CORTEX-II: A randomized trial to test the effectiveness of multi-modal cognitive training on yearlong physical activity self-regulation among middle-aged adults

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SPM contributed to the conceptualization, acquired funding, developed the methodology, administered the project, provided resources, supervised the work, validated the results, wrote the original draft, and reviewed and edited the manuscript; YL and SS contributed to the conceptualization, formal analysis, and reviewed and edited the manuscript, and SS also assisted in the development of the methodology and acquisition of the funding; XL reviewed and edited the manuscript; KM and DB contributed to data processing and archiving, revised and edited the manuscript; DDT and AT contributed to data curation, revised and edited the manuscript; IC, JA, JN, DP, TB, and JC contributed to the conceptualization, data curation, reviewed and edited the manuscript; AFK and EM contributed to the methodology, acquired funding and reviewed and edited the manuscript

Funding

Research reported in this publication was supported by the National Institute on Aging of the National Institutes of Health under Award Number R01AG052707. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Conflict of Interest

The authors declare that they have no conflicts of interest.

Ethical Approval

All procedures performed in this study involving human participants were in accordance with the ethical standards of the University of Illinois at Urbana-Champaign's Office of Protection for Research Subjects' Biomedical Institutional Review Board and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

Statement on the Welfare of Animals

This article does not contain any studies with animals performed by any of the authors.

Transparency Statement

- Study Registration: The CORTEX-II trial was pre-registered on clinicaltrials.gov.
- Analytic Plan Registration: The analysis conducted in this study is as planned in the grant proposal but was not initially preregistered.
- Availability of Data: The data used in this study is available on the Open Science Framework on PsyArXiv

Classification: Major: Social Sciences. Minor: Psychological and Cognitive Sciences.

Keywords: adherence, engagement, exergaming, self-efficacy, executive functioning

Significance Statement

This study demonstrates that cognitive training, when integrated with physical activity interventions, can significantly improve exercise adherence among low-active middle-aged adults. The CORTEX intervention targets cognitive control processes essential for maintaining physical activity in an unsupervised environment, providing a novel approach to addressing a key public health challenge. These findings have important implications for the design of scalable, real-world interventions aimed at promoting physical activity and reducing chronic disease risk in midlife populations.

Abstract

The purpose of this randomized controlled trial was to test the effectiveness of a multimodal cognitive training program for increasing physical activity engagement among middle-aged adults. Low-active adults (N=233; M_{age}=46.7) predominantly non-Hispanic (92.3%), White (81.1%), female (65.6%) with a college degree (74.7%) were recruited to participate in a 13-month study. Participants completed a battery of assessments (psychosocial, neuropsychological, and physical functioning) at baseline and subsequently were randomly assigned to receive 20 hours of cognitive training via *Games* (stationary computerized tasks emphasizing executive functioning and exerciser self-certainty, and exergaming with dual-task components; n=118) or attention-control health educational *Videos* (n=115). Training was split across five 2-hr lab sessions (overall adherence=98.3%), followed by five 2-hr home sessions. Among Games, 81.4% fully complied with our exergaming protocol (lab & home) and 88.4% completed the cognitive training protocol. Video engagement was assessed via accuracy to attentional checks (*Ms*=82.4% accuracy in lab, 82.0% accuracy at home). The primary outcome was physical activity engagement (PAE), a latent factor based on physical activity steps & moderate intensity minutes derived from yearlong Fitbit step recordings, visitations & classes, & *Godin Leisure-Time Exercise Questionnaire*). As hypothesized, Bayesian multiple-indicator, multiple-cause model analysis indicated a significant group effect (PAE score $M \pm SD$ is 4.20±1.02 in Games and 3.77±0.92 in Videos; Cohen's d=0.19 and one-sided p= 0.03) after adjusting for a set of background variables. Based on 58.4% respondents to our study evaluation survey, 87.3% enjoyed the intervention they were part of, 87.4% enjoyed the yearlong exercise program, and 97.1% would recommend it to friends/family. Only 4.1% of study completers were able to guess the study's true purpose. Results associated with hypothesized mechanisms of behavior change, including cognitive functioning and psychosocial outcomes, will be discussed. Our findings replicated our previous trial and show reliable effects for promoting exercise engagement within an unsupervised community-based exercise program for middle-aged adults.

Introduction

Our randomized controlled trial (RCT) aimed to investigate the effectiveness of the CORTEX intervention in promoting physical activity adherence and cognitive self-regulation among low-active middle-aged adults (35 to 64 years old). This age group is particularly important, as they represent one of the least active populations, with elevated risks for chronic conditions such as hypertension, cardiovascular disease, and mobility disability (Melzer et al., 2005; Wang & Wang, 2004). These risks are compounded by substantial life demands in midlife, which can deplete cognitive resources necessary for sustained engagement in physical activity. Cognitive control processes—such as goal setting, planning, and self-monitoring—are key to navigating these demands, as they involve attention, working memory, and executive function (Buckley et al., 2014). Prior research highlights a bidirectional relationship between exercise and cognitive functioning, with individuals demonstrating higher cognitive control being better able to maintain their exercise behaviors, while regular exercise contributes to cognitive improvements (Allan et al., 2016; Daly et al., 2015; McAuley et al., 2011).

Despite the well-established benefits of physical activity, alone and in combination with other health behaviors, in reducing all-cause, cardiovascular, and cancer mortality (Lacombe, Armstrong, Wright, & Foster, 2019), adherence to exercise programs remains a major public health challenge (Haskell et al., 2007). Most structured programs see adherence rates decline within the first six months, with dropout rates nearing 50% (Conn et al 2003; Dishman 1994). Bullard et al. (2018) has found higher rates of adherence (77%) among adults in clinical populations (e.g., heart disease, diabetes, cancer) in programs lasting at least three months, whether conducted in clinics or at home. However, few studies have tracked physical activity engagement for a full year, especially without ongoing supervision. In our study, participants received the intervention incentives upfront—a Fitbit and fitness club membership—with no ongoing supervision, relying on self-regulatory strategies and public health recommendations to maintain activity.

The CORTEX intervention builds on the body of evidence linking cognitive control and exercise adherence by integrating multimodal cognitive training (Games) with physical activity. This approach targets cognitive domains such as impulse control, task-switching, and planning, all essential for long-term exercise adherence. Moreover, brain structure and functioning have been linked to both adherence rates and dropout (Gürdere et al., 2023; Gujral et al., 2018; Szabo-Reed et al., 2023), reinforcing the value of cognitive training in promoting sustained behavior change. Notably, exercise videogames have shown promise in increasing moderate to vigorous physical activity levels and improving health outcomes. Bock et al. (2019) demonstrated that participants in a 12-week exercise videogame program engaged in more physical activity across nine months and showed greater reductions in health risk factors (e.g., cholesterol, HbA1c) compared to standard exercise modalities. These findings suggest that integrating gamified cognitive and physical training could lead to greater engagement and adherence, as our intervention hypothesizes.

This research aims to contribute to the growing literature on the neurocognitive mechanisms underlying health behavior maintenance. Evidence suggests that strengthening self-regulatory capacities through cognitive training can lead to transfer effects in other life domains, including physical activity (Ball et al., 2002; Kramer et al., 2014). Thus, we expect participants in the CORTEX trial to not only increase their physical activity levels but also enhance their cognitive functioning and self-regulatory strategies, leading to long-term health benefits. This novel approach has the potential for significant public health impact, particularly for populations that face substantial barriers to maintaining both physical and cognitive health.

Methods

Recruitment

Two-hundred thirty-three community-dwelling middle-aged adults (35-64 years old) were recruited to participate in a 12-month exercise study using a wide range of media outlets (i.e., electronic, print, and radio).

Inclusionary/Exclusionary Criteria

To generalize our findings, the study applied minimal exclusionary criteria. Participants were low-active (e.g., walked less than 2 days/week, 30 minutes/day in the past 3 months) and not cognitively impaired (score ≥21 on the Telephone Interview Cognitive Survey [TICS]), nor were they depressed (≤2 symptoms on the Geriatric Depression Scale [GDS]). Exclusion criteria also included any history of mental illness, pre-existing physical conditions, recent injury/surgery, or sensory impairments that would prevent cognitive assessments. Participants were English-speaking residents living within a 20-mile radius of the fitness facility, without a current fitness club membership or recent experience with brain training apps or active video games (e.g., Xbox™ Kinect).

Design

The study employed a double-blinded design by disguising the study's true purpose as "understanding the relationship between 'do-it-yourself-exercise' and memory." Blinded outcome assessors were rigorously trained, and participants were randomized into two interventions. One group received a 10-day multi-modal cognitive-motor training (Games condition) at the onset of the community-based exercise intervention. The control group viewed health and wellness videos. Cognitive testing and psychosocial measures were administered at baseline, 1 month post-intervention, at 6 months, and 12 months (study end).

Participants

Participants were recruited from a Midwestern city in central Illinois as part of the Cognitive Regulation Training and Exercise (CORTEX)-II trial. The sample consisted of 233 low-active adults (Mage = 46.7 years), predominantly White (81.1%) and female (65.6%), with 74.7% holding a college degree. At baseline, 72% of participants did not meet physical activity guidelines for moderate-intensity activity (≥150 minutes per week), and 56% were not meeting vigorous-intensity activity recommendations, with 50% meeting one but not both guidelines. The average body mass index (BMI) was 33.04 kg/m^2 (SD = 7.97). Participants reported long gaps since they were continuously active for more than two weeks, with lifetime exercise experience ranging between six months and two years.

Procedure

Participants were recruited biannually for six waves (terminated at the onset of the COVID-19 pandemic). Eligibility was assessed during a telephone screening based on inclusion/exclusion criteria. After receiving signed consent and necessary medical clearances, participants completed baseline testing involving cognitive assessments and physical activity monitoring with a wrist-worn Fitbit. Following baseline testing, participants were randomized to either the Games condition or the video group. The 12-month aerobic and resistive exercise program involved both group classes and self-guided components. Classes were led by certified fitness professionals and encouraged moderate-intensity effort (55-60% of Karvonen Max HR).

This randomized controlled trial (RCT) was designed to evaluate the effectiveness of a multimodal cognitive-motor training ("Games") intervention aimed at promoting physical activity adherence, compared to an attentional control ("Videos") condition. Participants were randomly assigned to either the Games group (n = 118), which focused on cognitive training through stationary computerized tasks and exergaming with dual-task components, or the Video group (n = 115), which involved health and wellness educational videos. The training was divided into five 2-hour lab sessions, followed by five 2-hour home sessions.

Participants were also provided a yearlong fitness facility membership, with opportunities to engage in group classes or self-guided activities and were encouraged to meet public health guidelines for aerobic and resistance training. Data collection, including cognitive, psychosocial, and physical assessments, was conducted at baseline and at one-month, six-month and 12-month post-intervention, with physical activity monitoring continuing from baseline for the full year.

Games Condition

Participants in the Games condition underwent five 2-hour supervised multi-modal cognitive-motor training sessions and five 2-hour at-home sessions using an iPad and Xbox Kinect console. Training involved both traditional cognitive tasks and kinetic dual-task mind-body exercises designed to improve self-regulation and cognitive functioning, with compliance tracked via online databases and Xbox logs. For details on the training, see *Supplemental Methods*.

Videos Condition

Participants in the attentional-control Videos condition watched 20 hours of health and wellness videos, matched in duration to the Games condition. Compliance was assessed via questions on video content, and engagement was tracked similarly to the Games condition.

Measures

Demographics. Baseline demographics included age, gender, education, race, employment status, and annual family income, all self-reported.

Exercise experience. Two single-item measures from Mullen (2011) were used to assess participants' overall *lifetime experience* with exercise with a range of "None" to "> 10 years," and the *Rating of Continuous Exercise* which was designed to assess their longest uninterrupted streak with a range from "Never intentionally exercised" to "Exercising 1+ years."

Estimated Cardiorespiratory Fitness. Cardiorespiratory fitness (CRF) was estimated using a formula incorporating gender, age, BMI, resting heart rate (RHR), and a self-reported physical activity (SRPA) index (Jurca et al., 2005). BMI was measured using a portable scale and stadiometer, and RHR was assessed after a 10-minute rest period using pulse oximetry. CRF was expressed in ml/kg/min and calculated as follows: CRF = Gender (2.77) – Age (.10) – BMI (.17) – RHR (.03) + SRPA + 18.07.

Physical activity self-regulation

Multiple measures were used to assess engagement in physical activity because it was operationally defined as a latent construct reflecting several facets that cannot be captured by a single measure (i.e., frequency, intensity, duration, type).

Self-reported exercise. The *Godin Leisure-Time Exercise Questionnaire* (GLTEQ; Godin, 1985) was used to assess participants' self-reported physical activity. The GLTEQ asks individuals to recall the frequency of their engagement in mild, moderate, and vigorous physical activities during their free time over the past week. Scores are calculated by multiplying the frequency of each activity by its respective metabolic equivalent (MET) value—3 METs for mild, 5 METs for moderate, and 9 METs for vigorous activities—and then summing the results to provide a composite score.

Fitbit. Physical activity steps at baseline were assessed from Fitbit Charge 2 portable devices over a period of seven days. Similar procedures were repeated at the end of each month post-intervention, for a period of 12 months. Participant accounts were configured to be remotely synchronized and aggregated with the 3rd party Fitabase service (Small Steps Labs LLC, San Diego, CA). Seven days of data collection prior to randomization were averaged. Days were considered "valid" if participants had at least 10 hours of consecutive heart-rate activity. Procedures for wear-time and non-wear procedures have been fully described by Troiano et al. (2008) and applied to Fitbit data by Gaudet et al. (2017). A multiple imputation procedure based on predictive mean matching was used to account for any missing data (ranged from 6.00% to 36.73% missing days per month, with a mean of 22.46% across the trial) prior to calculating the composite step score. Minutes spent in moderate and vigorous intensity (based on Fitbit's algorithmic classification utilizing participant profiles that include age, sex, height, weight, and heart rate measures) were used to generate binary variables indicating whether or not participants met physical activity guidelines (PAG; 1=yes, 0=no) each month (based on the last seven days of the month). The percentage of months in accordance with guidelines permitted the calculation of three continuous measures of PAG adherence (meeting moderate intensity-only guidelines, or meeting vigorous intensity-only guidelines, or meeting moderate or vigorous intensity). For descriptive purposes, we report the percentage of those meeting PAGs at baseline and group differences across the trial, whereas 7-day minute totals of moderate intensity were used in our modeling which was robust to missing data.

Fitness facility visitations. This was collected and computed using digital timestamp-verified unique keycard swipes scanned at the front desk of the fitness facility (general admission) plus unique daily self-check-ins to group fitness classes recorded via QR-code triggering an automated timestamped Qualtrics survey and drop-down options to select the class. Occasionally participants would visit the facility twice per day, to engage in a combination of self-guided training, morning and evening classes. To avoid attributing credit for long training sessions whereby participants added a class before or after their independent workout, or doing two consecutive classes within the same visit, we applied a decision rule to only credit unique check-ins separated by more than four hours.

Facility access non-compliance. This covariate reflects whether participants successfully retrieved and utilized their prepaid membership cards for exercising at the local fitness facility, as was required for study participation. Non-compliance with this step may have influenced engagement with the exercise intervention and required statistical adjustment to account for potential bias in the analysis.

Acceptability. Participants were asked to indicate the extent to which they enjoyed their intervention and whether they would recommend the study to their friends and family and response options included “Yes,” “Maybe,” or “No.”

Study Blinding Check. Participants were asked to identity the purpose of the study prior to debriefing at their 12-month follow-up appointment by circling one of five options and to verify their choice by providing a description of the study’s purpose in their own words.

Results

Study Attrition

By the end of the yearlong, unsupervised study, 61.4% (n = 143) of participants completed at least one assessment at the Month 12 follow-up, which included the end-of-study survey, cognitive testing, or a monthly log. Total study retention was 60.9%, as one participant withdrew despite having completed a portion of the follow-up testing. A total of 49 participants from the gaming condition and 42 from the video condition did not complete the study (n = 91). Non-completion included 48 participants (20.6%) who voluntarily withdrew, 42 (18.0%) who were lost to follow-up (i.e., non-responders despite repeated attempts to contact them), and one participant who withdrew due to pregnancy. Medical-related dropouts accounted for 3.9%. See Figure 1 for the CONSORT diagram with testing completion rates at each time point.

Adverse Events

Serious and other adverse events were collected both systematically (via unmonitored monthly log data) and passively (via emails and in-person communications from participants) across the two intervention conditions. Logs of adverse events were analyzed post-study and categorized by the nature of the incident and associated risk factors. All events were recorded regardless of frequency. No major health concerns were directly attributable to study procedures.

In the Gaming condition, one participant (0.85%) reported an adverse event related to pregnancy. In contrast, the Video condition saw a higher frequency of adverse events, with 13 participants (11.30%) affected. Among these, seven participants (6.09%) reported injuries with unknown causes, typically aggravating pre-existing conditions. Additionally, three participants (2.61%) reported injuries related to exercise at a fitness facility, also aggravating existing conditions. Another three participants (2.61%) experienced injuries unrelated to the study, such as injuries from housework or falls during hiking. In rare cases where participants promptly reported injuries, they were asked to renew their medical clearance before resuming participation. However, most participants did not inform us of their injuries until after withdrawing from the study, or they felt it was too late to return to exercise.

Training Completion

In-lab: Both groups had high adherence to the in-lab training, with 98.3% of the five in-person sessions completed. Overall engagement from the 118 participants in the gaming group was strong, with an average of 8.8 out of 10 iPad-based cognitive training sessions completed, and 81.36% fully complying with our exergaming expectations across lab and home settings.

Initially, we allocated 600 total minutes for cognitive training, spread across five in-lab and five at-home sessions (200 minutes per game/video session). However, logistical challenges and technical issues led to participants achieving only ~80% of the prescribed in-lab activities when scheduled activities proceeded as planned. As a result, we adjusted our expectations, determining that 67% of our original target (402 minutes) represented full compliance. At-home protocol compliance was similar for both groups.

At-home: The Game group completed an average of 76.7% (3.8 of 5 sessions) of the five-hour cognitive training at home. Video engagement was assessed through multiple-choice questions about each video, with an average accuracy of 82.4% for in-lab sessions and 82.0% for at-home sessions. Across all five at-home sessions, 70.4% of day 10 logs were completed, with an average of 58.8% of logs submitted. Games and Videos groups submitted similar percentages of logs (61.0% vs. 56.5%).

Physical Activity Engagement

Fitness Facility Usage: On average, participants visited fitness facilities 45.54 times over the year (SD = 49.62), equating to approximately 0.91 visits per week. These figures fall short of the fitness industry's "core member" standard of 100 visits per year (Bedford, 2016; International Health, Racquet & Sportsclub Association [IHRSA], 2020). While overall usage was low, participants in the Games group used their memberships more frequently in the first three months ($M = 10.00$, $SD = 10.15$) compared to the Video group ($M = 9.26$, $SD = 9.54$), though this usage was not statistically significant. According to IHRSA, the first three months are critical for establishing long-term membership usage. However, by month six, fewer than 50% of participants ($n = 94$, 40.3%) were still using their fitness facility memberships. Importantly, participants were strongly encouraged to accumulate physical activity whenever and wherever possible and the membership was merely provided as a resource to supplement activity they might otherwise get through other activities at home, through recreation or active transport.

Adherence to Public Health Guidelines: At baseline, participants averaged 7,610.13 steps per day (SD = 2,812.16; 4.23% of days were missing). After imputation for missing values, participants spent an average of 119.85 minutes (SD = 129.08) per week in moderate-intensity activity. According to public health guidelines (150+ minutes of moderate intensity or 75+ minutes of vigorous intensity per week), only 28% of participants met the guidelines for moderate-intensity activity at baseline (Games = 25%, Videos = 31%). This percentage increased to 35% for the first six months and remained at 31% over the year for the Games group. For the Video group, the percentage remained relatively stable at 29% and 32% at six and twelve months, respectively. Notably, by six months, 57% of participants in both groups met one or both intensity guidelines, although this percentage declined to 43% over the last six months, with the Games group maintaining a slight edge over the Video group (44% vs. 42%).

Model of Physical Activity Self-Regulation Regressed on Group and Covariates

As hypothesized, a Bayesian multiple-indicator, multiple-cause (MIMIC) model analysis revealed a significant group effect on physical activity engagement (PAE) scores. Participants in the Games group had higher PAE scores (M = 4.20, SD = 1.02) compared to the Video group (M = 3.77, SD = 0.92), with a small but meaningful effect size (Cohen's d = 0.19). The one-sided p-value was 0.03, indicating statistical significance after adjusting for baseline activity levels (Fitbit steps), exercise experience, recent continuous exercise, estimated cardiorespiratory fitness, race, income, education, injury/illness over the 12-month period, and whether participants picked up their membership cards.

The Bayesian approach allowed for greater flexibility in adjusting for these background variables while handling model complexity. This method provided robust estimates given the sample size and variance between the groups. The posterior distributions for model parameters consistently supported group differences, indicating the intervention's positive impact on physical activity adherence.

Model Fit Diagnostics and Convergence. Model fit was assessed using Posterior Predictive p-values (PPP) and the Potential Scale Reduction (PSR) diagnostic, both of which indicated a good fit. The PPP value for this model was 0.XXX, which is well above the 0.05 threshold, suggesting no significant discrepancies between the model and the data. PSR values were close to 1, confirming that the chains converged adequately. Approximate fit indices such as CFI and RMSEA were not emphasized due to the sample size, as recommended by

Asparouhov and Muthén (2021). For this analysis, trace plots, histograms, and kernel density plots of the parameters supported model convergence, and auto-correlations were negligible, ensuring stability in the posterior distributions. Additionally, a secondary run with double the number of iterations (from 2,500 to 5,000) confirmed local convergence, with the percent relative deviation (%RD) between the estimates from the two models averaging -X.X%. Importantly, none of the parameter estimates shifted from non-significant to significant, indicating stability in the results.

Study Evaluation

Most participants reported that they enjoyed the study and the intervention. Of those (58.4%) who completed end-of-study assessments, 87.3% enjoyed the intervention they were part of, 87.4% enjoyed the yearlong exercise program, and 97.1% reported that they would recommend this program to friends or family. We were also successful in blinding participants to the true purpose of the study, as only 4.1% were able to guess the true purpose to test the intervention's effects on their physical activity behavior. Rather, the majority (95.9%) believed the study aimed to "test the effects of exercise on memory."

Discussion

The results of this randomized controlled trial demonstrate that the CORTEX intervention effectively promoted physical activity adherence and improved cognitive self-regulation among low-active middle-aged adults. As hypothesized, participants in the Games group, who received multimodal cognitive-motor training, exhibited significantly greater physical activity engagement compared to the control group. This finding underscores the value of integrating cognitive training into physical activity interventions, particularly for middle-aged adults who face substantial life demands and cognitive depletion. These results are consistent with previous research linking cognitive control processes, such as goal setting, planning, and self-monitoring, to successful exercise adherence (Buckley et al., 2014; McAuley et al., 2011). The novelty of our study lies in its design: participants were provided with upfront incentives (i.e., Fitbit, fitness club membership) but received no direct supervision for the majority of the 12-month intervention. Unlike many previous studies that involve structured, supervised programs (Bullard et al., 2018), our study emphasizes self-regulation and autonomy, encouraging participants to maintain activity levels through self-monitoring and cognitive strategies. This design reflects real-world scenarios, where individuals must rely on intrinsic motivation and cognitive control to maintain health behaviors, and it broadens the understanding of how unsupervised physical activity programs can be sustained.

Our findings also add to the growing body of literature on the neurocognitive underpinnings of health behavior maintenance, particularly the bidirectional relationship between exercise and cognitive functioning. The Games intervention, which incorporated both stationary cognitive tasks and exergaming, effectively enhanced cognitive control processes such as impulse regulation, task-switching, and planning, contributing to better adherence outcomes. Previous studies have demonstrated the potential for dual-task training to improve cognitive and physical outcomes in older adults (Li et al., 2010; Silsupadol et al., 2009). Our results extend these findings to a middle-aged population, showing that cognitive training can facilitate long-term physical activity adherence in this demographic.

While the effect size was small (Cohen’s d = 0.19), it is important to note that any improvement in physical activity adherence can have substantial public health implications, particularly for populations with elevated risks of chronic disease. Moreover, the inclusion of cognitive training may help sustain exercise adherence beyond typical program durations, addressing a critical challenge in health behavior interventions (Bock et al., 2019). However, future studies should explore whether additional support mechanisms (e.g., digital nudges, intermittent check-ins) could further enhance adherence rates in unsupervised, long-term interventions.

Conclusion

This study provides compelling evidence that combining cognitive training with physical activity interventions can enhance adherence in low-active middle-aged adults. The CORTEX intervention, through its focus on self-regulation and cognitive control, effectively promoted physical activity engagement without the need for ongoing supervision. This approach offers a scalable solution to improving public health outcomes, particularly for populations that struggle with maintaining regular physical activity due to cognitive and motivational barriers.

Future research should continue to investigate the mechanisms underlying the cognitive-exercise relationship and explore the long-term effects of such interventions on both physical and cognitive health outcomes. Additionally, the integration of gamified elements into cognitive training holds promise for improving engagement and adherence, particularly in an unsupervised setting.

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Figure 1. CONSORT Diagram

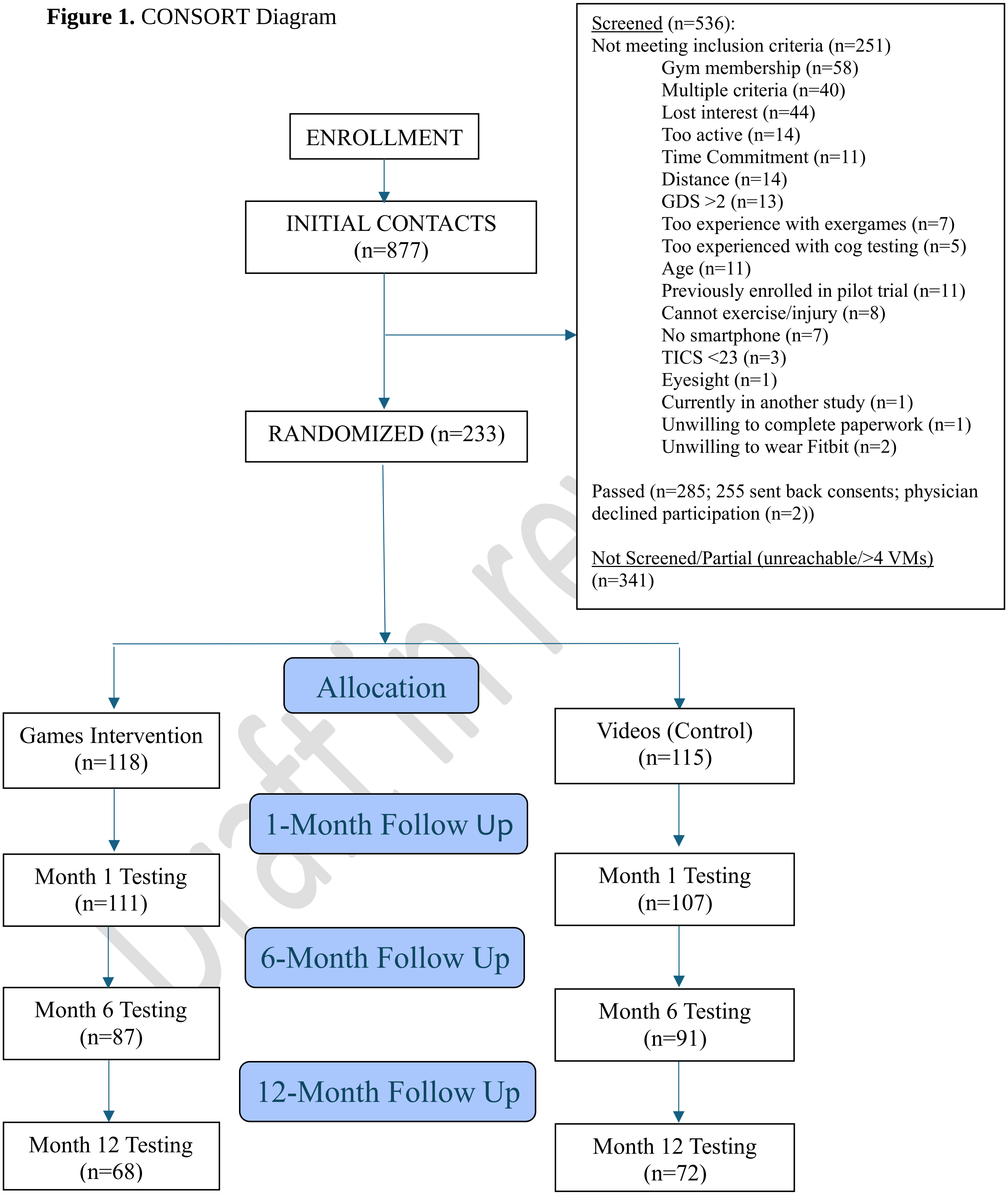

Figure 2. Diagram of the study protocol

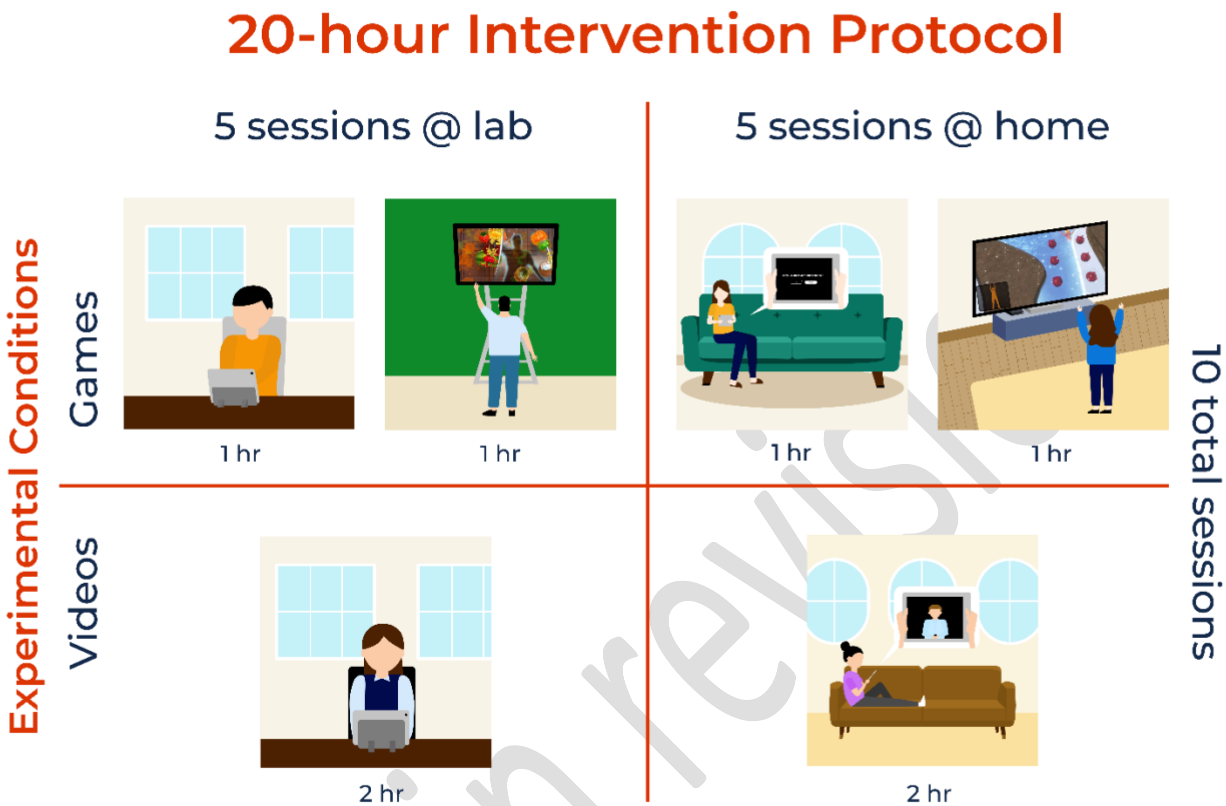

Table 1. Participant Demographics and Baseline Characteristics by Group

Variable	Overall Sample 233 M (SD)/ N(%)	Games 118 M (SD)/ N(%)	Videos 115 M (SD)/ N(%)
Age	46.73 (8.20)	46.49 (8.01)	46.97 (8.42)
Sex, % Female	153 (65.6%)	77 (65.3%)	76 (66.1%)
Race			
- White	189 (81.1%)	96 (81.4%)	93 (80.1%)
- Black or African American	32 (13.7%)	15 (12.7%)	17 (14.8%)
- Asian	10 (4.3%)	6 (5.1%)	4 (3.5%)
- American Indian	1 (0.4%)	1 (0.8%)	0 (0.0%)
- Native Hawaiian or Other Pacific Islander	1 (0.4%)	0 (1.0%)	1 (0.9%)
Ethnicity			
- Not Hispanic or Latino	215 (92.3%)	110 (93.2%)	105 (91.3%)
- Hispanic or Latino	18 (7.7%)	8 (6.8%)	10 (8.7%)
Education, 4-Year College Degree	93 (39.9%)	50 (42.4%)	43 (37.4%)
Employment			
- Full time	186 (78.8%)	96 (81.4%)	90 (78.3%)
- Part time	22 (9.4%)	12 (10.2%)	10 (8.7%)
- Retired, working part time	9 (3.9%)	4 (3.4%)	5 (4.3%)
- Retired, not working	3 (1.3%)	1 (0.8%)	2 (1.7%)
- Unemployed	13 (5.6%)	5 (4.2%)	8 (7.0%)
Annual Household Income			
- Less than $24,999	15 (6.4%)	8 (6.8%)	7 (6.1%)
- $25,000 to $39,000	14 (6.0%)	5 (4.2%)	9 (7.8%)
- $40,000 to $59,000	39 (16.7%)	24 (20.3%)	15 (13.0%)
- $60,000 to $79,000	41 (17.6%)	18 (15.3%)	23 (20.0%)
- $80,000 to $99,000	27 (11.6%)	11 (9.3%)	16 (13.9%)
- $100,000 to $124,999	29 (12.4%)	12 (10.2%)	17 (14.8%)
- $125,000 to $149,000	23 (9.9%)	11 (9.3%)	12 (10.4%)
- More than $150,000	21 (9.0%)	16 (13.6%)	5 (4.3%)
Body Mass Index	32.77 (7.84)	32.88 (7.99)	32.66 (7.72)
Cardiorespiratory Fitness	9.78 (2.43)	9.83 (2.39)	9.74 (2.48)
Exercise Experience [a]	5.75 (3.63)	5.81 (3.58)	5.70 (3.39)
Continuous Exercise [b]	3.83 (1.18)	3.91 (1.14)	3.76 (1.22)
Fitbit Steps [c]	7,682.76 (2,704.83)	7,662.16 (2688.90)	7,703.89 (2,732.69)
Facility Access Non-compliance	12 (5.2%)	4 (3.4%)	8 (7.0%)

Notes. [a] Range = None to > 10 years and a score of 5-6 means between 6 months to 1 year and 1-2 years; [b] Range = Never intentionally exercised to exercising 1+ years and a score of 2-3 means between “it has been years” to “it has been months”; [c] Measured via Fitbit Charge 2-derived step counts averaged over a 7-day period. 2.94% of days were missing and multiple imputation algorithm was used to estimate plausible values prior to computing the average