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ORIGINAL RESEARCH

Applying the Health Belief Model to Quantify and Investigate Expectations for Computerized Cognitive Training

Jerri D. Edwards [1,2] · Christine B. Phillips [3] · Melissa L. O'Connor [4] · Jennifer L. O'Brien [2,5] · Elizabeth M. Hudak [1] · Jody S. Nicholson [6]

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Abstract

Despite the demonstrated benefits of computerized cognitive training for older adults, little is known about the determinants of training behavior. We developed and tested scales to quantify expectations about such training, examine whether expectations predicted training adherence, and explore if training expectations changed from pre- to post-training. Participants ($N = 219$) were healthy older adults aged 55–96 years ($M = 75.36$, SD = 9.39), enrolled in four studies investigating Dakim, InSight, or Posit Science Brain Fitness computerized cognitive training programs. Instruments were adapted from existing health behavior scales: Self-Efficacy for Cognitive Training; Outcome Expectations for Cognitive Training; Perceived Susceptibility to Cognitive Decline, Dementia, or Alzheimer's Disease; and Perceived Severity of Cognitive Decline, Dementia, or Alzheimer's Disease. Participants completed scales at baseline ($N = 219$) and post-training ($n = 173$). Eight composites were derived from factor analyses. Adherence rates were high ($M = 81\%$), but none of the composites predicted training adherence. There was an overall significant effect of time, Wilks' $\lambda = 0.843$, $F(8, 114) = 2.65$, $p = 0.010$, partial $\eta^2 = 0.157$; a significant overall effect of training group, Wilks' $\lambda = 0.770$, $F(16, 228) = 1.99$, $p = 0.015$, partial $\eta^2 = 0.123$; and an overall significant group × time interaction, Wilks' $\lambda = 0.728$, $F(16, 226) = 2.44$, $p = 0.002$, partial $\eta^2 = 0.147$. Significant effects of time were found for *expected psychological outcomes* and *self-efficacy*. Post-training, participants more strongly agreed that training was enjoyable and increased their sense of accomplishment. Changes in *self-efficacy for cognitive training* varied by program, improving for Dakim, and declining for the more challenging Brain Fitness and InSight participants. These newly devised scales may be useful for examining cognitive training behaviors. However, more work is needed to understand factors that influence older adults' enrollment in and adherence to cognitive training.

Keywords Cognitive training · Expectations · Health beliefs · Intervention adherence

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✉ Jerri D. Edwards
usfcognitiveagelab@gmail.com

1 Department of Psychiatry and Behavioral Neurosciences, University of South Florida, Tampa, FL, USA

2 Department of Communication Sciences and Disorders, University of South Florida, Tampa, FL, USA

3 Atria Senior Living, Louisville, KY, USA

4 North Dakota State University, Fargo, ND, USA

5 Department of Psychology, University of South Florida, Tampa, FL, USA

6 Department of Psychology, University of North Florida, Jacksonville, FL, USA

Introduction

A great deal of research over the last two decades has focused on the efficacy of cognitive training among older adults (Edwards et al. 2017a; Hill et al. 2017; Kelly et al. 2014; Lampit et al. 2014; Rebok et al. 2014). Recent research indicated that a particular type of cognitive training (i.e., useful field of view training) longitudinally reduces dementia risk (Edwards et al. 2017b). To date, this is the only intervention shown to reduce dementia risk in a randomized clinical trial. Given the efficacy of cognitive training to enhance the cognitive skills targeted (Edwards et al. 2017a; Hill et al. 2017; Kelly et al. 2014; Lampit et al. 2014), as well as to transfer to improved everyday function (Ball et al. 2010; Edwards et al. 2017a; Lin et al. 2016; Smith-Ray et al. 2014b; Smith-Ray et al. 2014a), slow functional decline (Rebok et al. 2014;

Wolinsky et al. 2015), and possibly reduce dementia risk among older adults (Edwards et al. 2017b), an important next step is to learn more about the determinants of cognitive training engagement. The aim of the current study was to develop and test scales for quantifying beliefs and expectations about computerized cognitive training. We further examined if beliefs and expectations were predictive of adherence to computerized cognitive training regimens among older adult study participants. Finally, we further explored if beliefs and expectations about cognitive training changed during the course of study participation.

Prior studies indicate that participants in cognitive training programs tend to believe the training will benefit them (Goghari and Lawlor-Savage 2018; Foroughi et al. 2016; Rabipour and Davidson 2015). Positive expectations about training are associated with but do not mediate improvements in cognitive training efficacy (Foroughi et al. 2016; Sharpe et al. 2014). Rabipour and Davidsion (2015) found that older age and previous computer knowledge predicted positive training expectations. A few additional studies have examined factors that predict adherence to cognitive training regimes. These studies found that most participants complete at least some training sessions, even when the training is supervised remotely (Cruz et al. 2014; Turunen et al. 2019). Thus, participants' willingness to invest time in training may be predicted by older age, greater openness to experience, previous computer use, better memory performance, positive expectations about training, and self-perceived cognitive functioning (Double and Birney 2016; Harrell et al. 2019; Turunen et al. 2019).

We applied social cognitive theory and the health belief model to quantify expectations about computerized cognitive training (Champion and Skinner 2008; Janz and Becker 1984; Lorig et al. 1996; Rimer and Glanz 2005; Rosenstock et al. 1988). According to these approaches, an individual's engagement in health promotion activities is a result of the interaction between their beliefs and values as well as environmental factors that influence their ability to act. The health belief model posits that health behavior is determined by an individual's perceptions of health susceptibility if they do not act, the resulting health severity from inaction, the potential positive health benefits of action, the barriers to action, their exposure to factors that prompt action, and their confidence in ability to succeed following action (i.e., self-efficacy; Rimer and Glanz 2005).

Prior research establishing a relation of health belief model constructs to adherence to interventions has varied based on disease, adherence type, and study population. For example, a review of adherence to cancer screening established perceived barriers and perceived susceptibility as the most consistent predictor of adherence in 74 and 86% of studies, respectively; perceived severity was a significant predictor of adherence for 50% of articles reviewed (Day et al. 2010). In a review of articles using the original measures amended in the current study, patterns emerged on the connection of constructs of the health belief model to adherence. The health belief model constructs of self-efficacy and perceived susceptibility were more widely studied than perceived severity and outcome expectations, though outcome expectations and perceived susceptibility were each only significantly related to adherence in one study (outcome expectations—O'Brien, Finlayson, Kerr, Shortridge-Baggett, & Edwards, 2018; perceived susceptibility—Ouakrim, Lockett, Boussioutas, Hopper, & Jenkins, 2013). Self-efficacy was the health belief model construct most widely connected to adherence with those with higher self-efficacy being more likely to adhere to programming (Cheung, Wyman, & Savik, 2016; Jefferis et al. 2014; O'Brien, Finlayson, Kerr, Shortridge-Baggett, & Edwards, 2018; Resnick et al. 2008; Robinson, Newton, Jones, & Dawson 2014). In contrast, contradictory results were evident for perceived severity based on adherence type. For example, higher perceived severity was related to better adherence to medication use and self-care behaviors for those with mental illness (Adams and Scott 2000) and adolescents with food allergies (Jones et al. 2013), respectively, while higher perceived severity of health status was related to poorer adherence for individuals on antihypertensive medication (Lee et al. 2013).

Using constructs from social cognitive theory and the health belief model, instruments were adapted from existing health behavior scales to examine cognitive training beliefs. The scales include Self Efficacy for Cognitive Training (SECT; Lorig et al. 1996; Resnick and Jenkins 2000), Outcome Expectations for Cognitive Training (OECT; Wojcicki et al. 2009), Perceived Susceptibility to Cognitive Decline Dementia or Alzheimer's Disease (PSUS; Tiro et al. 2005), and Perceived Severity of Cognitive Decline, Dementia, or Alzheimer's Disease (PSEV; Champion and Skinner 2008). The scales are summarized in Table 1 and included in the Appendix. We examined the psychometric properties of the scales and devised composites. Further, we investigated if the composites derived from our scales were predictive of adherence to cognitive training and if beliefs about cognitive training changed after participating in a cognitive training study.

Materials and Methods

Participants

Participants included relatively healthy older adults ($N = 219$) enrolled across four different studies of computerized cognitive training conducted in the University of South Florida (USF) Cognitive Aging Lab. All participants provided informed consent and each study was approved by the USF Institutional Review Board. Participants ranged in age from

Table 1 Description of scales devised to quantify beliefs and expectations of computerized cognitive training

Title	Abbreviation	Items	Description	Composites
Self-Efficacy for Cognitive Training	SECT	13	Respondents rate their confidence in completing computer brain fitness programs under different circumstances on a 7-point Likert scale ranging from not at all confident to very confident. Items reflect potential barriers such as computer difficulties, being bored, not seeing improvement, feeling stressed or depressed	Self-Efficacy for Cognitive Training—13 items
Outcome Expectations for Cognitive Training	OECT	16	Respondents rate their expectations for outcomes of computerized brain fitness programs on a 5-point Likert scale ranging from strongly disagree to strongly agree	Expected Cognitive Outcomes—4 items Expected Social Outcomes—4 items Expected Psychological Outcomes—3 items Expected Negative Outcomes—2 items
Perceived Susceptibility to Cognitive Decline, Dementia, or Alzheimer's Disease	PSUS	4	Respondents rate their agreement with statements regarding their perceived susceptibility of cognitive decline, Alzheimer's disease, or dementia on a 5-point Likert scale ranging from strongly disagree to strongly agree	Perceived Susceptibility—4 items
Perceived Severity of Cognitive Decline, Dementia, or Alzheimer's Disease	PSEV	9	Respondents rate their agreement with items on the severity of cognitive decline, Alzheimer's disease, or dementia on a 5-point Likert scale ranging from strongly disagree to strongly agree	Perceived Severity of Consequences—5 items Perceived Severity of Relationships—3 items

55 to 96 years ($M = 75.36$, SD = 9.39), with education levels between 8th grade to doctorate ($M = 15.67$ years, SD = 2.50). Most participants reported being females (71%) and being of Caucasian race (94%), and 2.7% of participants reported Hispanic ethnicity. Participants were recruited from newspaper stories and advertisements, an older adult participant registry, and from community educational talks about brain health.

Inclusion criteria were highly similar across the studies: participants were required to be willing and available to complete study visits and to be native English speakers. All studies excluded persons who reported neurological disorders (e.g., history of stroke, traumatic brain injury, Parkinson's disease, multiple sclerosis) or showed evidence of dementia (Mini Mental State Examination score < 23). The studies involving Dakim or InSight cognitive training programs, which include primarily visual stimuli, required intact vision (i.e., near visual acuity of 20/80 and 20/50 or better, respectively). The studies examining the Posit Science Brain Fitness program, which includes auditory stimuli, assessed hearing and excluded persons who reported exposure to excessive noise or ototoxic agents that could damage hearing.

Procedure

The four studies each examined computerized cognitive training programs in randomized trials. Given that the goal for the scales is to predict computerized cognitive training behavior broadly, we combined data across the four studies. One study examined the Dakim Brain Fitness program, referred to hereafter as "Dakim," with methods and results published elsewhere (Hudak et al. 2019). A second study was a pilot test of the Posit Science InSight and Brain Fitness programs. The third study examined the efficacy and underlying mechanisms of the InSight program: methodological details and results are described in two prior publications (Edwards et al. 2015; O'Brien et al. 2013). The fourth study was a within-subjects design and, for our purposes, these participants' baseline data were included in factor analyses to derive scale composites.

Descriptions of the training programs are summarized in Table 2. Participants were assigned 20 h of training. Adherence was tracked by each of the computerized cognitive training programs and was conceptualized as percent of assigned training completed. Those randomized to training who did not ever attempt the training exercises were coded as 0% adherent.

Participants were administered the four scales (SECT, OECT, PSUS, PSEV) at a baseline visit ($N = 219$) and again at a post-test visit ($n = 173$) that occurred about 13 weeks later ($M = 13.13$, SD = 2.53). Of the 219 participants who completed the scales at baseline, 80 were randomized to a computerized cognitive training program, 23 were randomized to an active control group, and 116 were not randomized or served as wait-list controls. Of the 80 randomized to computerized

Table 2 Description of cognitive training programs

Program	Program descriptions
InSight	Five adaptive, computerized exercises that target visual processing, visual target identification, visual tracking and memory, visual attention, and visual speed and memory
Brain Fitness	Six adaptive, computerized exercises that target auditory speed of processing
Dakim	50 adaptive, computerized exercises that target short-term memory, long-term memory, language processing, computation, visuospatial orientation, and critical thinking

cognitive training, 25 were randomized to Dakim Brain Fitness, 38 were randomized to InSight, and 17 were randomized to Brain Fitness (i.e., Posit Science). The 23 active controls were randomized to pencil-and-paper cognitive stimulation exercises (see Hudak et al. 2019 for details). A total of 46 participants did not complete the scales at the second time point: 6 were deemed ineligible and were not invited to post-test, 37 did not complete study participation, and 3 were not administered the questionnaires at post-test due to tester error. See Fig. 1 for details.

Measures

Using constructs from social cognitive theory and the health belief model, four scales were adapted from existing health behavior scales. The scales are intended to assess beliefs about cognitive training including self-efficacy (SECT; Resnick and Jenkins, 2000) and expectations regarding outcomes (OECT; Wojcicki et al. 2009). Furthermore, we devised two scales to assess beliefs about susceptibility (PSUS; Tiro et al. 2005), and severity of cognitive decline, dementia, or Alzheimer's disease (PSEV; Champion and Skinner 2008) given that these are likely motivators of cognitive training behavior.

The SECT scale is grounded in social cognitive theory and was adapted from Resnick and Jenkins (2000) as well as from Lorig et al. (1996), which were devised to assess beliefs about exercise and health care interventions, respectively. Items probe about participants' confidence to complete computer brain fitness programs with responses on a Likert scale ranging from 0—Not at all confident, 4—Neutral, to 7—Very confident. The 13 items inquire if participants are confident that they can perform computer brain fitness programs successfully and in challenging circumstances such as if experiencing computer difficulties, being bored, not seeing immediate improvements, or if feeling too busy, tired, stressed, or depressed.

The OECT scale was adapted from Wojcicki et al. (2009) and queries about participants expectations for outcomes of computerized brain fitness programs. Responses are rated on a 5-point Likert scale ranging from 1—strongly disagree to 5—

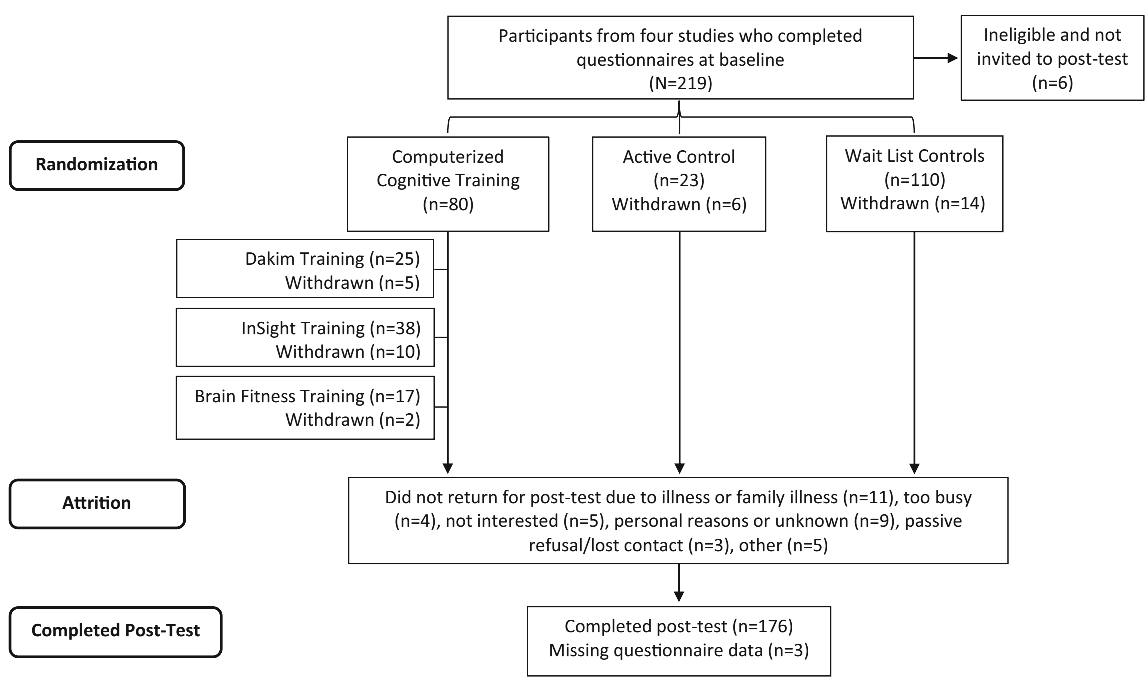

Fig. 1 Flow of participants included in analyses

strongly agree. Potential outcomes include improving ability to perform daily activities, brain functioning, memory, or alertness. Participants also rate if they enjoy, gain a sense of personal accomplishment, or derive social benefits from computerized brain fitness programs.

The PSUS and PSEV scales inquire about participants' beliefs regarding cognitive decline, Alzheimer's disease, or dementia. Ratings are on a 5-point Likert scale ranging from 1 strongly disagree to 5 strongly agree. The PSUS scale was adapted from Tiro et al. (2005) while the PSEV scale was adapted from Champion (1984). For PSUS items, participants rate the chance, risk, and likelihood that they will experience cognitive decline, Alzheimer's disease, or dementia. On the PSEV scale, participants rate the degree to which they believe cognitive decline, Alzheimer's disease, or dementia scares them, is hopeless, or would negatively affect their personal life and relationships. Given a primary motivation of older adults to complete cognitive training is to avoid decline and dementia, we felt that quantifying beliefs about susceptibility and severity was important and a likely predictor of adherence.

Results

Factor Analyses and Composites

An exploratory factor analysis with principal components extraction and varimax rotation using Kaiser normalization was conducted applying pairwise deletions. All baseline questionnaire data were included in these analyses. Using an eigenvalue cutoff of 1.0, results yielded a 10-factor solution that explained 70.91% of the variance. Table 3 shows the factor loadings after varimax rotation, applying a factor loading criterion of at least 0.4 for inclusion of an item in a factor, leaving eight factors. Results from the principal components factor analysis were applied to form composites from the questionnaires. We examined Cronbach's α of the items for each resulting composite to assess internal reliability.

Results indicated the existence of one factor for SECT with all 13 items loading at 0.70–0.90. The internal reliability of the 13 items loading on this factor was high at Cronbach's $\alpha =$ 0.96. This composite overall reflects self-efficacy for computerized cognitive training.

Four factors emerged from the OECT questionnaire. One outcome expectations factor included four items related to *expected cognitive outcomes* (OECT-COG; i.e., brain function, alertness, memory, improving daily function) with factor loadings ranging from 0.64 to 0.88. The internal reliability of the four items loading on this factor was high at Cronbach's $\alpha = 0.88$. The next factor included four items related to *expected social outcomes* (OECT-SOC) with factor loadings ranging from 0.64 to 0.85 and Cronbach's $\alpha = 0.84$. The items reflect expectations such as being at ease with people, improving social standing, providing companionship, and increasing acceptance by others. Another outcomes expectations factor included three items with Cronbach's $\alpha = 0.71$ reflecting *expected psychological outcomes* (OECT-PSY) of computerized cognitive training including enjoying the activity and feeling a sense of accomplishment. Factor loadings for the psychological outcomes factor ranged from 0.64 to 0.79. The final outcomes expectations factor included three items with factor loadings of 0.43–0.84. However, Cronbach's α improved from 0.66 to 0.71 when removing the item with the lowest factor loading (i.e., expecting important information about brain function). This factor was thus composed of two items including expectations of decreasing sense of accomplishment or acceptance by others and is indicative of *expected negative outcomes* (OECT-NEG).

Four *perceived susceptibility* items from the PSUS scale loaded on a single factor with Cronbach's $\alpha = 0.81$. The factor loadings ranged from 0.54 to 0.87 and items all ascertain participants' perception of risk for cognitive decline, Alzheimer's disease, or dementia. One item, which queried about whether participants were at lower risk, was reverse scaled prior to combining items to form a composite. One item from the outcome expectations questionnaire regarding information about brain decline also loaded on this factor, but its inclusion reduced the internal reliability of the composite overall, and it was thus removed from the composite.

The PSEV scale yielded two factors. The first included five items regarding consequences of cognitive decline, Alzheimer's disease, or dementia resulting in dependence, endangering finances, and being hopeless, serious, and life-changing. The *perceived severity of consequences* (PSEV-CON) factor loadings ranged from 0.43 to 0.79 and Cronbach's $\alpha = 0.68$. The second severity factor included three items on relationships regarding both how cognitive decline, Alzheimer's disease, or dementia affect feelings about self and relationships with factor loadings of 0.42–0.69 and Cronbach's $\alpha = 0.58$. This factor is called *perceived severity on relationships* (PSEV-REL).

Composites were formed based on these factor analytic results by summing items loading on the same factor. Since factors 9 and 10 each only included one item, these items were not included in further analyses. We examined these eight composites as potential predictors of adherence to computerized cognitive training regimens. We also examined if beliefs and attitudes changed from baseline to post-training across the eight composites.

Individual Differences

We examined Spearman correlations among the baseline questionnaire composites and individual difference factors such as education, ethnicity (coded as Hispanic or other), race

Table 3 Factor loadings of items and resulting composites from computerized cognitive training scales

Composites and items	Factor loadings									
	1	2	3	4	5	6	7	8	9	10
*Self-Efficacy (SECT)**										
Confidence Completing the Activity Alone	0.876									
Confidence Completing if Bored by the Activity	0.857									
Confidence Completing if Too Busy	0.821									
Confidence Completing if Computer Difficulties	0.709									
Confidence Completing if Feeling Depressed	0.862									
Confidence Completing if No Immediate Improvement	0.923									
Confidence Learning to Operate Computerized Program	0.773									
Confidence Completing if Not Enjoying the Activity	0.826									
Confidence Completing Program Successfully	0.819									
Confidence Performing Computerized Program Successfully	0.781									
Confidence Completing if Feeling Stressed	0.890									
Confidence Completing if Feeling Tired	0.900									
Confidence Completing if Bothersome Weather	0.877									
Expected Cognitive Outcomes (OECT-COG)										
Training Will Make Me More Mentally Alert		0.640								
Training Will Improve My Brain Function		0.880								
Training Will Improve My Ability to Perform Daily Activities		0.797								
Training Will Help My Memory		0.879								
Expected Social Outcomes (OECT-SOC)										
Training Will Increase My Acceptance by Others			0.855							
Training Will Provide Companionship			0.768							
Training Will Make Me More at Ease with People			0.641							
Training Will Improve My Social Standing			0.844							
Expected Psychological Outcomes (OECT-PSY)*										
I Will Enjoy Computerized Training				0.645						
I Will Enjoy Training				0.796						
Training Will Give Me a Sense of Personal Accomplishment				0.662						
Expected Negative Outcomes (OECT-NEG)										
Training Will Decrease My Sense of Accomplishment					0.832					
Training Will Decrease My Acceptance by Others					0.798					
Perceived Susceptibility (PSUS)										
It is Very Likely That I Will Experience Cognitive Decline						0.875				
The Chances I Might Experience Cognitive Decline are High						0.828				
I Am at Lower Risk for Cognitive Decline Compared to Others^{+}						− 0.554				
The Chances I Will Experience Cognitive Decline are High						0.835				
Perceived Severity of Consequences (PSEV-CON)										
Cognitive Decline Would Make Me Dependent on Others							0.618			
Cognitive Decline Would Endanger My Financial Security							0.431			
Cognitive Decline Is Hopeless							0.633			
Cognitive Decline Is More Serious Than Other Health Problems							0.735			
Cognitive Decline Would Change My Whole Life							0.798			
Perceived Severity on Relationships (PSEV-REL)										
Cognitive Decline Would Change My Feeling about Myself								0.625		
Cognitive Decline Would Endanger My Significant Relationships								0.697		
Cognitive Decline Scares Me								0.421		
Items not Included in a factor composite										
Training Will Give Important Information about My Brain Functioning *(OECT)*							− 0.438			
Training Will Show My Brain Functioning Has Declined *(OECT)*				0.435						
Training Is More Effective When Computerized *(OECT)*									− 0.684	
I Am Afraid to Think About Cognitive Decline *(PSEV)*										0.814

Loadings of |0.40| or larger magnitude are shown. $^{+}$ Item was reverse scaled prior to forming composite. *Lower scores reflect higher self-efficacy

(coded as minority or Caucasian), age, sex, and MMSE scores. Correlation results are shown in Table 4. Poorer self-efficacy for completing computerized cognitive training was associated with older age, lower education, and worse MMSE scores. Younger age was associated with higher expectations for cognitive outcomes. Non-Hispanic ethnicity was associated with higher social expectations. Greater perceived susceptibility was associated with younger age. Older age and lower MMSE scores were associated with more negative expectations. No other significant relationships were evident.

Table 4 Spearman correlations of cognitive training expectations with education, ethnicity, race, age, sex, and mental status

	Education	Ethnicity	Race	Age	Sex	MMSE
Self-Efficacy for Cognitive Training+	− 0.208**	0.073	− 0.070	0.397**	− 0.004	− 0.190**
Expected Cognitive Outcomes	− 0.035	0.075	− 0.029	− 0.191**	− 0.050	0.043
Expected Social Outcomes	− 0.104	0.184**	− 0.073	0.169*	0.100	− 0.167*
Perceived Susceptibility	0.032	0.004	0.018	− 0.205**	− 0.114	− 0.059
Expected Psychological Outcomes	− 0.001	0.066	− 0.062	− 0.168*	− 0.083	0.057
Expected Negative Outcomes	− 0.052	− 0.014	0.019	0.247**	0.048	− 0.206**
Perceived Severity of Consequences	− 0.095	0.066	− 0.054	0.074	− 0.095	− 0.041
Perceived Severity on Relationships	0.056	0.041	0.037	− 0.129	− 0.047	0.012

MMSE Mini Mental Status Examination

*Correlation is significant at $p = 0.05$, **correlation is significant at $p = 0.01$, $^+$ lower scores indicate higher self-efficacy

Attrition

We compared those who did and did not complete the study on their baseline questionnaire responses using MANOVA, and no overall group differences were found, Wilks' $\lambda = 0.933$, $F(8, 197) = 1.759$, $p = 0.087$. Univariate follow-up ANOVAs showed significant differences in self-efficacy for computerized cognitive training, $F(1, 204) = 4.710$, $p = 0.031$, $d = 0.38$ and for the cognitive outcome expectations composites, $F(1, 204) = 6.584$, $p = 0.010$, $d = 0.43$. As compared with those who completed the study, those who dropped out had lower baseline self-efficacy for completing computerized cognitive training and lower expectations about cognitive intervention improving cognition.

Adherence

We examined adherence among those randomized to a computerized cognitive training program (i.e., Brain Fitness, Dakim, or InSight) who completed the questionnaires pre- and post-training. See Table 5 for descriptive statistics on adherence. Adherence to computerized cognitive training varied from 0 to 281% of assigned exercises completed to (i.e., 0 to 56 h). An average of 81% of assigned computerized cognitive training exercises was completed, which is about 16 h, reflecting overall high adherence.

ANOVA was conducted to compare adherence by sex, $F(1, 141) < 1$, $p = 0.349$, partial $\eta^2 = 0.006$; race, $F(1, 141) < 1$, $p = 0.700$, partial $\eta^2 = 0.001$; and training program, $F(2, 140) < 1$, $p = 0.905$, partial $\eta^2 = 0.001$. Training adherence did not significantly differ by sex, race, or training program (i.e., Dakim, Brain Fitness, InSight). A Pearson correlation was conducted to examine if age was related to training adherence, but no significant relationship was found, $r = -0.063$, $p = 0.457$.

Linear multiple regression was used to examine the eight baseline composites (*Self-Efficacy, Expected Cognitive Outcomes*, *Expected Social Outcomes*, *Expected Psychological Outcomes*, *Expected Negative Outcomes*, *Perceived Susceptibility*, *Perceived Severity of Consequences*, *Perceived Severity on Relationships*) as predictors of computerized cognitive training adherence applying the enter method of entry and using pairwise deletions. Results indicated that participants' baseline beliefs/expectations were not predictive of subsequent training adherence, $R^2 = 0.045$, $F(8, 129) < 1$, $p = 0.635$. Regression results are shown in Table 6.

Repeated measures MANOVA was used to examine if beliefs/expectations changed from baseline to post-training by training group. For these analyses, participants in a computerized cognitive training who completed the questionnaires pre- and post-training were included. There was an overall significant effect of time, Wilks' $\lambda = 0.843$, $F(8, 114) = 2.65$, $p = 0.010$, partial $\eta^2 = 0.157$; a significant overall effect of training group, Wilks' $\lambda = 0.770$, $F(16, 228) = 1.99$, $p = 0.015$, partial $\eta^2 = 0.123$; and an overall significant group × time interaction, Wilks' $\lambda = 0.728$, $F(16, 226) = 2.44$, $p = 0.002$, partial $\eta^2 = 0.147$, across the outcomes.

Table 5 Adherence rates indicated by percent of assigned training completed by sex, race, and training program

Variable	*n*	*M*	SD
Sex			
Males	43	0.78	0.35
Females	100	0.85	0.56
Race			
Minority	5	0.73	0.37
White	138	0.80	0.43
Training program			
Brain Fitness	62	0.81	0.29
Dakim	44	0.82	0.67
InSight	37	0.78	0.32

Table 6 Multiple regression results for expectations and beliefs about computerized cognitive training as predictors of training adherence

	Beta	*t*	Significance
(Constant)		1.31	0.194
Self-Efficacy for Cognitive Training (SECT)*	− 0.129	− 01.40	0.166
Expected Cognitive Outcomes (OECT-COG)	0.010	0.09	0.927
Expected Social Outcomes (OECT-SOC)	0.117	1.26	0.210
Expected Psychological Outcomes (OECT-PSY)	0.028	0.27	0.786
Expected Negative Outcomes (OECT-NEG)	0.030	0.32	0.752
Perceived Susceptibility (PSUS)	0.069	0.77	0.442
Perceived Severity of Consequences (PSEV-CON)	0.049	0.49	0.627
Perceived Severity on Relationships (PSEV-REL)	− 0.119	− 01.21	0.230

*Lower scores reflect higher self-efficacy

Univariate follow-up ANOVAs indicated significant effects of time for the *expected psychological outcomes* factor, $F(1, 121) = 8.61$, $p = 0.004$, partial $\eta^2 = 0.066$. *Expected psychological outcome* scores increased across time indicating that post-training, participants more strongly agreed that computerized cognitive training was enjoyable and increased their sense of accomplishment.

For the *self-efficacy* factor, there were significant effects of time, $F(1,121) = 7.81$, $p = 0.006$, partial $\eta^2 = 0.061$; group, $F(2, 121) = 7.55$ $p = 0.001$, partial $\eta^2 = 0.111$; and a significant group × time interaction, $F(2, 121) = 13.79$, $p < 0.001$, partial $\eta^2 = 0.186$. For the Dakim training program, self-efficacy scores decreased from baseline ($M = 56.28$) to post-training ($M = 39.57$), while the Brain Fitness and InSight study participants showed increased self-efficacy from baseline (Brain Fitness $M = 33.43$, InSight $M = 33.80$) to post-training (Brain Fitness $M = 34.79$, InSight $M = 36.28$). At the end of the study, participants in the Dakim condition felt more confident in their ability to complete computerized cognitive training, while those who worked on the InSight or Brain Fitness programs felt less confident in their ability to complete computerized cognitive training. No other significant effects were found at the univariate level (ps > 0.05).

Discussion

We adapted health belief model scales used in prior research to examine beliefs and expectations about computerized cognitive training. The scales yielded eight factors with good internal reliability. Composites derived from the scales were not predictive of training adherence, indicating that beliefs and expectations about cognitive training did not significantly predict adherence.

Some beliefs and expectations related to computerized cognitive training significantly changed from baseline to post-training. Specifically, after completing cognitive training, participants were more likely to rate the programs as enjoyable and providing a sense of accomplishment. Interestingly, while self-efficacy for completing cognitive training was less for those randomized to the InSight and Brain Fitness programs at the end of the study, this was not the case for those randomized to the Dakim program. This is likely due to the more challenging nature of the InSight and Brain Fitness programs relative to the Dakim program. In contrast, other research has shown that self-efficacy in general or as related to locus of control is improved from pre- to post-cognitive training (Sharpe et al. 2014; Wolinsky et al. 2009). Notably, participants' expectations about the potential efficacy of computerized cognitive training to improve cognitive outcomes did not change during the course of study participation.

With regard to attrition, results showed that those who had lower baseline self-efficacy for computerized cognitive training and lower expectations about cognitive benefits were more likely to drop out of the study. These results suggest that to improve retention in cognitive intervention studies, we should target improving self-efficacy for and cognitive expectations of cognitive training.

In the current study, participants completed an average of 81% of the assigned exercises, and some even exceeded 100%. These findings support previous literature showing that adherence to cognitive training programs is high overall, particularly among older adults (Cruz et al. 2014; Harrell et al. 2019; Turunen et al. 2019). Prior studies have found that older age was positively associated with adherence (e.g., Double and Birney 2016), but adherence did not differ by age in the current study. This may be because the current study included only older adults, rather than adults of all ages. Contrary to previous studies (e.g., Turunen et al. 2019), beliefs and expectations about cognitive training did not significantly predict training adherence in the current study. It may be that beliefs are more strongly associated with starting training, rather than the percentage of sessions completed (Turunen et al. 2019).

To our knowledge, the current study was the first to examine whether older adults' beliefs and expectations about cognitive training changed after engaging in a training program.

The current study was also unique in that it integrated data from randomized controlled studies of several cognitive training programs, and the sample included only older adults.

Research has established differential impact of health belief model constructs in relation to adherence based on disease and adherence type. The current study suggests that further research should focus on self-efficacy, which has been more consistently tied to adherence as compared with the other constructs examined (see Cheung et al., 2016; Jefferis et al., 2014; O'Brien et al., 2018; Resnick et al. 2008; Robinson et al. 2014).

These analyses are not without limitations. While our sample is sufficiently powered, it was mainly composed of white females who were highly educated, which may limit generalizability to other populations. The observed rates of adherence (average of 81% of assigned training completed) may have resulted in ceiling effects that reduced the ability to detect associations between beliefs and adherence. It is possible that adherence rates would differ in more diverse study populations and may be related to beliefs and expectations. It is also possible that beliefs and expectations may explain greater variance in training behavior adoption than adherence to training. More work is needed to understand factors related to cognitive training behavior adoption. Lastly, we could not collect data from those who were not willing to complete post-test. Every effort was made to encourage the participants to complete post-test regardless of adherence, but some participants did not do so. Thus, the results regarding changes in self-efficacy are only applicable to those who completed post-training assessments.

A critique of cognitive training has been that participants' expectations or beliefs are responsible for cognitive gains. Research directly addressing this hypothesis has indicated that participants' expectations about training do not affect training efficacy (Kaur et al. 2014; Tsai et al. 2018). Unfortunately, it was not possible in this study to examine whether expectations predicted training gains or transfer, as each study examined distinct interventions and included different outcomes. Future research should examine if expectations measured by our scales predict training gains and transfer.

We developed and examined scales to quantify expectations for computerized cognitive training based on the health belief model. Our purpose was to derive composites from and establish the reliability of these newly developed scales. We further sought to examine if health beliefs significantly predicted adherence or if such beliefs changed pre- to post- training. We compiled data from four cognitive training trials using three different computerized cognitive interventions.

Future research is also needed to identify factors that serve to motivate or discourage older adults' enrollment in and adherence to cognitive training. Understanding older adults' motivation to participate in and adhere to computerized cognitive training is essential for determining cognitive training engagement, ultimately improving research success. Such factors may include experience using technology, motivation to use technology, and personality traits like openness to experience and conscientiousness. The current results may have implications in promoting adherence among participants in research intervention protocols, and in the design and/or promotion of cognitive training programs.

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Availability of Data and Material Deidentified data will be made available upon reasonable request to corresponding author. The scales used are included in the appendix.

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Compliance with Ethical Standards

Conflict of Interest Over an approximate 3-month period in 2008, J.D.E. worked as a limited consultant to analyze data and prepare a publication for Posit Science, Inc., who marketed the InSight and Brain Fitness programs. J.D.E. served on the data safety and monitoring board of NIH grants awarded to employees of Posit Science from 2016 to 2018.

Ethical Approval I confirm that all procedures performed in our study involving human participants were in accordance with the ethical standards of the 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.

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