CENTER *for* RETIREMENT RESEARCH *at* BOSTON COLLEGE

November 2016, Number 16-17

COGNITIVE AGING: A PRIMER

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Introduction

Cognitive aging has received growing attention in recent years as many researchers have documented a significant age-related decline in the brain's processing ability. This decline could potentially undermine retirement security in two ways: 1) by limiting the ability to work longer; and 2) by eroding the capacity to manage finances in retirement.

This *brief* summarizes the explosion of recent research on cognitive aging by answering basic questions about what researchers are learning and why their findings matter to retirement experts and the public. This overview is the first *brief* in a series of three; the other two will focus on how cognitive aging affects the ability of individuals to work between ages 50-70 and to handle personal finances between ages 70-90.

The discussion proceeds as follows. The first section introduces definitions and measures of cognitive ability. The second section discusses how researchers identify changes in cognitive ability with age, while the third summarizes their findings. The fourth section discusses how age-related changes in different cognitive capacities can affect real-world performance. The final section concludes that: 1) most older workers can maintain their productivity up to age 70, although they will generally need more time to learn new skills or concepts; and 2) many retirees can continue to manage their own financial affairs in their 70s and 80s, though about one quarter will likely develop a cognitive impairment that will pose a threat to their financial independence.

Defining and Measuring Cognitive Ability

A basic definition of cognition – "the act or process of knowing" – points out two aspects of cognitive ability: 1) having knowledge; and 2) acquiring knowledge.[1] Psychologists commonly refer to knowledge as "crystallized intelligence" and the ability to process new information as "fluid intelligence." Figure 1 (on the next page) illustrates how overall cognitive ability depends on these two aspects of cognition and provides some examples.

Most real-world activity relies on both crystallized and fluid intelligence. Some researchers have attempted to measure performance on everyday tasks directly. For example, driving performance

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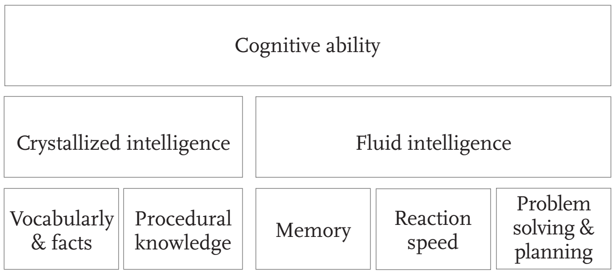
Figure 1. Components of Cognitive Ability



Source: Authors' illustration.

has been studied extensively using simulators, with performance depending on both knowledge, such as knowing traffic rules, and fluid ability, such as reacting quickly to avoid hazards.[2] But the results of such testing are hard to extrapolate to other tasks, because they do not address *why* performance varies. For example, reduced driving ability in one's 70s and 80s may not equate to poor financial capacity because driving could have deteriorated due to a decline in reaction speed, which is unrelated to financial decision-making ability. On the other hand, if driving performance declined due to difficulty remembering the meaning of road signs, the underlying memory problems could affect financial judgement as well.

Standardized tests offer an alternative to simulated tasks that is more generalizable because it identifies the processes underlying behavior. The IQ test, initially developed to assess whether young children had the cognitive ability to attend first grade, serves as a model for many of these tests.[3] This type of cognitive test typically consists of multiple choice questions that assess a mix of crystallized and fluid intelligence.

But standardized tests are an indirect measure of cognitive ability. A growing body of research relies on brain scans to directly observe brain activity. These scans are usually administered while participants perform a task like mentally rotating three-dimensional images.[4] Such scans have allowed researchers to explain where in the brain different cognitive activities originate. This knowledge, in turn, has helped explain how age-related changes in specific brain regions could affect cognitive ability and performance.[5]

Measuring Changes in Cognitive Ability

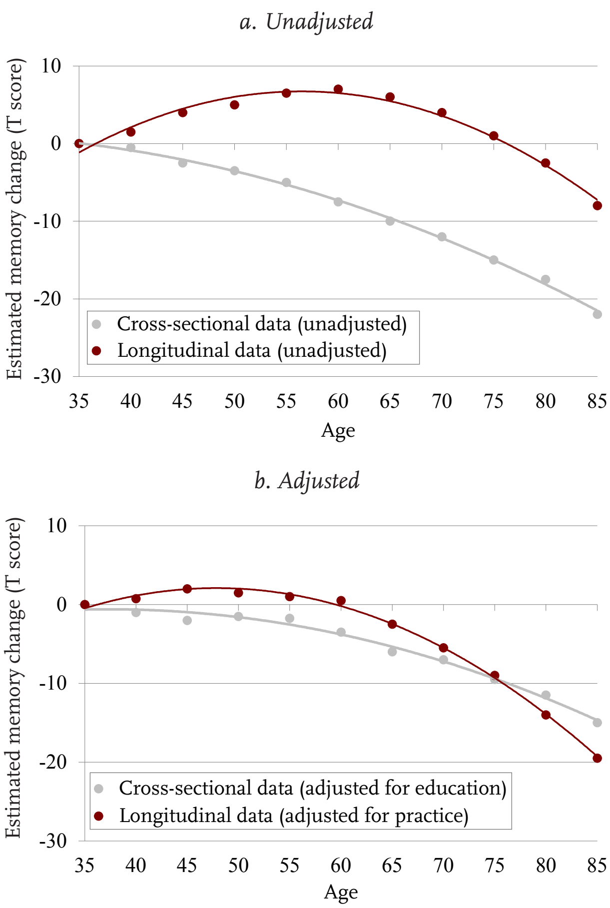
While a variety of tools exist to measure different aspects of cognitive ability at a given point in time, measuring changes over the life-cycle requires its own methodologies. For this purpose, researchers have relied on two basic study designs: 1) cross-sectional studies, which compare the performance of, say, a 30-year old to a 60-year old in a test conducted at the same point in time; and 2) longitudinal studies, which compare the performance of the same individual at, say, ages 30 and 60.

Cross-sectional studies are relatively easy to administer, but tend to overestimate the rate of cognitive decline because of cohort effects – factors such as better education and nutrition have led more recent cohorts to perform better on tests than earlier cohorts. As a result, any point-in-time comparison will yield large differences between the test scores of the young and old that may not be predictive of the younger generation's cognitive path.[6]

Longitudinal studies eliminate this problem by following the same individuals over time. However, this approach is expensive, since studies must last decades to be useful. They also can underestimate the rate of age-related decline in cognitive ability for two reasons: 1) people who drop out of the study may be more likely to have experienced steep decline (due to poor health or dementia); and 2) taking the same test on multiple occasions leads to improvements in performance due to practice. To make matters worse, both the longitudinal and cross-sectional approaches suffer from "noise" – the same person can do differently on the same test at different times, even if taken just seconds apart.

Fortunately, researchers have developed ways to correct for these shortcomings, such as taking the average of several tests to reduce the effect of noise from any single test. Problems associated with cross-sectional and longitudinal studies can also be addressed through statistical techniques. For example, in cross-sectional studies, one can account for the differences in test scores caused by differences in education by comparing scores only among individuals with similar educational attainment. In longitudinal studies, one can figure out how much, on average, practice boosts test scores, and adjust the scores of people who take the test often to reflect the boost they received from this practice. Figures 2a and 2b show the value of these adjustments.

Figure 2. Age-related Changes in Episodic Memory

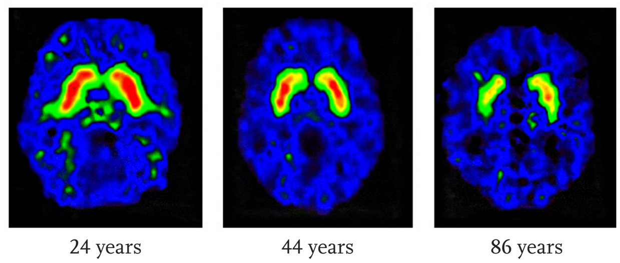


Source: Adapted from Nyberg et al. (2012).

What We Know About Age-related Cognitive Change

Several themes have emerged from research on age-related cognitive change using the methods outlined above. Brain scans reveal that the brain loses matter as one ages, with acceleration toward the end of life. This loss in neural matter follows a pattern – from the front to the back of the brain and from the outer parts of the brain to the inner parts of the brain.[7] Figure 3 shows these patterns in a brain scan, with the older brains having lower concentrations of neurotransmitter receptors in the front of the brain, as indicated by low amounts of red and green shading.

Figure 3. Difference in Concentration of Dopamine Receptors, by Age



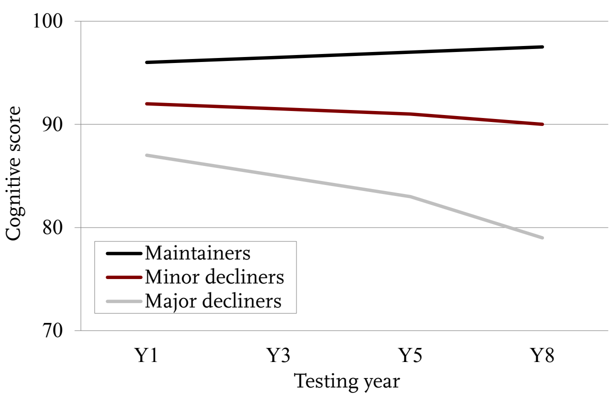
Note: These images are PET scans from three subjects, showing the concentration of dopamine receptors in the brain. Red indicates highest concentrations, dark spots indicate lowest.
Source: Brookhaven National Laboratory (1998).

These changes in the brain are correlated with predictable age-related changes in cognitive ability.[8] On average, starting in an individual's 30s or 40s, reaction speed starts to slow, working memory starts to deteriorate, and other components of fluid intelligence begin to weaken, with noticeable declines in fluid intelligence widespread by the time people are in their 50s and 60s. But crystallized intelligence tends to increase or remain steady into one's 70s and 80s among people without cognitive impairment.

With declining fluid intelligence on one hand, and resilient crystallized intelligence on the other, the ability to perform everyday tasks can either decline or improve with age, depending on both the task and the person. With respect to tasks, older adults have a harder time reading or hearing when confronted with distractions, are more prone to making errors when asked to perform under time pressure, and are less able to acquire and transfer new information.[9] On the other hand, older adults tend to score better than younger adults on tests of general and domain-specific knowledge.[10]

Of course, within any age group, the level of cognitive ability varies, as does the degree of cognitive change. Figure 4 illustrates these variations using a test of cognitive function that incorporates both fluid and crystallized intelligence. The test was administered several times over a 7-year period to a sample of 3,075 individuals who were ages 70-79 at the start of the study. In addition to showing variation in the level of cognitive score at age 70, the figure identifies three distinct groups who differ in the changes they experience over time. The "maintainers" have a higher initial score and show no decline over the 7-year period, while the other two groups have lower initial scores and show minor or major declines.

Figure 4. Cognitive Scores Over 7-Year Period for Individuals Initially Ages 70-79



Source: Reproduced from Yaffe et al. (2009).

How Change in Ability Affects Real-World Performance

The research clearly shows that fluid intelligence declines with age while crystallized intelligence accumulates, and that the brain changes in both structure and activity. These changes together predict the following three patterns: 1) the brain acquires the ability to react intelligently and automatically to a wider range of situations with age due to increased crystallized intelligence; 2) the maximum capacity and speed for processing information at any given moment diminishes with age, largely due to declining fluid abilities; and 3) the capacity of the brain to acquire completely new functions, such as learning how to play a musical instrument for the first time, is severely diminished due to changes in brain structure.

Since different cognitive capacities decline at different rates, the effect of cognitive aging on real-world performance depends on the situation. In situations where an individual has direct experience and extensive practice – like paying bills or speaking to a customer service representative – age generally improves performance through one's 50s and 60s, with little decline thereafter; performance speed, however, could decrease, especially in one's 70s and 80s. In situations where an individual has related experience, but reactions are not automatic, like driving on unfamiliar streets, age generally leads to decreased performance starting in one's 60s. Declines in performance are especially significant when a task is complex, such as driving on unfamiliar streets on a rainy night. In situations where an individual has little or no relevant experience, like learning a new language, age often results in significant declines in the quality and speed of performance starting as early as childhood.

Conclusion

Reviewing the ways in which cognitive aging could affect real-world performance provides useful insights for anyone concerned with the well-being of retirees, from policymakers to financial planners to individuals themselves.

One way that cognitive change could affect retirement security is by limiting the ability to work. In this respect, the wide range of cognitive skills that older workers build and maintain as they age implies that most workers can remain productive in their 50s and 60s despite cognitive aging. This finding is supported by numerous studies that show insignificant age-related losses in productivity across a variety of occupations.[11] However, declines in processing capacity and speed can affect the performance of some workers engaged in complex tasks under time pressure. For example, the performance of air-traffic controllers, who must track the flight paths of multiple airplanes at once while also quickly reacting to unusual situations, declines significantly by age 56.[12] And diminished ability to adapt, or acquire completely new skills, implies that older workers will require more time to adjust to occupational changes, a finding supported by studies that show that the ability to learn new material (both in the lab and on the job) diminishes with age.[13]

A second way in which cognitive change could affect retirement security is through a diminished capacity to manage money. This skill is largely learned through experience; thus, older individuals typically have already acquired the cognitive skills to carry out common tasks, like paying bills on time.[14] However, due to the increasing prevalence of 401(k) plans – where (unlike traditional pensions) retirees must decide how to invest their nest egg and how much to draw from it each month – even retirees used to making financial decisions might need help from a financial expert. And retirees who take over financial matters from a spouse (due to death or illness) must learn new financial concepts in their 70s and 80s if they want to avoid making financial mistakes.[15] Finally, the risk of dementia and severe cognitive impairment rises exponentially in one's 70s and 80s.[16] This pattern means that a significant share of retirees will eventually need help managing their finances in retirement, which includes being protected against financial fraud and abuse.

The next two *briefs* in this series will elaborate on how these two topics – work and finances – are affected by cognitive decline.

Endnotes

1 *Merriam-Webster's Collegiate Dictionary* (2010).

2 Andrews and Westerman (2012).

3 Other prominent tests include the Scholastic Aptitude Test (SAT) for assessing general academic potential and the Armed Forces Vocational Aptitude Battery test for determining suitability for an occupation. For examples of some other common cognitive tests, see the Appendix.

4 For example, see Ivanoff, Branning, and Marois (2009) or Langenecker, Nielson, and Rao (2004).

5 For example, see Casey et al. (2005).

6 For an excellent analysis of the methodological considerations, see Schaie and Willis (2015), Chapter 2.

7 See Chapter 1 of Craik and Salthouse (2008), DeCarli et al. (1995), Pantoni and Garcia (1997), or Sullivan et al. (1995).

8 Individuals who show greater changes in brain structure and activation also show greater decline in fluid cognitive abilities; brain regions that show the most deterioration correspond to a decline in the abilities mediated by those regions (for a summary, see Salat (2011)).

9 Mund, Bell, and Buchner (2010).

10 Ackerman (2000).

11 See Jeske and Rossnagel (2015) and Ng and Feldman (2013).

12 Heil (1999). The Federal Aviation Authority actually requires its air traffic controllers to retire at 56, with a provision allowing those with exceptional skills and experience to continue until 61.

13 Salthouse (2012).

14 Schaie and Willis (2016).

15 For example, see Agarwal et al. (2009).

16 Wilson et al. (2003).

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APPENDIX

Table A1. Tests of Cognitive Ability

Test name	Format	Time to complete	Description
Digit Symbol Substitution Test	Non-verbal memory	Timed, <90 seconds	The test requires the examinee to transcribe, from memory, a set of symbols corresponding to the numbers 1 to 9.
Mini-Mental State Examination	Battery	Not timed, 5-10 minutes	A 30-point questionnaire used to measure cognitive impairment.
Raven's Progressive Matrices	Non-verbal, Aptitude	Timed, 35-40 minutes	A 60-point multiple choice test in which the subject is asked to identify the missing element that completes a pattern.
Stroop Interference Task	Reaction	Timed/reaction	Participants are given words that are presented in certain colors and are asked to say the color of a word.
Trail Making Test	Non-verbal	Timed	Test of visual attention and task switching in which the subject connects a set of 25 dots as quickly as possible while maintaining accuracy.
Weschler Adult Intelligence Scale	Aptitude	Timed, 40 minutes	An IQ test designed to measure intelligence and cognitive ability in adults and adolescents.
Wisconsin Card Sorting Test	Non-verbal	Not timed, 20-30 minutes	The task is to match cards according to different principles – by color, form, or number of shapes, without being given these principles.

Source: Authors' compilation from various sources.

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