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ThinkRx Cognitive Training for Adults Over Age 50: Clinician–Caregiver Partners in Delivery as Effective as Clinician-Only Delivery

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Many cognitive training interventions described in the extant literature predominately target only 1 or 2 domains, are very short in duration, and fail to generalize beyond the trained tasks. The aim of the current study was to evaluate differences in cognitive outcomes and self-reported real-life improvements between 2 methods of delivering the ThinkRx cognitive training intervention: professional delivery solely by a clinician versus a partnership model where a caregiver or spouse delivers half of the intervention at home. ThinkRx cognitive training is a clinician-delivered intervention targeting multiple cognitive skills, including working memory, long-term memory, visualization and visual processing, auditory discrimination, logic and reasoning, processing speed, and attention. The sample included records from 292 participants ranging in age from 51 to 95 ($M = 60.77$, $SD = 9.04$) presenting with subjective memory or attention complaints at the time of pretest. Participants completed an average of 79 training hours. The results showed no significant differences between delivery methods on any cognitive skills measured and few remarkable differences in self-reported real-life changes. Both delivery methods resulted in significant pretest to posttest gains across all 6 cognitive skills measured and self-reported changes in 5 key areas: mood, memory, cognitive efficiency, life application skills, and focus/attention. The results of the current study also suggest sharing the delivery of an intense, lengthy, multiconstruct cognitive training program to adults over 50 with nonclinical, subjective memory and attention complaints is associated with cognitive improvements and generalized improvements in real life.

Keywords: cognitive training, LearningRx, neuropsychological rehabilitation

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Trends in age-related cognitive decline overwhelmingly include speed of processing, working memory capacity, and reasoning efficiency (see Goh & Park, 2009). Cognitive deficits can be evident as early as age 45, and the decline accelerates as a function of age over the adult life span (Singh-Manoux et al., 2012; Verhaeghen & Salthouse, 1997). As we age, cognitive function becomes a significant predictor of increasing difficulty with activities of daily living and loss of independence (Burdick et al., 2005). Interest in cognitive training for halting cognitive decline is growing among psychology and neuroscience researchers as evidenced by the explosion of literature examining various interventions. Given the recent update to the American Academy of Neurology practice guidelines for mild cognitive impairment includes the use of cognitive training as a potential intervention (Petersen et al., 2018), it is important to examine not only the efficacy of cognitive training interventions but also to examine the variables associated with cognitive training gains in older adults. That is, we need to determine under what conditions cognitive training is most effective (Jaeggi, Buschkuehl, Jonides, & Shah, 2011) and with what types of outcomes. The current study examines two conditions in which cognitive training can be delivered, one provided entirely by professional clinicians and second in a partnership model using a mixture of clinicians and caregivers. The purpose is to determine if there is a difference in outcomes based on mode of delivery. A finding of no difference may suggest a way to provide efficacious cognitive training that is more accessible and more cost-effective for seniors.

Three trends are evident in the existing literature on cognitive training for aging adults: Training programs are short in duration, interventions target only one or two cognitive domains, and performance on the trained tasks may improve but fails to generalize. First, the literature reveals a dearth of cognitive training interventions for older adults that last longer than a few sessions. In a meta-nalysis, Chandler, Parks, Marsiske, Rotblatt, and Smith (2016) reported on 14 studies of cognitive interventions delivered by a therapist with a mean intervention time of just 15.5 hr. Only one therapist-delivered cognitive intervention for mild cognitive impairment (MCI) included more than 20 training sessions (Nakatsuka et al., 2015). Given neurogenesis takes a minimum of 8 weeks to occur, this trend suggests a translational divide between neuroscience research and the psychology laboratory. Next, the cognitive training interventions described in the extant literature predominately target only one or two domains, such as memory (Greenaway, Duncan, & Smith, 2013; Kinsella et al., 2009; Rapp, Brenes, & Marsh, 2002; Troyer et al., 2008), attention (Barnes et al., 2009), reasoning (Chapman et al., 2015; Cheng et al., 2012), or both attention and memory (Buschert et al., 2011; Tsolaki et al., 2011). This trend runs contrary to the Cattel-Horn-Carroll theory of cognition and the assumption that cognition is multifaceted and comprised of many constructs, including memory, processing speed, visual processing, auditory processing, and fluid reasoning (see McGrew, 2005). Finally, the majority of published cognitive training studies with older adults reveals improvements in the trained tasks but does not indicate generalization or far transfer has occurred. For example, a meta-analysis by Huckans and colleagues (2013) revealed transfer of cognitive training effects to daily functioning and quality of life was rare—a more recently replicated finding that continues to support critics of cognitive training efforts who question the pragmatism of the practice (Melby-Lervag, Redick, & Hulme, 2016).

The current study seeks to address these three issues in the literature by reporting both cognitive and real-life outcomes from two methods of delivering a lengthy, multiconstruct cognitive training intervention called *ThinkRx*. Prior research on the ThinkRx method has revealed significant gains across multiple cognitive skills for children and adolescents with learning struggles (Carpenter, Ledbetter, & Moore, 2016; Gibson, Carpenter, Moore, & Mitchell, 2015). In addition, transfer of training effects to academic skills for children (Jedlicka, 2017) and to daily functioning for soldiers recovering from traumatic brain injury (Ledbetter, Moore, & Mitchell, 2017) has been reported following training with ThinkRx. Preliminary evidence of changes in functional brain connectivity and normalization of the default mode network following training with ThinkRx has also emerged (Moore, Ledbetter, & Carpenter, 2017; Moore & Ledbetter, 2018). However, no research on outcomes from ThinkRx cognitive training with older adults has been previously conducted.

To address the gap that outcomes for older adults have not been previously studied in the ThinkRx research, the aim of the current study was to examine two methods of delivering the ThinkRx cognitive training program to adults over age 50 with subjective memory or attention complaints. The current study addresses the gap in the broader extant cognitive training research that only targeted one or two cognitive constructs by examining an intervention that targets multiple cognitive constructs including working memory, long-term memory, visual and auditory processing, fluid reasoning, and processing speed. The study also addresses the gap in the cognitive training literature that fails to report transfer or generalization to real-life outcomes by examining both objective cognitive changes as well as subjectively reported life changes following ThinkRx cognitive training. Finally, the current study addresses a gap in the literature that shows no prior research on a partnership model of delivering a clinical cognitive training intervention. In the current study, the goal was to compare similarities and differences in cognitive outcomes and self-reported real-life changes between participants trained via professional delivery solely by a clinician versus a partnership model where a caregiver or spouse delivered half of the intervention at home. The partnership model has the potential to reduce the overall cost of training and can be more flexible in terms of scheduling—making the program accessible to more people who need it. This is particularly important, since prior research has revealed scheduling and commuting to multiple cognitive training appointments each week can be burdensome when juggling work, school, and other medical appointments (Biagianti et al., 2017). Encouragingly, a home-based model has been successfully implemented in neurofeedback training programs to reduce costs and improve access to treatment (Kober et al., 2016). Thus, if a partnership model of delivering cognitive training is similar in effectiveness, the aforementioned burdens could be reduced. In addition, the cost of each training session is comparable to the cost of a psychotherapy session but is not typically covered by health insurance. Because the number one reason reported by adults for not seeking treatment is cost (US Department of Health & Human Services, 2012), it is important to examine ways to increase affordability for clients paying out of pocket for the intervention. Therefore, the objective of the current study was to evaluate the partnership model of delivering ThinkRx in comparison to the professional delivery model of ThinkRx cognitive training for adults over age 50. Although we have not previously examined differences in outcome between the two models, we hypothesize that the professional delivery model will result in modestly higher pretest to posttest gains but that self-reported real-life changes will be similar.

Method

Research Questions

This study was guided by the following questions: Is there a significant difference in the change over time in long-term memory, visual processing, fluid reasoning, working memory, processing speed, and auditory processing between those who receive cognitive training through a partnership model and those who receive it entirely by professional trainers? What real-life changes are reported by participants of both delivery models of the ThinkRx cognitive training program?

Participants

The sample was selected from 329 records of clients of LearningRx cognitive training centers across the United States between 2010 and 2017 who were over the age of 50. The inclusionary criteria were (a) the client reported subjective memory and/or attention complaints on a symptom checklist at the time of pretesting, and (b) the client records included pretest and posttest reports. The sample meeting inclusionary criteria included records from 292 participants ranging in age from 51 to 95 (M = 60.77, SD = 9.04). Records excluded from the study included one client who did not have test data and 36 clients who did not report subjective memory or attention complaints at the time of pretest. All demographic information for the sample, including age, ethnicity, gender, and diagnosis of mild cognitive impairment or Alzheimer's disease was based on self or caregiver report annotated in the records.

The sample (n = 292) was subdivided into two groups based on method of intervention delivery: The pro group ($n = 172$), who had completed the entire cognitive training intervention with a professional clinician at a LearningRx center, and a partner group ($n = 120$), who had completed half of the intervention at a LearningRx center and the other half at home delivered by a spouse or caregiver. Note that participants were not randomly assigned; they chose the method of delivery. The study underwent ethics review and was approved by the Institutional Review Board of the Gibson Institute of Cognitive Research (Protocol# 20171203).

Intervention

ThinkRx cognitive training is a clinician-delivered program that includes 24 training procedures with 627 variations sequenced in difficulty and intensity. Each procedure targets a primary skill but engages multiple cognitive skills, including working memory, long-term memory, visualization and visual processing, auditory discrimination, logic and reasoning, processing speed, and attention. The program is delivered three or four times per week in 60–90 min intense sessions for a minimum of 60 total training hours. Training ranges in duration from three months to a full year and can encompass up to 180 hr of training time. Clinicians follow a standard curriculum that can be individualized to address the specific cognitive deficits of each client. Progression through the curriculum is carefully tracked in the 230-page training manual to ensure fidelity and to maximize treatment outcomes. A metronome is used with most training tasks to add intensity to the procedures and to prevent "mental breaks" by requiring the client to respond on beat. A key feature of the program is the dynamic feedback provided by the clinician who uses verbal encouragement, visual charting of progress, and "high 5s" to keep clients on track and motivated. Another feature is the use of deliberate distractions to train sustained, divided, and selective attention skills needed in the real world. Clients set goals for changes and improvements they hope to see outside of the training setting, and clinicians revisit the goals weekly to help the client apply the training gains to life outside of the training center. Training tasks are fundamentally different than assessment tasks. For example, a training procedure that targets working memory uses colorful cards with various shapes arranged on a grid by the clinician. The client must study the arrangement and reproduce it from memory. The 34 variations on this task include use of a timer, metronome, and up to nine spaces on each grid. Figure 1 illustrates the materials used for this working memory training procedure.

The curriculum uses visual, auditory, and sensory-motor training techniques to ensure a comprehensive approach to targeting the remediation of multiple cognitive skills. There are two methods for delivering the ThinkRx program. The original method is delivery by a clinician in an independent practice or at a LearningRx cognitive training center. An optional approach is for a spouse or caregiver to be trained to deliver half of the training sessions at home. This option significantly reduces the cost to clients and enables wider access to the training. In this alternative partnership model, the client attends two training sessions per week with the clinician and receives one or two training sessions per week at home. To provide training at home, partners are given a 20-min lesson each week on one or two training procedures. The clinician chooses procedures to teach the partner trainer based on the client's greatest deficits. That is, the partner delivers training procedures for which the client needs the most repetition. To learn how to train at home, the partner watches the clinician demonstrate the procedures and then practices them with the client in the presence of the clinician to ensure correct deliv-

Figure 1. Example of a working memory training task. *This figure is used with permission from LearningRx.* See the online article for the color version of this figure.

ery. Home training is documented by the partner trainer in the training manual and reviewed with the clinician at the next center-based training session to ensure compliance and fidelity.

Assessments

Subtests from the Woodcock Johnson III Tests of Cognitive Abilities and Tests of Achievement (Woodcock, McGrew, & Mather, 2001) were administered to each client before and after completing the cognitive training program. Tests were administered by trained clinicians not involved in the training of the clients they tested.

Long-term memory test. The visual-auditory learning test was administered to measure associative memory and delayed recall. The test requires encoding and retrieval of auditory and visual associations. The test administrator teaches the participant a set of pictures that each represents a word, and the participant must recall the associations between them. For adults, this test has a median reliability of .91 (Mather & Woodcock, 2001).

Visual processing test. The spatial relations test measures visual processing skills by asking the participant to match individual puzzle pieces to a completed shape. For adults, this test has a median reliability of .85 (Mather & Woodcock, 2001).

Auditory processing test. The sound awareness subtest measures four phonological awareness skills: sound rhyming, sound deletion, sound substitution, and sound reversal. The test administrator presents a series of language sounds, and the participant must manipulate the sounds and produce a response. For adults, this test has a median reliability of .86 (Mather & Woodcock, 2001).

Logic and reasoning test. The concept formation test measures fluid reasoning and inductive logic by requiring the participant to apply rules to sets of shapes that share similarities and differences by indicating the rule that differentiates one set of shapes from the others. For adults, this test has a median reliability of .96 (Mather & Woodcock, 2001).

Working memory test. The numbers reversed test measures working memory by asking the participant to remember a span of numbers and repeat them in reverse order from how they were presented. For adults, this test has a median reliability of .90 (Mather & Woodcock, 2001).

Processing speed test. The pair cancellation test measures executive processing, processing speed, and sustained attention by asking the participant to locate and mark matching objects in each row of shapes within a 3-min time limit. For adults, this test has a median reliability of .85 (Mather & Woodcock, 2001).

Data Analyses

Statistical analysis. Differences on baseline demographic variables were tested with independent samples *t* tests and chi square analyses, using Cohen's *d* and phi as effect sizes, respectively. We report effect sizes for Cohen's *d* using general guidance of small (.2), medium (.5), or large (.8) effects; and effect sizes for phi using general guidance of small (.1), medium (.3), or large (.5) effects (Cohen, 1988). To examine the difference in change from pretest to posttest between the delivery models on six outcome variables (long-term memory, working memory, visual processing, auditory processing, processing speed, and reasoning), we used 2×2 repeated measures multivariate analysis of covariance (MANCOVA) testing, with group (pro or partner) as the primary independent variable. The specific dependent variables were the pretest and posttest standard scores for each of the outcomes. We ran and report below two models—one with a full panel of covariates (age, race, gender, diagnosis, number of training hours) and a second with only the significant covariate (age). We report effect sizes for these measures using partial eta squared and general guidance of small (.2), medium (.5), or large (.8) effects (Cohen, 1988). We also used paired samples *t* tests to examine the significance of change for the whole sample on individual measures with effect size for change on each measure reported as Cohen's *d*. In the MANCOVA testing, the Box's test proved nonsignificant, indicating equality of covariance matrices.

Given the pre–post test design and the type of assessment used in this study, there is, of course, the possibility for practice effects (Busch, Lineweaver, Ferguson, & Haut, 2015; Chelune, Naugle, Lüders, Sedlak, & Awad, 1993; Collie, Maruff, Darby, & McStephen, 2003; Dikmen, Heaton, Grant, & Temkin, 1999). Collie, Darby, Falleti, Silbert, and

Maruff (2002) reviewed several means of controlling for these effects in multivariate analyses, with a regression technique generally considered among the strongest approaches. McSweeny, Naugle, Chelune, and Lüders (1993) provided a particularly useful regression-based means of controlling for practice effects and one we used here as a second analysis. Specifically, McSweeny et al. described a method by which regression is used to derive predicted posttest scores based on the pretest and relevant covariates. The predicted scores are then used to create what they call "T-scores for change"—essentially a measure of the change in scores that deviate from what might be expected based on controlled pretesting. Finally, the *T* scores are used in MANCOVA testing to determine if the difference between groups is statistically significant. In other words, does the treatment group exhibit comparatively and significantly greater change over and above what would be explained by practice effects?

For each test we used regression to derive predicted scores, using as the independent variable pretest score. The predicted scores and the relevant standard errors were used to create *T* scores in the following model: $T = 50 + [10^{*}Y_o - Y_p)/se)]$, where Y_o = observed posttest score, Y_p = predicted posttest score, and se = standard error of the estimate. The *T* scores were used in a MANCOVA model with pro/partner groups as the independent variable. Another model was run with covariates, but the results did not differ substantively, so we report the parsimonious model below. Full results are available from the authors.

Qualitative analysis. The qualitative data for this study were collected from an online exit survey completed at the end of each participant's training program. The data include responses to the following exit survey prompt: "Please share with us the changes you have seen as a result of LearningRx training." The survey was completed outside the presence of LearningRx staff members, which increased objectivity in responses from the participants and strengthened the integrity of the qualitative data (Tetnowski, 2015). The analysis employed grounded methodology and summative content analysis (Snyder, 2012) by annotating and evaluating participant comments without prior expectations of the outcome. In addition, the qualitative researcher was blinded to the treatment condition of the participants to achieve objectivity in audit and to increase rigor (Houghton, Casey, Shaw, & Murphy, 2013). Participant comments were appraised according to inductive thematic analysis, a technique of data assessment that requires the researcher to allow phenomenological themes to emerge and coalesce from the ground up (Percy, Kostere, & Kostere, 2015). This tactic ensures that emerging themes can be classified into categories for review, free from researcher bias or preconceived ideas of specific conclusions (Fereday & Muir-Cochrane, 2006). The subsequent data gleaned from such thematic analysis ultimately creates definitive indication of various notable conclusions (Braun & Clarke, 2006).

After initial coding of all responses, themes were discussed, evaluated, and clarified among members of the qualitative research team. We then collapsed the responses into five clearly emerging themes: attention/concentration, cognitive efficiency, life application skills, memory, and mood. For the current study, we analyzed any relevant differences in the distribution of these themes between the two groups using a series of 2 × 2 chi squares, one for each theme. Of the 273 participants who responded with comments, 155 trained via the pro delivery method, and 118 with the partner delivery method. In addition, in a second series of 2 × 2 chi squares we investigated any thematic variations due to age and categorized by participants (a) 50 to 65 years of age and (b) over age 65. Of the 155 pro graduates, 120 respondents were between the ages of 50–65, whereas 35 of them were over age 65. Partner graduates included 94 respondents age 50–65 and 24 respondents over age 65. The unit of analysis of qualitative data was at the phrase level. A complex sentence could be coded with more than one theme when necessary.

Results

Sample Demographics and Baseline Data

The sample included 292 participants, ranging in ages from 51 to 95 ($M = 60.77$, $SD = 9.04$). Fifty-nine percent of the sample was female. Forty-one percent of the sample received training through the partnership model. Participants received a mean of 78.16 hr of training ($SD = 25.58$, min. = 60, max. = 180) over a

Table 1
Sample Descriptive Statistics

Variable	Pro (n = 172) *n*	*M*	*SD*	%	Partner (n = 120) *n*	*M*	*SD*	%
Age								
All	172	60.88	9.27		120	60.63	8.74	
50–65	126	56.02	3.99		91	56.69	4.61	
66+	46	74.173	5.97		29	72.97	6.92	
Sex								
Female								
All	104			60.5%	68			56.7%
50–65	75				53			
66+	29				15			
Male								
All	68			39.5%	52			43.3%
50–65	51				38			
66+	17				14			
Diagnosis								
None								
All	144			83.7%	103			85.8%
50–65	104				81			
66+	40				22			
TBI								
All	28			16.3%	15			12.5%
50–65	22				10			
66+	6				5			
MCI								
All	0			0%	1			.8%
50–65	0				0			
66+	0				1			
Dementia								
All	0			0%	1			.8%
50–65	0				0			
66+	0				1			
Ethnicity								
Caucasian	108			62.7%	86			71.6%
African American	6			3.4%	8			6.6%
Asian	1			.5%	0			0%
Hispanic	5			2.9%	1			.8%
Native American	2			1%	0			0%
Mixed	3			1.7%	2			1.6%
Not reported	47			27.3%	23			19.2%

Note. TBI = traumatic brain injury.

mean of 213.76 days (30.5 weeks) between pre- and posttesting (SD = 112.27, min. = 62, max. = 749). Table 1 disaggregates these metrics by group (i.e., partner or professional). Mean age by group was almost identical between groups. The partnership group received fewer hours of training and saw less time between pre- and posttesting. Differences were tested with independent samples t tests. Results indicate no significant differences for age and days pre to post, but the hours of training were significantly different with a small effect size (t = 2.10, p = .04, d = −.21). For gender, the partner group had fewer females and more males than the pro group, but chi-square testing indicated the differences were not significant with a small effect size, $\chi^2(1) = .42$, $p = .52$, $\varphi = .038$. For diagnosis, there were more participants with traumatic brain injury in the pro group and more with MCI and dementia in the partner group, but chi square testing indicated the differences between groups in diagnoses were not significant with a small effect size, $\chi^2(3) = 3.59$, $p = .31$, $\varphi = .111$. There were also no significant differences between groups in racial/ethnic distribution with a small effect size, $\chi^2(1) = 2.50$, $p = .2$, $\varphi = .092$.

Independent *t* tests indicated no significant differences between groups on any of the pretest scores. Across all measures, differences between groups are consistently within a few points of each other. Thus, the pro and partnership groups were statistically equivalent on almost all measures prior to the intervention.

Results of Statistical Analysis of Cognitive Test Outcomes

We begin the presentation of results with descriptive statistics for the outcome variables. As seen in Table 2, the sample as a whole realized growth on all six outcome measures. The greatest growth was evident on long-term memory ($M = 15.7$ points), while the smallest was for processing speed ($M = 7.1$ points). Paired samples *t* tests with significance set at Bonferroni-corrected $p < .001$ indicated significant pretest to posttest change on all measures with large effect sizes.

Results from the repeated measures MANCOVA (with all covariates) on the effect of time with significance set at Bonferroni-corrected $p < .001$ indicated both groups improved significantly from pretest to posttest with a large effect size, Wilks' $\lambda = .848$, $F(6, 280) = 8.33$, $p < .001$, $\eta_p^2 = .15$. There was not a significant Time × Group effect, Wilks' $\lambda = .983$, $F(6, 280) = .807$, $p = .56$, $\eta_p^2 = .017$, with a small effect size or significant interaction effects with the covariates of diagnosis, training hours, gender, or race. There was, however, a significant interaction effect with the covariate of age with a medium effect size, Wilks' $\lambda = .939$, $F(6, 280) = 3.01$, $p = .007$, $\eta_p^2 = .061$. Therefore, we reran the repeated measures MANCOVA using only age as a covariate. Results from the repeated measures MANCOVA (with only age as the covariate) on the effect of time were substantively the same as the full model, indicating both groups improved significantly from pretest to posttest with a large effect size, Wilks' $\lambda = .805$, $F(6, 284) = 11.43$, $p < .001$, $\eta_p^2 = .20$, but there was not a significant time by group interaction, Wilks' $\lambda = .983$, $F(6, 284) = .819$, $p = .56$, $\eta_p^2 = .017$, with a small effect size. Table 3 displays the pretest, posttest, and difference scores by group along with statistical comparison results.

On all outcomes except for reasoning skills, those who completed training with a professional trainer saw greater difference scores than those who completed training in a partnership model. However, univariate tests indicated no significant Time × Group interaction on individual measures. There was a significant time by age interaction on three of the outcome measures with a small effect size: visual processing, $F(1, 289) = 4.31$, $p = .04$, $\eta_p^2 = .015$; fluid reasoning, $F(1, 289) = 7.90$, $p = .005$, $\eta_p^2 = .027$; and working memory, $F(1, 289) = 9.63$, $p = .002$, $\eta_p^2 = .032$, but there was not a significant Time × Group × Age interaction, Wilks' $\lambda = .513$, $F(6, 168) = .932$, $p = .715$, $\eta_p^2 = .10$, with a large effect size. When data are presented in percentiles, the story is essentially

Table 2
Significance Testing Results for Whole Sample

	Whole sample				Whole sample change		Effect size
	Pretest		Posttest				
Variable	*M*	*SD*	*M*	*SD*	Diff	*SD*	*d*
Long-term memory	91.26	21.3	106.96	21.9	15.70*	11.9	1.32
Visual processing	105.65	12.4	114.68	12.4	9.03*	9.1	.99
Fluid reasoning	103.88	14.3	113.60	13.6	9.72*	9.7	1.00
Working memory	100.16	17.4	109.28	16.9	9.12*	12.1	.75
Processing speed	96.73	12.1	103.86	12.4	7.13*	8.6	.83
Auditory processing	99.10	16.4	107.82	16.5	8.72*	10.6	.82

Note. Diff = difference; *d* = Cohen's *d* effect size.
* $p < .001$.

Table 3
Significant Testing Results Comparing Partner and Pro Groups

	Standard scores									Percentiles			
	Pro			Partner			Difference			Pro		Partner	
	Pre	Post	Change	Pre	Post	Change							
Variable	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*F*	*p*	$\hat{\eta}^2$	Pre	Post	Pre	Post
Long-term memory	90.8 (21.9)	107.1 (22.5)	16.2 (11.0)	91.8 (20.6)	106.8 (21.2)	14.9 (13.1)	.86	.35	.003	38.2	61.7	37.9	62.1
Visual processing	105.62 (13.2)	115.3 (12.8)	9.7 (9.5)	105.7 (11.1)	113.8 (11.7)	8.1 (8.5)	2.2	.14	.008	62.2	78.5	61.7	76.3
Fluid reasoning	104.45 (14.1)	113.9 (14.1)	9.5 (9.6)	103.1 (14.7)	113.1 (13.0)	10.0 (9.97)	.18	.67	.001	60.2	75.3	57.6	74.7
Working memory	100.9 (18.6)	110.9 (17.1)	9.9 (12.1)	98.9 (15.5)	106.9 (16.5)	7.9 (12.1)	2.1	.15	.007	53.2	68.1	47.7	62.1
Processing speed	96.5 (12.5)	104.0 (13.0)	7.6 (8.7)	97.1 (11.6)	103.6 (11.5)	6.5 (8.4)	1.1	.29	.004	43.7	58.8	43.9	58.2
Auditory processing	100.1 (16.9)	109.1 (16.80)	9.1 (11.1)	97.7 (15.6)	105.9 (16.0)	8.2 (9.9)	.47	.49	.002	51.2	66.5	45.9	61.5

* $p < .001$.

the same (see far right columns on Table 3). On all tests, participants in both groups saw increases from pre- to posttesting. Moreover, the pre- or posttest percentiles between groups are consistently within a few points of each other.

Turning to *T* score results to control for possible practice effects, Table 4 includes descriptive statistics and *p* values from the MANCOVA analysis. On all tests, the pro group consistently saw comparatively greater gains over and above what might be expected from practice effects, but none of the differences between groups was significantly different.

Results of Qualitative Thematic Analysis of Self-Reported Improvements

Turning to the qualitative results, recall that responses revealed five clear themes: attention/concentration, cognitive efficiency, life application skills, memory, and mood. A comparison of how each group responded to the exit survey is illustrated in Figure 2. Ninety-eight percent of the partner group and 90% of the pro group reported changes that fell into at least one of the qualitative themes. We found minimal variation in qualitative outcomes between the pro and partner groups.

Mood. The theme of mood encompasses aspects of bolstered confidence, hope, perseverance, reduced anxiety, and overall improvement in outlook. Almost half of the participants noted outcomes related to mood. Forty-six percent of the whole sample ($n = 125$) noted changes such as a boost in confidence, less anxiety, and more positive outlook. This trend held steady across both training groups and age categories. There was a small difference between the groups with 42% ($n = 64$) of the pro group and 52% ($n = 61$) of the partner group reporting changes in this area. However, the difference was not statistically significant, $\chi^2(1) = 2.92$, $p = .09$. The difference between age groups was also not significant, $\chi^2(1) = 2.71$, $p = .10$, with 44% of the younger age group and 46% of the older age group reporting changes in the theme of mood.

The comments from participants included reduced frustration and anxiety such as, "I'm better able to cope with things that had previously overwhelmed and depressed me," "I have less stress in my life because of what I learned here," and "The program has relieved my fears of Alzheimer's in the near future and has shown

Table 4
T-Score Results to Control for Practice Effects

	Pro		Partner		
Dependent variable	*M*	*SE*	*M*	*SE*	*p*
Long-term memory	51.31	9.93	37.71	11.89	.38
Visual processing	59.77	10.13	36.84	12.12	.15
Fluid reasoning	51.62	10.44	50.80	12.50	.96
Working memory	57.47	10.54	32.28	12.62	.13
Processing speed	58.51	10.29	46.08	12.32	.44
Auditory processing	62.78	10.89	47.67	13.03	.37

me that the brain can be improved." A spouse wrote, "I have noticed a reduced frustration level as [he] is able to do more things and communicate more clearly . . . especially more enthusiasm for the future." Participants also reported increased confidence and positive outlook such as, "[Training] has made me determined to not limit what I want to do—knowing that my brain can tackle new challenges," "I have gained personal confidence because of the process of the training . . . this confidence then spreads into other areas and brings a positive quality to all of life," and "I am recovering my self-confidence, self-acceptance, desire to engage in life again, to find and pursue a new direction and purpose in life, and others who know me will describe me as an entirely different person as compared to prior."

Memory. The theme of memory covers comments regarding changes in short-term, working, and long-term memory. Thirty-seven percent ($n = 101$) of the whole sample reported changes in memory. The difference between pro and partner results was not statistically significant, χ^2 (1) = .72, $p = .40$, with 41% ($n = 47$) in the partner group and 35% ($n = 54$) in the pro group reporting changes in memory. The number reporting changes in memory was not significantly different between age groups either, $\chi^2(1) = 3.44$, $p = .06$. Participants responded with comments such as, "I can remember things better because of the strategies that I learned here," and "I do not struggle in recalling certain items as much as I did before." Several participants specifically addressed memory in regard to aging such as, "It was exciting at my age to see the improvements I made especially with the short term memory," and "I have been able to keep my brain sharp and improve my memory . . . skills that will help me maintain my independence as I continue to age." Others made general observations such as, "My memory retention has really improved," and "I am much better at remembering details," as well as specific practical-application of memory changes such as "I no longer forget where I parked my car; I no longer walk from one room in the house to another, forgetting what I went for; I have much better name and word recall," and "Remembering little things that add up to a lot, hence, remembering to mail due bills, remembering stamps in glove box, remembering someone's phone number, recalling what the date is, LOL. It makes a HUGE difference because these 'little things' are everyday life!."

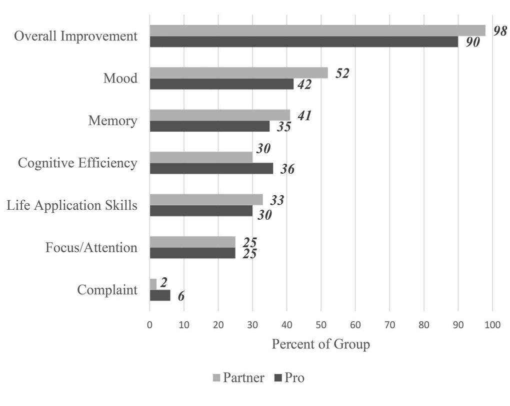

Figure 2. Comparison of qualitative themes by group.

One of the comments in the theme of memory was not positive, however. A participant reported improvement in long-term memory but felt "still hampered by selective memory."

Cognitive efficiency. The theme of cognitive efficiency refers to general changes reported in processing speed, problem solving, and multitasking. Regarding cognitive efficiency, 33% ($n = 90$) of the whole sample reported changes. There was a small difference between the groups with 36% ($n = 55$) of the pro group and 30% ($n = 35$) of the partner group reporting changes in this area, but the difference was not statistically significant, $\chi^2(1) = 1.36$, $p = .24$. One pro group participant commented, "I felt like my brain was getting sluggish and the program has definitely given my brain a much-appreciated jump start; I have experienced noticeable improvements in both my ability to think and the time it takes me to process information."

Others described similar effects: "I now have a mental camera I never was aware of before," and "I am able to get my thoughts together [more quickly] when writing." Partner group participants made analogous comments such as, "Improvement in distinguishing sounds and in processing numbers," "My mind and thinking are clearer; [I have] quicker decision making," and "I am quicker at processing information!" One participant in the pro group expressed concern that, "I don't feel I made the improvement in sound recognition I had hoped to."

There was a small difference in responses by age group as well. Although 38% ($n = 46$) of the pro participants between 50 and 65 years of age reported cognitive efficiency changes, just 26% ($n = 9$) over age 65 reported changes in this area. However, the difference was not statistically significant, $\chi^2(1) = .13$, $p = .72$.

Life application skills. The theme of life application skills includes changes reported with work and employment, education, hobbies and sports, driving, and other daily responsibilities. Regarding life application skills, 31% ($n = 84$) of the whole sample reported changes related to this theme. There was a small difference between the groups with 30% ($n = 46$) of the pro group and 33% ($n = 38$) of the partner group reporting changes in this area, but the difference was not statistically significant, $\chi^2(1) = .20$, $p = .65$.

The most notable difference was between age categories with 39% ($n = 80$) of participants between age 50 to 65 reporting changes in areas such as employment, hobbies, education, and driving, whereas only 10% ($n = 3$) of similar comments came from those over age 65. This difference was statistically significant with a small effect size, $\chi^2(1) = 9.45$, $p = .002$, $\varphi = -.200$. Those over 65 described "Improvements in athletics," and "I am quicker in making decisions and in driving." Comments from the 50- to 65-year-old participants included, "My ability to function again in society, drive, make decisions, and plan my day are back and better; I am looking forward to teaching again," "My speaking and writing skills have improved a lot; I am able to make much more effective presentations," and "I have seen a huge improvement in my studying for my classes . . . my grades are so much better." One participant in the younger age group did indicate a desire for the program to include, "more things that apply to adults."

Attention/concentration. The theme of attention/concentration includes responses regarding increased focus, selective attention, and concentration on tasks such as reading and/or listening. Of the whole sample, 24% ($n = 65$) reported changes in attention and/or concentration. There were no differences between groups, as 25% of both pro and partner groups reported changes in this area. Of course, this difference was not statistically significant, $\chi^2(1) = .001$, $p = .98$. There was a slight difference according to age group. Although 20% ($n = 6$) of those over age 65 mentioned changes in attention, 27% ($n = 55$) of participants 50 to 65 years old noted attention and/or concentration changes following cognitive training. This difference was not statistically significant, $\chi^2(1) = .59$, $p = .44$. Examples include statements such as, "I have learned to listen more attentively," and "Before I started, I didn't focus on any one thing; now I find myself concentrating on everything I work on." A 72-year old participant wrote, "My concentration is much better, and my reading, and I can read without being distracted; I am more focused than before." Another recounted his story of stopping medication for attention deficit disorder saying, "I went around feeling overwhelmed 80% of the time; 99% when I was off meds. I lost the overwhelmed feeling at around the last two weeks of training and I haven't felt the need to take (the meds) since. Here's how I feel now: Life is easier."

Other comments. About 5% ($n = 13$) of comments from the exit surveys did not fit into one of the five themes. The remaining comments were either general praise for the program or suggestions for improvement. Four comments were complaints about the high cost, and seven of the statements were suggestions such as, "Provide home-training opportunities even for adult Pro students," "More early morning training times," and "More coaching for the adult at-home coach." One participant suggested that trainers need additional guidance on working with adults and another suggested more progress testing during the program.

Discussion

The current study examined two methods of delivering the ThinkRx cognitive training program to adults over age 50 with subjective memory or attention complaints. We looked for similarities and differences between participants trained solely by a clinician in a cognitive training center versus participants trained by a clinician half of the time and by a caregiver or spouse the other half of the time. The results showed no significant differences between delivery methods on any of the cognitive skills measured and few remarkable differences in self-reported real-life changes. Both delivery methods resulted in significant pretest to posttest gains across all six cognitive skills measured, with a medium effect size for working memory and a large effect size for long-term memory, processing speed, visual processing, auditory processing, and fluid reasoning. In addition, both delivery methods resulted in self-reported changes in five key areas: mood, memory, cognitive efficiency, life application skills, and focus/attention.

The nonsignificant difference based on delivery type is an important finding. It supports the partner model of program delivery, which is a more affordable option for many families and potentially increases access to many for whom a purely clinician-driven method is essentially impossible. In addition to cost savings, the partner model is more flexible in terms of scheduling. Partners can train clients at home at any hour during the week or on weekends, which may appeal to older clients still managing work schedules. Finally, the partner model lends itself to maintenance training after the initial program is completed. This is an important option for aging clients who may need continued cognitive engagement. However, the practice comes with a caveat. The caregiver must be motivated to learn the training procedures and also possess the cognitive acuity to deliver them. The training sessions are demanding, and cooperation between the client and the person delivering the program is essential.

Although the effect size was small, the significant association between age and outcomes on measures of working memory, visual processing, and reasoning was an interesting finding and one that aligns with the existing research on age-related cognitive changes. The literature is replete with evidence that working memory and reasoning skills are impacted by senescence (Goh & Park, 2009). Whether decline in visual processing is a function of visual acuity or visual manipulation is not known, but both are also impacted by the aging process. Thus, our current results are not surprising. The implication for practice, then, should be explored. Perhaps the intervention should be adjusted to devote additional training time to procedures that target these three areas.

The small differences in age groups on qualitative outcomes were also noteworthy. The changes reported by participants ages 50–65 suggest transfer of training effects to the workplace or continuing education, where changes for participants over age 65 focused on maintaining independence. The small effect size notwithstanding, this finding still aligns with retirement age and a changing focus as we age.

Perhaps the most striking qualitative outcome was the numerous changes reported by the participants with regard to the theme of mood. Almost half of all participants saw improvements in this area. Our finding aligns with results from a recent study on cognitive training for healthy older adults that reported improvements in mood (Diamond et al., 2015). The hypothesized mechanism of change in mood from cognitive training is due to increasing control in the prefrontal cortex that minimizes disruptive emotion processing (Calkins, McMorran, Siegle, & Otto, 2015). That is, an intervention that targets executive functions may also be targeting limbic activity and emotional responses as well. The connection is indeed worthy of further study especially since other research on cognitive training and mood in healthy populations has not revealed significant associations between the two (Giuli, Papa, Lattanzio, & Postacchini, 2016). Therefore, we were encouraged by this finding and are examining the relationship further in ongoing research.

One limitation of the study is the nonrandom assignment of the groups. Because we examined the results of existing groups, the results must be interpreted in light of that limitation. Self-selection bias is unquestionably present when groups are examined post hoc rather than through randomization. However, this was not an efficacy study. Rather, the design enabled us to compare delivery methods of the same program to ensure similarity in outcomes. Indeed, the quantitative analysis indicated significant pretest to posttest changes across all cognitive skills regardless of program delivery method—an encouraging finding that aligns with our prior controlled studies with other populations. The qualitative findings also demonstrate important consistency. Qualitative data like these can provide evidence of outcomes in ways quantitative data simply cannot (Anderson, 2010). The findings from the current study begin to address a notable and negative trend in the cognitive training literature that advises training effects do not generalize. Our results, however, suggest they may. Not only did we see significant gains on standardized cognitive test scores, we also noted many examples of self-reported real-life changes.

Another limitation of the study is the lack of clinical descriptors of the sample. The study was based on all LearningRx clients regardless of prior diagnostic assessment or sociodemographic profile. Therefore, it is important to note the results can only be generalized to adults over the age of 50 with subjective attention and memory complaints but not necessarily those with comorbid clinical histories or lifestyle choices that may limit the progress they could make in the training program.

In future research, it will be important to examine neural correlates of cognitive changes and to compare this intervention to a dissimilar intervention in a randomized controlled trial in order to tease apart the mechanism of change that leads to the results found in the current study. The current study authors are conducting an ongoing trial with MRI to assess neural changes associated with cognitive training in MCI as part of an interdisciplinary treatment approach. Future research should also include the use of validated or standardized self-report measures and clinician rating scales measuring quality of life, self-efficacy, or activities of daily living.

The results of the current study suggest sharing the delivery of an intense, lengthy, multiconstruct cognitive training program to adults over 50 with nonclinical, subjective memory and attention complaints is associated with cognitive improvements and generalized improvements in real life. Much work is left to be done in this arena, and this study contributes to our ever-changing understanding of cognitive training intervention outcomes for older adults.

References

Anderson, C. (2010). Presenting and evaluating qualitative research. *American Journal of Pharmaceutical Education, 74,* 141. http://dx.doi.org/10.5688/aj7408141

Barnes, D. E., Yaffe, K., Belfor, N., Jagust, W. J., DeCarli, C., Reed, B. R., & Kramer, J. H. (2009). Computer-based cognitive training for mild cognitive impairment: Results from a pilot randomized, controlled trial. *Alzheimer Disease and Associated Disorders, 23,* 205–210. http://dx.doi.org/10.1097/WAD.0b013e31819c6137

Biagianti, B., Fisher, M., Howard, L., Rowlands, A., Vinogradov, S., & Woolley, J. (2017). Feasibility and preliminary efficacy of remotely delivering cognitive training to people with schizophrenia using tablets. *Schizophrenia Research Cognition, 10,* 7–14. http://dx.doi.org/10.1016/j.scog.2017.07.003

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3,* 77–101. http://dx.doi.org/10.1191/1478088706qp063oa

Burdick, D. J., Rosenblatt, A., Samus, Q. M., Steele, C., Baker, A., Harper, M., . . . Lyketsos, C. G. (2005). Predictors of functional impairment in residents of assisted-living facilities: The Maryland assisted living study. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences, 60,* 258–264. http://dx.doi.org/10.1093/gerona/60.2.258

Busch, R. M., Lineweaver, T. T., Ferguson, L., & Haut, J. S. (2015). Reliable change indices and standardized regression-based change score norms for evaluating neuropsychological change in children with epilepsy. *Epilepsy & Behavior, 47,* 45–54. http://dx.doi.org/10.1016/j.yebeh.2015.04.052

Buschert, V. C., Friese, U., Teipel, S. J., Schneider, P., Merensky, W., Rujescu, D., . . . Buerger, K. (2011). Effects of a newly developed cognitive intervention in amnestic mild cognitive impairment and mild Alzheimer's disease: A pilot study. *Journal of Alzheimer's Disease, 25,* 679–694. http://dx.doi.org/10.3233/JAD-2011-100999

Calkins, A. W., McMorran, K. E., Siegle, G. J., & Otto, M. W. (2015). The effects of computerized cognitive control training on community adults with depressed mood. *Behavioural and Cognitive Psychotherapy, 43,* 578–589. http://dx.doi.org/10.1017/S1352465814000046

Carpenter, D. M., Ledbetter, C., & Moore, A. L. (2016). LearningRx cognitive training effects in children ages 8–14: A randomized controlled trial. *Applied Cognitive Psychology, 30,* 815–826. http://dx.doi.org/10.1002/acp.3257

Chandler, M. J., Parks, A. C., Marsiske, M., Rotblatt, L. J., & Smith, G. E. (2016). Everyday impact of cognitive interventions in mild cognitive impairment: A systematic review and meta-analysis. *Neuropsychology Review, 26,* 225–251. http://dx.doi.org/10.1007/s11065-016-9330-4

Chapman, S. B., Aslan, S., Spence, J. S., Hart, J. J., Jr., Bartz, E. K., Didehbani, N., . . . Lu, H. (2015). Neural mechanisms of brain plasticity with complex cognitive training in healthy seniors. *Cerebral Cortex, 25,* 396–405. http://dx.doi.org/10.1093/cercor/bht234

Chelune, G. J., Naugle, R. I., Lüders, H., Sedlak, J., & Awad, I. A. (1993). Individual change after epilepsy surgery: Practice effects and base-rate information. *Neuropsychology, 7,* 41–52. http://dx.doi.org/10.1037/0894-4105.7.1.41

Cheng, Y., Wu, W., Feng, W., Wang, J., Chen, Y., Shen, Y., . . . Li, C. (2012). The effects of multidomain versus single-domain cognitive training in non-demented older people: A randomized controlled trial. *BMC Medicine, 10,* 30. http://dx.doi.org/10.1186/1741-7015-10-30

Cohen, J. (1988). *Statistical power and analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Collie, A., Darby, D. G., Falleti, M. G., Silbert, B. S., & Maruff, P. (2002). Determining the extent of cognitive change after coronary surgery: A review of statistical procedures. *The Annals of Thoracic Surgery, 73,* 2005–2011. http://dx.doi.org/10.1016/S0003-4975(01)03375-6

Collie, A., Maruff, P., Darby, D. G., & McStephen, M. (2003). The effects of practice on the cognitive test performance of neurologically normal individuals assessed at brief test-retest intervals. *Journal of the International Neuropsychological Society, 9,* 419–428. http://dx.doi.org/10.1017/S1355617703930074

Diamond, K., Mowszowski, L., Cockayne, N., Norrie, L., Paradise, M., Hermens, D. F., . . . Naismith, S. L. (2015). Randomized controlled trial of a healthy brain ageing cognitive training program: Effects on memory, mood, and sleep. *Journal of Alzheimer's Disease, 44,* 1181–1191. http://dx.doi.org/10.3233/JAD-142061

Dikmen, S. S., Heaton, R. K., Grant, I., & Temkin, N. R. (1999). Test-retest reliability and practice effects of expanded Halstead-Reitan Neuropsychological Test Battery. *Journal of the International Neuropsychological Society, 5,* 346–356. http://dx.doi.org/10.1017/S1355617799544056

Fereday, J., & Muir-Cochrane, E. (2006). Demonstrating rigor using thematic analysis: A hybrid approach of inductive and deductive coding and theme development. *International Journal of Qualitative Methods, 5,* 80–92. Retrieved from http://www.ualberta.ca/~iiqm/backissues/5_1/pdf/fereday.pdf. http://dx.doi.org/10.1177/160940690600500107

Gibson, K., Carpenter, D., Moore, A. L., & Mitchell, T. (2015). Training the brain to learn: Augmenting vision therapy. *Vision Development and Rehabilitation, 1,* 119–128. Retrieved from http://c.ymcdn.com/sites/www.covd.org/resource/resmgr/VDR/VDR_1_2/VDR1-2_article_Gibson_web_in.pdf

Giuli, C., Papa, R., Lattanzio, F., & Postacchini, D. (2016). The effects of cognitive training for elderly: Results from My Mind Project. *Rejuvenation Research, 19,* 485–494. http://dx.doi.org/10.1089/rej.2015.1791

Goh, J. O., & Park, D. C. (2009). Neuroplasticity and cognitive aging: The scaffolding theory of aging and cognition. *Restorative Neurology and Neuroscience, 27,* 391–403.

Greenaway, M. C., Duncan, N. L., & Smith, G. E. (2013). The memory support system for mild cognitive impairment: Randomized trial of a cognitive rehabilitation intervention. *International Journal of Geriatric Psychiatry, 28,* 402–409. http://dx.doi.org/10.1002/gps.3838

Harada, C. N., Natelson Love, M. C., & Triebel, K. L. (2013). Normal cognitive aging. *Clinics in Geriatric Medicine, 29,* 737–752. http://dx.doi.org/10.1016/j.cger.2013.07.002

Houghton, C., Casey, D., Shaw, D., & Murphy, K. (2013). Rigour in qualitative case-study research. *Nurse Researcher, 20,* 12–17. https://lopes.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=104246455&site=eds-live&scope=site. http://dx.doi.org/10.7748/nr2013.03.20.4.12.e326

Huckans, M., Hutson, L., Twamley, E., Jak, A., Kaye, J., & Storzbach, D. (2013). Efficacy of cognitive rehabilitation therapies for mild cognitive impairment (MCI) in older adults: Working toward a theoretical model and evidence-based interventions. *Neuropsychology Review, 23,* 63–80. http://dx.doi.org/10.1007/s11065-013-9230-9

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Shah, P. (2011). Short- and long-term benefits of cognitive training. *PNAS Proceedings of the National Acad-*

emy of Sciences of the United States of America, 108, 10081–10086. http://dx.doi.org/10.1073/pnas.1103228108

Jedlicka, E. (2017). LearningRx cognitive training for children and adolescents ages 5–18: Effects on academic skills, behavior, and cognition. *Frontiers in Education, 2,* 62. http://dx.doi.org/10.3389/feduc.2017.00062

Kinsella, G. J., Mullaly, E., Rand, E., Ong, B., Burton, C., Price, S., . . . Storey, E. (2009). Early intervention for mild cognitive impairment: A randomised controlled trial. *Journal of Neurology, Neurosurgery & Psychiatry, 80,* 730–736. http://dx.doi.org/10.1136/jnnp.2008.148346

Kober, S., Neuper, C., Pinter, D., Enzinger, C., Fuchs, S., & Wood, G. (2016). Evaluation of a neurofeedback-based cognitive telerehabilitation system for neurological patients. In *2016 IEEE International Conference on Systems, Man, and Cybernetics* (pp. 971–976). New York, NY: IEEE. http://dx.doi.org/10.1109/SMC.2016.7844367

Ledbetter, C., Moore, A. L., Mitchell, T. (2017). Cognitive effects of ThinkRx cognitive rehabilitation training for eleven soldiers with brain injury: A retrospective chart review. *Frontiers in Psychology, 8*(825). http://dx.doi.org/10.3389/fpsyg.2017.00825

Mather, N., & Woodcock, R. (2001). *Woodcock Johnson III Tests of Cognitive Abilities Examiner's manual: Standard and extended batteries*. Itasca, IL: Riverside.

McGrew, K. (2005). The Cattell-Horn-Carroll theory of cognitive abilities. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 151–179). New York, NY: Guilford Press.

McSweeny, A. J., Naugle, R. I., Chelune, G. J., & Lüders, H. (1993). T scores for change: An illustration of a regression approach to depicting change in clinical neuropsychology. *Clinical Neuropsychologist, 7,* 300–312. http://dx.doi.org/10.1080/13854049308401901

Melby-Lervag, M., Redick, T. S., & Hulme, C. (2016). Working memory training does not improve performance on measures of intelligence or other measures of "far transfer": Evidence from a meta-analytic review. *Perspectives on Psychological Science, 11,* 512–534. http://dx.doi.org/10.1177/1745691616635612

Moore, A. L., & Ledbetter, C. (2018, January). *MRI, qEEG, & neuropsychological outcomes following cognitive rehabilitation training for sever traumatic brain injury: A clinical case study*. Paper presented at the Brain Injury Summit, Vail, Colorado. Retrieved from https://www.gibsonresearchinstitute.org/wp-content/uploads/2018/01/2018-TBI-Summit-Presentation_MooreLedbetter_web.pdf

Moore, A. L., Ledbetter, C., & Carpenter, D. (2017, November). *MRI and neuropsychological outcomes following cognitive rehabilitation training in traumatic brain injury: A Multiple case study*. paper presented at the Society for Neuroscience, Washington, DC. Retrieved from https://www.gibsonresearchinstitute.org/wp-content/uploads/2017/11/2017-SFN_MooreLedbetterCarpenter.pdf

Nakatsuka, M., Nakamura, K., Hamanosono, R., Takahashi, Y., Kasai, M., Sato, Y., . . . Meguro, K. (2015). A cluster randomized controlled trail of nonpharmaceutical interventions for old-old subjects with a clinical dementia rating of 0.5: The Kurihara project. *Dementia and Geriatric Cognitive Disorders Extra, 5,* 221–232. http://dx.doi.org/10.1159/000380816

Percy, W. H., Kostere, K., & Kostere, S. (2015). Generic qualitative research in psychology. *Qualitative Report, 20,* 76–85. Retrieved from http://nsuworks.nova.edu/tqr/vol20/iss2/7/

Petersen, R. C., Lopez, O., Armstrong, M. J., Getchius, T. S. D., Ganguli, M., Gloss, D., . . . Rae-Grant, A. (2018). Practice guideline update summary: Mild cognitive impairment. *Neurology, 90,* 126–135. http://dx.doi.org/10.1212/WNL.0000000000004826

Rapp, S., Brenes, G., & Marsh, A. P. (2002). Memory enhancement training for older adults with mild cognitive impairment: A preliminary study. *Aging & Mental Health, 6,* 5–11. http://dx.doi.org/10.1080/13607860120101077

Singh-Manoux, A., Kivimaki, M., Glymour, M. M., Elbaz, A., Berr, C., Ebmeier, K. P., . . . Dugravot, A. (2012). Timing of onset of cognitive decline: Results from Whitehall II prospective cohort study. *British Medical Journal, 344,* d7622. http://dx.doi.org/10.1136/bmj.d7622

Snyder, C. (2012). A case study of a case study: Analysis of a robust qualitative research methodology. *Qualitative Report, 17,* 1–21. Retrieved from http://nsuworks.nova.edu/tqr/vol17/iss13/2

Tetnowski, J. (2015). Qualitative case study research design. *Perspectives on Fluency and Fluency Disorders, 25,* 39–45. http://dx.doi.org/10.1044/ffd25.1.39

Troyer, A. K., Murphy, K. J., Anderson, N. D., Hayman-Abello, B. A., Craik, F. I. M., Moscovitch, M. (2008). Item and associative memory in amnestic mild cognitive impairment: Performance on standardized memory tests. *Neuropsychology, 22,* 10–16. http://dx.doi.org/10.1037/0894-4105.22.1.10

Tsolaki, M., Kounti, F., Agogiatou, C., Poptsi, E., Bakoglidou, E., Zafeiropoulou, M., . . . Vasiloglou, M. F. (2011). Effectiveness of nonpharmacological approaches in patients with mild cognitive impairment. *Neurodegenerative Diseases, 8,* 138–145. http://dx.doi.org/10.1159/000320575

U.S. Department of Health and Human Services. (2012). *Results from the 2011 National Survey on Drug Use and Health: Mental Health Findings* (NSDUH Series H-45, HHS Publication No. [SMA] 12–4725). Rockville, MD: Substance Abuse and Mental Health Services Administration.

Verhaeghen, P., & Salthouse, T. A. (1997). Meta-analyses of age-cognition relations in adulthood: Estimates of linear and nonlinear age effects and structural models. *Psychological Bulletin, 122,* 231–249. http://dx.doi.org/10.1037/0033-2909.122.3.231

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson III*. Itasca, IL: Riverside Publishing.

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