Psychology and Aging
2014, Vol. 29, No. 3, 717–730

0882-7974/14/$12.00 http://dx.doi.org/10.1037/a0037363

Effects of Cognitive Training With and Without Aerobic Exercise on Cognitively Demanding Everyday Activities

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We investigated the potential benefits of a novel cognitive-training protocol and an aerobic exercise intervention, both individually and in concert, on older adults' performances in laboratory simulations of select real-world tasks. The cognitive training focused on a range of cognitive processes, including attentional coordination, prospective memory, and retrospective-memory retrieval, processes that are likely involved in many everyday tasks, and that decline with age. Primary outcome measures were 3 laboratory tasks that simulated everyday activities: Cooking Breakfast, Virtual Week, and Memory for Health Information. Two months of cognitive training improved older adults' performance on prospective-memory tasks embedded in Virtual Week. Cognitive training, either alone or in combination with 6 months of aerobic exercise, did not significantly improve Cooking Breakfast or Memory for Health Information. Although gains in aerobic power were comparable with previous reports, aerobic exercise did not produce improvements for the primary outcome measures. Discussion focuses on the possibility that cognitive-training programs that include explicit strategy instruction and varied practice contexts may confer gains to older adults for performance on cognitively challenging everyday tasks.

Keywords: cognitive training, aerobic exercise, strategy training, multi-modal training, improving prospective memory, aging

In light of the well-documented declines in cognitive function with age (e.g., see Craik & Salthouse, 2000, 2008, for overviews), a central challenge in cognitive aging research is to identify factors that moderate or forestall age-related decline in cognitive functioning. Experimental evaluations using a range of protocols have shown that cognitive training can improve older adults' performances on cognitive outcomes, particularly those closely related to the training protocols (Ball et al., 2002; Willis et al., 2006; see Hertzog, Kramer, Wilson, & Lindenberger, 2008, for a review). Though encouraging, the outcome measures typically assess a particular cognitive function (e.g., memory, attention, executive control) or process within a functional domain (e.g., Ball et al., 2002; Willis et al., 2006), and the measures are derived from laboratory-based tests designed to isolate a particular cognitive function. Arguably, a fundamental objective of cognitive training is to promote transfer to everyday functional tasks that demand an

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This research was supported by grant R01AG034581 from the National Institute on Aging, and by the Harvey A. Friedman Center for Aging. Emily Waldum was supported by National Institute on Aging grant 5T32AG000030. A pilot study for this project was supported by a 2004 MetLife Foundation Award for Medical Research in Alzheimer 's disease, Awarded to John C. Morris, MD. We are extremely grateful to the participants who volunteered their time and effort for this study. We also want to thank the administration and staff of St. Louis Jewish Community Center for their support and excellent exercise training services. We thank Janine Jennings for providing us with the "avoiding repetitions" training task, Julia Karbach for providing us with the task-switching training task, and Anna McKay-Brandt for sharing her version of the variable priority training task. We appreciate Peter Rendell and Nate Rose for their work in developing the computerized version of Virtual Week, and for making that task available to us.

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integration of cognitive processes (McDaniel & Bugg, 2012; cf. Ball et al.).

In this article, we introduce a novel, theoretically motivated cognitive-training protocol designed to improve older adults' capabilities in performing daily, real-world activities. We then report an experiment to evaluate the promise of this approach by assessing pre- and postperformances on laboratory simulations of cognitively demanding everyday tasks for a cognitive-training condition and an active control condition. Additionally, to gauge the degree to which the cognitive training possibly provided unique benefits for transfer, we implemented an aerobic exercise training condition with a factorial design that included cognitive training (presence, absence) and aerobic exercise (presence, absence; similar to the factorial design used in Fabre, Chamari, Mucci, Masse-Biron, & Prefaut, 2002, and Fabre et al., 1999). Aerobic exercise training has been shown to produce a broad range of benefits to nontrained tasks, including memory and cognitive control (e.g., task switching, interference resolution; Erickson et al., 2011; Kramer, Larish, Weber & Bardell, 1999).

The motivation for our cognitive-training platform and the theoretical underpinnings of our particular training protocol were as follows. Our training approach is based on the observation that real-world tasks rarely depend on a single component of cognition, as is typically isolated in laboratory tasks that are often used as outcomes in cognitive-training studies (e.g., Ball et al., 2002; West, Bagwell, & Dark-Freudeman, 2008; Willis et al., 2006). Consider, for instance, the everyday activity of cooking, which requires a variety of cognitive processes, including planning, attentional (executive) control, working memory, and prospective memory (Craik & Bialystok, 2006). Accordingly, a key component of our cognitive-training approach was to train a range of cognitive processes that are likely involved in many everyday tasks, and that decline with age. This approach mirrors video-game training approaches that are assumed to train multiple cognitive domains, specifically visual attention, working memory, and perceptual-motor skills (see Green & Bavelier, 2008). For the current training protocol, we identified three general domains of processes that appear to be centrally important to everyday functioning for older adults.

One domain is coordinating multiple concurrent activities (e.g., as is required in the everyday activity of cooking a meal) and switching between tasks. *Variable priority* training improves task coordination in older adults (Kramer, Larish, & Strayer, 1995; Kramer et al., 1999), and the notion of varying priorities is arguably inherent in many everyday challenges. Similarly, task-switching training improves older adults' task-switching abilities (Karbach & Kray, 2009). To provide a broad training platform for task coordination, we included variable priority training and task-switching training.

The second domain is retrospective memory, which displays robust age-related decline (see Zacks, Hasher, & Li, 2000, for review). A concern with some extant memory training approaches with regard to enhancing everyday function is the focus on improving older adults' encoding of information (Verhaeghen, Marcoen, & Goossens, 1992). This might not provide a benefit in the daily lives of older adults, who may find more difficulty when retrieving information (e.g., Craik, 1986; Craik & McDowd, 1987) than when encoding information (in which external recording can be exploited; see McDaniel & Bugg, 2012, for further discussion). Building on previous work that reported improvement in older adults' memory performances when they were instructed to use retrieval strategies for recall (Dornburg & McDaniel, 2006), and when given practice at resisting interference (i.e., Jennings & Jacoby, 2003), we implemented a memory training component that focused on training explicit retrieval strategies and reliance on recollection (rather than familiarity), a process that is especially susceptible to age-related decline (McDaniel, Einstein, & Jacoby, 2008).

Perhaps the most novel domain targeted by our cognitive-training protocol was prospective-memory training. Prospective memory refers to memory tasks in which one has to remember to perform an intended action at some point in the future, such as remembering to take a prescription, pay a bill, or attend a social event. Good prospective memory is critical to normal functioning and supportive interpersonal relations (McDaniel & Einstein, 2007), yet a majority of older adults' memory failures and complaints are prospective in nature (McDaniel & Einstein, 2007). To date, large-scale training studies have not included prospective-memory training (e.g., Senior Odyssey Project, see Stine-Morrow, Parisi, Morrow, Greene, & Park, 2007; Everyday Memory Clinic Project, see Bagwell & West, 2008; IMPACT study, see Zelinski, et al., 2011; but see Schmidt, Berg, & Deelman, 2001, for a limited prospective-memory training protocol with older adults). The current cognitive-training protocol addressed this significant limitation of previous cognitive-training programs by developing a prospective-memory training procedure informed by current prospective-memory theory and basic empirical work (described in detail in Waldum, Dufault, & McDaniel, 2014).

Several other interrelated features of our cognitive-training protocol are worth highlighting. First, in the prospective-memory and the memory-retrieval training components, we explicitly instructed older adults on strategies that have been documented to enhance older adults' memory performances (Buitenweg, Murre, & Ridderinkhof, 2012; also, for retrospective memory, Baltes & Kliegl, 1992; Dornburg & McDaniel, 2006; West et al., 2008; for prospective memory, Liu & Park, 2004). More generally, strategy training, though not always included in cognitive-training studies (see, e.g., Harrison et al., 2013; Jennings & Jacoby, 2003; Kramer et al., 1995; Redick et al., 2013), is a standard procedure in other rehabilitation areas, such as occupational therapy (Toglia, Rodger, & Polatajko, 2012).

Second, appealing to the basic cognitive literature on transfer (e.g., Gick & Holyoak, 1983), a companion literature on cognitive rehabilitation in occupational therapy (Toglia, Johnston, Goverover, & Dain, 2010), and the observation that some existing training programs have produced little, if any, transfer (see Hertzog et al., 2008), we assumed that with strategy training alone, older adults might not recognize the opportunity for applying the strategy in their everyday tasks, and they might not be able to map the trained strategy to the demands of the everyday tasks. Accordingly, we incorporated "homework" in our training protocol to facilitate participants' ability to notice when and how to apply the trained strategies.

Finally, for theoretical and pragmatic reasons, the training of the different cognitive processes was spaced and also interleaved (see McDaniel, 2012, for a brief overview). We also thought having participants engage in a variety of training tasks each week would help maintain interest and motivation levels more so than repeating the same training task throughout the week.

Outcome Measures of Everyday Activities

To evaluate whether the cognitive-training approach outlined here might have value in enhancing older adults' functioning on everyday tasks, we administered, at pre- and post-intervention, three laboratory tasks that simulated everyday activities as our primary outcome measures: Cooking Breakfast (Craik & Bialystok, 2006), Virtual Week (VW; Rendell & Craik, 2000), and Memory for Health Information (see Method). Older adults' performance on the laboratory Cooking Breakfast task has been shown to significantly correlate with performance on a cooking task in older adults' own homes (Edwards & Ryan, 2004). Thus, this task is well suited to provide a valid assessment of transfer of the present interventions to an everyday-life activity in a controlled setting, and for which objective and precise measures can be obtained. VW is a board game that guides participants through daily activities as they move around the board for 3 consecutive virtual days, during which they encounter prospective-memory tasks (Rendell & Craik, 2000). VW has the advantages of providing reliable measures of prospective memory (Rose, Rendell, McDaniel, Aberle, & Kliegel, 2010), which is not typical for laboratory prospective-memory tasks (Kelemen, Weinberg, Alford, Mulvey, & Kaeochinda, 2006), and of having high face validity with regard to realistic prospective-memory behaviors. Additionally, recent studies have established age-related performance declines on both the Cooking Breakfast task (Craik & Bialystok, 2006) and VW task (Rendell & Craik, 2000; Rose et al.); accordingly, positive effects of the cognitive-training intervention would represent valuable performance gains on everyday tasks (at least proxies) for older adults.

Researchers have underscored the challenges that older adults face in accurately remembering important domains of information in the face of interference and with regard to the source of this information (Jacoby, Bishara, Hessels, & Toth, 2005; McDaniel et al., 2008). For instance, effective decision making for health-related issues depends, in part, on accurately remembering medical information, as well as remembering the source of the information (because sources will vary in terms of their accuracy). To reflect this important everyday memory task, we developed a novel measure in which medical information is presented to participants from three sources. Participants are then tested for the content and source of the information in a recognition paradigm that also introduces interference from lures (we label this the Memory for Heath Information task).

Method

Design

The experimental design was a $2 \times 2 \times 2$ mixed factorial design, with the presence or absence of cognitive training, and the presence or absence of aerobic exercise, as the between-subjects variables. The within-subjects variable reflected the two testing times: pretraining and posttraining.

Participants

Men and women aged 55 to 75 years were recruited from the community-at-large to participate in a study of exercise and cognitive training, using mass media, direct electronic mailings to individuals enrolled in a research volunteer registry, and community efforts. One hundred fifty-six individuals provided informed consent for this study (approved by the Institutional Review Board of Washington University) and underwent the screening procedures. Individuals were excluded from participation for the following reasons: (a) not English-speaking; (b) less than a 10th-grade education; (c) insufficient visual and auditory perception to complete testing; (d) current participation in a regular exercise program (defined as 3 or more times per week for $\geq$20 min) or a cognitive-training program; (e) mild cognitive impairment or dementia (Clinical Dementia Rating [CDR] $\geq$0.5); (f) inability to walk on a treadmill or ride an exercise bike or complete the VO_2 testing; (g) major and/or unstable medical, neurological, or psychiatric disorder (e.g., myocardial infarction within previous 6 months, insulin-dependent diabetes, unstable cardiopulmonary disease, disabling stroke, late-stage renal or liver disease, major affective disorder with active symptoms); (h) cigarette smoking within the previous year; (i) history of alcohol or substance abuse; or (j) a positive exercise stress test for ischemia. After a brief telephone screening interview, individuals who met inclusion criteria were invited to complete a detailed in-person interview. The Uniform Data Set (Morris et al., 2006) protocol was administered to the participant and a collateral source historian, to collect information about medical history and medications, and to objectively evaluate for signs and symptoms of dementia and depression. Individuals with a CDR (Morris, 1993) score of zero (cognitively normal) and without symptoms of major depression or other psychiatric disorders were invited to undergo further screening, which included a physical exam, blood chemistries, a complete blood count, the Yale Physical Activity Survey (Dipietro, Caspersen, Ostfeld, & Nadel, 1993), standardized interviews about performance of activities of daily living, and a treadmill exercise stress test with measurement of peak aerobic power.

Ninety-six men and women were enrolled and randomized to the four intervention groups. The baseline characteristics of the sample are described in Table 1. Educational level was slightly higher in the cognitive-training group; there were no other significant group differences. Of the 96 individuals randomized, 74 completed the assigned interventions and provided cognitive (primary outcome) data at the conclusion of the intervention (6 months); five individuals (control = two; exercise = three) did not complete the interventions but provided post-intervention cognitive data; and 17 participants did not complete the interventions or provide follow-up cognitive data (control = six, cognitive = five, exercise = one, combined = five). There were no significant differences in the baseline characteristics between participants who provided cognitive follow-up data (n = 79) and those who did not (n = 17).

Procedure

Peak oxygen uptake (VO_{2peak}) was assessed during graded treadmill walking. This baseline VO_{2peak} was established so that we could determine the fitness gains in the exercise training condition, as well as fitness changes in the no-exercise training

Table 1
Baseline Characteristics of the Sample

Variable	Control (n = 25)	Cognitive (n = 23)	Exercise (n = 24)	Combined (n = 24)	p value[a]
Age (years)	64 ± 7	64 ± 4	67 ± 6	65 ± 6	.274
Sex (% female, n)	60 (15)	70 (16)	71 (17)	67 (13)	.856
White (%, n)	96 (24)	78 (18)	71 (17)	88 (21)	.080
Years education[b]	16 ± 2	17 ± 2	15 ± 2	16 ± 2	.023
BMI (kg/m^2)	29 ± 5	28 ± 5	29 ± 5	29 ± 6	.852
MMSE Score	29 ± 1	29 ± 2	29 ± 1	29 ± 1	.209
GDS Score	1 ± 1	1 ± 2	1 ± 1	1 ± 2	.866
VO_{2peak}, ml/kg/min	23.3 ± 3.8	21.7 ± 3.8	21.2 ± 4.4	21.5 ± 5.1	.353

Note. For continuous variables, the mean ± the standard deviation is provided. BMI = body mass index; MMSE = Mini-Mental State Examination; GDS = Geriatric Depression Scale.
[a] Chi-square tests were used to compare the between-group difference for categorical variables; ANOVAs were used to compare the between-group difference for continuous variables, except for Education which was not normally distributed and the Wilcoxon test was used. [b] $p_{\text{Control vs. Cognitive}} = 0.018$, $p_{\text{Cognitive vs. Exercise}} = 0.005$.

condition. During a 3- to 5-min warm-up on the treadmill at 0% grade, the speed was adjusted to identify the fastest comfortable walking speed for the individual. Speed was then held constant during the test, and elevation was progressively increased 2% to 3% every 2 min. Cardiorespiratory data were collected at 30-s intervals using a computerized system. The test was terminated when the participant became too fatigued to continue the test or developed symptoms or signs concerning for cardiac ischemia. The objective measures used to determine that peak VO_2 was achieved were that two out of the following three criteria were met: (a) the leveling off criterion, such that no further increase in VO_2 occurred in response to an increase in work rate; (b) attainment of a respiratory exchange ratio >1.10; and (c) attainment of 85% of predicted maximum heart rate (HR).

All participants who met study inclusion criteria were also administered a battery of psychometric tests interleaved with the primary outcome tasks (described next). The testing order was Stroop Part 1, Logical Memory Immediate (Wechsler, 1945), Late Life Function and Disability instrument (Sayers et al., 2004), Logical Memory Delayed (Wechsler), VW (5-min break), Memory for Health Information Part 1, Digit Symbol task, Motor Control task, Memory for Health Information Part 2, Trailmaking A and B (Bowie & Harvey, 2006), Stroop Part 2, and the Cooking Breakfast task. Research staff members who administered the outcome tasks and tests were blinded to the participant's group assignment.

Primary outcome tasks. Cooking Breakfast is a computerized laboratory simulation of a cooking task (see Craik & Bialystok, 2006, for complete details). The simulation requires participants to cook a breakfast of five foods (eggs, sausage, toast, coffee, and pancakes), while simultaneously setting a table with silverware and flatware. The foods take a different amount of time to cook, and thus the starting times for cooking must be staggered so that all of the foods can be stopped at the same moment and have cooked sufficiently (neither under nor overcooked). The simulation has three levels of difficulty, with difficulty varying according to how many different screen displays must be navigated to control and monitor each food's starting time, cooking time, and stopping time, while setting the table. The easiest level displays all pertinent information, cooking-control activities, and table setting on a single screen, and served as a warm-up for the task. After completing the warm-up "game," participants proceeded to the next (intermediate) difficulty level, which displayed the table setting task on one screen and all of the five foods on another screen. Once this level was completed, participants moved to the most difficult level. At this level, each food and the table setting were displayed on different screens (i.e., six separate screens), thereby requiring participants to switch display screens to control cooking and monitoring of each food and to perform the table-setting task.

The VW task was used to gauge everyday prospective remembering in the context of daily living (see Foster, Rose, McDaniel, & Rendell, 2013; Rose et al., 2010, for details). VW is a computerized board game in which participants move a game token around a "board" on the screen; in the process of moving around the board, participants are engaged in simulation activities normally encountered throughout a day (for the hours of the day that people are typically awake: 7:00 a.m. to 10:00 p.m.). The hours of the day are marked on the board, and each circuit of the board represents 1 day. For the pretest and posttests, participants completed three circuits (days). Time-appropriate activities for which participants are required to make decisions are initiated each time the token lands on or passes an event square (labeled "E"; e.g., "It's breakfast. Do you have [a] eggs, [b] cereal, [c] only coffee?"). Ten prospective-memory tasks were embedded within each day (circuit). Four were regular tasks that were repeated each day (e.g., "take antibiotics at breakfast"), four were irregular tasks that changed from day to day ("drop off dry cleaning when you go shopping"), and two were time-based tasks. Participants were prompted to learn the four regular tasks and the two time-based tasks by requiring them to proceed through a practice day, which included all of these tasks. If the participant forgot to perform a task, the experimenter asked the participant to consider whether they needed to do anything, and if this failed to elicit a response, the experimenter reminded the participant about the task. Thus, during the practice day, every participant performed all of the prospective-memory tasks.

For the irregular tasks, at the beginning of each day, a "Start Card" button was clicked and two of these tasks were described. The other two irregular tasks were presented sometime during the day on event cards, and these tasks were then to be performed later in the day at some specified time or activity. The time-based tasks involved making a prospective-memory response ("perform" a lung-capacity test) when a particular time was reached on the clock displaying real elapsed time. Irregular tasks were also implemented during the practice day, but unlike the regular tasks and time-based tasks, the particular intentions were not the same as those instructed for the three test days.

A Memory for Health Information task was designed to examine participants' ability to accurately remember facts about health and correctly recognize the source of those facts, a challenge that older adults commonly face when attempting to remember information conveyed by a doctor and making decisions about their health on the basis of this information. The task was modeled from Jennings and Jacoby's (2003; see also Jennings & Jacoby, 1997) "avoiding repetitions" procedure. Instead of using simple verbal materials (i.e., words), however, factual sentences were used to convey information about a medical disease. In the study phase, participants read aloud and tried to remember 30 sentences that were displayed on a computer screen one at a time for 7 s. Accompanying each sentence was a picture of a newspaper, a doctor, or a "friend" (i.e., a picture of a similarly aged individual), and participants were instructed that the picture represented the source of the information. Sources were blocked such that the first 10 sentences were accompanied by one source, the second 10 by the second source, and the final 10 by the third source. After an approximately 5-min delay, participants began the test phase. Seventy sentences were presented, one at a time, and participants judged whether they were read aloud previously ("old"; 30 sentences) or were not read aloud previously ("new"; 30 sentences). For items designated old, participants were immediately prompted to make a source judgment. Participants chose one of the three relevant sources or the option "I am unsure." Following Jennings and Jacoby (2003), the test phase included repeated lures, which were new sentences that were presented a second time (repeated) during the test phase. We included 10 repeated lures with the lag between the first presentation of a new item and its repetition, ranging from four to 22 items. In pilot work, we found that older adults' performance was very comparable across two versions of the task, one in which the disease was dwarfism and the other in which it was Chagas disease (e.g., mean corrected recognition = .51 vs. .52, mean false alarms (FAs) to repeated lures = .33 vs. .45, mean source memory accuracy = .41 and .37, for dwarfism and Chagas versions, respectively). In the current study, the Chagas-disease version was used for the preintervention baseline assessment, and the alternate version (dwarfism) was used for the posttest.

After completing the preintervention baseline assessments, participants were randomized to one of four groups (control, exercise, cognitive, and combined), using a computer generated random permutations procedure. All the intervention procedures were conducted at the same community exercise facility.

Cognitive training absent and aerobic exercise absent (control group). Participants in this group were prescribed a low-intensity home-exercise program for 6 months, and participated in face-to-face health education sessions for 8 weeks (Months 5 and 6, to correspond to the cognitive-training protocol). The low-intensity home-exercise program included nine exercises and focused primarily on flexibility (Binder et al., 2004); it was designed to not improve aerobic capacity. At the outset, participants attended a 1-hr training session at a community exercise facility. They were expected to perform the exercises at home 2 to 3 times per week for 6 months, and not to engage in any other exercise aside from what they were already doing (such as low-intensity walking once or twice per week). To enhance adherence to the protocol, the control participants attended a monthly exercise session with an exercise trainer who observed them performing the exercises. Home exercise participants also completed daily calendars to document their performance of the exercises.

After 4 months of home exercise, participants additionally began participation in a weekly educational session for 8 weeks (during Months 5 and 6). This protocol schedule was implemented because the cognitive training also began 4 months after initiation of the aerobic exercise (in the combined group), which was to allow putative neurophysiological benefits of exercise to fully upregulate (e.g., see Hertzog et al., 2008, for review.). The educational sessions were conducted at the community center by a designated research team member who did not conduct any of the cognitive-training sessions. Education sessions lasted approximately 1 hr, and consisted of an oral review of information presented in a printed PowerPoint presentation format. Each session covered a separate topic: aging skin, problems with smell, hearing loss, sleep and aging, eating well, energy savings at home, taking medications, and stroke. To encourage the participants to pay attention to the presentations, short quizzes were administered at the end of each presentation (as in Zelinski et al., 2011). We also administered a 20-item cumulative test prior to, and upon completion of, all the education sessions. Performance on this test significantly improved ($M = 15.62$ prior to the sessions; $M = 18.62$ after the sessions), $t(33) = 8.15$, $p < .001$ (note that this analysis includes those in the exercise group, as described next; some participants did not take the cumulative test at the conclusion of the education sessions).

Aerobic exercise present and cognitive training absent (exercise group). Participants in this group engaged in a supervised aerobic exercise training program conducted on-site at the community center. They were able to choose between a treadmill walking program and an exercise bicycle program. Participants were expected to attend exercise training sessions 3 times per week for 6 months. Polar heart rate monitors were used biweekly to monitor heart rate, and self-ratings of perceived exertion were also used to evaluate exercise intensity. Following 10 min of warm-up exercises, participants were expected to perform aerobic training, initially for 15 to 20 min at 50% to 60% of heart rate reserve (HRR) and/or perceived exertion level of 12 to 13, and to gradually progress over 3 months to 45 to 50 min of aerobic training at 65% to 85% of HRR and/or perceived exertion level of 15 to 16. Exercise trainers worked with between two and five participants during a single session. A few individuals who missed exercise sessions because of travel were allowed to continue training 3 times per week on their own in accordance with their individualized training parameters. Exercise participants were instructed not to perform other forms of intense exercise training, such as weightlifting. To monitor protocol adherence and participant effort, research staff reviewed Polar HR tracings and exertion ratings for each participant on a weekly basis. Starting at Month 5, these participants also began the weekly educational sessions described in the previous section.

Aerobic exercise absent and cognitive training present (cognitive group). Participants in this group performed the home-exercise program for 6 months. Starting at Month 5, they also began the cognitive-training intervention. The cognitive training was administered at the community center 3 days a week for 8 weeks. On each of the 3 days of the week, training focused on different cognitive processes; we describe the training procedures for each process (each day of a week) in turn.

One day focused on attention-control training using several training tasks. One task was variable priority training, first developed by Kramer et al. (1995) and further examined by MacKay-Brandt (2011). Briefly, this task involves performing two concurrent tasks on a computer. For example, one version of this task involved "cutting" a flower image that occurred at random locations on the monitor (cutting required the participant to use the mouse to position an image of a scissors over the flower and clicking). Simultaneously, single digits enclosed in a box were shown serially in the middle of the monitor, and the participants had to press a number key to indicate the correct sum (1, 2, or 3; see MacKay-Brandt, 2011, for details). The other task involved a task-switching training paradigm reported by Karbach and Kray (2009). The variable priority training and the task-switching training alternated across the 8 weeks of training. Additionally, we included both post-task discussions regarding perceived difficulty, performance, and strategies participants may have used to perform that day's task. The trainer offered feedback on strategy effectiveness. Additionally, in the early weeks of training, the trainer assigned specific homework tasks, such as asking participants to attempt switching between reading a book and watching TV. In later weeks of training, participants were asked to self-generate homework assignments by identifying instances of task coordination in their everyday life during which they could practice using the strategies discussed in training.

A second day of training for each week focused on prospective memory. We developed the prospective-memory training by appealing to basic theoretical and empirical work indicating that to support prospective remembering, the cognitive system exploits several processes: spontaneous retrieval processes (retrieval of the intended action when encountering a relevant event) as well as attentional processes devoted to evaluating environmental events for the appropriate moment for performing the intended action (i.e., monitoring) (McDaniel & Einstein, 2000, 2007, 2011). Accordingly, our primary training goals were to improve participants' identification of prospective-memory tasks that rely on spontaneous retrieval versus those that rely on monitoring, and additionally to train participants to associate the correct strategies with each type of prospective-memory task. To this end, the prospective-memory training sessions were designed to provide participants with an extensive amount of practice associating the appropriate strategy with each different type of prospective-memory task (Waldum et al., 2014, provide a detailed description of the prospective-memory training protocol and activities). Early on in training, the trainer informed the participant which strategies (e.g., implementation intention vs. monitoring) would be most beneficial, but as training progressed, participants were allowed to apply whatever strategies they felt were appropriate for the prospective-memory task demands. At the end of each session, the trainer elicited a discussion regarding participants' strategy use. Participants were encouraged to think about an everyday prospective-memory challenge that they would likely face in the next week, and to apply one of the trained techniques to that challenge.

A third day of training for the week focused on training recollection. One component of the training adopted the Jennings and Jacoby (2003; see also Jennings, Webster, Kleykamp, & Dagenbach, 2005) "avoiding repetitions" procedure. The procedure required participants to respond differentially to words that were remembered as having been presented in a study list and foils that were made familiar by having been repeated in the test list. Increasing the spacing of repetition of foils served to increase the difficulty of recollecting that the foil had been earlier presented in the test list rather than during study. During the first part of each session (approximately 30 min), participants completed four runs of the avoiding repetitions procedure.

In the second part of the recollection-training session, participants read text passages that were approximately 300 to 400 words long. The following week, participants were instructed to recall the text passage (recall was written) from the previous week using a technique designed to foster use of retrieval cues (this technique was first instructed during the second session when participants recalled the first text). The recall technique instructed was patterned after the cognitive interview (see Dornburg & McDaniel, 2006). Participants read a different text each week to recall the following week. At the end of the session, the trainer elicited a discussion regarding the participants' use of the trained recall technique and regularly asked participants to self-generate a homework assignment. The homework consisted of having participants identify a scenario they would likely encounter in the upcoming week in which they could apply the recollection techniques used during the training session. For instance, many participants suggested that they could attempt using the recollection strategy during their next grocery store visit rather than relying on a list.

Aerobic exercise and cognitive training present (combined group). Participants in this group participated in the 6-month aerobic exercise program. During Months 5 and 6, they also concurrently were administered the cognitive-training program.

Once a participant completed the intervention to which they were assigned, they were scheduled for their posttest (within 7 days after the intervention was completed).

Statistical Analysis

A priori, we adopted an intention-to-treat analysis plan. Accordingly, the analyses included all participants who provided post-intervention data, including the 74 who completed the interventions and the five who did not (two controls and three in the exercise condition). Note that these 79 participants did not provide data for every outcome task (for every task, because of computer failure, one to two participants did not have data). Our analysis procedure was to evaluate whether the interventions produced significantly augmented gains from pre- to posttest relative to pre- to posttest changes in the absence of interventions; that is, intervention effects would be revealed by interactions of the interventions with testing time. For these analyses, we conducted 2 (cognitive training presence or absence) $\times$ 2 (aerobic exercise presence or absence) $\times$ 2 (pretraining test, posttraining test) mixed analyses of variance (ANOVA), with testing time as the within-subjects variable, for each of the outcome measures associated with each of the three primary tasks (except for cooking breakfast, in which the difficulty level of the task was included as a fourth, within-subjects variable). For all effects, the significance level was set at .05; effect sizes are reported as partial eta squared (η_p^2), and for completeness η_p^2 values are reported for both significant and nonsignificant intervention effects (i.e., group interactions with test time).

Results

Adherence to Interventions

Adherence, as measured by number of total sessions attended, was high. For the exercise intervention, exercise-group participants attended 68 ± 5 of 72 sessions (excluding the three participants who did not complete the intervention; these participants attended 43 ± 15 sessions), and combined participants attended 69 ± 5 sessions. For the cognitive intervention, cognitive participants attended 22 ± 0.5 of 24 training sessions, and combined participants attended 24 ± 0.5 sessions.

At 6 months after baseline, participants in the two aerobic exercise training groups achieved greater improvements in peak aerobic power than those who performed home exercises (see Table 2). A two-way analysis of covariance (ANCOVA), with VO_{2peak} at 6 months as the dependent variable, adjusted for baseline VO_{2peak} (the covariate), confirmed a significant main effect for the presence of exercise training, $F(1, 71) = 11.18$, $MSE = 6.61$, $p = .001$.

VW

There were three primary prospective-memory measures derived from VW: regular prospective memory (the same four tasks were repeated over the 3 virtual days), irregular prospective memory (12 different tasks, four on each of the 3 days), and time-based prospective memory (making a prospective-memory response at a specified time on the clock that showed the actual elapsed time during the play of the game; the two same time-based tasks were administered every virtual day). All measures represent the proportion correct prospective-memory responses across the 3-day week. For the regular and irregular task, a correct response was initiating the appropriate prospective-memory activity subsequent to the dice roll that landed the token on (or passed over) the target square, and prior to the next dice roll. The proportion was computed from 12 possible responses for the regular prospective-memory task and from 12 for the irregular task. For the time-based prospective-memory task, a response was scored as correct if it was initiated within 10 s of the target time. The proportion was computed from six possible responses (see Table 2 for means).

For the regular prospective-memory task, a benefit of cognitive training was revealed by a significant interaction of test time with the presence or absence of cognitive training, $F(1, 74) = 9.77$, $MSE = .024$, $p = .003$, $\eta_p^2 = .117$. As presented in Table 3, from approximately equivalent preintervention baseline levels of performance (relative to no cognitive training), participants with cognitive training achieved gains in performance from pre- to posttest (.14 gain), whereas participants without cognitive training displayed no hint of any gain (.02 decrease). There were no significant benefits of aerobic exercise, either overall ($F < 1$, $\eta_p^2 = .004$) or interacting with cognitive training ($F < 1$; $\eta_p^2 < .001$). The cognitive-training effect also produced a significant main effect of test time, with regular prospective-memory performance generally improving from pre- to posttest, $F(1, 74) = 4.40$, $MSE = .024$, $\eta_p^2 = .056$, and better overall performance when cognitive training was present relative to when it was absent, $F(1, 74) = 4.56$, $MSE = .065$, $\eta_p^2 = .058$.[1]

The irregular prospective-memory task displayed parallel effects. The interaction between test time and presence or absence of cognitive training was significant, $F(1, 74) = 8.66$, $MSE = .018$, $p = .004$, $\eta_p^2 = .105$, reflecting that gains from pre- to posttest were observed after cognitive training (.13 gain), but not in the absence of cognitive training (.00 gain). There were no significant benefits of aerobic exercise, overall ($F < 1$; $\eta_p^2 = .005$) or interacting with cognitive training ($F < 1$; $\eta_p^2 = .006$). The cognitive-training effect produced significant performance gains from pre- to posttest, $F(1, 74) = 9.20$, $MSE = .018$, $\eta_p^2 = .111$.

For time-based prospective memory, neither cognitive training nor aerobic exercise effects emerged ($F < 1$, $\eta_p^2 < .001$, for cognitive training; $F = 1.02$, $\eta_p^2 = .014$, for aerobic exercise; and $F < 1$, $\eta_p^2 = .005$ for Cognitive Training × Aerobic Exercise). Performance generally improved from pretest to posttest, $F(1, 74) = 4.98$, $MSE = .051$, $\eta_p^2 = .063$. These patterns in concert suggest that time-based prospective memory improved with practice (as there was no interaction of test time with absence or presence of the interventions). The cognitive-training groups performed better overall than the other groups (performance averaged across pre- and posttest), $F(1, 74) = 7.05$, $MSE = .115$, $\eta_p^2 = .087$.

Memory for Health Information

There were three measures derived from this task: corrected recognition (Hits – FAs to nonrepeated lures), FAs to repeated lures, and source memory (proportion of correct source responses, given a hit). Pre- and posttest mean values are presented in Table 4. For corrected recognition, the ANOVA revealed no significant effects. (For the intervention effects [interactions with test time], $F < 1$, $\eta_p^2 = .003$ for cognitive training; $F = 1.17$, $\eta_p^2 = .016$ for aerobic exercise; and $F < 1$, $\eta_p^2 < .001$, for Cognitive Training × Exercise.)

For FAs (to repeated lures), there was a practice effect such that FAs significantly declined from the pretest to the posttest, $F(1, 73) = 12.80$, $MSE = .022$, $\eta_p^2 = .149$. No intervention effects emerged ($F < 1$, $\eta_p^2 = .011$, for cognitive training; $F = 1.56$, $\eta_p^2 = .021$, for aerobic exercise, but note that the means show nominally greater reduction of FAs for the exercise absent than present condition; $F < 1$, $\eta_p^2 = .001$, for Cognitive Training × Exercise). We also conducted exploratory ANOVAs to examine whether

[1] For several of the Virtual Week and Cooking Breakfast measures, an interaction between presence and absence of cognitive training and presence and absence of aerobic exercise indicated that the combined group performed better than the other groups, beginning at pretest and persisting to posttest. For efficiency, the significant *F*s for the measures for which that interaction appeared are reported here. For Virtual Week: regular prospective memory, $F(1, 74) = 5.46$, MSE = .065; irregular prospective memory, $F(1, 74) = 4.40$, $MSE = .100$. For Cooking Breakfast: time range, $F(1, 73) = 4.94$, $MSE = 1094.28$; ideal performance, $F(1, 65) = 9.56$, $MSE = 278.37$, with the combined group advantage most prominent for the difficult version of cooking breakfast (for the three-way interaction, $F[1, 65] = 5.85$, $MSE = 154.91$).

Table 2
Changes in Peak Aerobic Power Over 6 Months (Mean ± SD)

	Training condition			
	Control (n = 17)	Cognitive (n = 14)	Exercise (n = 21)	Combined (n = 19)
Baseline VO_{2peak} (ml/kg/min)	23.4 ± 3.7	22.7 ± 3.8	22.0 ± 4.1	22.1 ± 5.3
6-month VO_{2peak}(ml/kg/min)	23.7 ± 3.7	22.2 ± 4.4	23.7 ± 4.6	24.5 ± 6.1
Change at 6 months (ml/kg/min)	+0.4 ± 1.7	−0.5 ± 1.4	+1.8 ± 3.3	+2.5 ± 2.8

Note. Eight participants who provided cognitive data at 6 months did not perform VO_2 testing at 6 months (control = 2; cognitive = 4; exercise = 2).

training effects could have emerged at the longest, most challenging lags (Lags 10, 16, and 22). Although there were no effects involving the training manipulations at Lag 10 or 22 (largest F = 2.56, $\eta_p^2 = .034$, for test time by presence or absence of cognitive-training interaction), at Lag 16, there was a significant test time by presence or absence of cognitive-training interaction, $F(1, 73) = 5.70$, $MSE = .113$, $p = .020$, $\eta_p^2 = .072$. This interaction indicated that without cognitive training, FAs did not decline from pretest (M = .51) to posttest (M = .50); by contrast, cognitive training produced a robust decline in FAs (M = .55 at pretest, and M = .28 at posttest). The Test Time × Aerobic Exercise interaction was also significant, $F(1, 73) = 5.64$, $MSE = .113$, $p = .020$, η_p^2 = .072, but in this case, FAs declined only for the condition without exercise (M = .57 at pretest, and M = .35 at posttest; for the condition with exercise Ms = .44 and .48, respectively). These results are suggestive, but must be interpreted with caution, as the cognitive-training effect was not consistent across the three longest lags; in this regard, one potential concern is that the particular facts used for each lag were not counterbalanced.

For source memory, accuracy significantly declined from pre- to posttest, $F(1, 73) = 4.04$, $MSE = .014$, $p = .048$ (Fs <1 for all intervention effects [i.e., interactions with test time], with η_p^2 = .001 for cognitive training, $\eta_p^2 < .001$ for aerobic exercise, and $\eta_p^2 = .004$ for Cognitive × Exercise).

Cooking Breakfast

There are dozens of possible measures that can be computed to summarize the behaviors on the Cooking Breakfast task (cf. Craik & Bialystok, 2006). Our approach was to first compute a minimum number of summary measures to gauge overall accuracy (to limit the number of comparisons, and thereby minimize likelihood of Type I errors), with the intent to perform more fine-grained analyses if training effects emerged. A first simple measure, the difference in time between stopping the first and last food (labeled *Stopping Time Range*), accounts for how well the participant met the objective of finishing all foods at the same time (with smaller differences indicating better performance). This measure, however, does not index whether the foods were accurately cooked (foods could have been stopped at the same time, but could have been under- or overcooked), and also would not necessarily reflect the degree of planning at the outset of the task. We thus derived a second summary measure to capture critical components of planning and execution that would support accurate performance. Initial planning and execution were gauged by the average deviation between ideal start times for each food and when it was actually started. This could be perfect, yet the foods might not be cooked appropriately (not stopped correctly), and thus we also computed the average disparity between required cooking time and actual cooking time. Note that if these components are both zero, then performance is perfect (the cooking is perfectly coordinated, and foods are cooked accurately). Our summary measure, *ideal performance*, was the sum of the two just-mentioned components, with lower values (in seconds) equaling more accurate performance. This measure could not be computed for participants who did not start and stop all foods (there was one participant in the combined group, one in the cognitive group, and three in each of the other two groups who did not start and stop all foods). Finally, we computed the number of table settings accomplished, as this provides an index of how busily engaged participants were on this ongoing activity. Mean values are displayed in Table 5.

Table 3
Means and Standard Errors for Pre- (Baseline) and Post- (Month 6) Tests for Measures From the Virtual Week Task as a Function of Training Condition

		Training condition			
Measure	Test time	Control (n = 19)	Cognitive (n = 18)	Exercise (n = 22)	Combined (n = 19)
Regular PM	Pre	.71 (.05)	.62 (.05)	.64 (.04)	.74 (.05)
	Post	.67 (.05)	.74 (.05)	.63 (.05)	.89 (.05)
Irregular PM	Pre	.53 (.06)	.46 (.06)	.53 (.05)	.60 (.06)
	Post	.53 (.06)	.62 (.06)	.53 (.05)	.70 (.06)
Time-Based PM	Pre	.30 (.07)	.42 (.07)	.27 (.06)	.44 (.07)
	Post	.37 (.07)	.43 (.07)	.37 (.06)	.58 (.07)

Note. PM = prospective memory.

Table 4
Means and Standard Errors for Pre- (Baseline) and Post- (Month 6) Tests for Measures From the Memory for Health Information Task as a Function of Training Condition

Measure	Test time	Training condition: Control (n = 19)	Cognitive (n = 17)	Exercise (n = 23)	Combined (n = 18)
Corrected recognition	Pre	.60 (.04)	.59 (.04)	.65 (.04)	.64 (.04)
	Post	.62 (.03)	.62 (.04)	.63 (.03)	.64 (.04)
FAs to repeated lures	Pre	.40 (.05)	.38 (.05)	.40 (.04)	.32 (.05)
	Post	.31 (.05)	.24 (.05)	.36 (.04)	.24 (.05)
Source memory	Pre	.47 (.02)	.47 (.03)	.47 (.02)	.53 (.03)
	Post	.42 (.03)	.43 (.03)	.45 (.03)	.47 (.03)

Note. FA = false alarm.

The ANOVAs for these measures included the two difficulty levels of the task. For stopping time range, for all intervention effects (i.e., interactions with test time), Fs $<$ 1 (with η_p^2 = .001 for cognitive training, η_p^2 $<$ .003 for aerobic exercise, and η_p^2 = .003 for Cognitive $\times$ Exercise). As would be expected, the difference in stopping times was significantly more exaggerated for the more difficult version of the task, $F(1, 73) = 15.40$, $MSE = 577.22$, $\eta_p^2 = .174$. For ideal performance, there were also no significant interactions of test time with the intervention conditions ($F < 1$, $\eta_p^2 = .004$, for cognitive training; $F < 1$ for Cognitive Training $\times$ Exercise, $\eta_p^2 = .012$), though there was a marginal interaction between test time and exercise training, such that performance improved with aerobic exercise but declined in the absence of exercise, $F(1, 65) = 2.92$, $p = .092$, $\eta_p^2 = .043$. Performance was significantly better for the easier than the more difficult game, $F(1, 65) = 86.59$, $MSE = 154.91$, $\eta_p^2 = .571$. Further, from pre- to posttest, there was improvement in performance for the less difficult game (20.41 s to 17.83 s), but a worsening of performance for the more difficult game (30.70 s to 35.54 s), $F(1, 65) = 6.78$, $MSE = 138.86$, $\eta_p^2 = .084$.

For the number of complete table settings, test time and cognitive training significantly interacted, $F(1, 73) = 5.22$, $MSE = 16.61$, $p = .025$, $\eta_p^2 = .067$, indicating that the cognitive-training group demonstrated virtually no change in the number of table settings from pre- to posttest, whereas no cognitive training was associated with a slight increase in the number of table settings from pre- to posttest ($F = 2.61$, $\eta_p^2 = .035$, for aerobic exercise; $F < 1$, $\eta_p^2 = .001$, for Cognitive Training $\times$ Exercise). The only other significant effect was that the number of table settings was significantly lower for the more difficult than the less difficult version of the task, $F(1, 73) = 16.51$, $MSE = 8.16$, $\eta_p^2 = .184$.

Supplementary Analyses

Similar to the primary outcome measures, three-factor mixed ANOVAs were conducted for the psychometric tests. As there were no significant effects of the interventions (interactions of test time [pre/post] with presence or absence of the interventions), and because these outcomes were not the primary focus of this article, we simply summarize the F values for the intervention effects (and provide brief descriptions of intervention patterns for several treatment effects with Fs $>$ 2.00) in Table 6. As described in Table 6, even the largest (but nonsignificant) intervention effects were for the most part reflective of *poorer* performance from pre- to posttest for particular intervention groups (see motor control, Trails A, Trails B), sometimes along with augmented improvement for the control group (Trails B).

Discussion

The present theoretically and empirically motivated and broad-based training approach produced mixed results in terms of improving outcomes associated with everyday task performance (proxy tasks). We first discuss the importance of the cognitive-training effect for VW, and then consider possible reasons for the absence of cognitive-training effects for the other two primary outcomes, and the failure of the aerobic exercise program to promote gains on the everyday (proxy) outcome tasks that were assessed.

Table 5
Means and Standard Errors for Pre- and Post- (Month 6) Tests for Measures From the Cooking Breakfast Task as a Function of Training Condition

Measure	Test time	Training condition: Control (n = 19)	Cognitive (n = 17)	Exercise (n = 23)	Combined (n = 18)
Stopping time range	Pre	30.61 (4.93)	32.44 (5.21)	31.13 (4.48)	19.17 (5.06)
	Post	27.32 (4.84)	30.68 (5.12)	33.87 (4.40)	17.31 (4.98)
Ideal performance(s)	Pre	23.74 (2.50)	29.86 (2.50)	26.10 (2.24)	22.50 (2.43)
	Post	26.87 (2.73)	34.24 (2.73)	26.73 (2.44)	18.90 (2.65)
Number of table settings	Pre	20.97 (1.44)	21.27 (1.53)	19.76 (1.31)	23.78 (1.48)
	Post	23.84 (1.40)	21.71 (1.48)	20.83 (1.27)	23.00 (1.44)

Table 6
Summary of Treatment Effects (Interactions Between Interventions and Testing Time) for the Psychometric Measures

Measure	Baseline (*SE*)	Treatment effects
Logical Mem (Imm)	0.53 (.01)	All *F*s <1.0
Logical Mem (Delay)	0.49 (.02)	All *F*s <1.0
Digit Symbol	52.12 (1.13)	Cognitive training, $F = 2.10$, $p = .152$, $\eta_p^2 = .027$[a]
Motor Control	63.13 (1.27)	Cognitive Training × Exercise, $F = 3.48$, $p = .066$, $\eta_p^2 = .044$[b]
Trails A	35.85 (1.12)	Cognitive Training × Exercise, $F = 2.13$, $p = .149$, $\eta_p^2 = .028$[c]
Trails B	77.59 (2.61)	Cognitive Training × Exercise, $F = 2.62$, $p = .110$, $\eta_p^2 = .034$[d]

Note. Largest treatment effect is reported ($N = 79$; $df = 1, 75$). Baseline is the overall average pretest score: Logical Mem = proportion recall; Digit Symbol = symbol boxes filled within 90 s; Motor Control, Trails A, and Trails B = seconds to complete. *SE* = standard error; Mem = memory; Imm = immediate.
[a] Cognitive-training groups improved from pre- to posttest by 1.3; no cognitive training decreased performance by .08. [b] Exercise-only group slowed (got worse) by 9.6 s from pre- to posttest, whereas all other groups varied by no more than ±3.2 s across pre- to posttest. [c] Control and combined groups improved by between 1 and 2 s from pre- to posttest; the cognitive-only and exercise-only groups slowed by 2 s. [d] Control and combined groups improved by 6 s; cognitive-only group slowed by 4 s.

Cognitive-Training Benefits on VW

The significant improvement in prospective-memory performance in VW following cognitive training is noteworthy for several reasons. First, VW poses substantial prospective-memory challenges for older adults (multiple prospective-memory tasks, e.g., Einstein, Holland, McDaniel, & Guynn, 1992; introduction of irregular prospective-memory tasks during ongoing activities, e.g., Einstein, Smith, McDaniel, & Shaw, 1997), challenges that produce age-related declines in VW prospective memory (Rendell & Craik, 2000; Rose et al., 2010). These challenges are such that older adults do not easily improve their performance in VW. Having practiced the same regular prospective-memory tasks repeatedly during the pretest (once on the “practice” day, and then for 3 successive virtual days), in the absence of cognitive training, older adults showed no hints of improvement at the posttest, with a nominal decline in performance. Similarly, there was no improvement from the pre- to posttests for irregular prospective-memory tasks, and there was no effect of aerobic exercise. Yet after the cognitive-training intervention, older adults were able to increase their prospective remembering.

It should be emphasized that the control (no cognitive training) condition to which the cognitive-training intervention was compared involved active cognitive processing with social engagement. Accordingly, the cognitive-training effects (on VW) were evidenced relative to a strong control condition. Thus, the present effects of cognitive training cannot be a consequence of a weak control condition (inactive, no-contact control) against which the training groups displayed improvement.

The source of the benefit on VW from cognitive training was likely the inclusion of prospective-memory training. Thus, a second important contribution of the present findings is that they underscore the value of including prospective-memory training as a component of cognitive-training interventions. We suggest that prospective-memory training would be valuable for future interventions designed to foster improvement for older adults in everyday tasks (in which prospective memory is intimately involved). A next step for researchers is to evaluate whether the training-related benefits seen for prospective memory in the VW laboratory task will hold for prospective memory in the real world.

Another potential contribution of our findings is revealed by contrasting the present prospective-memory training approach with that of a recently reported approach. In an unpublished prospective-memory training study by Rose, Craik, Kliegel, Hering, and Rendell (2012), participants either practiced several kinds of prospective-memory tasks or did not practice prospective memory. There was no significant transfer to a new prospective-memory task. One interpretation of the limited transfer across the prospective-memory tasks is that Rose et al. had older adults simply practice—no explicit strategy instruction was given. By contrast, the present prospective-memory training component provided explicit instruction on effective cognitive strategies for improving prospective-memory performance and strongly encouraged older adults to attempt to apply these strategies to their everyday prospective-memory tasks. It appears that explicit strategy training, along with practice at applying those strategies to other tasks outside training, may be important features of training that promote transfer (also see Toglia et al., 2010, 2012, for a similar approach used for occupational therapy).

One potential interpretational issue is that cognitive-training participants may have developed expectations for improvement (on cognitively demanding tasks), whereas those without cognitive training (controls) may not have developed such expectations. These differential expectancies might have mediated the observed cognitive-training effects (Boot, Simons, Stothart, & Stutts, 2013). This possible interpretation is disfavored by the absence of cognitive-training effects on two of the outcome tasks, as discussed next.

Why Did Cognitive Training Not Transfer to Other Tasks?

One possible explanation is that the Memory for Health Information and Cooking Breakfast tasks were less similar to the cognitive tasks used for training than was the VW prospective-memory task, thereby reflecting farther transfer from training than for the VW task. Counter to this explanation, consider that the Memory for Health Information task overlapped highly with the cognitive training. The cognitive-training intervention (the retrospective-training component) involved a task that directly trained participants to learn to reject repeated lures in the recognition test (i.e., discouraging reliance on familiarity), identically to that required in the Memory for Health Information task. Similarly, the Cooking Breakfast task required task switching, variable priority assignment, and prospective memory (i.e., interleaving setting the table, starting foods, monitoring foods, and remembering to stop foods), all of which were a focus in cognitive training. Moreover, the correlations at baseline among the outcome-task performances (and with VO_{2peak}; see Table 7), shows that prospective-memory performances (on VW) were significantly correlated with Cooking Breakfast performances, reinforcing the assumption that cooking breakfast involves prospective memory (Craik & Bialystok, 2006). In sum, the outcome tasks that did not show transfer appear related to the training tasks in much the same way that VW was.

Another possible explanation for the absence of transfer to Cooking Breakfast or Memory for Health Information is that the training tasks most closely related to these outcomes did not incorporate explicit strategy instruction. No explicit strategy instruction was incorporated into the variable priority training or task switching, two processes that presumably were involved in the Cooking Breakfast task. Similarly, the training that focused on resistance to relying on familiarity did not provide explicit strategy instruction. Interestingly, all of the just-mentioned training tasks were designed to provide practice for participants, sometimes adaptive practice, with the assumption that transferable (perhaps implicit) skills would be acquired through practice alone. It may be that skill training without explicit strategy instruction produces skills that are entrained to the specific stimuli and tasks that were practiced, thereby fostering brittleness for transfer (e.g., see Healy, Wohldmann, Parker, & Bourne, 2005; also see Redick et al., 2013). More theoretical and empirical work is needed in light of other findings showing transfer from these mentioned training tasks (Jennings et al., 2005; Karbach & Kray, 2009; Kramer et al., 1999).

A third possible explanation for the absence of benefits of cognitive training for Memory for Health Information and Cooking Breakfast is that participants had limited opportunity to apply what they learned as related to controlling attentional priority, task switching, or resistance to influences of familiarity. Impressions by one of the trainers (EW) dovetail with this possibility. Participants seemed better able to identify everyday situations for which the trained prospective-memory strategies could be applied as homework. For the recollection and attention priority training sessions, homework discussions were generally limited to repeatedly identifying the same strategy for the same training task each week. Participants appeared much less interested in doing the same kind of homework repeatedly across the 8-week cognitive-training program, and consequently may not have practiced transfer of recollection and attention skills to tasks outside of the training as frequently as they did for prospective-memory skills. Based on other training literatures (e.g., rehabilitation training), it seems that practicing application of newly learned cognitive tasks outside the training context is important to foster transfer. It may be that only prospective-memory training supported effective homework practice, and accordingly, transfer was limited to the outcome task most closely aligned with the PM training (VW).

The fact that the attentional control and retrospective-memory training tasks remained the same throughout 8 weeks of training, may have lessened participants' enthusiasm and motivation over the duration of the training. To the degree that motivation waned for attentional control and retrospective-memory training during the course of training, diminished training effects might be expected (see, e.g., West et al., 2008). It is perhaps telling that the prospective-memory training incorporated quite different ongoing activities over the course of each week of training, and this may have been another aspect of the prospective-memory training that contributed to positive benefits on the VW task.

Finally, cognitive-training effects may have been limited because the older adults in this sample represented a relatively lower age range (mean age = 65 years.), were well educated, and were high functioning in their daily lives. However, their performance on the VW (Rose et al., 2010) and Cooking Breakfast (Craik & Bialystok, 2006) tasks was comparable with other studies in which significant age-related declines have been documented. Similarly, in a pilot experiment during the development of the Memory for Health Information task, we found significant age-related declines on this task. In addition, at least for VW, these levels of perfor-

Table 7
Pearson r Correlations Among the Primary Outcome Measures at Baseline (n = 96).

	Reg PM	Irreg PM	Time PM	Corr Recog	FAs to Lures	Source Mem	Stop Time Range	Ideal Perf	#Table Sets	VO_2 (ml)
Reg PM	1	.47**	.14	.21#	−.05	.16	−.36**	−.39**	.27*	.16
Irreg PM		1	.39**	.32**	−.16	.07	−.25#	−.39**	.42**	.25#
Time PM			1	.26#	−.24#	.04	−.19	−.24#	.20	.02
CorrRecog				1	−.60**	.17	−.004	−.10	.15	.03
FAs to Lures					1	−.13	−.01	−.04	.03	.15
Source Mem						1	.01	−.08	.10	−.17
Stop Time Range							1	.40**	−.26#	−.17
Ideal Perf								1	−.30*	−.22#
#Table Sets									1	.38**
VO_2 (ml)										1

Note. Reg PM = regular prospective memory; Irreg PM = irregular prospective memory; Time PM = time-based prospective memory; Corr Recog = corrected recognition; FAs to Lures = false alarms to repeated lures; Source Mem = source memory; Stop Time Range = stopping time range; Ideal Perf = ideal performance; #Table sets = number of complete table settings. Because of technical problems, one participant had missing data for Memory for Health Information (corrected recognition, FAs, and source memory).
# $p < .05$. * $p < .01$. ** $p \leq .001$.

mance for the older adults did not reflect a functional (or asymptomatic) ceiling, as performance gains were evidenced. Clearly, an important question remains concerning whether older adults' level of functioning is associated with the potential benefits of cognitive training.

Why Did Aerobic Exercise Not Produce Gains on the Cognitive Outcome Measures?

Previous randomized trials of aerobic exercise interventions have demonstrated mixed effects, with some studies showing improvements in cognitive function (most prominently executive control, e.g., Colcombe et al., 2004; Kramer et al., 2003), whereas others have not (Hill, Storandt, & Malley, 1993). Recent meta-analyses have also had mixed findings (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008; Colcombe & Kramer, 2003), and a recent expert-panel review reported that there is insufficient evidence to conclude that exercise interventions improve cognitive function (Snowden et al., 2011). The current study did not show significant exercise effects on the cognitive outcome measures, despite the fact that two of the outcome measures (Cooking Breakfast and VW) involved several executive control processes. Participants in the exercise groups achieved between 8.5% (exercise group) and 11.3% (combined group) increases in aerobic power, which are not substantially different from the 10% gain observed by Colcombe et al. (2004) using a similar 6-month training paradigm that did yield benefits. Moreover, the relatively young age of the participants ($M = 65$ years) was unlikely to have reduced the effects of exercise on cognitive function, because previous studies using participants of a similar age have demonstrated benefit (e.g., Colcombe et al., 2004).

To our knowledge, the current study is the first to evaluate the effects of aerobic exercise training on complex real-world cognitive tasks. Correlations between baselines performances on these cognitive tasks and the baseline aerobic-fitness index (VO_{2peak}) indicated that, for the most part, aerobic fitness was not significantly associated with the outcome-task performances (see Table 7). Thus, aerobic fitness may not be an important moderator of these outcome measures for individuals in the performance ranges in this sample. Regarding benefits of exercise, it may be informative that for one (ideal performance in Cooking Breakfast) of three measures (the others being table settings in Cooking Breakfast and irregular prospective memory in VW) that did display a modest correlation with baseline fitness, there was a marginally significant benefit of aerobic exercise. It thus seems possible that aerobic fitness is correlated with performance on select cognitive tasks, with performance gains from an aerobic exercise intervention accordingly limited to that select set of tasks.

A possible objection is that the absence of exercise effects in the present study reflected inadequate power to detect effects. This possible objection is disfavored by two observations. First, inspection of the means in Tables 3 through 5 shows there was no outcome measure for which aerobic exercise produced hints of gains from pre- to posttest that were of a greater magnitude than displayed in the control (e.g., note that an exception is for ideal performance for cooking breakfast, which did produce a marginally significant effect). Second, our power was adequate to detect significant effects for cognitive training. If aerobic exercise had an effect that was as robust as cognitive training, the power was sufficient to detect it.

Though these possibilities cannot be definitively determined from the current findings, the overall patterns strike a somewhat different chord than may be evident from the current intervention literature, which has shown more consistent effects of aerobic exercise training on "process pure" laboratory-based tasks (see Hertzog et al., 2008, for caution that the type of cognitive processes assessed moderates the benefit of aerobic exercise on cognitive performance). The present findings suggest that, at least for everyday-oriented prospective-memory tasks involving cognitive challenges, well-designed cognitive-training programs may confer more robust gains in performance than a standard aerobic exercise program over a limited (6-month) period of time.

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Received January 9, 2014
Revision received May 1, 2014
Accepted May 5, 2014 ■