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Promotion of cognitive health through cognitive activity in the aging population

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Abstract

There is both popular and scientific interest in keeping the brain young and avoiding cognitive impairment and dementia. Older adults may be able to modify their cognitive health status through certain health behaviors. The aim of this review is to highlight the potential impact that cognitive activity may have on cognitive health outcomes in late life. Evidence from observational studies and randomized, controlled trials suggests that engagement in activities that are cognitively stimulating is beneficial to cognitive functioning. There are many issues and questions that need to be addressed before specific recommendations can be made at the population level or to individual patients. However, older adults should be encouraged to stay active and to try new and challenging activities in general to promote their cognitive and overall health.

Keywords

cognitive activity; cognitive aging; cognitive impairment; cognitive intervention; cognitive stimulation; cognitive training; dementia; mild cognitive impairment; mental stimulation

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The health of the brain, similar to that of the heart, is increasingly being recognized as influenced by our lifestyle and environment. The idea that older adults can modify their risk for cognitive impairment and dementia is quite appealing given the looming public health crisis of dementia in the coming decades. The sale of books, computer programs and games claiming to increase 'brain fitness' or to 'keep the brain young' has exploded in recent years, demonstrating the public's desire to maintain their brain and cognitive faculties as they age. However, empirical evidence supporting or refuting these claims is only emerging.

Several modifiable factors, including cognitive activity, exercise, vascular health and diet and nutrition, are being studied regarding their potential to reduce the risk of cognitive impairment and dementia [1,2]. The potential utility of a cognitive activity approach is considered to be underappreciated since it may be the most direct pathway for improving cognitive health outcomes via a spectrum of biological changes in brain structure and function [3]. The purpose of this review is to highlight cognitive activity as a promising nonpharmacological method for maximizing cognitive health in old age. First, the spectrum of cognitive health in old age is presented. Second, the theoretical background supporting cognitive activity is reviewed, followed by evidence from select observational studies and randomized, controlled trials (RCTs) of cognitive activity. Finally, a discussion of some important issues that should be considered when evaluating this evidence and designing future studies is presented.

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Spectrum of cognitive health in late life

Where older adults are on the spectrum of cognitive abilities in late life has important implications with regard to the effect that cognitive activity participation in everyday life or specific preventative/intervention approaches may have on cognitive health. This section reviews the three levels of cognitive functioning that are recognized in older adults: normative cognitive aging, mild cognitive impairment (MCI) and dementia. It is of note that this delineation is somewhat arbitrary, with cognitive declines falling along a continuum.

Normative cognitive aging

Although determining what changes can be expected as part of the normal aging process is still an active area of inquiry, in general, two patterns of change occur in cognitive functioning during the course of adult development. Some abilities remain relatively stable into old age, while others follow a trajectory of decline [4]. Verbal abilities, including vocabulary, information and comprehension, are those that typically show minimal decline until very old age. Abilities such as speed of processing, memory, spatial ability and reasoning tend to decline more with aging. Importantly, these declines do not substantially affect the ability of older adults to perform activities of daily living. Older adults who experience normative cognitive changes are able to remain independent in the absence of any other conditions causing physical or mental disability.

Mild cognitive impairment

Mild cognitive impairment is an intermediate state between normal cognitive aging and dementia, where individuals experience cognitive deficits that are greater than expected for their age but do not fulfill the diagnostic criteria for dementia [5]. Other terms are also used to describe this state, such as age-associated memory impairment [6], age-related cognitive decline [6], age-associated cognitive decline [7] and cognitive impairment no dementia [8]. MCI is associated with a heightened risk of progression to dementia [9], although many individuals with MCI remain stable or even revert back to normal status [10]. The prevalence of MCI varies widely from 3 to 54% depending on the criteria used to define it and how it is put into operation [11]. In addition, whether the study was conducted in a clinical or community-based setting can also affect the prevalence, with estimates from community-based studies generally being lower [12]. Recent studies suggest that MCI patients experience subtle deficits in everyday functioning [13] and have mood disturbances [14].

Dementia

Dementia is a chronic syndrome characterized by acquired cognitive deficits in more than one cognitive domain, currently including memory, that are severe enough to affect daily (social and occupational) functioning, do not occur solely in the context of delirium and cannot be fully accounted for by another mental disorder [15]. Alzheimer's disease (AD) is the most common subtype of dementia, followed by vascular dementia and mixed dementias with both degenerative and vascular pathology. Approximately 35.6 million individuals are expected to be affected by dementia worldwide in 2010, with the prevalence expected to double every 20 years to over 100 million in 2050 [[101]]. Dementia poses a large burden for families and society owing to the level of care that is necessary throughout the disease process. In the mild stage, those with dementia may need supervision in order to prevent accidents (e.g., leaving the stove turned on) and help with complex activities of daily living such as managing medication and finances. As the disease progresses, individuals lose the ability to perform basic activities of

[101]Alzheimer's Disease International: World Alzheimer report 2009, executive summary www.alz.co.uk/research/files/World%20Alzheimer%20Report%20Executive%20Summary.pdf.

daily living, including dressing, bathing and toileting, are no longer able to speak or comprehend language, and experience personality changes [16].

Environmental complexity & cognitive reserve

Two theoretical perspectives, environmental complexity and cognitive reserve, may provide explanations as to how cognitive activity affects the expression of cognitive impairment. Although they originated from different empirical roots – the sociology of work and brain injury, respectively – together, they provide complimentary explanations of how cognitive activity may benefit the cognitive system at both the psychosocial (environmental complexity) and neurophysiologic (cognitive reserve) levels, allowing individuals to compensate for age-related brain changes or disease pathology and to not outwardly express symptoms of cognitive impairment or dementia [17].

Environmental complexity

Simply stated, the environmental complexity hypothesis suggests that complex environments have a positive effect on cognitive functioning and simple environments have a negative effect on cognitive functioning. More specifically, the complexity of an environment is a function of the diversity of the stimuli, the number of decisions required, the number of considerations that need to be taken into account when making decisions and the ill-defined and apparently contradictory contingencies resulting from these decisions. Accordingly, complex environments are expected to reward cognitive effort, where individuals should be motivated to develop their intellectual capacities and to apply their use to other situations. Continued exposure to relatively simple environments may have the opposite effect, since the low level of environmental demand does not foster the development or maintenance of intellectual functioning [18].

Cognitive reserve

The concept of cognitive reserve has been proposed to explain the heterogeneity in clinical outcomes between individuals who have similar neural deficits related to disease pathology or normal age-related brain changes. Two types of cognitive reserve have been proposed to describe this variation: passive and active [19]. The passive model of reserve suggests that neuron and synapse number or brain size provide the basis for reserve, which is consequently determined primarily by genetics but may be influenced, to some degree, by environmental influences. The active model of reserve, more commonly know as ‘cognitive reserve’, is more concerned with neural processing and synaptic organization than neuroanatomical differences. Neural processing and synaptic organization are more sensitive to environmental influences; therefore, it is these changes that provide the greatest potential for increasing reserve. It is likely to be a combination of active and passive reserve that provides the most comprehensive explanation of the cognitive variation between individuals at the neurophysiologic level.

Support for the cognitive reserve hypothesis at the neural level has been demonstrated in animal models and in humans [3]. Studies in rodents have shown that mental exercise induces neuro genesis and synaptogenesis, increases hippocampal synaptic reactivity, enhances cerebrovasculature and reduces brain β-amyloid deposition. Human studies have suggested that cognitive activity may lead to a reorganization of neurocognitive networks, attenuate the adverse effects of stress hormones on the brain and increase activity in brain regions (i.e., prefrontal cortical regions) subserving executive functioning [20].

Empirical studies of cognitive activity & late-life cognitive health

The field of gerontology has long recognized the importance of older adults remaining actively involved with the environment for a variety of health outcomes [21]. Activities that require cognitive effort (e.g., reading, hobbies or learning a new language) may be especially important for cognitive health. By increasing the complexity of the environment, these activities may increase cognitive reserve. In general, there appears to be support for a positive association between cognitive activity and cognitive functioning in late life. This section will review the most methodologically sound observational studies and RCTs conducted in this area to date.

Observational studies of cognitive activity

Prospective studies of cognitive activity and risk of cognitive impairment and dementia have generally found that more frequent participation in cognitive activity is associated with a reduced rate of cognitive decline [22,23] and a reduced risk of cognitive impairment [24,25], dementia [26-28] and AD [29,30]. The most informative data comes from studies that used sophisticated techniques that allow for the direct assessment of the temporal order among the variables tested and studies that assessed lifestyle activities across the life course. For example, Ghisletta and colleagues examined whether changes in lifestyle activities led to a change in cognitive functioning or whether changes in cognitive functioning led to a change in lifestyle activities using a bivariate dual change score model approach [23]. The results of the study revealed that increased frequency of participation in media- (e.g., listening to the radio or watching television) and leisure- (e.g., playing games or doing crossword puzzles) type activities was associated with less decline in perceptual speed, but that cognitive performance did not influence change in cognitive activity. This finding provides increased confidence that higher engagement in cognitive activities leads to less cognitive decline, rather than cognitive decline leading to lower activity levels. A life course approach was taken by Wilson and colleagues to examine how participation in cognitively stimulating activities measured at 6, 12, 18 and 40 years of age, and current age, was related to function in different cognitive systems [31]. They found that more frequent participation in activities across the lifespan was related to better perceptual speed, visuospatial ability and semantic memory, but not to episodic memory or working memory. Additional evidence from prospective studies using twin pairs discordant for dementia to assess participation in leisure activities in midlife also supports a protective role of higher engagement against dementia [32] and AD [33]. There are studies that have reported no association between cognitive activities and cognition in older adults [34-36], but methodological limitations may explain these null associations [17].

Randomized, controlled studies of cognitive activity

The benefits of engaging in a cognitively stimulating leisure activity seen in observational studies has prompted cognitive intervention trials that are designed to stimulate cognitive functioning. One of the main objectives of these RCTs is to establish whether there is a causal relationship, since a major problem in the interpretation of most observational study findings is the inability to distinguish cause from consequence (i.e., does engagement in cognitively stimulating activity lead to better cognitive health outcomes or does poor cognitive health lead to less engagement in cognitive activity?). Three types of cognitive interventions have been described: cognitive stimulation, cognitive training and cognitive rehabilitation [37]. Cognitive stimulation involves a broad range of activities, typically in a group setting, with the goal of enhancing general cognitive and social functioning. Cognitive training is a more specific approach in which repeated training is carried out on a set of structured tasks that target one or more specific cognitive domains (e.g., attention, memory and executive functioning). Cognitive rehabilitation has been broadly defined as ‘any intervention strategy or technique that intends to enable clients or patients and their families to live with, manage, bypass, reduce or come to terms with deficits precipitated by injury to the brain’ [38]. Pathology-associated dementia would be considered injury to the brain. Since the primary goal of cognitive rehabilitation is to provide support for everyday functioning in those who are already experiencing cognitive deficits, the focus of this review is on cognitive stimulation and training studies. The reader is referred to a Cochrane review of cognitive rehabilitation and cognitive training for early-stage AD and vascular dementia [37].

Cognitive stimulation—Owing to the many methodological challenges in testing the types of cognitively stimulating activities measured in observational studies, only a few large-scale RCTs have been conducted to examine the efficacy of engaging in cognitively stimulating leisure activities. The Experience Corps (EC) [[102]] is the most well-known cognitive stimulation approach [39]. EC is a social health promotion model that targets older adults who are at a higher risk of poor health outcomes owing to their low educational attainment and socioeconomic status (SES). Participants in EC volunteer in the public school setting as tutors for elementary school-aged children. The activities involved in EC are designed to enhance physical, social and cognitive activity simultaneously. It has been demonstrated that EC participants show increased activity [38], improved executive function and memory [40], and enhanced brain activity in regions that are important for executive function [20] compared with their control counterparts. Another ‘everyday activity’ intervention is the Senior Odyssey program (University of Illinois, IL, USA) [41,[103]]. This program was designed to be ‘a community-based program that takes advantage of existing social structures’ by being modeled, in part, on the Odyssey of the Mind program (Creative Competitions, Inc., NJ, USA) for children and young adults. Participants in the Senior Odyssey program work together in teams to solve selected problems, exercising basic cognitive processes, decision making, creativity and evaluation of ideas in a friendly, competitive environment. Postintervention assessments revealed that compared with controls, participants who were randomly assigned to the program performed better on a composite measure of fluid ability and in the specific domains of speed, inductive reasoning and divergent thinking, but not in working memory or visuospatial ability. Taken together, these two programs offer promise that an ‘everyday’ cognitive stimulation approach may improve cognitive health in older adults that are cognitively unimpaired.

Studies are needed to examine the efficacy of everyday cognitive stimulation in decreasing the likelihood of developing cognitive impairment and dementia. In addition, there have been no RCTs that have examined an everyday cognitive stimulation intervention in older adults with MCI to examine whether the cognitive deficits and associated impairments can be improved or stabilized.

Cognitive training—The largest cognitive training study conducted is the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) trial [42]. In this study, unimpaired, community-dwelling older adults were trained in one of four cognitive areas (i.e., memory, reasoning, speed of processing and control) during ten group sessions over a period of 5–6 weeks, with four booster sessions at 11 and 35 weeks postintervention in a subsample of participants. Assessment of cognitive and functional measures at the 2- and 5-year follow-ups revealed improvement in the domains trained and less self-reported decline in instrumental activities of daily living functioning with reasoning training [43]. Recently, computer-based cognitive training formats have started being tested. One such example is the Improvement in Memory with Plasticity-Based Adaptive Cognitive Training (IMPACT) study, a large RCT using the Brain Fitness Program from Posit Science (San Francisco, CA, USA) [44]. This program consists of six computerized exercises designed to improve the speed and accuracy of auditory information processing. Initial results of this trial comparing pre- and postassessment scores suggest that the experimental program improved performance in untrained tests of memory and attention relative to the active control condition. The positive

[102]Experience Corps: National Office: 2120 L Street NW, Suite 610, Washington, DC 20037 (2010) www.experiencecorps.org
[103]Senior Odyssey: The Adult Learning Lab, Beckman Institute and the College of education at the University of Illinois at Urbana-Champaign (2008) www.seniorodyssey.org

findings of these two examples of cognitive training studies are supported by a systematic review of the effect of cognitive training RCTs in healthy older adults over time. Among seven trials meeting the inclusion entry for the analyses, including the ACTIVE trial, a strong effect size for cognitive training was found compared with the control conditions, and this effect persisted in studies with more than 2 years of follow-up [45].

Randomized, controlled cognitive training studies have also been conducted in older adults with MCI and dementia. In older adults with MCI, the majority of these studies report improvements in cognitive performance following training; for example, a 1-year cognitive motor intervention, consisting of cognitive exercise drills plus social and psychomotor activities, was compared with a psychosocial support control condition in individuals with MCI and early AD who were taking cholinesterase inhibitors (ChEIs). The authors found that those in the intervention group maintained their cognitive status after 6 months, whereas the control group showed declines in cognitive status [46]. Two computer-based cognitive training studies have also demonstrated improved cognitive abilities in individuals with MCI. The first study was designed to stimulate memory, language, abstract reasoning and visuospatial abilities in those with MCI taking ChEIs. The findings revealed that memory and abstract reasoning improved more in the cognitive training plus ChEI treatment group compared with those on ChEI treatment alone [47]. The second computer-based program was designed to improve auditory processing speed and found promising preliminary results, where those in the intervention group demonstrated greater, although not statistically significant, improvements in the Repeatable Battery for Assessment of Neuropsychological Status total score compared with the control group [48]. Each of these described RCTs was conducted with less than a total of 100 participants, so additional large-scale RCTs are necessary before the efficacy of cognitive training in MCI patients can be determined. Evidence in favor of cognitive training benefiting older adults with AD is mixed. A meta-analysis of 17 controlled studies revealed a medium overall effect size across the cognitive training strategies and cognitive domains tested. A medium effect size was also observed for other secondary outcomes including activities of daily living, depression and self-rated general functioning [49]. Conversely, a Cochrane review of cognitive training in AD came to the conclusion that there is ‘no evidence for the efficacy of cognitive training in improving cognitive functioning for people with mild-to-moderate AD’ [37]. Thus, it seems that those with MCI, and possibly AD, may benefit from cognitive training strategies, although additional studies are needed in these populations.

Considerations in the study of cognitive activity

While the studies conducted thus far seem to point to a beneficial effect of cognitive activity for cognitive health in later life, especially for healthy individuals, there are certain issues that should be considered when interpreting these results, as well as additional questions that need to be answered before specific recommendations can be made at the population level or to individual patients. First, limitations of observational studies can lead to misinterpretation and inconsistencies, and the findings from RCTs are generally more robust compared with observational studies. Second, there may be differences in the protective effects of cognitive activity depending on the etiology of the cognitive impairment, the current level of cognitive functioning or the stage of life. Finally, other characteristics (e.g., educational attainment, SES, apolipoprotein E [*APOE*] genotype and personality) may influence the potential for cognitive activity to improve cognitive health as well as other secondary outcomes such as everyday functioning.

Interpreting observational studies & randomized, controlled trials

The drive to confirm the findings of observational studies through RCTs necessitates that the basic strengths and limitations of each study design be reviewed. First, the strengths of observational study designs are the large number of participants (and clinical events) that can be included, that exposure–disease associations are studied under real-life conditions and that they are generally lower in cost. The major limitation is that risk estimates from observational studies do not necessarily imply a direct causal relationship. This is particularly problematic when studying cognitive health outcomes since observational studies cannot generally (except with very long follow-ups or sophisticated statistical analyses) distinguish whether higher engagement in cognitive activities actually prevented or lowered the risk of cognitive decline or dementia, or if lower engagement in cognitive activities resulted from declining cognition owing to aging or preclinical dementia. For this reason, the observed association should only be interpreted as a signal that suggests where there is an underlying mechanism to be explored. RCTs are conducted after there is sufficient evidence from observational studies to warrant the randomization of individuals to a treatment (e.g., drug or behavioral intervention) or control condition. Because causal associations can be tested, RCTs are considered the gold standard for testing the efficacy of treatments or interventions in health research. A limitation of RCTs is that they can often not be generalized to the population.

While the findings of RCTs are stronger than those of observational studies, the role of observational studies in discovering the what, when and how much, as well as generating hypotheses regarding potential biological mechanisms of certain behaviors that may enhance cognitive health in old age, should not be overlooked. In some cases, such as the life-course study of cognitive activity, the findings from observational studies cannot be tested in RCTs owing to practical or ethical reasons, and alternatives to the RCT may therefore be the gold standard [50]. It is also important to note that when there is a discrepancy between observational and interventional studies, it may not always be that the observational study results are incorrect. It may be that the experimental intervention was undertaken with the wrong exposure, the exposure may be in the causal pathway but may not be modifiable or the timing and duration of the exposure may have been critical in determining whether it leads to disease and when it may be modifiable. However, with that said, the findings of RCTs should take precedence over observational studies since the methodological strengths of RCTs better delineate the true causal risk factors from factors that may be a marker of the disease or moderate or mediate the association between a causal risk factor and cognitive health outcomes. Thus, researchers and clinicians should evaluate each type of study for its strengths and limitations when drawing conclusions regarding the utility of a particular cognitive activity strategy, noting that factors that are demonstrated to be protective in observational studies may not necessarily have a preventative effect when tested in RCTs.

Etiology of MCI & response to intervention

Efforts to better understand the syndrome of MCI are primarily related to its association with an increased rate of progression to AD. However, different etiologies are likely to explain symptoms associated with MCI, including mood disorders (e.g., major depression) and vascular disorders as well as other degenerative (e.g., frontotemporal dementia and Lewy body dementia) or comorbid conditions [5]. No studies have examined whether, for example, cognitive impairment associated with major depression responds differently to intervention therapies compared with cognitive impairment owing to a progressive brain disorder such as AD. The general assumption is that the latter would show less benefit. Future large RCTs need to test whether the efficacy of cognitive interventions targeting MCI vary as a function of etiology. At this time, physicians should be aware of the fact that patients with MCI may respond differently to cognitive intervention.

Timing of cognitive activity engagement

The cognitive activities reviewed here primarily fall into the categories of primary and secondary prevention. Briefly, primary prevention methods aim to keep older adults' levels of cognitive functioning within the 'normal' or 'mildly impaired' range and avoid the development of clinically expressed dementia. Secondary prevention would then identify those with early cognitive impairment (e.g., MCI) so interventions could be targeted in order to prevent further deterioration to dementia. Among the studies of cognitive activity that have been conducted, only the ACTIVE trial has shown benefits in both healthy participants and those with MCI [51]. Additional studies of cognitive activity are needed that include older adults across the cognitive continuum in order to determine if the same or similar strategies can be used in healthy, mildly impaired and dementia populations.

Another issue related to timing is that the extent to which cognitive activity benefits cognitive health outcomes may be specific to the stage of the life course. This is because the underlying pathological process of degenerative dementias probably begins many years before the clinical symptoms are expressed. Thus, whether cognitive activity is a true risk factor or a preclinical symptom (i.e., a contributing cause or an effect) of cognitive impairment or dementia can often be confusing, especially if there is insufficient time between the assessment of the cognitive activity and the onset of symptoms [52]. This is evidenced by the nonlinear or time-dependent association between hyper tension in observational studies [53] and hormone therapy in RCTs [54,55]. Thus, it is important to consider that the results of both observational and RCTs may be influenced by the stage of life at which the study was conducted. The general assumption is that cognitive stimulation across the entire life course is likely to be most beneficial and will follow a linear pattern, although this has not been empirically supported as of yet.

Other characteristics

The goal is to develop recommendations for cognitive activity that can be disseminated at the population level, but a more patient-centered approach may also be needed. Certain characteristics known to be associated with the likelihood of engaging in cognitive activities and with the risk of cognitive impairment and dementia will need to be considered. The characteristics include, but are not limited to, educational attainment [56], SES [56], *APOE* genotype [57] and personality [58]. These characteristics may affect the overall efficacy of cognitive activity by providing a baseline level of brain/cognitive reserve (e.g., educational attainment), determining access to cognitively stimulating activities (e.g., SES), limiting or enhancing the extent to which cognitive activity can increase reserve and cognitive functioning (e.g., *APOE* genotype) and influencing motivation and adherence to cognitive activity recommendations (e.g., personality). Further understanding of the role that these characteristics play will be an important step in tailoring cognitive activity recommendations.

Conclusion

Many older adults are at an increased risk of cognitive impairment and dementia owing to their genetic make-up or early life environment [59,60]. Since these influences cannot be modified, the search is on for effective strategies to prevent or slow the onset of cognitive impairments in these individuals. In addition, it is also important to find ways of keeping the cognition functioning of all older adults at an optimal level, regard-less of whether or not they are at a high risk for cognitive decline. Engagement in activities that stimulate cognitive functioning, be it through leisure or structured training tasks, is emerging as one of the most promising approaches to promote cognitive health with aging [61]. The environmental complexity and brain/cognitive reserve hypotheses offer explanations at the psychosocial and neurophysiologic levels for the effect of cognitive activity on cognitive functioning. Based on this review of select observational studies and RCTs, healthy and cognitively impaired older adults are likely to benefit from engaging in activities that ‘exercise the brain’. A number of considerations should be taken into account when evaluating studies of cognitive activity, including the study design (observational vs RCT), the underlying etiology of the cognitive impairment (e.g., degenerative, vascular, psychiatric or other illness), whether the cognitive activity strategy has been examined in older adults across the cognitive spectrum, the timing between the assessment of cognitive activity or intervention in relation to the cognitive outcome and other participant/patient characteristics such as education, SES, *APOE* genotype and personality that may influence the impact of cognitive activity on cognitive health.

So what recommendations can be made at this time regarding cognitive activity? The simple answer is that there is inadequate evidence to make any specific recommendations. Questions remain concerning which particular activities (i.e., what), timings (i.e., when), dosages (i.e., how much) and durations (i.e., how long) are most effective. Furthermore, this is likely to be highly individualized and to depend on a number of factors. However, the current evidence does support the general recommendation of encouraging adults to engage in activities that are new and challenging. This means that individuals who frequently engage in activities that are considered to be of high cognitive demand (e.g., reading or playing bridge) will need to do different activities that are novel and require active learning. With that said, until definitive studies have been conducted, physicians should avoid creating the false hope in their patients that they can avoid MCI and dementia by increasing their cognitive activity or, even worse, creating the misperception that patients are to blame for their cognitive problems.

Future perspective

In the future, large, well-designed RCTs based on a number of observational studies will need to be conducted in order to make evidence-based recommendations to the pubic and to individual patients about ways in which they can maintain their cognitive health with aging through cognitive activity. Observational studies will need to take advantage of existing longitudinal data and collect more detailed information in order to address questions related to the timing of cognitive activities, dosage, duration, specific types of activities, interactions between activities and level of cognitive demand. At the same time, the design and conduct of RCTs will need to be improved to tackle a number of challenges in this field, including those described in this review, and other issues such as increasing the sample size in order to achieve adequate power, more precisely defining the cognitive outcome, using active control conditions, adding sensitive performance or informant-based measures of everyday functioning, and including other secondary outcomes such as mood, perceived cognitive performance and quality of life measures [45].

A burgeoning area of investigation is related to the use of video games and other technologies by older adults. Given the increasing importance of using technology in everyday life (e.g., using the automated teller machine [ATM] or navigating websites for health information), cognitive stimulation strategies using technology may prove to be beneficial on a number of fronts [62]. Interactive video game play using the Nintendo Wii™ (Nintendo, WA, USA) is occuring across the country in senior centers, public libraries and retirement communities. Researchers are now beginning to explore how video games can contribute to improvement in cognitive functioning [[104]].

Executive summary

Introduction

- There is both popular and scientific interest in strategies to maximize cognitive health with aging.

[104]Gains Through Gaming Laboratory, Department of Psychology, North Carolina State University, Better cognition through video gaming www.gainsthroughgaming.org/

- Several modifiable factors (e.g., cognitive activity, physical exercise, diet and nutrition, and social engagement) are being studied for their potential to reduce the risk of cognitive impairment and dementia.
- Activities that are cognitively stimulating may be the most direct way to enhance cognitive health via structural and functional brain changes.

Spectrum of cognitive change with aging

- Declines in processing speed, memory and reasoning are typical with aging, with verbal abilities and comprehension generally being preserved into old age.
- Mild cognitive impairment (MCI) is an intermediate state between normal cognitive decline owing to aging and dementia. It is associated with an increased risk of dementia, but many older adults with MCI do not progress to dementia and may even improve their cognitive functioning over time.
- Dementia is a degenerative condition characterized by cognitive decline interfering with work, social and everyday functioning.

Environmental complexity & brain/cognitive reserve

- The environmental complexity hypothesis posits that complex environments have a positive effect on cognitive functioning and simple environments have a negative effect on cognitive functioning.
- The cognitive reserve theory suggests that complex environments benefit cognitive systems by increasing the efficiency of neural networks and producing redundancy within the network.
- The greater one’s reserve is, the more neuropathology associated with aging or brain disease can be tolerated without producing outward cognitive symptoms.

Empirical studies of cognitive activity

- Observational studies focusing on leisure activities, such as reading, hobbies, learning a new language or taking a course, support a positive association between cognitive activity and cognitive health.
- Cognitive interventions promoting cognitive health can be divided into the categories of cognitive stimulation and cognitive training.
- Cognitive stimulation involves a broad range of activities, typically in a group setting, with the goal to enhance general cognitive and social functioning. Experience Corps and Senior Odyssey (University of Illinois, IL, USA) are examples of cognitive stimulation programs. Each has observed improved cognitive functioning in program participants compared with control participants.
- Cognitive training is a more specific approach that includes repeated training on a set of structured tasks that target one or more specific cognitive domains. Results from the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) trial, the largest cognitive training trial to date, and other computer-based programs suggest that cognitive training can improve performance on trained and untrained cognitive tasks.

Considerations in the study of cognitive activity

- Observational studies and randomized controlled trials (RCTs) have strengths and weaknesses that should be considered when evaluating studies of cognitive activity and cognitive health. RCTs are considered the gold standard in testing the efficacy of interventions and treatments in health research since causal relations can be examined.

- MCI is a heterogeneous condition in which symptoms can result from degenerative, psychiatric, vascular and other illnesses. It is unclear how different etiologies of MCI respond to cognitive interventions.
- The insidious development of dementia can lead to confusion as to whether cognitive activity is a true risk factor or a preclinical symptom (i.e., a contributing cause or an effect) of cognitive impairment or dementia.
- Studies are needed that assess the efficacy and effectiveness of cognitive interventions across the cognitive continuum.
- Other participant/patient characteristics, such as educational attainment, socioeconomic status, *APOE* genotype and personality, should be considered when studying cognitive activity in research studies or making recommendations about cognitive activity to patients.

Conclusion

- Engagement in cognitively stimulating activities has demonstrated promise in the promotion of cognitive health with aging.
- At this time, there is inadequate evidence to make specific recommendations. In general, older adults should be encouraged to engage in new and challenging activities.
- Physicians should communicate to their patients that there is no guarantee that engaging in cognitive activities will prevent or delay MCI or dementia.

Future perspective

- Both observational studies and RCTs are needed to establish a definitive connection between cognitive activity and cognitive health in late life.
- Studying video games and technology is a new area that may demonstrate positive effects on cognitive health outcomes with aging.
- Including neuroimaging in studies of cognitive activity will provide new knowledge of the underlying mechanisms and help target intervention approaches.

A more complete picture of the role of cognitive activity in cognitive health will also be drawn using neuroimaging techniques such as functional MRI. Measuring changes in the brain in response to cognitive interventions is already being carried out in studies such as EC [20]. Knowledge of the correspondence between cognitive activity and patterns of brain activation will permit the development of more targeted cognitive interventions. In these neuroimaging studies, as well as in all future studies, a multidisciplinary collaborative effort will be necessary.

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Bibliography

Papers of special note have been highlighted as:

• of interest

•• of considerable interest

1. Andel R, Hughes TF, Crowe MG. Strategies to reduce the risk of cognitive decline and dementia. Aging Health 2005;1:107–116.
2. Hughes TF, Ganguli M. Modifiable midlife risk factors for cognitive impairment and dementia in late life. Curr. Psychiatry Rev 2009;5:73–92. [PubMed: 19946443]
3. Valenzuela MJ, Breakspear M, Sachdev P. Complex mental activity and the aging brain: molecular, cellular, and cortical network mechanisms. Brain Res. Rev 2007;56:198–213. [PubMed: 17870176] • Comprehensive summary of the neurological mechanisms underlying the association between cognitive activity and cognitive health outcomes in late life.
4. Salthouse TA. Mental exercise and mental aging: evaluating the validity of the 'use it or lose it' hypothesis. Perspect. Psychol. Sci 2006;1:68–87. • Concludes that there is little empirical evidence for cognitive activity as a strategy to promote cognitive health.
5. Winblad B, Palmer K, Kivipelto M, et al. Mild cognitive impairment – beyond controversies, towards a consensus: report of the International Working Group on Mild Cognitive Impairment. J. Intern. Med 2004;256:240–246. [PubMed: 15324367]
6. Crook T, Bartus RT, Ferris SH, Whitehouse P, Cohen GD, Gershon S. Age-associated memory impairment: proposed diagnostic criteria and measures of clinical change: report of the National Institute of Mental Health Work Group. Dev. Neuropsychol 1986;2:261–276.
7. Levy R. Aging-associated cognitive decline. Working part of the International Psychogeriatric Association in collaboration with the World Health Organization. Int. Psychogeriatr 1994;6:63–68. [PubMed: 8054494]
8. Ritchie K, Artero S, Touchon J. Classification criteria for mild cognitive impairment: a poplation-based validation study. Neurology 2001;56:37–42. [PubMed: 11148233]
9. Hsiung GY, Donald A, Grand J, et al. Outcomes of cognitively impaired not demented at 2 years in the Canadian Cohort Study of Cognitive Impairment and Related Dementias. Dement. Geriatr. Cogn. Disord 2006;22:413–420. [PubMed: 16966831]
10. Ganguli M, Dodge HH, Shen C, DeKosky ST. Mild cognitive impairment, amnestic type: an epidemiologic study. Neurology 2004;63:115–121. [PubMed: 15249620]
11. Decarli C. Mild cognitive impairment: prevalence, prognosis, aetiology, and treatment. Lancet Neurol 2003;2:15–21. [PubMed: 12849297]
12. Farias ST, Mungas D, Reed BR, Harvy D, DeCarli C. Progression of mild cognitive impairment to dementia in clinic- vs community-based cohorts. Arch. Neurol 2009;66:1151–1157. [PubMed: 19752306]
13. Farias ST, Mungas D, Reed BR, Harvy D, Cahn-Weiner D, DeCarli C. MCI is associated with deficits in everyday functioning. Alzheimer Dis. Assoc. Disord 2006;20:217–224. [PubMed: 17132965]
14. Butters MA, Young JB, Lopez O, et al. Pathways linking late-life depression to persistent cognitive impairment and dementia. Dialogues Clin. Neurosci 2008;10:345–57. [PubMed: 18979948]
15. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders (4th Edition – Text Revision). American Psychiatric Associations; Washington, DC, USA: 2000.
16. Sloane PD, Zimmerman S, Suchindran C, et al. The public health impact of Alzheimer's disease, 2000–2050: potential implication of treatment advances. Annu. Rev. Public Health 2002;23:213–231. [PubMed: 11910061]
17. Small, BJ.; Hughes, TF.; Hultsch, DF.; Dixon, RA. Lifestyle activities and late-life changes in cognitive performance. In: Stern, Y., editor. Cognitive Reserve: Theory and Application. Taylor & Francis; PA, USA: 2007. p. 173-186.
18. Schooler C. Psychological effects of complex environments during the life span: a review and theory. Intelligence 1984;8:259–281.

19. Stern Y. Cognitive reserve. Neuropsychologia 2009;47:2015–2028. [PubMed: 19467352]

20. Carlson MC, Erickson KI, Kramer AF, et al. Evidence for neurocognitive plasticity in at-risk older adults: the Experience Corps Program. J. Gerontol. A Biol. Sci. Med. Sci 2009;64:1275–1282. [PubMed: 19692672]

21. Rowe JW, Kahn RL. Successful aging. Gerontologist 1997;37:443–440.

22. Wilson RS, Bennett DA, Bienias JL, Mendes de Leon CF, Morris MC, Evans DA. Cognitive activity and cognitive decline in a biracial community population. Neurology 2003;61:812–816. [PubMed: 14504326]

23. Ghisletta P, Bickel JF, Lövdén M. Does activity engagement protect against cognitive decline in old age? Methodological and analytical considerations. J. Gerontol. B Psychol. Sci. Soc. Sci 2006;61:P253–P261. [PubMed: 16960228] •• Uses the dual change score model approach to examine the temporal order of the association between cognitive activity and cognitive performance.

24. Wang JY, Zhou DH, Li J, et al. Leisure activity and risk of cognitive impairment: the Chongqing Aging Study. Neurology 2006;66:911–913. [PubMed: 16291928]

25. Verghese J, LeValley A, Derby C, et al. Leisure activities and the risk of amnestic mild cognitive impairment in the elderly. Neurology 2006;66:821–827. [PubMed: 16467493]

26. Karp A, Paillard-Borg S, Wang H-X, Silverstein M, Winblad B, Fratiglioni L. Mental, physical, and social components in leisure activities equally contribute to decrease dementia risk. Dement. Geriatr. Cogn. Disord 2006;21:65–73. [PubMed: 16319455]

27. Wang H-X, Karp A, Winblad B, Fratiglioni L. Late-life engagement in social and leisure activities is associated with a decreased risk of dementia: a longitudinal study from the Kungsholmen Project. Am. J. Epidemiol 2002;155:1081–1087. [PubMed: 12048221]

28. Verghese J, Lipton RB, Katz MJ, et al. Leisure activities and the risk of dementia in the elderly. N. Engl. J. Med 2003;348:2508–2516. [PubMed: 12815136]

29. Wilson RS, Bennett DA, Bienias JL, et al. Cognitive activity and incident AD in a population-based sample of older adults. Neurology 2002;59:1910–1914. [PubMed: 12499482]

30. Wilson RS, Scherr PA, Schneider JA, Tang Y, Bennett DA. Relation of cognitive activity to risk of developing Alzheimer disease. Neurology 2007;69:1911–1920. [PubMed: 17596582]

31. Wilson RS, Barnes LL, Bennett DA. Assessment of lifetime participation in cognitively stimulating activities. J. Clin. Exp. Neuropsychol 2003;25:634–642. [PubMed: 12815501]

32. Carlson MC, Helms MJ, Steffens DC, Burke JR, Potter GG, Plassman BL. Midlife activity predicts risk of dementia in older male twin pairs. Alzheimers Dement 2008;4:324–331. [PubMed: 18790459]

33. Crowe M, Andel R, Pedersen NL, Johansson B, Gatz M. Does participation in leisure activities lead to reduced risk of Alzheimer's disease? A prospective study of Swedish twins. J. Gerontol. B Psychol. Sci. Soc. Sci 2003;58B:P249–P255. [PubMed: 14507930]

34. Aartsen MJ, Smits CHM, van Tillburg T, Knipscheer KCPM, Deeg DJH. Activity in older adults: cause or consequence of cognitive functioning? A longitudinal study on everyday activities and cognitive performance in older adults. J. Gerontol. B Psychol. Sci. Soc. Sci 2002;57B:P153–P162. [PubMed: 11867663]

35. Mackinnon A, Christensen H, Hofer SM, Korten AE, Jorm AF. Use it and still lose it? The association between activity and cognitive performance established using latent growth techniques in a community sample. Neuropsychol. Dev. Cogn. B Aging Neuropsychol. Cogn 2003;10:215–229.

36. Salthouse TA, Berish DE, Miles JD. The role of cognitive stimulation on the relations between age and cognitive functioning. Psychol. Aging 2002;17:548–557. [PubMed: 12507353]

37. Clare L, Woods B, Moniz Cook ED, Orrell M, Spector A. Cognitive rehabilitation and cognitive training for early-stage Alzheimer's disease and vascular dementia. Cochrane Database Syst. Rev. 2003;(4) CD003260.

38. Wilson BA. Cognitive rehabilitation: how it is and how it might be. J. Int. Neuropsychol. Soc 1997;3:487–496. [PubMed: 9322409]

39. Fried LP, Carlson MC, Freedman M, et al. A social model for health promotion for an aging population: initial evidence on the Experience Corps model. J. Urban Health 2004;81:64–78. [PubMed: 15047786] •• Provides a description of the Experience Corps Model of Cognitive Stimulation.

40. Carlson MC, Saczynski JS, Rebok GW, et al. Exploring the effects of an 'everyday' activity program on executive function and memory in older adults: Experience Corps®. Gerontologist 2008;48:793–801. [PubMed: 19139252]

41. Stine-Morrow EAL, Parisi JM, Morrow D, Park DC. The effects of an engaged lifestyle on cognitive vitality: a field experiment. Psychol. Aging 2008;23:778–786. [PubMed: 19140649]

42. Ball K, Berch DB, Helmers KF, et al. Effects of cognitive training interventions with older adults. A randomized controlled trial. JAMA 2002;288:2271–2281. [PubMed: 12425704] •• Provides a description of the Advanced Cognitive Training for Independent and Vital Elderly cognitive training study.

43. Willis SL, Tennstedt SL, Marsiske M, et al. Long-term effects of cognitive training on everyday functional outcomes in older adults. JAMA 2006;296:2805–2814. [PubMed: 17179457]

44. Smith GE, Housen P, Yaffe K, et al. A cognitive training program based on principles of brain plasticity: results from the Improvement in Memory with Plasticity-Bases Adaptive Cognitive Training (IMPACT) study. J. Am. Geriatr. Soc 2009;57(4):594–603. [PubMed: 19220558]

45. Valenzuela M, Sachdev P. Can cognitive exercise prevent the onset of dementia? Systematic review of randomized clinical trials with longitudinal follow-up. Am. J. Geriatr. Psychiatiry 2009;17:179–187.

46. Olazaran J, Muniz R, Reisberg B, et al. Benefits of cognitive-motor intervention in MCI in mild to moderate Alzheimer disease. Neurology 2004;2:2348–2353. [PubMed: 15623698]

47. Rozzini L, Costardi D, Chilovi V, Franzoni S, Trabucchi M, Padovani A. Efficacy of cognitive rehabilitation in patients with mild cognitive impairment treated with cholinesterase inhibitors. Int. J. Geriatr. Psychiatry 2007;22:356–360. [PubMed: 17117398]

48. Barnes DE, Yaffe K, Belfor N, et al. Computer-based cognitive training for mild cognitive impairment: results from a pilot randomized controlled trial. Alzheimer Dis. Assoc. Disord 2009;23:205–210. [PubMed: 19812460]

49. Sitzer DI, Twamly EW, Jeste DV. Cognitive training in Alzheimer's disease: a meta-analysis of the literature. Acta Psychiatr. Scand 2006;114:75–90. [PubMed: 16836595]

50. West SG, Duan N, Pequegnat W, et al. Alternatives to the randomized clinical trial. Research innovations and recommendations. Am. J. Public Health 2008;98:1359–1366. [PubMed: 18556609]

51. Unverzagt FW, Smith DM, Rebok GW, et al. The Indiana Alzheimer Disease Center's Symposium on mild cognitive impairment. Cognitive training in older adults: lessons from the ACTIVE Study. Curr. Alzheimer Res 2009;6:375–383. [PubMed: 19689237]

52. Ganguli M, Kukull WA. Lost in translation: epidemiology, risk, and Alzheimer's disease. Arch. Neurol 2010;67:107–111. [PubMed: 20065137]

53. Qiu C, Winblad B, Fratiglioni L. The age-dependent relation of blood pressure to cognitive function and dementia. Lancet Neurol 2005;4:487–499. [PubMed: 16033691]

54. Shumaker SA, Legault C, Rapp SR, et al. Estrogen plus progestin and the incidence of dementia and mild cognitive impairment in postmenopausal women: The Women's Health Initiative Memory Study: a randomized controlled trial. JAMA 2003;289:2651–2662. [PubMed: 12771112]

55. Zandi PP, Carlson MC, Plassman BL, et al. Hormone replacement therapy and incidence of Alzheimer disease in older women: the Cache County Study. JAMA 2002;288:2123–2129. [PubMed: 12413371]

56. Evans DA, Hebert LE, Beckett LA, et al. Education and other measures of socioeconomic status and risk of incident Alzheimer disease in a defined population of older persons. Arch. Neurol 1997;54:1399–1405. [PubMed: 9362989]

57. Corder EH, Saunders AM, Strittmatter WJ, et al. Gene dose of apolipoprotein E type 4 allele and the risk of Alzheimer's disease in late onset families. Science 1993;261:921–923. [PubMed: 8346443]

58. Crowe M, Andel R, Pedersen NL, Fratiglioni L, Gatz M. Personality and risk of cognitive impairment 25 years later. Psychol. Aging 2006;21:573–580. [PubMed: 16953718]

59. Ashford JW, Mortimer JA. Non-familial Alzheimer's disease is mainly due to genetic factors. J. Alzheimer Dis 2002;4:169–77.

60. Borenstein AR, Copenhaver CI, Mortimer JA. Early-life risk factors for Alzheimer's disease. Alzheimer Dis. Assoc. Disord 2006;20:63–72. [PubMed: 16493239]

61. Hertzog C, Kraemer AF, Wilson RS, Lindenberger U. Enrichment effects on adult cognitive development. Can the functional capacity of older adults be preserved and enhanced? Psychol. Sci. Public Interest 2009;9:1–65. •• Comprehensive monograph that summarizes the body of evidence of whether cognitive activity can enhance cognitive functioning from a lifespan developmental psychology perspective.

62. Acevedo A, Loewenstein DA. Nonpharmacological cognitive interventions in aging and dementia. J. Geriatr. Psychiatr. Neurol 2007;20:239–249.

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