Government Office for Science

Foresight

Mental Capital and Wellbeing:

Making the most of ourselves in the 21st century

State-of-Science Review: SR-E22
Cognitive Training: Influence on Neuropsychological and Brain Function in Later Life

Professor George W. Rebok
Department of Mental Health, The Johns Hopkins University

This review has been commissioned as part of the UK Government's Foresight Project, Mental Capital and Wellbeing. The views expressed do not represent the policy of any Government or organisation.

Summary

Recent success of cognitive training with normally functioning, older adults has engendered growing optimism about the modifiability of neuropsychological and brain function in later life and the potential to influence everyday behaviour, mental wellbeing, and quality of life. This paper reviews the latest scientific advances and results in this rapidly evolving area, factors that affect training responsiveness, and the challenges that researchers will face in trying to implement new training platforms in the future. Cognitive training is currently being conducted against a backdrop of increasing sophistication of methods, design, and analysis. At the same time, advances in emerging technologies, electrophysiology, biomarker assays, and genetics are moving the field forward at an accelerating pace. There is increasing evidence that training can affect multiple cognitive variables, including memory, reasoning, speed of processing, and spatial relations, that the effects can be long-lasting, and that training gains may transfer to more distal outcomes related to everyday cognitive functioning and behaviour. Large-scale cognitive training studies such as project ACTIVE (Advanced Cognitive Training for Independent and Vital Elderly) and other recent intervention studies are contributing significant new knowledge that validates the efficacy of training for members of the older population. However, important questions remain about the neural and psychological mechanisms underlying training and transfer effects, the dosage levels needed to produce these effects, who benefits most from training and why, how to cross-train and combine training modalities, and the best ways to embed training programmes within the broader context of everyday life and ageing. The contributions of cognitive training to the development of mental capital and mental wellbeing across the life course are discussed, along with the need for lifespan public health models and policies to deliver cost-effective training at a population-based level.

1. Introduction

There is growing optimism in both scientific and lay communities about the modifiability of neuropsychological and brain function in later life and the potential of cognitive training to influence everyday behaviour, mental wellbeing, and quality of life (Ball et al., 2007; Centers for Disease Control and Prevention and the Alzheimer's Association, 2007; Elias and Wagster, 2007; Fillit et al., 2002; Kramer and Willis, 2002; Park et al., 2007; Rebok et al., 2007; Shumaker et al., 2006; Studenski et al., 2006; Willis and Schaie, 1994). Recent research studies provide increasing evidence that: training can affect multiple cognitive variables, even when measured with different modalities, including working memory, abstract reasoning, attention and concentration, speed of information processing, and spatial relations; the effects can last months or, in some cases, even years;, and that training gains may transfer to more distal outcomes related to everyday cognitive functioning (Bherer et al., 2005, 2006; Bottiroli, et al., 2007; Cavallini et al., 2003; Craik et al., 2007; Erickson et al., 2007; Jennings and Jacoby, 2003; Jennings et al., 2005; Kramer et al., 1995; Mahncke, Connor et al., 2006; Stuss et al., 2007; West et al., 2003; Willis et al., 2006), everyday behaviour (Ball et al., 2007; Kramer and Willis, 2002; Studenski et al., 2006), and quality of life (Fabre et al., 1999; Wolinsky et al., 2006a; Wolinsky et al., 2006b).

This review aims to summarise the latest scientific advances and results on cognitive training with older adults, factors that affect transfer of training and training responsiveness, and challenges that researchers will face in trying to implement innovative training approaches in the future. The review will focus on cognitive training in normally functioning elderly, but the responsiveness of cognitively impaired elderly to training also will be briefly considered. In addition to cognitive training studies targeting specific domains of cognition such as working memory, attention, and speed of processing, the review will include cognitive stimulation approaches involving group activities that are designed to increase cognitive and social functioning in a nonspecific manner.

2. Early results of cognitive training research: 1980s and 1990s

Over two decades of research have established that older adults can improve their cognitive abilities (Ball and Sekuler, 1986; Ball et al., 1988; Hayslip et al., 1995; Kliegl et al., 1989; 1990; Rasmusson, et al., 1999; Rebok and Balcerak, 1989; Schaie and Willis, 1986; Willis et al., 1981) with training protocols targeting working memory, abstract reasoning, speed of processing, and spatial abilities, among other cognitive neuropsychological domains showing early age decline. These studies also involved teaching strategies or skills in order to optimise cognitive functioning (e.g. mnemonic strategies).

For reasons of experimental control, early training studies tended to be ability-specific, targeting single cognitive abilities rather than multiple ability domains. Typically, these studies showed significant training effects compared to no-treatment or social contact control groups, with training gains averaging 0.19-0.73 SD (Floyd and Scogin, 1997; Verghaeghen et al., 1992). This research also demonstrated that cognitive training is specific to the ability being trained with little transfer of training to untrained cognitive domains, and improvements are limited to tasks similar to the training itself (Kramer and Willis, 2002; Neely and Bäckman, 1995; Willis et al., 1981; Willis and Schaie, 1994). Early studies showed some evidence of the durability of training effects ranging from between one or two months and up to one year or more (Oswald et al., 1996; Sheikh et al., 1986; Stigsdotter and Bäckman, 1989; Stigsdotter et al., 1993; Willis and Nesselroade, 1990; Willis and Schaie, 1994), although not every study found evidence for maintenance effects (e.g. see Anschutz et al., 1987; Scogin and Bienias, 1988).

3. Recent training approaches: 2000 to the present

Ultimately, the goal of cognitive training is to enhance or sustain cognitive abilities at healthy levels for longer portions of the lifespan, in the hope that everyday functioning will benefit. Following the early studies, new questions arose for cognitive training research, including the long-term clinical outcomes of interventions and the transfer of training to measures of functioning on everyday tasks (Jobe et al., 2001). There were also questions about the representativeness of the samples, as most of these were regional, convenience samples that lacked diversity. Other concerns involved the lack of intent-to-treat designs, failure to control for attrition, replicability of the findings, and the clinical meaningfulness of the findings.

To address these questions, later research has turned to more sophisticated designs with larger and more representative samples and with everyday abilities as the primary target outcome. An example of this newer approach can be seen in the ACTIVE (Advanced Cognitive Training for Independent and Vital Elderly) intervention trial jointly funded by National Institute on Aging (NIA) and the National Institute of Nursing Research (NINR), which is the single, largest cognitive training study undertaken to date (Ball et al., 2002; Jobe et al., 2001; Willis et al., 2006). ACTIVE was a randomised controlled trial of three cognitive interventions (memory, reasoning, speed of information processing) designed to maintain functional independence in older adults aged 65 and above by improving basic mental abilities (Ball et al., 2002; Jobe et al., 2001). Several features made ACTIVE unique in the field of cognitive interventions: (a) use of a multi-site, randomised, controlled, single-blind design; (b) intervention on a large, diverse sample of older adults (N = 2,832, mean age = 73.6 years, range = 65-94 years; 26% African-Americans); (c) use of common multi-site intervention protocols; (d) primary outcomes focused on long-term, far-transfer effects as measured by performance-based tests of daily activities; and (e) an intent-to-treat analytical approach.

The trial phase consisted of baseline assessment followed by the cognitive interventions, immediate post-test, booster training for a subsample, and post-tests at one, two, three, and five years. The three interventions had equivalent intensity and duration across ten, 60-75 minute sessions and were conducted in small group settings. In all three conditions, Sessions 1-5 focused on strategy instruction and exercises to practice the strategy. Sessions 6-10 provided additional practice exercises, but no new strategies were introduced.

Memory training focused on verbal episodic memory. Participants were taught mnemonic strategies for remembering lists and sequences of items, text material, and main ideas and details of stories and other text-based information. Training exercises involved laboratory-like tasks as well as everyday tasks and activities such as recalling a shopping list. *Reasoning training* focused on the ability to solve problems that follow a serial pattern. Participants were taught how to identify, block, and mark patterns in abstract series. Training involved both laboratory-type tasks and reasoning in everyday activities, such as understanding the pattern in a bus schedule. *Speed training* focused on visual search and the ability to identify and locate visual information quickly in a divided attention format, with and without distractors. Participants practiced tasks on a computer and proceeded to more complex tasks and faster presentation speeds at their own pace.

Results of the ACTIVE trial showed immediate and significant task-specific effects for all three interventions (Ball et al., 2002) that were durable through five years (memory: effect size, 0.23; reasoning: effect size, 0.26; speed of processing: effect size, 0.76) (Willis et al., 2006). Some evidence also was found for transfer of intervention effects to everyday functional performance, as measured by IADL difficulty (reasoning: effect size, 0.29) and everyday speeded performance (speed of processing – booster only: effect size, 0.30) (Willis et al., 2006). Plans are currently under way to continue to follow the ACTIVE sample through 10 years post-training to determine the very long-range effects of cognitive training and transfer to everyday abilities, and to examine heath, genetic, and cognitive moderators (including cardiovascular disease, diabetes, depression, APOE genotype, and low cognition and engagement) in individual response to training.

Although effective, there are limits on the wide-scale dissemination of costly training platforms such as ACTIVE that involve participants meeting in small groups for paper-and-pencil training sessions led by a trained facilitator. Increasingly, researchers are exploring alternative training approaches to improve cognitive abilities in older adults (Park et al., 2007; Rebok et al., 2007). These include collaborative training (Margrett and Willis, 2006; Saczynski, Margrett and Willis, 2004), online and CDROM-based training (Baldi et al., 1996; Bond et al., 2001; Günther et al., 2003; Plude and Schwartz, 1996; Mahncke et al., 2006; Morrell et al., 2006; Saczynski, Rebok et al., 2004; 2007; Shapira et al., 2007), and videotaped and audiotaped training (Rebok et al., 1997; West and Crook, 1992). These novel, 'trainer-less' training platforms are designed to overcome limitations of the more traditional approaches, including problems related to accessibility and costs of training. Limiting training to small-group didactic sessions with a certified trainer may limit the number of older persons able to access the training, thereby reducing its public health impact.

4. Activity-based approaches to cognitive improvement

Much recent research in cognitive ageing has demonstrated the effectiveness of stimulating mental, social, and physical activity for retaining mental function in later life (Butler et al., 2004; Hultsch et al., 1999; Kramer et al., 2006; Noice and Noice, 2006; Noice et al., 2004; Stine-Morrow et al., 2007; Verghese et al., 2003; Wilson et al., 1999; Wilson et al., 2002). A growing number of observational epidemiologic studies have shown that leisure-time cognitive, physical, and social activities are each consistently associated with better cognitive and functional health (for review, see Studenski et al., 2006). Multiple large-scale studies have demonstrated that mid- and later-life cognitive activity is associated with better cognitive health (Stern et al., 1999; Wang et al., 2002; Wilson et al., 1999; Wilson et al., 2002). Observational studies, however, are limited in their capacity to draw causal inferences between lifestyle activity and amelioration of age-related cognitive decline and impairment (Christensen et al., 1999; Hultsch et al., 1999; Wilson et al., 1999). These studies may reflect bias in high-functioning individuals' predisposition toward cognitively and physically enriching activities, or prodromal changes in activity occurring prior to the clinical onset of incipient neuropathology, such as Alzheimer's disease (e.g., Saczynski et al., 2006; Salthouse, 2006; Small et al., 2001).

There have been a few recent attempts to experimentally manipulate the types and amount of activity in order to overcome the limitations of observational studies. Fried et al. (2004) evaluated the feasibility of recruiting, retaining, and increasing activity levels in older, at-risk individuals using the multi-modal, Experience Corps®: Baltimore (ECB), activity intervention. Core features of the ECB programme that led to unprecedented 'doses' of exposure included: placing a critical mass of trained, older volunteers in teams of 10 or more in schools; having them fulfil meaningful roles to meet school needs in literary development, library support, and behavioural conflict resolution; requiring a commitment of 15 hours/week over an academic year; and providing an incentive reimbursement to offset volunteer expenses. Seniors worked with children in Kindergarten through 3rd grade, an age-range where such support can be most beneficial to future academic success (Heckman, 2006). The multimodal ECB activity programme was designed to further bolster memory and components of executive functioning in the volunteers via programme activity in four ways: 1) exercise mental flexibility through the need to shift across ECB roles; 2) develop working memory skills via reading comprehension exercises with children; 3) apply library skills in learning and using the Dewey decimal system to help children locate and select age-appropriate books; and 4) cooperatively problem-solve with team members, students, and teachers. The cognitive activity embedded within this social health promotion programme and roles resulted in measurable gains in executive functioning and working memory, with the gains being greatest for older adults who showed executive functioning deficits at baseline (Carlson et al., in press).

In another recent study using an activity-based intervention, Stine-Morrow and her colleagues (Parisi, Greene, Morrow and Stine-Morrow, 2007; Stine-Morrow, Parisi, Morrow et al., 2007) reported preliminary results from the Senior Odyssey programme, an ongoing team-based programme of creative and collaborative problem-solving. Participants in the first year of the programme showed improved speed of processing, marginally improved divergent thinking, and higher levels of mindfulness and need for cognition from pre- to post-training, compared with controls.

Larger scale, controlled trials of the Baltimore Experience Corps® programme and the Senior Odyssey programme are currently in progress.

5. Neural mechanisms of training-related change

A growing number of neuroimaging studies have examined the effects of training and practice on neural dynamics, or training-induced plasticity (Bor and Owen, 2007; Erickson et al., 2007; Imamizu et al., 2007; Jancke et al., 2001; Nyberg, 2005; Nyberg et al., 2003; Olesen et al., 2004; Valenzuela et al., 2003). Research using animal models (Briones et al., 2004; Kempermann et al., 1998; van Praag et al., 2005) has provided a basis for these studies by showing selective effects of experience on brain structure and function. There is also a growing literature on the effects of experience on *human* brain structure and function (Draganski et al., 2004; Kramer and Erickson, 2007; Maguire et al., 2003).

The neuroimaging studies cited above show several different patterns of results. Erickson et al. (2007) studied training-related changes in cortical activity as measured by functional magnetic resonance imaging (fMRI) in a sample of young adults during a dual task requiring executive control. They found that most regions involved in dual task processing before training showed reductions in activation following training. Olesen et al. (2004) investigated the effect of working memory training with young adults on brain activity measured with fMRI and found increased activity in prefrontal and parietal regions after training. Nyberg and colleagues (2003) trained younger and older adults in the use of the method of loci technique where one learns to associate words that are to be memorised with a particular spatial location. Patterns of brain activation were then assessed both pre- and post-training using positron emission tomography (PET). Only half of the older adults showed any benefit from training. Using neuroimaging data, the researchers found that younger adults showed increased activity in dorsal frontal regions of the brain associated with mental imagery and integration of information in working memory, but older adults showed no such difference. This may reflect a deficit in the reserve capacity of older adults. However, both young and those older adults who showed improvement in memory performance after method of loci training had increased activity in the occipitoparietal and retreosplenial regions of the brain. These regions have been associated with spatial imagery and route-based learning, respectively. Thus, although not all older adults are able to benefit from training, those who did showed similar changes in neural activation patterns to the younger adults in the posterior regions of the brain.

In summary, the literature suggests that changes in neural activity following training are not accompanied by a simple monotonic increase or decrease in activity, and that changes are likely to be specific to certain brain regions (Erickson et al., 2007; Landau et al., 2004).

6. Individual differences affecting training responsiveness

It is often unclear what factors contribute to the success of cognitive training with older adults. What processes or strategies are being trained? Why do some individuals appear to benefit more than others? Recently, Bissig and Lustig (2007) examined the role of self-initiation of cognitive control in a training programme targeting recollection memory. Relative time spent on an open-ended, intentional encoding task that requires the self-initiation of cognitive control was highly predictive of improvement in the training task, and fully accounted for individual differences related to age and crystallised intelligence.

Studies to date have not systematically examined individual differences determining who benefits most from cognitive training (Park et al., 2007). As acknowledged by Salthouse (2006), it is possible that older adults with the poorest cognitive functioning or from the oldest age ranges stand to benefit the most from training. Longer-term longitudinal follow-up studies may be needed to evaluate the impact of training on less impaired individuals relative to untrained control participants, as in the ACTIVE study (Ball et al., 2007). Cognitive training studies demonstrate that diverse socioeconomic, ability level, and ethnic populations benefit from traditional forms of cognitive training. Training effects have been demonstrated for wide age ranges including the oldest-old (Kramer and Willis, 2002; McDougall, 2002; Singer et al., 2003; Yang et al., 2006), normal elderly (Ball et al., 2002; Baltes, 1987; Baltes and Willis, 1982; Rasmusson et al., 1999; Willis et al., 2006), and those with mild cognitive impairment (Belleville, 2008; Belleville et al., 2006; Haslam et al., 2006; Rapp et al., 2002; Troyer et al., 2008; Unverzagt et al. 2007; also see recent meta-analyses by Grandmaison and Simard, 2003 and Sitzer et al., 2006 on cognitive training effects in Alzheimer's disease), indicating that human brains continue to have substantial neural plasticity in later life.

The benefit from cognitive training does not appear to depend primarily upon demographic variables such as age or education (Ball et al., 2007). However, poor cardiovascular health, use of anticoagulants and other medications (e.g. antihistamines, antilipemic agents), mild neuropsychological deficits, and lack of physical activity/fitness all may serve to reduce responsiveness to training (Boron, Turiano et al., 2007; Hill et al., 1989; Kramer and Willis, 2002; Rasmusson et al., 1999; Unverzagt et al., 2007). There is some evidence that better health status is associated with maintaining and improving cognitive status and independent living following a combined memory and psychomotor training programme (Oswald et al., 2002).

One additional factor that might affect training responsiveness is the extent to which the individual invests in the training programme and complies with instructions. In a recent study, Bagwell and West (2008) showed that older trainees in a memory intervention programme who were compliant with the training regimen (using trainer ratings based on attendance, homework completion, and class participation), made significantly greater training-related gains compared to an inactive training group and a control group.

7. Transfer of cognitive training

Transfer of training-induced cognitive changes across time, to broader measures of functional abilities, and across different modalities of measurement, is imperative if training is to have value beyond the procedural specifics of individual exercises (Barnett and Ceci, 2002; Mahncke et al., 2006; Salomon and Perkins, 1989). Prior cognitive training research has shown that the training outcomes are highly specific to the cognitive ability being trained (Brooks et al., 1993; Hill et al., 1988; Kliegl et al., 1990; Mohs et al., 1998; Neely and Bäckman, 1995; Oswald et al., 1996; Rebok and Balcerak, 1989; Yesavage, 1985) and are limited to tasks that are very similar to the training itself (Jennings et al., 2005; van Hooren et al., 2007). That is, there is frequently little transfer to other laboratory cognitive tasks or to analogues of the training tasks encountered in everyday situations. However, techniques for improving processing speed have shown evidence of transfer to laboratory-based everyday activities such as Timed Instrumental Activities of Daily Living (Edwards et al., 2002; 2005) and faster complex reaction time on a Road Sign Test (Roenker et al., 2003). In addition, people trained using speed-of-processing interventions make fewer dangerous manoeuvres on subsequent on-road driving evaluations (Roenker et al., 2003).

With regard to optimising transfer effects, one approach would be to train at the level of complex activities reflecting real-world tasks, not at the level of basic abilities (Salomon and Perkins, 1989). For example, in a memory training programme, we might integrate value-based processing with the need for accuracy and completeness in memory performance (Castel, 2008; Goldsmith and Koriat, 2008). Through deliberate exercise of complex tasks, we may simultaneously exercise the underlying constituent abilities on which those tasks depend, *and* their coordination. Transfer may be more likely to occur under these conditions because individuals practice component skills in varying and relevant contexts which provide continuous opportunities to meet tractable challenges (Stine-Morrow et al., 2007; Swezy and Llaneras, 1997). This is the implied mechanism from correlational data suggesting that complex activity is a protective mechanism for late-life cognition (e.g., Wilson et al., 2002; but see Hultsch et al., 1999).

One major problem of intervening at the level of complex activity is that we do not yet have a good understanding of which activities, at which intensity, exercise particular cognitive abilities. What we need is the equivalent of understanding which 'muscle groups' are moved by particular physical exercises. Another problem lies in how to measure improvement in complex activities. Careful experimental work needs to be done to link particular abilities to particular training-related activities and experiences.

8. Multimodal training

An important limitation of many traditional cognitive training approaches is that they do not incorporate multiple training modalities. Approaches that combine cognitive training with pharmacotherapy (Rozzini et al., 2007; Yesavage et al., 2007), exercise (Colcombe and Kramer, 2003; Fabre et al., 2002; Larson et al., 2006), nutrition (Gillette et al., 2007; González-Gross et al., 2001), life style change (Gomez-Pinilla, 2008; Small et al., 2006), self-efficacy enhancement (Cervone et al., 2006; West et al., 2008), and other modes of intervention may potentially produce additive, or even synergistic benefits.

Combining training modalities, however, also has the potential for producing interference effects: 'more' may not always be better. Researchers need to carefully plan and sequence multimodal interventions, taking into account participants' limited capacity for processing multiple modalities. Some forms of training may work better in isolation, and some may work better when combined with other modalities. We recommend that researchers investigate the relative contributions of individual interventions before advocating a combined approach.

Although multimodal approaches to cognitive training show considerable promise, they have seldom been implemented. Yesavage and his colleagues are currently studying the use of donepezil as a augmentation strategy to enhance the effects of cognitive training in normal, older adults and those diagnosed with mild cognitive impairment (MCI) (Yesavage et al., 2007). In a study by Rozzini et al (2007), an MCI group receiving cholinesterase inhibitors (ChEIs) and cognitive training showed significantly improved memory and abstract reasoning and reduced depressive mood at a three-month follow-up compared with a ChEIs-only-treated group. However, the study did not include a cognitive-training alone group so the effects of combining treatment strategies remains unknown.

The cognitive benefits of physical exercise have been noted for both aerobic and anaerobic activity (Colcombe and Kramer, 2003). Fabre and colleagues (2002) combined cognitive and physical training using a full factorial design. They reported that combined aerobic and cognitive training led to greater effects on memory performance than aerobic training or cognitive training alone. However, their study was limited to a small convenience sample (N=32) of unimpaired older adults aged 60-76. Small and his colleagues (2006) studied the effects of a short-term healthy lifestyle programme combining mental and physical exercise, stress reduction, and healthy diet on cognition and brain metabolism in 17 non-demented middle-aged and older adults (mean age = 53 years, range = 35-69 years) with mild age-related memory complaints. They reported improved measures of verbal fluency and reduced dorsolateral prefrontal cortical metabolism, suggesting that such a programme may result in greater cognitive efficiency of a brain region involved in working memory functions.

To date, though, no studies have examined the combined effects of physical training and structured cognitive training on cognitive function in a large, representative sample of community elderly. There also have been few combined intervention studies systematically examining the different types of training using multiple comparison groups.

9. Statistical modeling of training effects

Researchers are developing new designs and statistical models for analysing training effects (Elias and Wagster, 2007). One approach for the assessment of intervention effects that has attracted considerable attention is growth mixture modelling (McArdle, 2006; McArdle and Nesselroade, 2002; Muthén et al., 2002). These models allow for the inclusion of both categorical and continuous latent variables in the same model. With regard to training, the models allow for the identification of subsamples that respond differentially to the training, based on variable response patterns. Investigators can study this, based on who best responds to the intervention and individual difference variables that contribute to growth (improvement) or lack of improvement (Elias and Wagster, 2007; Langbaum et al., in press). There is also interest in documenting test-retest effects (Salthouse et al., 2004) and the cost-effectiveness of cognitive training and cognitive stimulation programmes for older adults (Becker et al., 2008; Frick et al., 2004; McCrory, 2007).

10. Designing a public health framework for training delivery

These are exciting times for cognitive training research. The possibilities of increasing cognitive abilities in later life that transfer to everyday function and confer lasting benefit are rapidly increasing. New approaches that combine cognitive training with exercise, pharmacotherapy, nutritional interventions, and lifestyle modification are propelling the field forward at an accelerating pace. Interest in developing more effective cognitive training that can be used to promote healthy cognitive ageing at a population level is rapidly growing in both scientific and lay communities.

At the same time, there is growing concern about the current use of cognitive training with older adults, and its widespread application. As stated in a recent editorial in *Nature Neuroscience,* 'Mental exercise games are being claimed to slow brain ageing, but the evidence for this idea is not yet conclusive' (Editorial, 2007). Salthouse (2006) systematically reviewed the literature on the 'mental-exercise hypothesis' and concluded that there is little evidence to suggest that mental training alters the rate of cognitive ageing. Although training alone may not be sufficient to alter the life course with respect to decline, it may compress the point of cognitive decline and disability into a smaller window at the end of life. Training gains may also be a useful predictor of future mental status (Boron, Willis and Schaie, 2007).

Overall, based on the present review and previous reviews of this area (McDougall, 1999; Verhaeghen et al., 1992; Willis and Schaie, 1994), the bulk of the cognitive training literature appears to support the ability of older adults to benefit from cognitive training. This has far-reaching public health implications in terms of improving the mental capital and wellbeing of the older population. As Brookmeyer and his colleagues (2007) have demonstrated, even modest delays in the onset and progression of cognitive decline in Alzheimer's disease (AD) would produce widespread benefit at the population level. In 2006, the worldwide prevalence of AD was 26.6 million. By 2050, this will quadruple, such that one in 85 persons worldwide will be living with the disease. If interventions could delay both its onset and progression by a modest one year, there would be nearly 9.2 million fewer cases in 2050, with nearly all the decline attributable to decreases in persons needing high level of care (Brookmeyer et al., 2007). In other words, modest advances in therapeutic and preventive strategies that lead to even small delays in Alzheimer's onset and progression can significantly reduce the global burden of the disease.

At present, there is little direct evidence that cognitive training can delay the onset of AD, but it may increase the cognitive resources available to compensate for the impact of increasing cognitive deficits. This may delay the outward presentation of symptoms and have positive benefit for patients, their families, and society.

In their review of the accumulated longitudinal evidence supporting the cognitive reserve hypothesis, Frataglioni et al., (2004, p343) concluded that there is little doubt that "an active and socially integrated lifestyle in late life protects against dementia [and Alzheimer's disease]". However, training research has not adequately studied the effects of maintained cognitive abilities on the everyday functioning of older adults and their quality of life (Ball et al., 2002). Consistent with current conceptualisations of the disablement process (Wolinsky and Miller, 2006), the presumed etiological mechanism is that the age-related decline of cognitive abilities increases the likelihood of difficulty of performing activities of daily living (ADLs) and instrumental activities of daily living (IADLs), that in turn, leads to deterioration in health-related quality of life (HRQoL) (Ball et al., 2002; Jobe et al., 2001).

The ACTIVE study has reported evidence on the ability of speed-of-processing training to delay clinically relevant declines in HRQoL two years (Wolinsky et al., 2006a) and five years (Wolinsky et al., 2006b) post-training. The ACTIVE memory and reasoning training interventions did not have similarly protective effects. One plausible explanation for these findings is that speed-of-processing training is more clearly procedural, operating through sensory-motor elaboration and repetition, whereas the memory and reasoning interventions emphasise or require the explicit learning of new concepts (Wolinsky et al., 2006a; Wolinsky et al., 2006b). Procedural tasks exhibit a broader pattern of regional brain activation (i.e. neostriatum and cerebellum in addition to neocortex) than do explicit memory tasks (Cabeza and Nyberg, 2000), which may account for a greater sense of wellbeing reflected in the HRQoL ratings. It remains to be seen whether the speed-of-processing training will translate into more appropriate and reduced levels of health services utilisation and increased longevity. Attempts are currently under way to examine these more objective outcomes in the ACTIVE study, 10 years post-training.

Rapid growth in the population of older adults coupled with the findings reporting links between cognitive decline and institutionalisation (Langa et al., 2001; Strain et al., 2003), hospitalisation (Chodosh et al., 2004), chronic health conditions (Di-Carlo et al., 2000; Izquierdo-Porrera and Waldstein, 2002), and mortality (Schupf et al., 2005; Shipley et al., 2006) have resulted in an increased need for population-level alternatives to formal group-based cognitive interventions such as ACTIVE. The increasing demand for such intervention alternatives necessitates the development of cost-effective, self-administered, and flexible training platforms that can be easily distributed to the public.

11. Proposed next steps

There are a number of unanswered questions with regard to the efficacy of cognitive training with older adults and the underlying mechanisms of training-related improvements. In addition to the question of whether training can prevent cognitive decline in later life, we need to know: what constitutes 'successful training'; who are the best candidates for successful training; when to intervene; and how we can enhance training to broaden its transfer effects and durability. We also need to know more about optimal dosage and sequencing for delivering cognitive training, the best way to extend it to the cognitively impaired, and how to match interventions to individual risk profiles. From a public health perspective, we need to know how we can make training accessible and worthwhile to the entire older population, particularly those at highest risk for pathologic cognitive decline, and how to increase its cost-effectiveness. In future efforts, it will be important to draw on current cognitive ageing theory to inform cognitive training and *vice versa*.

With regard to proposed next steps, the field needs more well-controlled studies of multi-faceted interventions that combine multiple cognitive skill-based training and other behavioural and non-behavioural intervention techniques. If these studies demonstrate interactive effects, combining cognitive training techniques with exercise, nutritional supplements, or drug therapy could magnify the benefits of existing training programmes for older adults. There is also a need for hybrid approaches that target both cognitive and functional abilities.

Many of the cognitive training interventions have been low-dose. We need more intensive, high-exposure interventions (e.g. activity-based, life style management, web-based, computerised, in-home, self-administered).

We also need to direct more attention to individual difference variables (health status, depression, self-efficacy) that may affect training responsiveness, transfer, and maintenance.

We need more studies focusing on the neural mechanisms of training, such as fMRI studies showing changes in brain activation levels during, and after, cognitive training, along with more studies of strategy usage and the strategy maintenance over time, and their role in training gains. Greater effort is now being focused on monitoring strategy usage, both during cognitive training and during the follow-up period, in order to determine whether those who improved did so because of increased strategy utilisation (Carretti et al., 2007; Dunlosky et al., 2007; Dunlosky et al., 2003; Lachman and Andreoletti, 2006; O'Hara et al., 2007; Saczynski, Rebok et al., 2007). The importance of understanding the mechanisms underlying training effects cannot be overstated, given that it is only through an understanding of mechanisms that interventions can be effectively targeted.

More attention also needs to be paid to cognitive plasticity across the lifespan (Brehmer et al., 2007; Brehmer et al., 2008). This includes studies of adults past age 80, since most training studies have involved younger-old cohorts (Verhaeghen et al., 1992) and since the prevalence of cognitive impairments increases steeply with age (Evans et al., 1989). Although the evidence seems clear that plasticity of cognitive functions declines with advancing age (e.g. Singer et al., 2003; Verhaeghen and Marcoen, 1996), it is also clear that the ageing brain does retain a considerable amount of reserve capacity (Reuter-Lorenz, 2002). Studies further developing cognitive training techniques with older adults who are just beginning to experience preclinical cognitive decline, but who do not yet have mild cognitive impairment (MCI) or dementia, will be an important direction for future cognitive training research (Acevedo and Loewenstein, 2007). Such interventions may provide a window of opportunity in which to delay, and possibly reverse, the further progression of impairment (Rebok et al., 2007).

Future research also needs to focus more attention on a frequently-overlooked factor in training – the nature of the social engagement experience, given that most training programmes (e.g. ACTIVE) are group-based. Social engagement, defined as the maintenance of many social connections and a high level of participation in social activities, is associated with cognitive functioning in older adults (Bassuk et al., 1999; Seeman et al., 2001; Holtzman et al., 2004). For instance, Barnes et al. (2004) found that regular participation in structured social activities may reduce cognitive impairment by 91% among those with higher levels (*versus* lowest levels) of social engagement. Other studies have found that greater social engagement is protective of the onset of dementia (Fratiglioni et al., 2000), and even longevity (Bennett, 2002). A possible explanation for these findings is that a social network could provide a sense of purpose, community, and opportunities for increased self-efficacy (Holtzman et al, 2004). Additionally, social engagement challenges people to communicate effectively and participate in complex personal exchanges (Bassuk et al., 1999), which may enhance cognitive performance. To the extent that cognition in adulthood is motivated by social and emotional goals (Carstensen, 1995, 2006), a socially collaborative context may be particularly effective for older adults (Dixon and Gould, 1996; 1998) and contribute to overall satisfaction with an intervention (e.g. Paggi and Hayslip, 1999; Parisi et al., 2007).

Finally, there is scope for more animal studies designed to elucidate the underlying biological mechanisms that may help inform the development of cognitive training interventions. Studies have shown that factors such as social stress can exacerbate the pathology and worsen cognitive performance in animal models of Alzheimer's disease (Dong et al., 2004; Jeong et al., 2006). A stimulatory environment, on the other hand, has been shown to slow development of pathology and improve cognitive performance in similar transgenic mouse models (Adlard et al., 2005; Lazarov et al., 2005). If the biological mechanisms that underlie these effects in animal models can be elucidated, then not only appropriate physical interventions might be developed for humans, but also there may be pharmacological interventions based upon the biological mechanisms.

References

Acevedo, A. and Loewenstein, D.A. 2007. Nonpharmacological cognitive interventions in aging and dementia. *Journal of Geriatric Psychiatry and Neurology,* 20:239-249.

Adlard, P.A., Perreau, V.M., Pop, V. and Cotman, C.W. 2005. Voluntary exercise decreases amyloid load in a transgenic model of Alzheimer's disease. *Journal of Neuroscience,* 25:4217-.

Anschutz, L., Camp, C.J., Markley, R.P. and Kramer, J.J. 1987. Remembering mnemonics: A three year follow-up on the effects of mnemonics training in elderly adults. *Experimental Aging Research,* 13:141-143.

Bagwell, D.K. and West, R.L. 2008. Assessing compliance: Active versus inactive trainees in a memory intervention. *Clinical Interventions in Aging,* 3:371-382.

Baldi, R.A., Plude, D.J. and Schwartz, L.K. 1996. New technologies for memory training with older adults. *Cognitive Technology,* 1:25-35.

Ball, K. and Sekuler, R. 1986. Improving visual perception in older observers. *Journal of Gerontology*, 41:176-182.

Ball, K.K., Beard, B.L., Roenker, D.L., Miller, R.L. and Griggs, D.S. 1988. Age and visual search: Expanding the useful field of view. *Optics, Image Science, and Vision,* 5: 2210-2219.

Ball, K.K., Berch, D.B., Helmers, K.F., Jobe, J.B., Leveck, M.D., Marsiske, M., Morris, J.N., Rebok, G.W., Smith, D.M., Tennstedt, S.L., Unverzagt, F.W. and Willis, S.L. 2002. Effects of cognitive training interventions with older adults: A randomized controlled trial. *Journal of the American Medical Association,* 288:2271-2281.

Ball, K.K., Edwards, J.D. and Ross, L.A. 2007. The impact of speed of processing training on cognitive and everyday functions. *Journal of Gerontology: Psychological Sciences 62B, Special Issue* I:19-31.

Baltes, P.B., and Willis, S.L. 1982. Plasticity and enhancement of intellectual functioning in old age: Penn State's Adult Development and Enrichment Project (ADEPT). In F.I.M. Craik and S. Trehub (Eds), *Aging and cognitive processes* (pp353-390). New York: Plenum Press.

Baltes, P. B. 1987. Theoretical propositions of life-span developmental psychology: on the dynamics between growth and decline. *Developmental Psychology,* 23:611-626.

Barnes, L.L., Mendes de Leon, C.F., Wilson, R.S., Bienias, J.L. and Evans, D.A. 2004. Social resources and cognitive decline in a population of older African Americans and Whites. *Neurology,* 63:2322-2326.

Barnett, S.M. and Ceci, S.J. 2002. When and where do we apply what we learn? A taxonomy for far transfer. *Psychological Bulletin,* 128:612-637.

Bassuk, S.S., Glass, T.A., and Berkman, L.F. 1999. Social disengagement and incident cognitive decline in community-dwelling elderly persons. *Annals of Internal Medicine,* 131:165-173.

Becker, H., McDougall, G.J., Jr., Douglas, N.E. and Arheart, K.L. 2008. Comparing the efficiency of eight-session versus four-session memory intervention for older adults. *Arch Psychiatric Nursing,* 22:87-94.

Belleville, S., Gilbert, B., Fontaine, F., Gagnon, L., Menard, E., and Gauthier, S. 2006. Improvement of episodic memory in persons with Mild Cognitive Impairment and healthy older adults: Evidence from a cognitive intervention program. *Dementia and Geriatric Cognitive Disorders,* 22:486-499.

Belleville, S. 2008. Cognitive training for persons with mild cognitive impairment. *International Psychogeriatrics,* 20:57-66.

Bennett, K.M. 2002. Low level social engagement as a precursor of mortality among people in later life. *Age and Aging,* 31:165-168.

Bherer, L., Kramer, A.F., Peterson, M.S., Colcombe, S., Erickson, K. and Becic, E. 2005. Training effects on dual-task performance: Are there age-related differences in plasticity of attentional control? *Psychology and Aging,* 20:695-709.

Bherer, L., Kramer, A.F., Peterson, M.S., Colcombe, S., Erickson, K. and Becic, E. 2006. Testing the limits of cognitive plasticity in older adults: Applications to attentional control. *Acta Psychologia,* 123:261-278.

Bissig, D. and Lustig, C. 2007. Who benefits from memory training? *Psychological Science,* 18:720-726.

Bond, G.E., Wolf-Wilets, V., Fiedler, F.E. and Burr, R.L. 2001. Computer-aided cognitive training of the aged: A pilot study. *Clinical Gerontologist,* 22:19-42.

Bor, D. and Owen, A.M. 2007. Cognitive training; Neural correlates of expert skills. *Current Biology,* 17:R95-97.

Boron, J.B., Turiano, N.A., Willis, S.L. and Schaie, K.W. 2007. Effects of cognitive training on change in accuracy in inductive reasoning training. *Journal of Gerontology Psychological Sciences,* 62:P179-186.

Boron, J.B., Willis, S.L. and Schaie, K.W. 2007. Cognitive training gain as a predictor of mental status. *Journal of Gerontology Psychological Sciences,* 62:P45-52.

Bottiroli, S., Cavallini, E. and Vecchi, T. 2007. Long-term effects of memory training in the elderly: A longitudinal study. *Archives of Gerontology and Geriatrics,* 11 [Epub ahead of print].

Brehmer, Y., Li, S-C., Müller, V., von Oertzen, T. and Lindenberger, U. 2007. Memory plasticity across the life span: Uncovering children's latent potential. *Developmental Psychology,* 43: 465-478.

Brehmer, Y., Li, S-C., Straube, B., Stoll, G., von Oertzen, T., Müller, V. and Lindenberger, U. 2008. Comparing memory skill maintenance across the life span: Preservation in adults, increase in children. *Psychology and Aging,* 23:227-238.

Briones, T.L., Klintsova, A.Y. and Greenough, W.T. 2004. Stability of synaptic plasticity in the adult rat visual cortex induced by complex environmental exposure. *Brain Research,* 1018:130-135.

Brookmeyer, R., Johnson, E., Ziegler-Graham, K. and Arrighi, H.M. 2007. Forecasting the Global Burden of Alzheimer's Disease. *Dementia 3*.3:186-191.

Brooks, J.O., Friedman, L. and Yesavage, J.A. 1993. A study of the problems older adults encounter when using a mnemonic technique. *International Psychogeriatrics,* 5:57-65.

Butler, R.N., Forette, F. and Greengross, B.S. 2004. Maintaining cognitive health in an ageing society. *Journal of the Royal Society of Health,* 124:119-121.

Cabeza, R. and Nyberg, L. 2000. Imaging cognition II: An empirical review of 275 PET and MRI studies. *Journal of Cognitive Neuroscience,* 12:1-47.

Carlson, M.C., Saczynski, J.S., Rebok, G.W., Seeman, T., Glass, T.A., McGill, S., Tielsch, J., Frick, K., Hill, J. and Fried, L.P. (in press). Exploring the effects of an "everyday" activity program on executive function and memory in older adults: Experience Corps®. *The Gerontologist,* 62:53-61.

Carretti, B., Borella, E. and De Beni R. 2007. Does strategic memory training improve the working memory performance of younger and older adults? *Experimental Psychology,* 54:311-320.

Carstensen, L.L. 1995. Evidence for a life-span theory of socioemotional selectivity. *Current Directions in Psychological Science,* 4:151-156.

Carstensen, L.L. 2006. The influence of a sense of time on human development. *Science,* 312:1913-1915.

Castel, A.D. 2008. Value-directed remembering and aging. In A.S. Benjamin and B.H. Ross (Eds), *Skill and Strategy in Memory Use,* 225-270. London: Academic Press.

Cavallini, E., Pagnin, A. and Vecchi, T. 2003. Aging and everyday memory: The beneficial effect of memory training. *Archives of Gerontology and Geriatrics,* 37:241-257.

Centers for Disease Control and Prevention and the Alzheimer's Association, 2007. *The Healthy Brain Initiative: A National Public Health Road Map to Maintaining Cognitive Health.* Chicago, IL: Alzheimer's Association.

Cervone, D., Artistico, D., and Beryy, J.M. 2006. Self-efficacy and adult development. In C.H. Hoare (Ed.), *Handbook of adult development and learning,* 169-195. London: Oxford University Press.

Christensen, H., Mackinnon, A.J., Korten, A.E., Jorm, A.F., Henderson, A.S., Jacomb, P. and Rodgers, B. 1999. An analysis of diversity in the cognitive performance of elderly community dwellers: individual differences in change scores as a function of age. *Psychology and Aging,* 13:365-379.

Chodosh, J., Seeman, T.E., Keeler, E., Sewall, A., Hirsch, S.H., Guralnik, J.M. and Reuben, D.B. 2004. Cognitive decline in high-functioning older persons is associated with an increased risk of hospitalization. *Journal of the American Geriatrics Society,* 52:1456-1462.

Colcombe, S. and Kramer, A.F. 2003. Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science,* 14:125-130.

Craik, F.I.M., Winocur, G., Palmer, H., Binns, M.A., Edwards, M., Bridges, K., Glazer, P., Chavannes, R. and Stuss, D.T. 2007. Cognitive rehabilitation in the elderly: Effects on memory. *Journal of the International Neuropsychological Society,* 13:132-142.

Dixon, R.A. and Gould, O.N. 1996. Adults telling and retelling stories collaboratively. In P. B. Baltes and U. M. Staudinger (Eds), *Interactive minds: Life-span perspectives on the social foundation of cognition,* 221–241. New York: Cambridge University Press.

Dixon, R.A., and Gould, O.N. 1998. Younger and older adults collaborating on retelling everyday stories. *Applied Developmental Science,* 2:160-171.

Dong, H., Goico, B., Martin, M., Csernansky, C.A., Bertchume, A. and Csernansky, J.G. 2004. Modulation of hippocampal cell proliferation, memory, and amyloid plaque deposition in APPsw (Tg2576) mutant mice by isolation stress. *Neuroscience,* 127:601-609.

Draganski, B., Gaser, C., Busch, V., Schuierer, G., Bogdahn, U. and May, A. 2004. Changes in grey matter induced by training. *Nature,* 427:311-312.

Dunlosky, J., Kubat-Silman, A.K. and Hertzog, C. 2003. Training monitoring skills improves older adults' self-paced associative learning. *Psychology and Aging,* 18:340-345.

Dunlosky, J., Cavallini, E., Roth, H., McGuire, C.L., Vecchi, T. and Hertzog, C. 2007. Do self-monitoring interventions improve older adult learning? *Journals of Gerontology: Series B,* 62B:70-76.

Edwards, J.D., Wadley, V.G., Myers, R.S., Roenker, D.L., Cissell, G.M. and Ball, K.K. 2002. Transfer of a speed of processing intervention to near and far cognitive functions. *Gerontology,* 48:329-340.

Edwards, J.D., Wadley, V.G., Vance, D.E., Roenker, D.L. and Ball, K.K. 2005. The impact of speed of processing training on cognitive and everyday performance. *Aging and Mental Health,* 9:1-10.

Elias. J.W. and Wagster, M.V. 2007. Developing context and background underlying cognitive intervention/ training studies in older populations. *Journal of Gerontology: Psychological Sciences, 62B Special Issue* I:5-10.

Erickson, K.I., Colcombe, S.J., Wadhwa, R., Bherer, L., Peterson, M.S., Scalf, P.E., Kim, J.S., Alvarado, M. and Kramer, A.F. 2007. Training-induced plasticity in older adults: Effects of training on hemispheric asymmetry. *Neurobiology and Aging,* 28:272-283.

Evans, D.A., Funkenstein, H.H., Albert, M.S., Scherr, P.A., Cook, N.R., Chown, M.J., Hebert, L.E., Hennekens, C.H. and Taylor, J.O. 1989. Prevalence of Alzheimer's disease in a community population of older persons. Higher than previously reported. *Journal of the American Medical Association,* 262:2551-2556.

Fabre, C., Masse-Biron, J., Chamari, K., Varray, A., Mucci, P. and Prefaut, C.H. 1999. Evaluation of quality of life in elderly healthy subjects after aerobic and/or mental training. *Archives of Gerontology and Geriatrics,* 28:9-32.

Fabre, C., Chamari, K., Mucci, P., Masse-Biron, J. and Prefaut, C. 2002. Improvement of cognitive function by mental and/or individualized aerobic training in healthy elderly subjects. *International Journal of Sports Medicine,* 23:415-421.

Fillit, H.M., Butler, R.N., O'Connell, A.W., Albert, M.S., Birren, J.E., Cotman, C.W., Greenough, W.T., Gold, P.E., Kramer, A.F., Kuller, L.H., Perls, T.T., Sahagan, B.G. and Tully, T. 2002. Achieving and maintaining cognitive vitality with aging. *Mayo Clinic Proceedings,* 77:681-696.

Floyd, M. and Scogin, F. 1997. Effects of memory training on the subjective memory functioning and mental health of older adults: a meta-analysis. *Psychology and Aging,* 12:150-161.

Frataglioni, L., Wang, H.X., Erickson, K., Maytan, M. and Winblad, B. 2000. Influence of social network on occurrence of dementia: a community-based longitudinal study. *Lancet,* 355:1315-1319.

Frataglioni, L., Paillard-Borg, S. and Winblad, B. 2004. An active and socially integrated lifestyle in late life might protect against dementia. *Lancet Neurology,* 3:343-353.

Frick, K.D., Carlson, M.C., Glass, T.A., McGill, S., Rebok, G.W., Simpson, C. and Fried, L.P. 2004. Modeled cost-effectiveness of the Experience Corps® Baltimore based on a pilot randomized trial. *Journal of Urban Health,* 81:106-117.

Fried, L.P., Carlson, M.C., Freedman, M., Frick, K.D., Glass, T.A., McGill, S., Rebok, G., Seeman, T., Tielsch, J., Wasik, B. and Zeger, S. 2004. A social model for health promotion for an aging population: Initial evidence on the Experience Corps. *Journal of Urban Health,* 81:64-78.

Gillette, G.S., Abelian, V.K., Andrieu, S., Barberger, G. and Berr, C., Bonnefoy, M., Dartigues, J.F., de Groot, L., Ferry, M., Galan, P., Hercberg, S., Jeandel, C., Morris, M.C., Nourhashemi, F., Payette, H., Poulain, J.P., Portet, F., Roussel, A.M., Ritz, P., Rolland, Y. and Vellas, B. 2007. IANA task force on nutrition and cognitive decline with aging. *Journal of Nutrition, Health, and Aging,* 11:132-152.

Goldsmith, M. and Koriat, A. 2008. The strategic regulation of memory accuracy and informativeness. In A.S. Benjamin and B.H. Ross (Eds), *Skill and Strategy in Memory Use,* 1-53. London: Academic Press.

Gomez-Pinilla, F. 2008. The influences of diet and exercise on mental health through homesis. *Aging Research Review,* 7:49-62.

González-Gross, M., Marcos, A. and Pietrzik, K. 2001. Nutrition and cognitive impairment in the elderly. *British Journal of Nutrition,* 86:313-321.

Grandmaison, E. and Simard, M. 2003. A critical review of memory stimulation programs in Alzheimer's disease. *Journal of Neuropsychiatry and Clinical Neurosciences,* 15:130-144.

Greenwood, P.M. 2007. Functional plasticity in cognitive aging: Review and hypothesis. *Neuropsychology,* 21:657-673.

Günther, V.K., Schäfer, P., Holzner, B.J. and Kemmler, G.W. 2003. Long-term improvements in cognitive performance through computer-assisted cognitive training: A pilot study in a residential home for older people. *Aging and Mental Health,* 7:200-206.

Haslam, C., Gilroy, D., Black, S. and Beesley, T. 2006. How successful is errorless learning in supporting memory for high and low-level knowledge in dementia? *Neuropsychological Rehabilitation,* 16:505-536.

Hayslip, B., Maloy, R.M. and Kohl, R. 1995. Long-term efficacy with fluid ability intervention with older adults. *Journal of Gerontology: Psychological Sciences,* 50B:141-149.

Heckman, J.J. 2006. Skill formation and the economics of investing in disadvantaged children. *Science,* 30:1900-1902.

Hill, R.D., Sheikh, J.I. and Yesavage, J.A. 1988. Pretraining enhances mnemonic training in elderly adults. *Experimental Aging Research,* 14:207-211.

Hill, R.D., Yesavage, J.A., Seikh, J. and Friedman, L. 1989. Mental status as a predictor of response to memory training in older adults. *Educational Gerontology,* 15:633-639.

Holtzman, R.E., Rebok, G.W., Saczynski, J.S., Kouzis, A.C., Wilcox-Doyle, K., and Eaton, W.W. 2004. Social network characteristics and cognition in middle-aged and older adults. *The Journal of Gerontology: Psychological Sciences,* 59:278-284.

Hultsch, D.F., Hertzog, C., Small, B.J. and Dixon, R.A. 1999. Use it or lose it: engaged lifestyle as a buffer of cognitive decline in aging? *Psychology and Aging,* 14:245-263.

Imamizu, H., Higuchi, S., Toda, A. and Kawato, M. 2007. Reorganization of brain activity for multiple internal modes after short but intensive training. *Cortex,* 43:338-349.

Izquierdo-Porrera, A.M. and Waldstein, S.R. 2002. Cardiovascular risk factors and cognitive function in African Americans. *Journal of Gerontology: Psychological Sciences,* 57B:377-380.

Jancke, L., Gaab, N., Wustenberg, H., Scheich, H. and Heinze, H.J. 2001. Short-term functional plasticity in the human auditory cortex: an fMRI study. *Cognition and Brain Research,* 12:479-485.

Jennings, J.M. and Jacoby, L.L. 2003. Improving memory in older adults: Training recollection. *Neuropsychological Rehabilitation,* 13:417-440.

Jennings, J.M., Webster, L.M., Kleykamp, B.A. and Dagenbach, D. 2005. Recollection training and transfer effects in older adults: Successful use of a repetition-lag procedure. *Aging, Neuropsychology, and Cognition,* 12:278-298.

Jeong, Y.H., Park, C.H., Yoo, J., Shin, K.Y., Ahn, S.M., Kim, H.S., Lee, S.H., Emson, P.C. and Suh, Y.H. 2006. Chronic stress accelerates learning and memory impairments and increases amyloid deposition in APPV717I-CT100 transgenic mice, an Alzheimer's disease model. *FASEB,* 20:729-731.

Jobe, J.B., Smith, D.M., Ball, K., Tennstedt, S.L., Marsiske, M., Willis, S.L., Rebok G.W., Morris J.N., Helmers K.F., Leveck M.D. and Kleinman, K. 2001. ACTIVE: A cognitive intervention trial to promote independence in older adults. *Controlled Clinical Trials,* 22:453-479.

Jones, S., Nyberg, L., Sandblom, J., Stigsdotter Neely, A., Ingvar, M., Magnus Petersson K. and Bäckman, L. 2006. Cognitive and neural plasticity in aging: General and task specific limitations. *Neuroscience and Biobehavioral Review,* 30:864-871.

Kempermann, G, Kuhn, H.G. and Gage, F.H. 1998. Experience-induced neurogenesis in the senescent dentate gyrus. *Journal of Neuroscience,* 18:3206-3212.

Kliegl, R.K., Smith, J. and Baltes P.B. 1989. Testing the limits and the study of adult age differences in cognitive plasticity of a mnemonic skill. *Developmental Psychology,* 25:247-256.

Kliegl, R.K., Smith, J. and Baltes P.B. 1990. On the locus and process of magnification of age differences during mnemonic training. *Developmental Psychology,* 26:894-904.

Kramer, A.F., Larish, J.F. and Strayer, D.L. 1995. Training for attentional control in dual task settings: A comparison of young and old adults. *Journal of Experimental Psychology: Applied,* 1:50-76.

Kramer, A.F. and Willis, S.L. 2002. Enhancing the cognitive vitality of older adults. *Current Directions in Psychological Science,* 11:173-177.

Kramer, A.F., Erickson, K.I. and Colcombe, S.J. 2006. Exercise, cognition, and the aging brain. *Journal of Applied Physiology,* 101:1237-1242.

Kramer, A.F. and Erickson, K.I. 2007. Capitalizing on cortical plasticity: influence of physical activity on cognition and brain function. *Trends in Cognitive Science,* 11:342-348.

Lachman M.E. and Andreoletti, C. 2006. Strategy use mediates the relationship between control beliefs and memory performance for middle-aged and older adults. *Journal of Gerontology: Psychological and Social Sciences,* 61B:88-94.

Landau, S.M., Schumacher, E.H., Garavan, H., Druzgal, T.J. and D'Espisito, M.D. 2004. A functional MRI study of the influence of practice on component processes of working memory. *Neuroimage,* 22:211-221.

Langa, K.M., Chernew, M.E., Kabeto, M.U., Hertzog, A.R., Ofstedal, M.B., Willis, R.J., Wallace, R.B., Mucha, L.M., Straus, W.L. and Fendrick, A.M. 2001. National estimates of the quantity and cost of informal caregiving for the elderly with dementia. *Journal of General Internal Medicine,* 16:770-778.

Langbaum, J., Rebok, G.W., Bandeen-Roche, K and Carlson, M.C. (in press). Predicting memory training response patterns: Results from ACTIVE. *Journal of Gerontology: Psychological Sciences.*

Larson, E.B., Wang, L., Bowen, J.D. McCormick, W.C., Teri, L., Crane, P. and Kukull, W. 2006. Exercise is associated with reduced risk for incident dementia among persons aged 65 years of age and older. *Annals of Internal Medicine,* 144:73-81.

Lazarov, O., Robinson, J., Tang, Y.P., Hairston, I.S., Korade-Mirnics, Z., Lee, V.M., Hersh, L.B., Sapolsky, R.M., Mirnics, K. and Sisodia, S.S. 2005. Environmental enrichment reduces abeta levels and amyloid deposition in transgenic mice. *Cell,* 120:701-713.

Maguire, E.A., Spiers, H.J., Good, C.D., Hartley, T., Frakowiak, R.S.J. and Burgess, N. 2003. Navigation expertise and the human hippocampus: A structural brain imaging analysis. *Hippocampus,* 13:208-217.

Mahncke, H.W., Bronstone, A. and Merzenich, M.M. 2006. Brain plasticity and functional losses in the aged: Scientific bases for a novel intervention. *Progress in Brain Research,* 157:81-109.

Mahncke H.W., Connor B.B., Appelman, J., Ahsanuddin, O.N., Hardy, J.L., Wood, R.A., Joyce, N.M., Boniske, T., Atkins, S.M. and Merzenich, M.M. 2006. Memory enhancement in healthy older adults using a brain plasticity-based training program: A randomized, controlled study. *Proceedings of the National Academy of Sciences,*103:12523-12528.

Margrett, J.A. and Willis, S.L. 2006. In-home cognitive training with older married couples: Individual versus collaborative learning. *Aging, Neuropsychology, and Cognition,* 13:173-195.

McArdle, J.J. and Nesselroade, J.R. 2002. Growth curve analysis in contemporary psychological research. In J. Schinka and W. Velicer (Eds), *Comprehensive handbook of psychology: Vol. 2. Research methods in psychology,* 447-480. New York: Wiley.

McArdle, J.J. 2006. Latent curve analyses of longitudinal twin data using a mixed effects biometric approach. *Twin Research Human Genetics,* 9:343-359.

McCrory, P. 2007. Cheap solutions for big problems? *British Journal of Sports Medicine,* 41:545.

McDougall, G.J. 1999. Cognitive interventions among older adults. In J.J. Fitzpatrick (Ed). *Annual Review of Nursing Research,* 17:219-240. New York: Springer Publishing.

McDougall, G.J. 2002. Memory improvement in octogenarians. *Applied Nursing Research,* 15:2-10.

Mohs, R.C., Ashman, T.A., Jantzen, K., Albert, M., Brandt, J., Gordon, B., Rasmusson, X., Grossman, M., Jacobs, D. and Stern Y. 1998. A study of the efficacy of a comprehensive memory enhancement program in healthy elderly persons. *Psychiatry Research,* 77:183-195.

Morrell, R.W., Rager, R., Harley, J.P., Herrmann, D.J., Rebok, G.W. and Parenté, R. 2006. Developing an online intervention for memory improvement: The Sharper Memory Project. *Cognitive Technology,* 11:34-46.

Muthén, B., Brown, C.H., Masyn, K., Jo, B., Khoo, S., Yang, C., Wang, C.P., Kellam, S.P., Carlin, J.B. and Liao, J. 2002. General growth mixture modeling for randomized preventive interventions. *Biostatistics,* 3:459-475.

Nature Neuroscience. 2007. Exercising to keep aging at bay. *Nature Neuroscience,* editorial.

Neely, A.S. and Bäckman, L. 1995. Effects of multifactorial memory training in old age: Generalizability across tasks and individuals. *Journal of Gerontology: Psychological Sciences,* 50B:134-140.

Noice, H., Noice, T. and Staines, G. 2004. A short-term intervention to enhance cognitive and affective functioning in older adults. *Journal of Aging and Health,* 16:562-585.

Noice, H. and Noice, T. 2006. What studies of actors and acting can tell us about memory and cognitive functioning. *Current Directions in Psychological Science,* 15:14-18.

Nyberg, L., Sandblom, J., Jones, S., Stigsdotter Neely, A. S., Petersson, K. M., Ingvar, M., et al. 2003. Neural correlates of training-related memory improvement in adulthood and aging. *Proceedings of the National Academy of Sciences,* 100:13728-13733.

Nyberg, L. 2005. Cognitive training in healthy aging: A cognitive neuroscience perspective. In R. Cabeza, L. Nyberg, and D. Park (Eds), *Cognitive neuroscience of aging: Linking cognitive and cerebral aging,* 309-321. New York: Oxford University Press.

O'Hara, R., Brooks, J.O., 3rd, Friedman, L., Schröder, C.M., Morgan, K.S. and Kraemer, H.C. 2007. Long-term effects of mnemonic training in community-dwelling older adults. *Journal of Psychiatric Research,* 41:585-590.

Olesen, P.J., Westerberg, H. and Klingberg, T. 2004. Increased prefrontal and parietal activity after training of working memory. *Nature Neuroscience,* 7:75-79.

Oswald, W.D., Rupprecht, R., Gunzelmann, T. and Tritt, K. 1996. The SIMA-project: Effects of one year cognitive and psychomotor training on cognitive abilities of the elderly. *Behavioural Brain Research,* 78:67-72.

Oswald, W., Hagen, B., Rupprecht, R.. and Gunzelmann T. 2002. Maintaining and supporting independent living in old age (SIMA) Part XVII: Summary of long-term training effects. *Zeitschrift fur Gerontopschologie and Psychiatrie,* 15:13-31.

Paggi, K. and Hayslip, B. 1999. Mental aerobics: Exercises for the mind in later life. *Educational Gerontology,* 25:1-12.

Parisi, J.M., Greene, J., Morrow, D.G. and Stine-Morrow, E.A.L. 2007. The Senior Odyssey: Participant experiences of a program of social and intellectual engagement. *Activities, Adaptation and Aging,* 31:31-49.

Park, D.C., Gutchess, A.H., Meade, M.L. and Stine-Morrow, E.A.L. 2007. Improving cognitive functioning in older adults: Nontraditional approaches. *Journal of Gerontology: Psychological Sciences Social Sciences,* 62:Special I:45-52.

Plude, D.J. and Schwartz, L.K. 1996. The promise of compact-disc interactive technology for memory training with the elderly. In D. Herrmann, C. McEvoy, C. Hertzog, P. Hertel, and M. Johnson (Eds), *Basic and applied memory: New findings on the practical aspects of memory,* 333-342. Mahwah, NJ: Erlbaum.

Rapp, S., Brenes, G. and Marsh, A.P. 2002. Memory enhancement training for older adults with mild cognitive impairment: a preliminary study. *Aging & Mental Health,* 6:5-11.

Rasmusson, D.X., Rebok, G.W., Bylsma, F.W. and Brandt, J. 1999. Effects of three types of memory training in normal elderly. *Aging, Neuropsychology and Cognition,* 6: 56-66.

Rebok, G.W. and Balcerak, L.J. 1989. Memory self-efficacy and performance differences in young and old adults: The effect of mnemonic training. *Developmental Psychology,* 25:714-721.

Rebok, G.W., Rasmusson, D. X., Bylsma, F.W. and Brandt, J. 1997. Memory improvement tapes: How effective for elderly adults? *Aging, Neuropsychology and Cognition,* 4:304-311.

Rebok, G.W., Carlson, M.C. and Langbaum, J.B.S. 2007. Training and maintaining memory abilities in healthy older adults: Traditional and novel approaches. *Journal of Gerontology: Psychological Sciences Social Sciences,* 62: Special I: 53-61.

Reuter-Lorenz, P.A. 2002. New visions of the aging mind and brain. *Trends in Cognitive Sciences,* 6:393-400.

Roenker, D.L., Cissell, G.M., Ball, K.K., Wadley, V.G. and Edwards, J.D. 2003. Speed-of-processing and driving simulator training result in improved driving performance. *Human Factors,* 45:218-233.

Rosenzweig, M.R. and Benett, E.L. 1996. Psychobiology of plasticity: Effects of training and experience on brain and behavior. *Behavioural Brain Research,* 78:57-65.

Rozzini, L., Costardi, D., Chilovi, B.V., Franzoni, S., Trabucchi, M., and Padovani, A. 2007. Efficacy of cognitive rehabilitation in patients with mild cognitive impairment treated with cholinesterase inhibitors. *International Journal of Geriatric Psychiatry,* 22: 356-360.

Saczynski, J.S., Margrett, J.A. and Willis, S.L. 2004. Older adults' strategic behavior: Effects of individual versus collaborative cognitive training. *Educational Gerontology,* 30: 587-610.

Saczynski, J.S., Rebok, G.W., Whitfield, K.E. and Plude, D.J. 2004. Effectiveness of CD-ROM memory training as a function of within-session autonomy. *Cognitive Technology,* 9:24-32.

Saczynski, J.S., Pfeifer, L.A., Masaki, K., Korf, E.S., Laurin, D., White, L. Launer, L.J. 2006. The effect of social engagement on incident dementia: the Honolulu-Asia Aging Study. *American Journal of Epidemiology,* 163:433-440.

Saczynski J.S., Rebok, G.W., Whitfield, K.E. and Plude, D.L. 2007. Spontaneous production and use of mnemonic strategies in older adults. *Experimental Aging Research,* 33:273-294.

Salomon, G. and Perkins, D.N. 1989. Rocky roads to transfer: Rethinking mechanisms of a neglected phenomenon. *Educational Psychologist,* 24:113-142.

Salthouse, T.A., Schroeder, D.H. and Ferrer, E. 2004. Estimating retest effects in longitudinal assessments of cognitive functioning in adults between 18 and 60 years of age. *Developmental Psychology,* 40:813-822.

Salthouse, T. A. 2006. Mental exercise and mental aging: Evaluating the validity of the "use it or lose it" hypothesis. *Perspectives on Psychological Science,* 1:68-87.

Schaie, K.W. and Willis, S.L. 1986. Can decline in intellectual functioning be reversed? *Developmental Psychology,* 22:223-232.

Scogin, F. and Bienas, J.L. 1988. A three-year follow-up of older participants in a memory-skills training program. *Psychology and Aging,* 3:334-337.

Schupf, N., Tang, M.X., Albert, S.M., Costa, R., Andrews, H., Lee, J.H. and Mayeux, R. 2005. Decline in cognitive and functional skills increases mortality risk in nondemented elderly. *Neurology, 65:*1218-1226.

Seeman, T. E., Lusignolo, T. M., Albert, M. and Berkman, L. 2001. Social relationships, social support, and patterns of cognitive aging in healthy, high-functioning older adults: MacArthur studies of successful aging. *Health Psychology,* 20:243-255.

Shapira, N., Barak, A. and Gal, I. 2007. Promoting older adults' well-being through internet training and use. *Aging and Mental Health,* 11:477-484.

Sheikh, J.I., Hill, R.D. and Yesavage, J.A. 1986. Long-term efficacy of cognitive training for age-associated memory impairment: A six-month follow-up study. *Developmental Neuropsychology,* 2:413-421.

Shipley, B.A., Der, G., Taylor, M.D. and Deary, I.J. 2006. Cognition and all-cause mortality across the entire adult age range: health and lifestyle survey. *Psychosomatic Medicine,* 68:17-24.

Shumaker, S.A., Legault, C. and Coker, L.H. 2006. Behavior-based interventions to enhance cognitive functioning and independence in older adults. *Journal of the American Medical Association,* 296:2852-2854.

Singer, T., Lindnberger, U. and Baltes, P.B. 2003. Plasticity of memory for new learning in very old age: A story of major loss? *Psychology and Aging,* 18:306-317.

Sitzer D.I., Twamley, E.W. and Jeste, D.V. 2006. Cognitive training in Alzheimer's disease: A meta-analysis of the literature. *Acta Psychiatrica Scandanavia, 114:*75-90.

Small, B. J., Fratiglioni, L. and Backman, L. 2001. Canaries in a coal mine: cognitive markers of preclinical Alzheimer disease. *Archives of General Psychiatry,* 58:859-860.

Small, G.W., Silverman, D.H.S., Siddarth, P., Ercoli, L.M., Miller, K.J., Lavretsky, H., Wright, B.C., Bookheimer, S.Y., Barrio, J.R. and Phelps, M.E. 2006. Effects of a 14-day healthy longevity lifestyle program on cognition and brain function. *American Journal of Psychiatry,* 14:538-545.

Stern, Y., Albert, S., Tang, M. X. and Tsai, W.Y. 1999. Rate of memory decline in Alzheimer's disease is related to education and occupation: Cognitive reserve? *Neurology,* 53:1942-1947.

Stigsdotter, A. and Bäckman, L. 1989. Multifactorial memory training with older adults: How to foster maintenance of improved performance. *Gerontology,* 35:260-267.

.

Stigsdotter Neely, A. and Bäckman, L. 1993. Long-term maintenance of gains from memory training in older adults. Two 3½ year followup studies. *Journal of Gerontology,* 48:233-237.

Stine-Morrow, E.A., Parisi, J.M., Morrow, D.G., Greene, J. and Park, D.C. 2007. An engagement model of cognitive optimization through adulthood. *Journal of Gerontology. Series B, Psychological Sciences and Social Sciences,* 62:62-69.

Strain, L.A., Blandford, A.A., Mitchell, L.A. and Hawranik, P.G. 2003.Cognitively impaired older adults: Risk profiles for institutionalization. *International Psychogeriatrics,* 15:351-366.

Studenski, S., Carlson, M.C., Fillit, H., Greenough, W.T., Kramer, A. and Rebok, G.W. 2006. From bedside to bench: Does mental and physical activity promote cognitive vitality in late life? *Science Aging Knowledge Environment,*10:pe21.

Stuss, D.T., Robertson, I.H., Craik, F.I.M., Levine, D., Alexander, M.P., Black, S., Dawson, D., Binns, M.A., Palmer, H., Downey-lame, M. and Winocur, D. 2007. Cognitive rehabilitation in the elderly: A randomized trial to evaluate a new protocol. *Journal of the International Neuropsychological Society,* 13:120-131.

Swezy, R.W. and Llaneras, R.E. 1997. Models in training and instruction. In G. Salvendy (Ed). *Handbook of human factors and ergonomics,* 512-577. New York: Wiley.

Troyer, A.K., Murphy, K.J., Anderson, N.D., Moscovitch, M. and Craik, F.I.M. 2008. Changing everyday memory behaviour in amnestic mild cognitive impairment: A randomised controlled trial. *Neuropsychological Rehabilitation,* 18:65-88.

Unverzagt, F., Kasten, L., Johnson, K.E., Rebok, G.W., Marsiske, M., Koepke, K.M., Elias, J.W., Morris, J.N., Willis, S.L., Ball, K., Rexroth, D.F., Smith, D.M., Wolinsky, F.D. and Tennstedt, S.L. 2007. Effect of memory impairment on training outcomes in ACTIVE. *Journal of the International Neuropsychological Society,* 13:953-960.

Valenzuela, M.J., Jones, M., Wen, W., Rae, C., Graham, S., Shnier, R. and Sachdev, P. 2003. Memory training alters hippocampal neurochemistry in healthy elderly. *Neuroreport,* 14:1333-1337.

van Hooren, S.A.H., Valentijn, S.A.M., Bosma, H., Ponds, R.W.H.M., van Boxtel, M.P.J., Levine, B., Robertson, I. and Jolles, J. 2007. Effect of a structured course involving goal management training in older adults: A randomised controlled trial. *Patient Education and Counseling,* 65:205-213.

van Praag, H., Shubert, T., Zhao, C. and Gage, F.H. 2005. Exercise enhances learning and hippocampal neurogenesis in aged mice. *Journal of Neuroscience,* 21:8680-8685.

Verghese, J., Lipton, R. B., Katz, M. J., Hall, C. B., Derby, C. A., Kuslansky, G., Ambrose, A.F., Sliwinski, M. and Buschke, H. 2003. Leisure activities and the risk of dementia in the elderly. *New England Journal of Medicine,* 348:2508-2516.

Verhaeghen, P., Marcoen, A. and Goosens, L. 1992. Improving memory performance in the aged through mnemonic training: A meta-analytic study. *Psychology and Aging,* 7:242-251.

Verhaeghen, P. and Marcoen, A. 1996. On the mechanisms of plasticity in young and older adults after instruction in the method of loci: Evidence for an amplification model. *Psychology and Aging,* 11:164-178.

Wadley, V.G., Benz, R.L., Ball, K.K., Roenker, D.L., Edwards, J.D. and Vance, D.E. 2006. Development and evaluation of home-based speed-of-processing training for older adults. *Archives of Physical Medicine and Rehabilitation,* 87:757-763.

Wang, H.X., Karp, A., Winblad, B. and Fratiglioni, L. 2002. Late-life engagement in social and leisure activities is associated with a decreased risk of dementia: a longitudinal study from the Kungsholmen project. *American Journal of Epidemiology,* 155:1081-1087.

West, R.L. and Crook, T.H. 1992. Video training and imagery for mature adults. *Applied Cognitive Psychology,* 6:307-320.

West, R.L., Thorn, R.M. and Bagwell, D.K. 2003. Memory performance and beliefs as a function of goal setting and aging. *Psychology and Aging,* 18:111-125.

West, R.L., Bagwell, D.K. and Dark-Freudeman, A. 2008. Self-efficacy and memory aging: The impact of a memory intervention based on self-efficacy. *Aging Neuropsychology and Cognition,* 15:302-329.

Willis, S.L., Bliezner, R. and Baltes, P.B. 1981. Intellectual training research in aging: Modification of performance on the fluid ability of figural relations. *Journal of Educational Psychology,* 73:41-50.

Willis, S.L. and Nesselroade, C.S. 1990. Long-term effects of fluid ability training in old-old age *Developmental Psychology,* 26:905-910.

Willis, S.L. and Schaie, K.W. 1994. Cognitive training in the normal elderly. In F. Forette, Y. Christen, and F. Boller (Eds), *Plasticité cerebral et stimulation cognitive* [Cerebral Plasticity and Cognitive Stimulation]. Paris: Fondation Nationale de Gérontologie.

Willis, S.L., Tennstedt, S.L., Marsiske, M., Ball, K., Elias, J., Koepke, K.M., Morris, J.N., Rebok, G.W., Unverzagt, F.W., Stoddard, A.M. and Wright, E. 2006. Long-term effects of cognitive training on everyday functional outcomes in older adults. *Journal of the American Medical Association,* 296:2805-2814.

Wilson, R.S., Bennett, D.A., Beckett, L.A., Morris, M.C., Gilley, D.W., Bienias, J.L., Scherr, P.A. and Evans, D.A. 1999. Cognitive activity in older persons from a geographically defined population. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences,* 54:155-160.

Wilson, R.S., Mendes de Leon, C.F., Barnes, L.L., Schneider, J.A., Bienias, J.L., Evans, D.A. and Bennett, D.A. 2002. Participation in cognitively stimulating activities and risk of incident Alzheimer disease. *Journal of the American Medical Association,* 287:742-748.

Wolinsky, F.D., and Miller, D. 2006. Disability concepts and measurement: contributions of the epidemiology of disability to gerontological inquiry. In J. Wilmoth and K. Ferraro (Eds), *Gerontology: Perspectives and issues, 3rd edition.* New York: Springer Publishing Company.

Wolinsky, F.D., Unverzagt, F.W., Smith, D.M., Jones, R., Stoddard, A. and Tennstedt, S.L. 2006a. The ACTIVE cognitive training trial and health-related quality of life: Protection that lasts for 5 years. *Journal of Gerontology: Biological Sciences,* 61:1324-1329.

Wolinsky, F.D., Unverzagt, F.W., Smith, D.M., Jones, R., Wright, E. and Tennstedt, S.L. 2006b. The effects of the ACTIVE cognitive training trial on clinically relevant declines in health-related quality of life. *Journal of Gerontology: Social Sciences,* 61: S281-S287.

Yang, L., Krampe, R.T. and Baltes, P.B. 2006. Basic forms of cognitive plasticity extended into the oldest-old: Retest learning, age, and cognitive functioning. *Psychology and Aging,* 21:372-378.

Yesavage, J.A. 1985. Nonpharmacologic treatments for memory losses with normal aging. *American Journal of Psychology,* 142:600 605.

Yesavage, J., Hoblyn, J., Friedman, L., Mumenthaler, M., Schneider, B. and O'Hara, R. 2007. Should one use medications in combination with cognitive training: If so, which ones? *Journal of Gerontology: Psychological Sciences,* 62B:Special I:11-18.

All the reports and papers produced by the
Foresight Mental Capital and Wellbeing Project may be downloaded from the Foresight website
(www.foresight.gov.uk).
Requests for hard copies may also be made through this website.

First published September 2008.

The Government Office for Science.