cognitive complaints.

Qualitative feedback pertaining to acceptability suggested that the intervention was attractive and beneficial to participants. Participants found the program to be cohesive and the components to work well together. Considering that the content of the Memory and Aging Program, the cognition-oriented component, includes lifestyle coaching, participants found that a primary benefit of the combined program was that it provided an opportunity to practice or reinforced what they had learned in class. Participants reported that, due to the combined nature of the program, they had an increased sense of holistic health and the interrelation between physical and brain health. This take-away is salient as it addresses a barrier to physical activity faced by many older adults when physical activity is seen as leisure and not related to health and well-being (Chao et al., 2000; Hui & Morrow, 2001; Schutzer & Graves, 2004).

Participants reported encountering barriers including illness, lack of time, and weather. Illness was the only barrier that applied equally to both components of the intervention. Lack of time and weather were endorsed as impediments to physical activity, and this is consistent with earlier research (Schutzer & Graves, 2004; Sullivan & Lachman, 2017). Notably, several participants who endorsed the above barriers also reported facing no barriers during the qualitative interviews and, when queried, clarified that what had presented as a barrier (i.e., something preventing exercise) earlier on in the intervention was seen more as an obstacle (i.e., something that can be overcome) as the intervention progressed. This change in viewpoint, from barrier to obstacle, parallels an earlier finding by Kononova and colleagues (2019). In that study, long-time exercisers and users of wearable technology were distinguished from non- and short-term users in their appraisal of barriers. Long-term users perceived external factors, such as weather, as opportunities and used these factors to determine the types of activities they engaged in (as opposed to whether they engaged in activities at all). Although most of participants in our program would be short-term users as per that study's definitions, it is promising that many demonstrated a similar resiliency in their description of different activities (e.g., walking in the park, mall, apartment hallway etc.) that they had identified to ensure they exercised regardless of external constraints.

Technology was not frequently identified as a barrier within this study. One other combined intervention has utilized wearable trackers to date (de Souto Barreto et al., 2021). In that study, they noted that technological problems (e.g., difficulty with syncing) were frequent (de Souto Barreto et al., 2021). There are several reasons why participants may have experienced few technology-related issues within this study. To begin, participants were self-selected, so it may be that those with high levels of comfort with technology chose the intervention. In fact, participants reported high levels of comfort with technology at baseline. Participants were also given several resources (e.g., a Wiki document of Fitbit use) and ongoing technological support that was offered in-person initially and remotely throughout the intervention. It is likely that a combination of both factors helped make the adoption of trackers successful in this intervention.

Sentiments of the intervention's desirability were not unanimous. Specifically, for a few participants, the addition of wearable devices was seen as superfluous. Due to the sample size and the descriptive nature of our qualitative analysis, this lack of unanimity provides an opportunity for future studies to examine patient characteristics for whom the intervention is most effective. In fact, analyses of population subgroups are a recommended standard for effectiveness studies to evaluate intervention impact across different population variables, such as gender and social class (Gottfredson et al., 2015). Based on what we observed in this study, two characteristics that might warrant further investigation include baseline activity levels and gender.

Despite this, the prevailing sentiment from interviews were high levels of satisfaction. Indeed, even those disliking the wearable device reported overall enjoyment of the program. Together with these high levels of satisfaction, low levels of barriers, and an appreciation for the behavior change techniques implemented within the program, the program was deemed to be acceptable.

Combined Program Outcomes

The primary goals of this combined intervention were to increase participants' daily activity, decrease sedentary behavior, and increase participants' knowledge of memory and aging. The over 1400-step increase relative to baseline seen in this study is much higher than the only other completed combined study utilizing trackers as the physical activity component. In their study, De Souto Barreto and colleagues used a web-based platform for their intervention, which included computer training and nutrition advice (2021). Older adults participating in the intervention were given an accelerometer for their physical activity intervention. Relative to baseline, step counts increased 140 steps in the first month (de Souto Barreto et al., 2021). However, those participants started at much higher levels (over 8800 steps per day at baseline) relative to our sample (just over 5400 steps at baseline), so it may be that the absence of a statistically significant change in steps reflects a ceiling effect given baseline levels already meeting daily activity recommendations for older adults (Tudor-Locke et al., 2011).

Considering the paucity of comparable combined studies, it is helpful to evaluate this change in physical activity as compared to unimodal approaches. Two physical activity interventions employing trackers found similar increases in step counts (Cadmus-Bertram et al., 2015; Lyons et al., 2017). The study samples were composed of middle-aged postmenopausal women or older adults, and step counts increased relative to baseline by 789 steps and 1090 steps, respectively (Cadmus-Bertram et al., 2015; Lyons et al., 2017). Regarding cognition-oriented treatments, two studies have examined physical activity changes following strategy and lifestyle-focused psychoeducation (Denny et al., 2020; Vandermorris et al., 2020). In fact, in an earlier evaluation of the Memory and Aging Program, participants endorsed greater engagement in physical activity after the program relative to controls (Vandermorris et al., 2020). Yet, these changes were not verified against objective measures of physical activity, and group differences in self-reported physical activity were no longer significant at follow-up. In the current study, there was no interaction on the Physical Activity subscale of the Health Promoting Lifestyle

Profile indicating that groups did not differ in self-reported physical activity over time. This is interesting given objective findings of increased activity levels in the combined group. This disparity between self-report and objective measures of physical activity may be attributable to reporting bias and overestimation on the self-report measure which obfuscated gains made in the combined intervention group. However, without the objective measurement of physical activity levels in the two comparison groups, this cannot be ascertained definitively.

Another study provided older adults with subjective cognitive complaints an 8-week psychoeducation program discussing compensation strategies and lifestyle activities such as exercise and cognitive enrichment (Denny et al., 2020). Participants were tasked with increasing daily physical activity independently and were provided with exercise guidelines and examples. The authors found that although there was an effect of intervention on cognitive activities, there was no impact on self-reported physical activity levels, despite exercise being assigned as homework (Denny et al., 2020). The current study builds upon both findings, showing that the addition of a physical activity component can objectively increase physical activity and maintain these changes over a course of 10 weeks.

The study by Denny and colleagues is but one example that psychoeducation alone may be insufficient to instigate lasting change in physical activity levels (for a review, see Chase, 2015). Indeed, there is an entire of body of literature investigating the "intention-behavior gap," which describes individuals who develop an intention to change their behavior but fail to act upon it. This gap appears particularly prominent when examining physical activity (Rhodes & Dickau, 2013). In one meta-analysis consisting of 10 studies and 3,899 participants, 46% of participants in exercise interventions were found to be unsuccessful intenders. That is, despite an appreciation for and a stated desire to engage in greater activity levels, those participants did not change their behavior (Rhodes & de Bruijn, 2013). To navigate this gap, several variables that may moderate the relationship between intention and action have been identified, including planning, habit formations, and environmental proximity (Rhodes & Dickau, 2013). Within the current study, we addressed all three of these variables through the provision of a planning resource when participants first began the intervention, the formation of habits through daily activity, and by offering an activity intervention that could be completed in any geographical location. Together, these aspects of our study design may have served to bridge the intention-behavior gap, yielding the positive results seen in the current study.

Sedentary behavior impacts cognitive health distinctly from physical activity (Voss et al., 2014) with independent health implications (Harvey et al., 2013). Thus, both are important to target in lifestyle interventions. A strength of this study was its objective evaluation of sedentary behavior, which has not been examined previously in combined interventions. We found that the combined program had a small effect that was nonsignificant on sedentary behavior when comparing baseline to follow-up, yielding decreases in sedentary time by over an hour and a half daily. This change was also identified through qualitative interviews in which participants discussed how they had replaced their previous sedentary behaviors with other activities. In earlier exercise studies, only one study using wearable activity trackers has investigated minutes of sedentary behavior, and that study also showed a small effect (Lyons et al., 2017).

Of prominent interest were memory-related outcomes considering that most of our study sample had subjective memory concerns at baseline. This is a novel contribution of the current study to the research literature, as previous combined interventions in patient populations with subjective concerns have looked at global cognition rather than subjective memory measures (Barnes et al., 2013; Boa Sorte Silva et al., 2018). Here, we found that the program was effective in increasing participants' knowledge of memory strategies and processes. Moreover, participants reported high levels of adoption of memory strategies in their everyday lives, which is consistent with previous findings (Vandermorris et al., 2020). We also saw similar improvements in memory-related affect through normalization (Vandermorris et al., 2017).

We were not able to examine changes in primary outcomes as part of our relative efficacy analyses as these measures had not been collected in previous evaluations of the Memory and Aging Program. This has implications on our ability to decipher whether the gains made on these outcomes were attributable to the combined nature of the program. Analyses of changes made between baseline and post-test (when both the cognitive and physical interventions were ongoing) and between post-test and follow-up (when only the physical intervention continued) offered an opportunity to look at within-group changes with the presence and absence of the cognition-oriented portion of the combined intervention. Effect sizes suggest that gains made in steps and memory knowledge and decreases in sedentary behavior were greatest when the two intervention components occurred simultaneously, that is, between baseline and post-test. Further, although step counts continued to increase to follow-up, decreases in sedentary behavior were negligible without the presence of the co-occurring intervention. Also, knowledge about memory and aging showed small decreases by follow-up despite the ongoing nature of the physical activity component. However, it is important to note that the absence of the cognitive component is also confounded by time. Indeed, earlier investigations of the Memory and Aging Program have shown that intervention gains are greatest between baseline and post-test, and that gains on some outcomes are lost, or gained, with time (Vandermorris et al., 2020). Considering that, it may also be that the greater degree of intervention-related gains were not attributable to the combined nature of the intervention but the novelty of the intervention and the tracker itself.

Several qualitative themes identified within the study, including the importance of activities to brain health, an increased intention to engage in healthy lifestyle behaviors, and enhanced knowledge of compensation strategies have been shown before in interventions providing compensatory strategies and coaching in healthy lifestyle behaviors (Denny et al., 2020; Vandermorris et al., 2017). In addition, previous qualitative studies of the Memory and Aging Program have also shown an effect of normalization of memory difficulties, resulting in emotional impacts (of increased feelings of hope and confidence) and positive coping (Vandermorris et al., 2017).

A novel theme that was identified through qualitative inquiry was increased levels of social engagement. Several participants noted increased social connectedness, either in the formation of new friendships or more consistent engagement with existing relationships. Notably, this finding was descriptive within the current sample and not unanimously endorsed, so its generalizability would be a fruitful avenue of future investigation. Examining this more closely, with targeted qualitative inquiry and quantitative measures would be particularly meaningful, considering that older adults, as a demographic, report higher levels of social isolation and loneliness (Newall & Menec, 2017) and that low social contact is itself a risk factor for dementia (Livingston et al., 2020). Offering programs that combat social isolation and loneliness, then, is of particular benefit to this older population and has been shown to increase adherence (Fan et al., 2012). Interestingly, individuals who have used activity trackers over an extended period of time reported that they had high levels of social support owing to relationships built as they established their exercise routines (Kononova et al., 2019). Thus, as opposed to other remote physical activity options (most commonly exergames, which are video games that incorporate exercise; Malmberg-Gavelin et al., 2021), it may be that the use of wearable activity trackers offers a social aspect not otherwise seen in remote activities.

Identified themes of self-efficacy, independence and improved mood are notable because they are intrinsic motivators, according to self-determination theory (Deci & Ryan, 2008). The theory posits that to adopt and maintain change, three needs must be met: autonomy (independence of external constraints), competence (self-efficacy), and social relatedness (sense of attachment to other people; Deci & Ryan, 2008). The qualitative findings within this sample speak directly to these three needs. That is, participants reported feeling increased agency regarding their cognitive and physical health, they identified a renewed sense of self-efficacy in their capabilities, and they benefited from the normalization of their difficulties within the group or sought out greater connection outside of the group. Considering that participants reported such intrinsic motivation is meaningful when one considers the sustainability of these changes, as intrinsic motivators produce longer lasting change than external motivators such as study goals or doctor recommendations (Deci & Ryan, 2008; Teixera et al., 2012). It is important to note, however, that the data did not triangulate on these themes. That is, quantitative metrics of self-efficacy did not show significant improvement within or across the groups.

The dissonance between our qualitative and quantitative findings regarding self-efficacy may be explained by our choice of quantitative measure. We used the Generalized Self-Efficacy Scale in this study, a 10-item measure indexing personal agency (Schwarzer & Jerusalem, 1995). Yet, it has been argued that self-efficacy is behavior and situation specific, and should be evaluated with according specificity (Maibach & Murphy, 1995). Within our study, participants voiced sentiments of agency with respect to aging and their ability to engage in physical activity, so it may be that a domain-specific measure (e.g., the Self-Efficacy for Exercise Scale; Resnick

& Jenkins, 2000) would have been more appropriate and would have captured this change quantitatively. Additionally, it could be that the brevity of this measure may have impacted its responsiveness to detect intervention-induced benefits.

Relative Efficacy

In the current study, we compared performance of the combined intervention to participants of the original Memory and Aging Program and a waitlist group. Like the original Memory and Aging program, the combined intervention had a positive impact on metamemory and lifestyle behaviors, indicating that the addition of physical exercise did not garner added benefits. The one exception to this was on the Ability subscale of the Multifactorial Memory Questionnaire where the combined intervention showed medium, significant gains in perceived memory ability and the original program showed small gains that were nonsignificant. This effect is likely attributable to the low baseline scores of the combined intervention group on this measure, indicating that the combined group perceived their memory abilities to be lower, which aligns with descriptive data that the combined intervention group had greater memory concerns at baseline than the waitlist or Memory and Aging control groups.

These relative efficacy findings align with research from the previous chapter which noted no additional benefit of combined interventions on mood and self-efficacy compared to passive and active controls. Improved performance in the combined intervention on metrics of metamemory was largely proportional to improvements by our cognitive comparison, the Memory and Aging Program. This is consistent with a previous meta-analysis showing that participants in the combined intervention group did not outperform participants in cognitive controls, specifically (Zhu et al., 2016). However, it is noteworthy that that meta-analysis looked at global cognition, not metamemory.

Results indicated that the combined intervention did not significantly impact objective memory or psychological well-being relative to no or single modality control interventions. The lack of relative benefit on objective memory is consistent with previous studies of combined interventions for participants with subjective cognitive complaints (Barnes et al., 2013; Boa Sorte Silva et al., 2018) but lies in contrast to several other reviews and meta-analyses showing a positive impact of combined interventions on general cognition (Bruderer-Hofstetter et al., 2018; Malmberg Gavelin et al., 2021). Interestingly, we also did not replicate a finding described in the previous chapter showing a superiority of combined interventions on quality-of-life outcomes (indexed by the RAND-36 in this study). This lack of replication may be attributable to the type of measure that we used. The RAND-36 Short Form Health Survey measures physical and mental health and is often used to determine health-related quality of life (e.g., fatigue, pain, and physical health problems; Ware & Gandek, 1998). Considering that our participants were engaging in greater levels of physical activity through the intervention, some level of fatigue or discomfort could be expected, so it may be that the health focus of this measure obfuscated gains in other aspects of quality of life. A less health-centric quality of life index could be used in future studies to investigate this further and to determine whether gains were made in other aspects of quality of life, such as social functioning and emotional well-being.

Finally, it is notable that participants in the cognitive group showed greater improvement relative to controls on the Health Responsibility and Stress Management subscales of the HPLP than the combined group. In fact, regarding health responsibility, the cognitive group had significantly greater improvements on health responsibility when compared to the combined group. Groups were not randomized in this study design so it may be that baseline differences account for this effect. Indeed, there were medium and small effect sizes that were nonsignificant at baseline indicating that the combined group had higher ratings of health responsibility and stress management. Considering that the combined group was self-selected, it may be that participants were already demonstrating high levels of health responsibility and showed less intervention-related change as a result.

Study Limitations

In this study, I utilized data from a previously conducted RCT for my active and passive comparison groups. The disadvantages of this approach are that the data were not collected concurrently, which introduces the possibility of a cohort effect, and the groups were not randomized. However, efforts were made to mitigate these shortcomings including analyses of key group demographics. Although a moderate effect was noted for age of the combined intervention group relative to the comparison group, other effects for education and telephone screening tools scores were small, and all these effects were statistically nonsignificant. Notably, several outcomes of interest in the combined intervention had not been evaluated in the comparison groups. Physical activity metrics, for example, were a novel addition to this trial for which there was no comparison group and thus were constrained to a single-arm evaluation. Additionally, although there were previously collected qualitative data, differences in interview questions and structure preclude a side-by-side evaluation, particularly with qualitative content analysis.

This study was conducted within a short time frame which impacted the duration of the intervention. Although an earlier review suggested that intervention length does impact cognitive outcomes (Lauenroth et al., 2016), two meta-analyses, one examining exercise interventions and the other combined interventions, found no moderating effects of intervention length on cognitive outcomes (Northey et al., 2018; Zhu et al., 2016). An additional issue is the intensity of exercise. A meta-analysis by Northey and colleagues (2018) found that the intensity of exercise plays a significant moderating role, namely, studies requiring at least moderate intensity activity had the greatest cognitive benefit. Considering this, one limitation of the current study is that participants were encouraged to increase their physical activity primarily through increased walking, a low intensity form of exercise, so it may be that a more vigorous form of exercise would have rendered greater improvements in measured outcomes.

This study was designed with due attention to standards of effectiveness research put forth by the Society of Prevention Research (Gottfredson et al., 2015). In particular, I focused on standards of intervention description, generalizability, and outcomes measured specifically, as these were areas of opportunity identified during the completion of the meta-analysis in Chapter 2. However, there were two standards that were not feasible to implement, namely the replication of an efficacy trial and the evaluation of population subgroups. The former is a salient issue, as the recommendation to replicate a previous study with established efficacy is considered fundamental. Yet, a primary motivating factor for the current study was the development of an accessible and scalable combined intervention, for which we had no prior model. Therefore, this study limitation is also a strength of the current research. The second standard not implemented, evaluating population subgroups, was due to an insufficient sample size. I offer suggestions to guide such investigations in the discussion of future directions below.

In this study, tracker adherence was measured using the number of days that participants reached at least 1000 steps (Hardcastle et al., 2020). A limitation of the type of tracker used was that the device does not offer data on minutes of wear time. Though participants were asked by study administrators to wear their devices throughout the day and most participants indicated that they did so, there is no objective data to verify length of wear time which could lead to an underestimation of daily steps or overestimation of sedentary time if the participants removed their devices for extended periods of time throughout the day.

A key feature of effectiveness studies is the use of a target sample, or the participants for whom the intervention was originally intended. Through the eligibility criteria, the aim was to offer the intervention to as many participants who expressed interest as possible, so the sample did not exclude participants with comorbid health conditions or histories of psychiatric illness. However, individuals without access to a computer or smart phone were ineligible for the study, and this has implications for generalizability and future directions in this line of work. Indeed, research has already identified that access to technology and reliable internet service for wearables research could exacerbate existing socioeconomic health inequalities (Allen & Christie, 2016; Cadmus-Bertram, 2017).

Notably, in conducting the study, the primary investigator had several responsibilities involving program design, program implementation, and analysis. Although efforts were made to limit the investigator's direct contact with participants to preserve independence (with research assistants recruiting, providing support, and conducting testing), the investigator did conduct all qualitative interviews. Further, she facilitated the Memory and Aging Program in one offering of the program over the span of the intervention. Efforts to mitigate subjective influence on study analyses included the use of research assistants in most client-facing roles, statistical consultation independent of research questions, and explicit identification of assumptions in the methodology section. In addition, qualitative content analysis was chosen to analyse the qualitative outcomes, a method requiring less interpretation than other qualitative methodologies in its use of systemic, rule-based coding (Morgan, 1993; Vaismoradi et al., 2013).

Future Directions

This research could be extended in several ways. Notably, since the data were collected for this study, the COVID-19 pandemic has occurred. More than ever, there is a need for interventions that can be conducted remotely, and this is especially important for vulnerable populations such as older adults. To date, combined interventions that can be offered remotely are in the minority. In one review, 4 of a possible 30 combined studies in healthy older adults were unsupervised (Malmberg Gavelin et al., 2021). Notably, all those interventions featured exergames. One advantage of using physical activity trackers as an element of physical activity is that participants report bolstered sentiments of social support (Kononova et al., 2019). Indeed, a few participants endorsed something similar within this study. Considering that social isolation and loneliness were pervasive issues for older adults previously (Newall & Menec, 2017) and that these issues have been exacerbated through the pandemic (Kotwal et al., 2021; Krendl & Perry, 2021; van Tilburg et al., 2020), the development of programs that can foster a sense of social connections is crucial (Morrow-Howell et al., 2020; Wu, 2020). The current study used a hybrid model, with the physical activity intervention being conducted remotely while the cognition-oriented component was offered in-person. However, the Memory and Aging Program has recently been developed and validated as an online program (Yusupov et al., 2021). Thus, one avenue of future exploration could be the addition of physical activity to the online program to determine whether results are similar in a fully remote offering of this intervention.

Efforts to determine fit between participant characteristics and this intervention type could also be a promising avenue for future research. In our study, a subset of participants who had high levels of baseline physical activity were less enthusiastic about the intervention, rating it as less cohesive and suggesting that activity tracker had minimal impact on activity levels. In fact, early survey research suggests that there may also be gender differences in the adoption and maintenance of wearable tracker use (Kononova et al., 2019), which could impact outcomes in similarly designed studies. Further research investigating population subgroups could thus serve to identify characteristics for whom a combined approach might be most effective and characteristics for whom a single approach might be equally effective. Doing so would be pragmatic on both a personal and public health level, thereby ensuring maximum benefit for those participating and cost effectiveness for those administering the intervention.

Conclusions

This study evaluated the effectiveness of a combined, community-based intervention in older adults with subjective cognitive concerns. The intervention was feasible, acceptable, and successful in increasing participants' physical activity, decreasing sedentary behavior, and enhancing participants' knowledge of memory and aging. The supplement of a physical activity component to an established memory intervention program offered participants an opportunity to put new information and skills into practice by acting upon didactic recommendations, utilizing key strategies, and experiencing the benefits. However, compared to the original program, the combined intervention did not yield additional benefits on outcomes of metamemory, objective memory, psychological well-being, or lifestyle. In sum, this study shows that combined interventions can be adapted for community use and that the current design effectively increases physical activity, decreases sedentary behavior, and supports healthy lifestyle change.

Table 4

Outcome Measures Evaluated in the Clinical Trial

Outcome Category	Description
Physical Activity	
Daily Step Counts	Daily step counts were obtained from participants' Fitbit devices
Sedentary Minutes	Sedentary minutes were defined as minutes without discernible activity and were obtained from participants' Fitbit devices
Memory Measures	
Memory Knowledge Quiz	A modified version (Troyer, 2001; Troyer & Vandermorris, 2012) assessing knowledge about memory processes, age-related changes, and memory strategies
Multifactorial Memory Questionnaire	A questionnaire with three scales evaluating subjective memory ability, memory strategy use, and satisfaction with memory performance (Troyer & Rich, 2002)
Memory Strategy Toolbox	A previous modification (Vandermorris et al., 2020) of the Memory Strategy Toolbox (Troyer, 2001) used to quantify behaviour change in memory-dependent everyday situations
Surname Learning Task	A test quantifying objective memory performance based on participants' recollection of surnames presented visually (based on Troyer et al., 2006)
Psychological Well-being	
Positive and Negative Affect Schedule	A survey used to assess positive and negative affect across two scales (Watson et al., 1988)
Generalized Self-Efficacy Scale	A short measure quantifying generalized self-efficacy (Schwarzer & Jerusalem, 1995)
Health and Lifestyle Measures	
RAND-36	A short-form health survey which provides summary scores of physical and mental health, reflecting health-related quality of life (Ware & Gandek, 1998)
Health Promoting Lifestyle Profile II	A multi-scale measure quantifying changes in healthy lifestyle behaviours (Walker et al., 1987)

Table 5

Participant Demographics by Group

	Current Participants	Comparison Participants		Effect Sizes		
	Group 1 Cognitive + Physical (*n = 22*)	Group 2 Cognitive (*n = 34*)	Group 3 Control (*n = 33*)	Cohen's *d*		
	M (SD)	M (SD)	M (SD)	Group 1 – Group 2	Group 1 – Group 3	Group 2 – Group 3
Age (years)	75 (5.8)	71 (8.8)	72 (8.3)	0.53	0.42	0.12
Education (years)	16 (1.8)	16 (2.2)	15 (3.2)	0.00	0.41	0.36
TICS total score	35 (3.2)	34 (2)	35 (2.4)	0.37	0.00	0.45
	Proportion	Proportion	Proportion			
Female	73%	77%	67%	0.07	0.13	0.20
Memory Concerns	95%	79%	70%	0.49	0.69	0.20

Note. TICS = Telephone Interview for Cognitive Status

Table 6

Participants' Level of Comfort with Technology on a 5-point Scale

	Computers n (%)	Internet n (%)	Smart Phone n (%)
1 (not comfortable)	2 (9)	2 (9)	2 (9)
2	1 (5)	0 (0)	2 (9)
3	3 (14)	6 (27)	3 (14)
4	7 (32)	4 (18)	3 (14)
5 (very comfortable)	9 (41)	10 (45)	12 (55)

Table 7

Qualitative Themes and Subthemes Regarding Program Acceptability

Themes	Frequency of Endorsement	
	n	%
Theme 1: Program Acceptability		
Satisfaction with the Program	14	78
Perceptions of Program Cohesion	11	44
Barriers Encountered During the Program	11	61
Health or Illness	3	17
Lack of Time	1	6
Forgetting to Wear Activity Tracker	1	6
Weather	4	22
Difficulty with Technology	1	6
No Barriers Faced	4	22
Suggestions for Improvement	4	22
Integration of the Activity Tracker into the Class	2	11
Incorporation of Other Types of Exercise	2	11
Theme 2: General Program Feedback		
Positive Aspects of the Program	17	94
Automaticity and Accountability	11	61
Flexibility	11	61
Research Grounding	6	33
Facilitator Support	4	22

“Putting into Practice”	11	61
What I liked About the Tracker	10	56
Negative Aspects of the Intervention	11	61
Program Specific	5	28
Aspects of the Activity Tracker That Were Disliked	7	39
Theme 3: Nature of Program Engagement		
Activity Tracker Use Details	13	72
Tracker Features Used	9	50
Interaction with the App	9	50
How Participants Got Their Steps	14	78
Concerted Effort to Walk More	14	78

Note. Lower order categories are indented in this table and are not mutually exclusive. Individual codes which had insufficient representation to warrant a lower order category also contributed to endorsement of higher order categories.

n = the number of participants endorsing a theme.

Table 8

Descriptive Statistics for Primary Outcomes

	Baseline (*n* = 22)		Post-test (*n* = 22)		Follow-up (*n* = 22)		Effect Size (Cohens' *d*)		
	M	SD	M	SD	M	SD	Baseline – Post-test	Post-test – Follow-up	Baseline – Follow up
Daily Steps *	5406.1	2875.8	6232	3136.6	6869.9	3752.8	0.46	0.32	0.57
Sedentary Minutes	958.1	207.3	873	186.9	865	199.4	0.47	0.06	0.40
Memory Knowledge Quiz *	4.1	3.3	12.8	6.0	11.8	6.7	1.49	0.36	1.16

Note. *= significant effect of time for within-group repeated measures analysis at $p = .05$.

Table 9

Qualitative Themes and Subthemes Relating to Program Outcomes

Themes	Frequency of Endorsement	
	n	%
Theme 1: Behavior Change		
Lifestyle Changes	18	100
Physical Activity	18	100
Other Activity Types	9	50
Enrolling in Classes and Committees	5	28
Increased Social Engagement	3	17
Exploring the Community	3	17
Memory Strategy Use	11	61
Increased Strategy Utilization	10	56
No Changes in Strategy Use	1	6
Theme 2: Psychological Well-being		
Sentiments of Agency and Independence	12	67
Agency in Aging	5	28
Sense of Independence	2	11
Impact on Mood	10	56
Sentiments of Confidence	5	28
Feeling More Positive	4	22
Change in Perspective	10	56
Accept Where I Am, Do What I Can	9	50

Hope for the Future	3	17
Theme 3: Impact on Memory		
Memory Function	7	39
Improvement in Memory Abilities	2	11
No Notable Change in Memory	5	28
How I Feel About My Memory	16	89
Normalization of Memory Struggles	13	72
Theme 4: Subjective Health		
Changes in Subjective Health	9	50
Energized	2	11
Healthier	8	44
Happier with My Body	2	11
Less Tired	2	11
Theme 5: Sustainability and Continuity		
Intention to Maintain Behavior Changes	18	100
Will Continue to Use Activity Tracker	16	89
No Plans to Continue Activity Tracker Use	2	11

Note. Lower order categories are indented in this table and are not mutually exclusive. Individual codes which had insufficient representation to warrant a lower order category also contributed to endorsement of higher order categories.

n = the number of participants endorsing a theme.

Table 10

Descriptive Statistics for Relative Efficacy Analyses by Group

	Current Participants			**Comparison Participants**					
	Combined Intervention (*n* = 22)			Cognitive Intervention (*n* = 34)			Waitlist Control (*n* = 33)		
	Baseline M(SD)	Post-test M(SD)	Follow-up M(SD)	Baseline M(SD)	Post-test M(SD)	Follow-up M(SD)	Baseline M(SD)	Post-test M(SD)	Follow-up M(SD)
Metamemory									
MMQ- Ability*	43.5 (9.9)	50.3 (8.6)	51.6 (8.3)	45.4 (9.6)	50 (10.2)	51.6 (9.4)	51.8 (9)	53.3 (8.7)	53.3 (9.3)
MMQ- Strategy*	38.7 (9.1)	47.2 (10.5)	44.7 (10.2)	34.8 (8.7)	43 (8)	41.5 (7.7)	38.9 (8)	39.7 (9.7)	42.1 (8.7)
MMQ- Satisfaction*	32.5 (9.7)	39.5 (13.4)	41.4 (13.7)	34.7 (11.9)	43.6 (14.8)	42.8 (12.2)	44.2 (13)	43.6 (14.4)	43.5 (12.9)
Memory Strategy Use*	9.3 (4.1)	13.6 (5.1)	13.6 (5.6)	8.8 (3.9)	14.2 (6.5)	14.1 (6.0)	11.7 (4)	12.4 (4.6)	11.8 (4.8)
Objective memory									
Surname Task	6.5 (1.9)	6.5 (2.3)	6.7 (2.2)	6.7 (2.3)	6.9 (1.8)	7.5 (2.3)	6.7 (1.6)	7.1 (1.8)	7.4 (1.9)
Psychological well-being									
PANAS- Positive	30.4 (4.1)	30.4 (6.1)	30.1 (4.0)	35.8 (7.5)	34.7 (8.1)	35.3 (7.3)	35.8 (6.5)	34.1 (9.2)	35 (7)
PANAS- Negative	21.8 (3.7)	21.3 (4.7)	20.5 (3.2)	17 (6.2)	16.0 (6.1)	14.7 (4.1)	15.9 (5.6)	16.2 (5)	15.3 (4.8)
GSE	31.1 (4.8)	31.6 (4.5)	33.1 (5.2)	30.9 (4.3)	31.1 (4)	31.4 (4)	30.9 (5)	31.1 (5)	32.4 (3.7)
Health & lifestyle									
RAND 36- Total	71.5 (16.6)	74.8 (15.1)	73.5 (16.6)	71.5 (16.8)	71 (15.2)	72.5 (13.6)	69.4 (15)	69.8 (17.3)	71.7 (13.7)
HPLP-II – Total*	148.1 (25.2)	151.7 (21.4)	152.4 (20.9)	139.1 (17.6)	142 (16.1)	146.6 (19.5)	140.6 (18.2)	131.3 (30.8)	137.8 (18.2)
HPLP-II – HR*	2.8 (.6)	2.7 (.5)	2.8 (.5)	2.5 (.6)	2.6 (.6)	2.6 (.6)	2.7 (.3)	2.7 (.4)	2.7 (.3)
HPLP-II – PA	2.4 (.9)	2.7 (.9)	2.7 (.7)	2.3 (.6)	2.5 (.6)	2.4 (.6)	2.4 (.7)	2.4 (.7)	2.5 (.6)

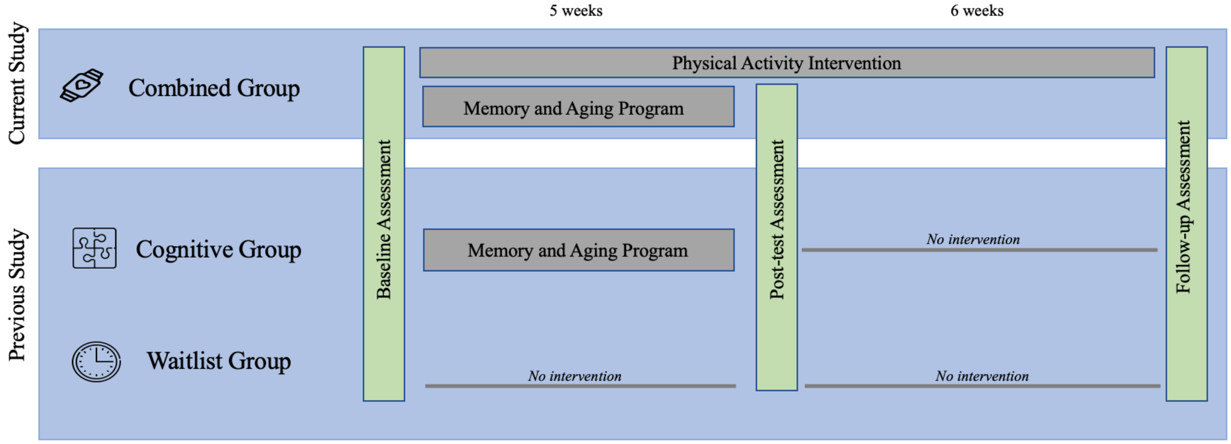
HPLP-II – Nutrition	2.9 (.6)	3 (.6)	3 (.5)	3 (.4)	3.1 (.5)	3.1 (.5)	2.9 (.4)	2.9 (.4)	2.8 (.6)
HPLP-II – SG	3 (.6)	3 (.6)	3 (.6)	2.9 (.6)	2.9 (.6)	3.0 (.6)	2.8 (.6)	2.7 (.6)	2.8 (.5)
HPLP-II – IR	3.2 (.4)	3.3 (.4)	3.3 (.5)	3.1 (.5)	3.1 (.6)	3.1 (.6)	3 (.6)	3 (.5)	2.9 (.5)
HPLP-II – SM*	2.7 (.6)	2.8 (.5)	2.8 (.5)	2.5 (.6)	2.5 (.5)	2.7 (.5)	2.6 (.5)	2.5 (.5)	2.5 (.5)

Note. Values are means and standard deviations of raw scores by group and time. MMQ = Multifactorial Memory Questionnaire; PANAS = Positive and Negative Affect Schedule; GSE = Generalized Self Efficacy; RAND-36 = RAND 36-Item Health Survey; HPLP = Health Promoting Lifestyle Profile II; HR = Health Responsibility subscale; PA = Physical Activity subscale; SG = Spiritual Growth subscale; IR = Interpersonal Relations subscale; SM = Stress Management

* = significant group by time interaction at $p < .05$.

Figure 4

Study Timeline



Note. Participants in the combined intervention received their Fitbits upon receipt of physician consent. For most participants, this occurred at the first session of the Memory and Aging Program.

Figure 5

CONSORT Participant Flow Chart

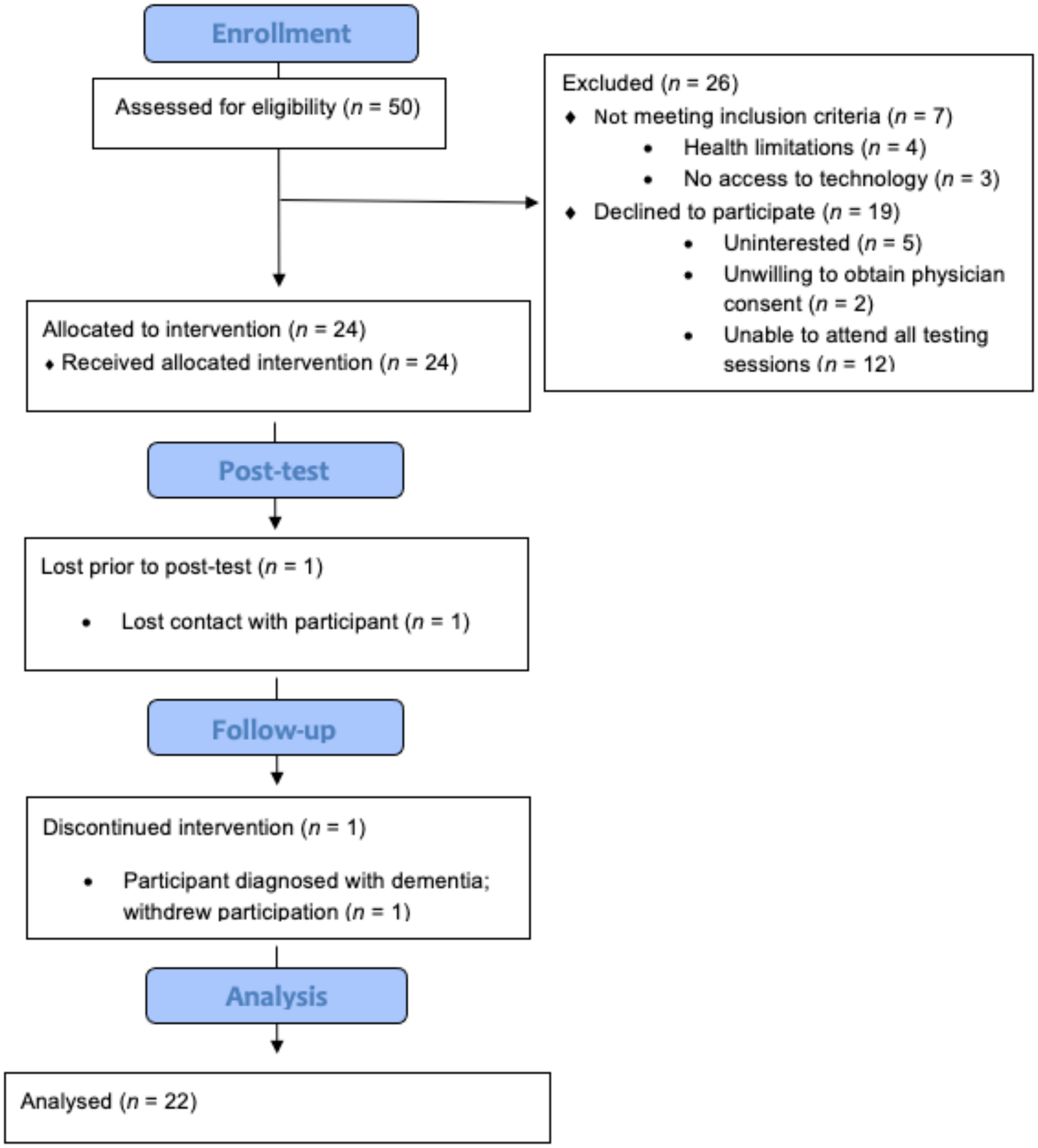
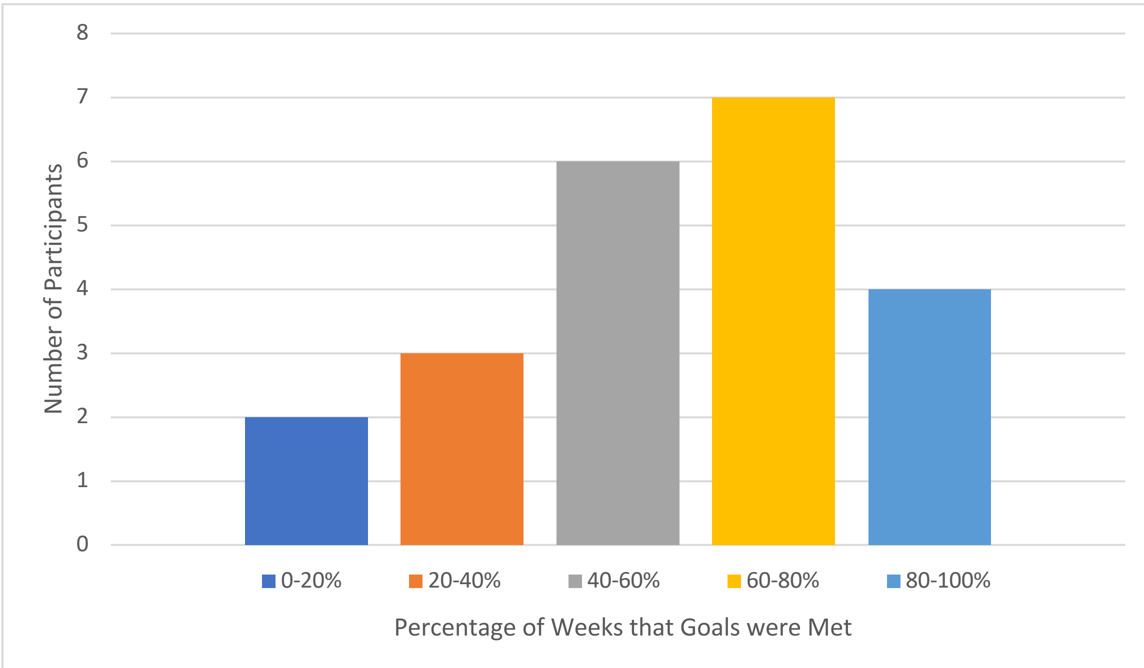


Figure 6

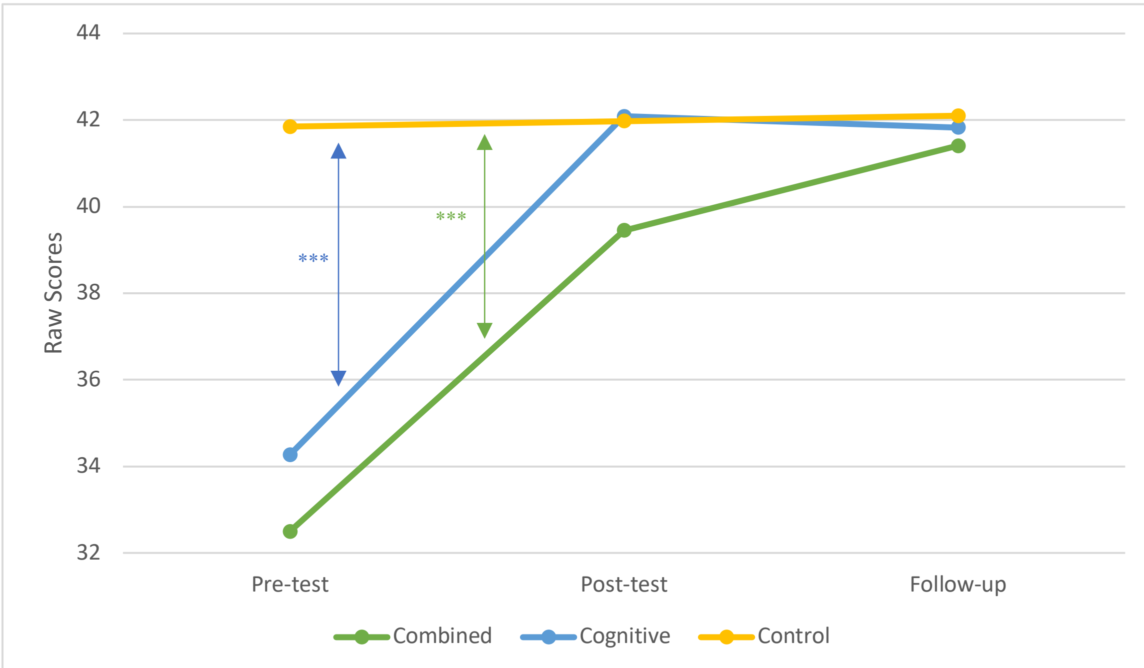
Weekly Step Goal Adherence



Note. Values are percentages representing the number of weeks that goals were met out of the total number of weeks goals were set for each participant.

Figure 7

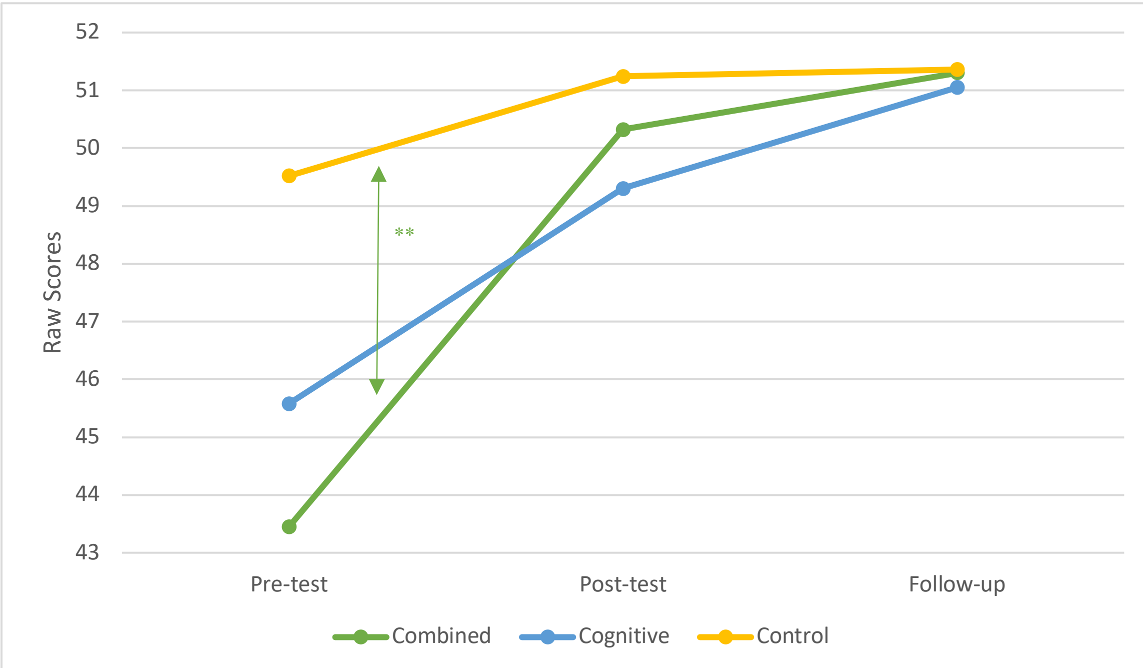
Group by Time Interaction of the MMQ Satisfaction Subscale



Note. *** = large effect size.

Figure 8

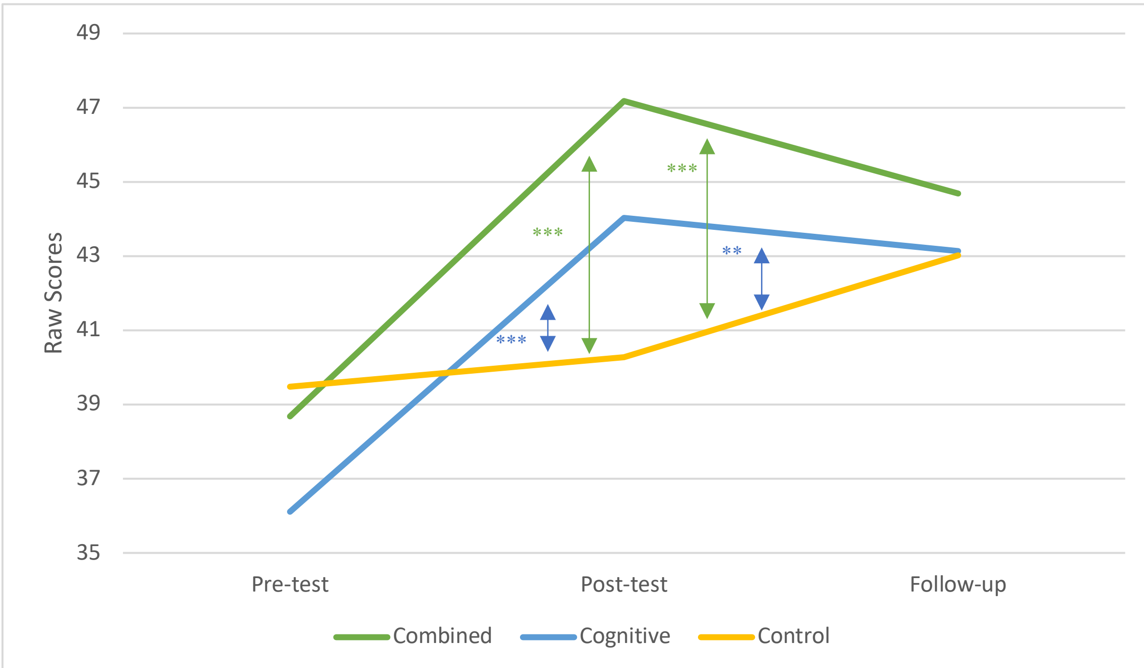
Group by Time Interaction of the MMQ Ability Subscale



Note. ** = medium effect size.

Figure 9

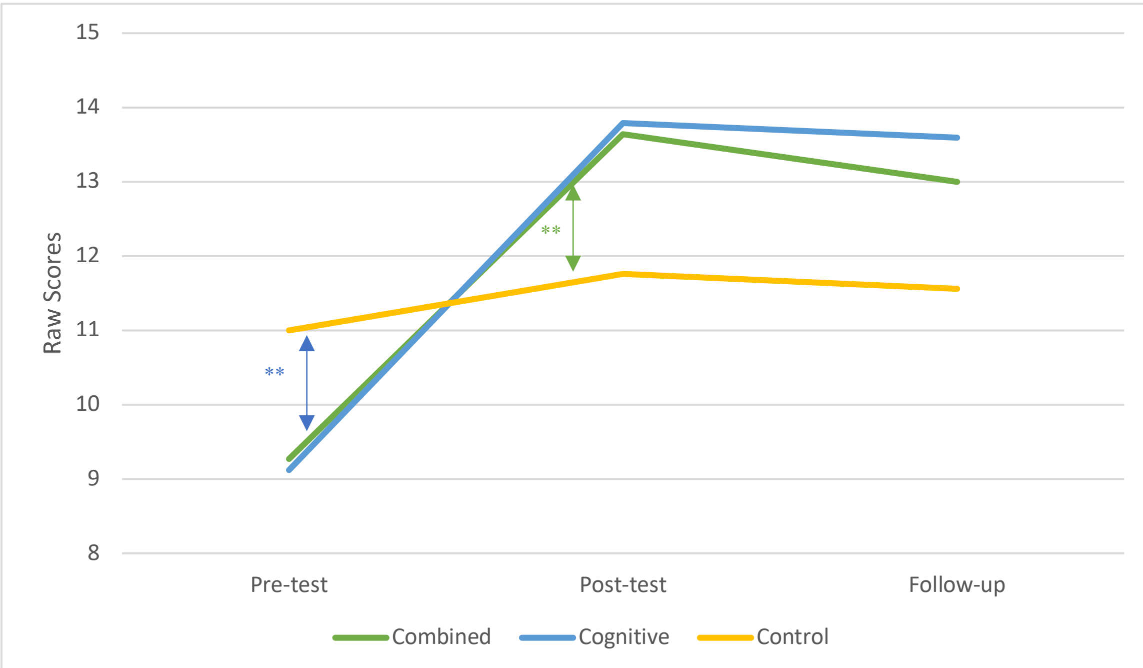
Group by Time Interaction of the MMQ Strategy Subscale



Note. ** = medium and *** = large effect size

Figure 10

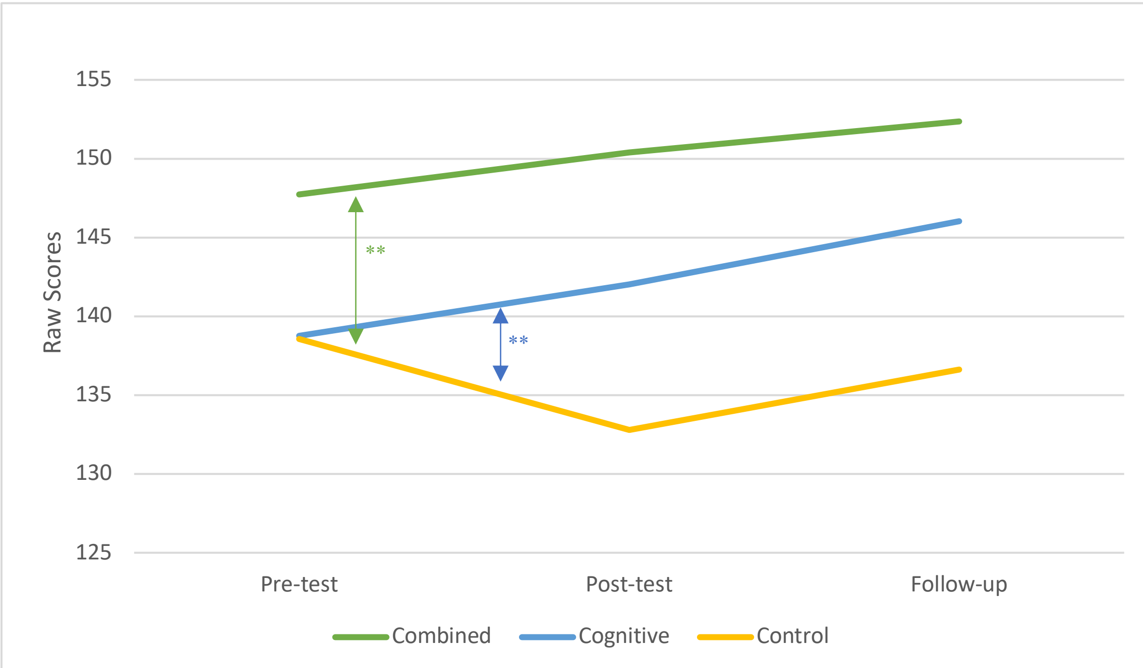
Group by Time Interaction of Strategy Use as Measured by the Memory Strategy Toolbox



Note. ** = medium effect size.

Figure 11

Group by Time Interaction of the Health Promoting Lifestyle Profile



Note. ** = medium effect size.

CHAPTER 4

General Discussion

General Summary

The overarching goal of this dissertation was to evaluate the generalizability of a growing trend in neurocognitive interventions; the use of combined physical and cognitive activity interventions to promote healthy brain aging and minimize dementia risk. The extent to which these interventions impact everyday life or can be translated into accessible, community-based interventions had yet to be investigated. In view of this, I conducted two studies, each focusing on an aspect of generalizability. In this chapter, I provide a summary of each study and finish with a discussion of clinical implications and future directions.

In Chapter 2, I reported a systematic review and meta-analysis evaluating the everyday impact of combined cognitive and physical activity interventions in healthy older adults. Twelve studies contributed to the meta-analysis that showed that combined interventions had small, positive effects on participant quality of life. Combined interventions did not yield additional benefits to a combined control comparison (featuring active and passive control groups) with respect to mood, activities of daily living, or self-efficacy. Implications stemming from this review include calls for the increased adoption of everyday outcomes in intervention designs, as the lack of such outcomes was the most common reason for study exclusion. In addition, the heterogeneous nature of the outcomes evaluated underscored a need for consensus guidelines of everyday outcomes known to be impacted by age-related changes and of importance to participants when enrolling in interventions. The establishment of such guidelines would facilitate consistency and comparability between studies and be an important step in ensuring greater development of person-centered interventions.

In Chapter 3, I reported the development and evaluation of a combined, community-based intervention. Recognizing an opportunity to evaluate real-world combined interventions as identified in the meta-analysis, the purpose of this study was to determine the effectiveness of a replicable and accessible program for healthy, community dwelling older adults. The intervention involved the addition of physical activity, facilitated by the provision of wearable activity trackers, to a well-established memory intervention program providing psychoeducation, training in compensatory memory strategies, and coaching on lifestyle behaviors. The combined intervention was determined to be feasible and acceptable, and participants demonstrated an increase in physical activity, a decrease in sedentary behavior, and improvement on subject knowledge of memory and aging. Relative to the original program, the combined program did not yield additional benefits on quantitative measures of metamemory, objective memory, psychological well-being, or health and lifestyle. This study showed that combined interventions can be adapted to community-based settings using accessible interventions but provided further credence to previous research suggesting that the superiority of combined interventions is contingent on the nature of the control group. Indeed, in this study psychoeducation and coaching on lifestyle modification in the comparison program was sufficient to yield improvements in metamemory, and even increased participants' sense of health responsibility and stress management capabilities significantly compared to the combined intervention group. Future research investigating participant subgroups would help ascertain moderating factors of intervention success.

Collectively, these studies built upon previous research and demonstrated that outcomes, as well as the combined interventions themselves, can extend beyond the research laboratory.

However, they also underscore an opportunity for greater investigation of the real-life impact and real-world implementation of combined interventions.

Clinical Implications and Future Directions

Recognizing a need for early intervention, programs promoting cognitive health and management of modifiable risk factors have become research priorities (WHO, 2018). Although great strides have been made in the development of interventions impacting cognitive outcomes, questions of generalizability remained unanswered. The present set of studies addressed two of these questions, establishing greater generalizability of combined interventions in terms of everyday impacts and their implementation. Ultimately, if the goal of health promotion research is widespread dissemination, it will be important to continue ascertaining whether these interventions impact everyday outcomes of value to participants and to determine effectiveness when such interventions are administered in real-world settings.

Chapter 2 of this dissertation contributes to a body of literature calling for greater examination of outcomes impacting everyday life in cognitive aging interventions (Chandler et al., 2016; Rodakowski et al., 2015). The current research suggests that combined interventions have a positive effect on everyday life but, like previous reviews of everyday outcomes in the parallel literature, the heterogeneity of outcomes makes it difficult to determine this precisely (Cooper et al., 2013; Gates et al., 2011; Huckans et al., 2013; Kurz et al., 2011). Thus, consistency in examining and reporting these outcomes will be critical to better understand the everyday impact of these interventions (Chandler et al., 2016; Huckans et al., 2013). Granted, there are limits to the number of outcomes that can be assessed within a study owing to factors of time and participant capacity. To circumvent this, measures assessing multiple aspects of everyday impact could be prioritized. For instance, the Multifactorial Memory Questionnaire

(Troyer & Rich, 2002), which was used in Chapter 3, has been recognized for its frequency of use within the field and its flexibility (indexing metacognition, memory satisfaction, and the use of memory strategies; Chandler et al., 2016).

One take-away from the meta-analysis in Chapter 2 was that the greater investigation of everyday impact is a necessary step in the conduct of client-oriented research and client-centered care to ensure clients' expressed needs are met (Barrios et al., 2016; Harrison et al., 2016; Watson et al., 2019). Although health promotion seems inherently client oriented, it has been argued that typical measures of intervention success (e.g., changes in cognitive scores or mortality) are researcher oriented, emphasizing evaluation and treatment (Godlee, 2012; Sacristán, 2013). Client-centered research, by contrast, pays heed to outcomes that are of value to the clients themselves (Reuben & Tinetti, 2012; Sacristán, 2013). Of course, the goal of participant-oriented research is not to replace "hard" or researcher-oriented outcomes (Reuben & Tinetti, 2012). Instead, this approach advocates for the closing of the gap between clinical research and clinical practice. The inclusion of outcomes that consider clients' perspectives (e.g., examining social and role functions and quality of life) is one way this gap can be closed (Reuben & Tinetti, 2012). If future health promotion and dementia risk reduction interventions were to adopt a more client-oriented approach, everyday outcomes could become a routine outcome evaluated. Greater investigation and consistency could facilitate the creation of clinical practice guidelines that consider everyday outcomes, offering clinicians additional evidence of intervention success in domains appealing to clients and study participants that could help inform their recommendations.

Another central tenet of client-centered care is that clients should benefit from clinical research. Yet, a gap exists between health promotion research and clinical practice owing to a lack of generalizability (Clark, 1995; Glasgow et al., 2003). One suggested contributor to this problem is the assumption that effectiveness research naturally follows efficacy research, so internal validity and external validity can be addressed independently at each stage (Glasgow et al., 2003). Certainly, a desire to establish generalizability and applicability of combined interventions was the motivating factor underlying the empirical study reported in Chapter 3. Moving forward, it has been suggested that a shift away from this two-pronged approach is necessary as the characteristics that make efficacy research successful are at odds with characteristics of successful community-based programs, which makes translation between the two difficult (Glasgow et al., 2003). There are several recommendations for future efficacy research that could bridge this growing divide to better ensure effective translation of new prevention approaches (Glasgow et al., 2003; Gottfredson et al., 2015; Schloemer & Schröder-Bäck, 2018). These include (a) exploration of population subgroups in research, recognizing heterogeneity in patient populations; (b) use of participatory research methods, eliciting participant input during intervention design, and incorporating qualitative and quantitative measures; and (c) inclusion of a variety of levels of expertise for the persons administering the intervention (Glasgow et al., 2003; Schloemer & Schröder-Bäck, 2018).

The two topics addressed within the present studies, generalizability of impact and generalizability of implementation, are also important to consider in parallel fields of research. One such field is the development of multidomain interventions, which consist of at least three intervention types, such as cognitive engagement, physical activity, and nutrition (for a review, see Bott et al., 2019). Although early research within the field has focused on cognitive outcomes and risk scores (Kivipelto et al., 2018; Ngandu et al., 2015), protocols of ongoing longitudinal trials are promising in their holistic approaches. Studies such as the Age well.de project

(Germany), the Systematic Multi-Domain Alzheimer's Risk Reduction Trial (United States), and Efficacy of Multiple Nonpharmacological interventions study (Italy) are all evaluating several participant-oriented outcomes, including mood, activities of daily living, lifestyle change and subjective cognitive concerns (Rolandi et al., 2020; Yaffe et al., 2019; Zülke et al., 2019).

Another area whereby future research can build upon the present work pertains to accessibility. As can be seen in the meta-analysis in Chapter 2, many combined studies employed strict eligibility criteria or interventions requiring substantive equipment. Although this enables researchers to determine intervention efficacy more precisely, it also means that many potential participants would be excluded. Efforts made to enhance accessibility in the current study included the use of broad eligibility criteria and the identification of intervention components that were relatively low-cost and available to be scaled up. Yet, there are numerous additional ways that we can and, in the interest of equity, should continue to address accessibility.

When reflecting on accessibility, it will be important to consider the role of cultural and socioeconomic barriers in future research within the field. The use of health technology in interventions, for example, has the potential to exacerbate existing socioeconomic health disparities (Allen & Christie, 2016; Cadmus-Bertram, 2017). Regarding culture, the studies featured in our systematic review and the clinical trial itself were all conducted in high-income countries. This is particularly noteworthy considering that dementia prevention efforts, and lifestyle modification, would have the greatest impact in low-income and middle-income countries where protective factors against dementia (such as elementary education or successful management of chronic health conditions) may be less commonly available (Livingston et al., 2020). There are also opportunities to investigate accessibility within high-income countries, with an identified need to design and deliver interventions to socially disadvantaged groups who are at highest risk of developing dementia and related diseases (Livingston et al., 2020). Indeed, research suggests that patterns of risk and lifestyle behaviors (e.g., physical activity) are different amongst cultural and ethnic groups (Livingston et al., 2020), underscoring the need for intentional investigation of intervention impact in population subgroups (Glasgow et al., 2003).

Conclusion

This dissertation began with, and was fuelled by, questions of generalizability. Within these pages, I showed that combined interventions can have impacts generalizable to everyday life and can be implemented in community-based settings with replicable and accessible treatment components. Yet several questions remain unanswered. It remains to be seen whether, with greater assessment of everyday outcomes, combined interventions offer greater benefit to participants' everyday lives as compared to other interventions. The adoption of consensus guidelines, identifying outcomes known to be impacted by aging and of importance to older adults, would be a critical step in advancing the field in this direction. Also, the evaluation of participant characteristics and population subgroups would serve to identify individuals who might benefit most from interventions of a combined nature, an important step in ensuring cost-effectiveness in intervention administration. Finally, it will be vital to consider greater issues of accessibility and barriers to participation, to ensure research effectiveness in populations less frequently studied, including ethnic minorities, individuals living in rural areas, and in lower income countries.

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Appendices

Appendix A: Detailed Search Strategy

OVID MEDLINE(R) and In-Process & Other Non-Indexed Citations

1. Aged/ or "Aged, 80 and Over"/
2. Bicycling/ or Circuit-Based Exercise/ or Endurance Training/ or Exercise/ or Golf/ or Gymnastics/ or High-Intensity Interval Training/ or Jogging/ or Martial arts/ or Muscle Stretching Exercises/ or Physical Conditioning, Human/ or Plyometric Exercise/ or Racquet sports/ or Resistance Training/ or Running/ or Skating/ or Skiing/ or Snow sports/ or Soccer/ or Sports/ or Stair Climbing/ or Swimming/ or Tai ji/ or Tennis/ or "track and field"/ or Volleyball/ or Walking/ or Weight lifting/ or Yoga/
3. Attention/ or Cognitive Behavioral Therapy/ or Combined Modality Therapy /or Executive function/ or Learning/ or Meditation/ or Memory/ or Mindfulness/ or Relaxation therapy/ or ((dual adj2 task*) or cognitive restructuring or self-instructional training or brain train* or (train* adj2 brain)).ti,ab,kw
4. (infant* or infancy or newborn* or baby* or babies or neonat* or preterm* or prematur* or postmatur* or child* or schoolchild* or school age* or preschool* or kid or kids or toddler* or adoles* or teen* or boy* or girl* or minors* or pubert* or pubescen* or prepubescen* or paediatric* or paediatric* or peadiatric* or nursery school* or kindergar* or primary school* or secondary school* or elementary school* or high school* or highschool* or youth).ti,ab,kw.
5. (obese or obesity or diabetes* or cancer* or epilep* or parkinson* disease or stroke*).ti,ab,kw.
6. 1 and 2 and 3
7. 6 not 4
8. 7 not 5
9. limit 8 to English language

10. limit 9 to (bibliography or comment or editorial or letter or “review” or “scientific integrity review” or “systematic review” or systematic reviews as topic or webcast)

11. 9 not 10

Embase

1. Aged/ or "Aged, 80 and Over"/

2. Bicycling/ or Circuit-Based Exercise/ or Endurance Training/ or Exercise/ or Golf/ or Gymnastics/ or High-Intensity Interval Training/ or Jogging/ or Martial arts/ or Muscle Stretching Exercises/ or Physical Conditioning, Human/ or Plyometric Exercise/ or Racquet sports/ or Resistance Training/ or Running/ or Skating/ or Skiing/ or Snow sports/ or Soccer/ or Sports/ or Stair Climbing/ or Swimming/ or Tai ji/ or Tennis/ or "track and field"/ or Volleyball/ or Walking/ or Weight lifting/ or Yoga/

3. Attention/ or Cognitive Behavioral Therapy/ or Combined Modality Therapy /or Executive function/ or Learning/ or Meditation/ or Memory/ or Mindfulness/ or Relaxation therapy/ or ((dual adj2 task*) or cognitive restructuring or self-instructional rtaining or brain train* or (train* adj2 brain)).ti,ab,kw

4. (infant* or infancy or newborn* or baby* or babies or neonat* or preterm* or prematur* or postmatur* or child* or schoolchild* or school age* or preschool* or kid or kids or toddler* or adoles* or teen* or boy* or girl* or minors* or pubert* or pubescen* or prepubescen* or paediatric* or paediatric* or peadiatric* or nursery school* or kindergar* or primary school* or secondary school* or elementary school* or high school* or highschool* or youth).ti,ab,kw.

5. (obese or obesity or diabetes* or cancer* or epilep* or parkinson* disease or stroke*).ti,ab,kw.

6. 1 and 2 and 3

7. 6 not 4

8. 7 not 5

9. limit 8 to English language

10. limit 9 to (editorial or letter or “review”)

11. 9 not 10

APA PsycInfo

1. (aged, 80 and over) or Aged or Centenarian* or Elderly or Geriatric or Nonagenarian* or Octogenarian* or Old* adult or Oldest old or Senior or Young old
2. “track and field"/or Bicycling/or Circuit-based exercise/or Endurance training/or Exercise/or Golf/or Gymnastics/or High-intensity interval training/or Jogging/or Martial arts/or Muscle stretching exercises/or Physical activity/or Physical conditioning, human/or Plyometric exercise/or Racquet sports/or Resistance training/or Running/or Skating/or Skiing/or Snow sports/or Soccer/or Sports/or Stair climbing/or Swimming/or Tai ji/or Tennis/or Volleyball/or Walking/or Weight lifting/or Yoga/
3. Attention/or Brain training/or Cognitive behavioral therapy/or Combined modality therapy/or Dual task performance/or Executive function/or Learning/or Meditation/or Memory/or Mindfulness/or Relaxation therapy/
4. 1 and 2 and 3
5. 4 not (infant* or infancy or newborn* or baby* or babies or neonat* or preterm* or prematur* or postmatur* or child* or schoolchild* or school age* or preschool* or kid or kids or toddler* or adoles* or teen* or boy* or girl* or minors* or pubert* or pubescen* or prepubescen* or paediatric* or paediatric* or peadiatric* or nursery school* or kindergar* or primary school* or secondary school* or elementary school* or high school* or highschool* or youth)
6. limit 5 to (bibliography or "column/opinion" or "comment/reply" or editorial or encyclopedia entry or letter or obituary or poetry or publication information or review-book or review-media or review-software & other or reviews)
7. 5 not 6
8. 7 not (obes* or diabetes* or cancer* or epilep* or parkinson* disease or stroke*)

EBM Reviews - Cochrane Central Register of Controlled Trials

1. Aged/ or "Aged, 80 and Over"/
2. Bicycling/ or Circuit-Based Exercise/ or Endurance Training/ or Exercise/ or Golf/ or Gymnastics/ or High-Intensity Interval Training/ or Jogging/ or Martial arts/ or Muscle Stretching Exercises/ or Physical Conditioning, Human/ or Plyometric Exercise/ or Racquet sports/ or Resistance Training/ or Running/ or Skating/ or Skiing/ or Snow sports/ or Soccer/ or Sports/ or Stair Climbing/ or Swimming/ or Tai ji/ or Tennis/ or "track and field"/ or Volleyball/ or Walking/ or Weight lifting/ or Yoga/
3. Attention/ or Cognitive Behavioral Therapy/ or Combined Modality Therapy /or Executive function/ or Learning/ or Meditation/ or Memory/ or Mindfulness/ or Relaxation therapy/ or ((dual adj2 task*) or cognitive restructuring or self-instructional training or brain train* or (train* adj2 brain)).ti,ab,kw
4. (infant* or infancy or newborn* or baby* or babies or neonat* or preterm* or prematur* or postmatur* or child* or schoolchild* or school age* or preschool* or kid or kids or toddler* or adoles* or teen* or boy* or girl* or minors* or pubert* or pubescen* or prepubescen* or paediatric* or paediatric* or peadiatric* or nursery school* or kindergar* or primary school* or secondary school* or elementary school* or high school* or highschool* or youth).ti,ab,kw.
5. (obese or obesity or diabetes* or cancer* or epilep* or parkinson* disease or stroke*).ti,ab,kw.
6. 1 and 2 and 3
7. 6 not 4
8. 7 not 5
9. limit 8 to English language

Appendix B: Semi-Structured Interview

Introductory Remarks:

> *"The purpose of this interview is to give an opportunity to hear what participating in the intervention was like for you, and to provide a forum for you to discuss things that may not have been captured in the paper measures. For example, changes that you have made since the intervention started. As you know, the program is new, so we are also interested in hearing about any suggestions for the program or improvements that you think could be helpful.*
> *Are you comfortable with me audio-recording this interview? Everything you share will be kept confidential. Once transcribed, the recording will be deleted."*

Interview Script:

How did using a tracker during the Memory and Aging program influence you?

> How did you use your tracker?
>
> Did you encounter any barriers to using the tracker and/or participating in physical activity?
>
> What did you like most about using the tracker? Least?
>
> Will you continue to use the tracker? What other changes do you plan to maintain?

How did increasing your physical activity over the course of this study impact you? (Any changes in socialization, mood etc.)

> How did it change the way you feel about your memory?
>
> How did it change the way you feel about your own capabilities? (Self-efficacy)

How has participation in this program impacted the way that you feel about your memory?

Do you think your day-to-day memory performance has changed as a result of what you learned in this program?

How has the program impacted your sense of health and well-being? (Mental, emotional, physical)

If you had participated in the Memory and Aging Program (and not had the Fitbit add-on), how do you think your experience would have been different?

How has the combination of the two impacted you?

Is there anything you would like to add that I haven't asked about?