The Canadian Journal of Neurological Sciences (2024), **51**, 157–160
doi:10.1017/cjn.2023.259

Canadian Journal of Neurological Sciences
Journal Canadien des Sciences Neurologiques

Commentary

Cognition in Normal Aging – A Brief Review

Andrew Kirk
Division of Neurology, Department of Medicine, University of Saskatchewan, Saskatoon, SK, Canada

Keywords: Cognition; aging

Introduction

Clinical medicine requires that we have a concept of normal. We must know how brisk reflexes should be or what hemoglobin levels should be. In assessing adults for the presence of an illness affecting cognition, we need to have a good idea of what normal cognition looks like so that we can compare an individual patient's performance against our normal "gold standard." However, just as some laboratory tests may have different normal ranges for different ages, if cognitive performance is not static throughout the lifespan, we need a framework to allow for different normals in different cognitive tasks as patients age.

If there are significant cognitive changes as we age, this also has societal implications with regard to work performance as workers age and raises questions regarding mandatory retirement ages in certain occupations.

Methodology

PubMed was accessed through the University of Saskatchewan library on December 1, 2022, with a search for "cognition + aging." I then looked at the 6,551 results in English for the past twenty years. After reading abstracts, I discarded irrelevant studies and selected those I found most pertinent and useful based on my personal judgment. References in those articles guided me to other studies, including older ones.

Results

Biases and pitfalls that make answers difficult

In examining aging and cognition, it is first important to review several biases and pitfalls that make these questions very difficult to definitively answer.[1–3]

Cohort bias[4]

It is tempting to say that one could answer these questions by testing a large group of 25-year-olds and a large group of 80-year-olds without any known cognitive impairment and attributing any differences in neuropsychological test results to the effects of age. However, if we were to do this in 2023, we must remember that persons born in 1998 and persons born in 1943 may have had, on average, very different life experiences. Access to education, nutrition, exposures to various toxins, technologies, social stressors, and many other things may have changed and may have contributed to any differences we observe. Thus, it would be difficult to confidently attribute any observed differences solely to the effect of aging.

Recruitment bias[5,6]

In recruiting participants for clinical studies, we are always dependent on who is willing and able to participate. For example, persons who are ill may be unable or unwilling to participate as may those in difficult social or financial situations. This may mean that we tend to end up testing only the healthiest and wealthiest individuals, potentially biasing our results toward testing subjects prone to do well on cognitive testing and tending to lower our chances of detecting cognitive changes with aging.

Misclassification bias[4,7]

In studying normal aging, we may inadvertently include subjects with neurodegenerative diseases or other neurological or systemic conditions that have not been diagnosed and thus the group we think represents normal aging is in fact contaminated with subjects who are not normally aging. Although conditions affecting cognition can occur at any age, they are more common as people age. A group of people who start off healthy will be prone to developing illnesses with age that may affect cognition. This would tend to make an older group perform worse on average and lead us to overestimate the effects of age in a healthy population. Any real-life population at any particular age will include both healthy individuals as well as those with diseases affecting their cognition.

Practice effect[8,9]

We have seen above in number 1 that testing different cohorts at the same time may be misleading so it may seem that the correct way to do things is to test a group of subjects at one age and then retest them periodically. For example, we might test a large group of 25-year-olds and then retest them annually until death in an attempt to uncover the effects of aging. Unfortunately, we may see practice effects where persons tested on the same or similar tests repeatedly may improve or not decline as much as they should, leading us to underdetect decline with aging. Studies of this type also introduce huge logistical barriers in finding and following up the same people over such a long periods of time.

Survival or attrition bias[10]

If we follow a large group of subjects over years, not only does this become an expensive and difficult study to sustain but we will also

Corresponding author: A. Kirk; Email: andrew.kirk@usask.ca
Cite this article: Kirk A. (2024) Cognition in Normal Aging – A Brief Review. *The Canadian Journal of Neurological Sciences* **51**: 157–160, https://doi.org/10.1017/cjn.2023.259

lose subjects as the years go by to death, disease, physical frailty making participation difficult, and so on. If we are only testing the healthiest subjects, this may tend to underestimate changes with age.

Neuropsychological testing is not real life[11]

Most studies in this area are based on standardized neuropsychological tests administered in controlled environments. Subjects are focussed on the tests and distractions are minimized. If we see declines on testing results with age, this may or may not translate into real-life problems as life experience and accumulated learning may mitigate adverse effects. It is difficult to measure the effects of accumulated "wisdom," which may improve an individual's abilities in certain tasks. Driving is one example of a real-life skill that has been studied.[12,13] Studies in this area consistently show that car crashes are more common in teenagers than in any other age cohort.[14] This rate goes down with age and then rises slightly after about the age of 70. However, people over 80 years of age still have a lower rate of crashes than do teenagers.[14] Of course, there are many confounding factors. People over 80 may not drive as much as teenagers do, for example. However, I bring this up to show that we are not very good at measuring the effects of experience and accumulated knowledge on ability.

Salthouse[11] explores the paradox of why healthy elderly individuals do so much better in real life than they do in the laboratory. For example, while laboratory studies of analytical reasoning show declines with age, the ability to complete crossword puzzles continues to improve throughout life. Although age-related declines in job performance have been described in air traffic controllers[15] and athletes,[16] most studies have not shown a close relationship between age and job performance[1–22] across a wide variety of occupations. It has been suggested that although age may affect the limits of cognitive abilities on neuropsychological testing, our occupations do not routinely test the limits of these abilities day to day.[11]

Effects of sensory decline and physical changes

Senses become less acute with age. For example, hearing acuity typically begins to decline after the age of about 30.[23] Most persons over 80 have significant hearing loss. Testing needs to account for the fact that older subjects may have more trouble perceiving stimuli. Physical limitations of aging may also make response to testing more difficult.

Fewer studies of the very old

Very old people are fewer in number in the population. Fewer of them are still healthy enough to participate in neuropsychological research and more of them have acquired neurological disease that affects their performance so that we are no longer necessarily studying normal aging. Many studies have examined normal cognitive functions up to the age of 80, but the studies beyond that age become few and far between.

Review of evidence

Now that we have examined some of the pitfalls that make this subject a difficult one about which to draw conclusions, we can look at the evidence we do have.

Studies of cognition and aging generally find that "crystallized abilities" tend to be relatively preserved with age.[2,3,11,43,25] These include vocabulary, general knowledge, reading comprehension, and other well-learned abilities. Numerous studies have shown that these abilities tend to improve until about the age of 60 and then plateau until about age 80. "Fluid abilities" are more susceptible to the effects of aging.[2,3,11,24,25] These are abilities that involve attending to the environment and processing new information quickly. Studies show that these abilities tend to steadily decline between the ages of 20 and 80.

Processing speed

How quickly tasks can be performed begins to decline in the twenties and does so steadily throughout life.[26–28] Tasks as simple as reaction time steadily decline throughout adulthood.[29] This is considered a fluid ability. This decline can affect one's ability to do other cognitive tasks and lead to false conclusions about the effect of age on other cognitive abilities. For example, verbal fluency is often measured by the number of words an individual can say from a specific category within a minute.[30] Slower processing will affect the ability to perform this task despite preservation of language skills.

Attention

Performance on complex attentional tasks declines with age.[27,28] Simple attention tests such as digit span (a subject is asked to listen to a series of numbers and then recite them back) are not significantly affected by age at least up to the age of about 80 after which there is a slight decline.[4] Selective attention is an ability to focus on specific stimuli while ignoring other irrelevant information in the environment. This skill is needed to carry out a conversation in a busy environment or to drive a car. Divided attention is the ability to focus on multiple tasks at the same time. Following a specific walking path while simultaneously reciting the alphabet backwards would be an example. Carrying out a conversation while driving might be another. Working memory, the ability to briefly hold information in memory while at the same time manipulating the information, is considered a complex attentional task and also declines with age.[31] A real-life example might be calculating a restaurant tip in one's head. Working memory, selective and divided attention steadily decline throughout adult life, beginning in the early twenties.

Memory

Some aspects of memory remain stable during normal aging while others decline. Immediate, or sensory, memory remains stable.[4] This is often classed as a simple attentional task and would include tasks such as reciting back a list of numbers as mentioned above.

Long-term memory of autobiographical or historical events remains essentially stable throughout life.[32] However, attribution memory or source memory does decline with age. This facet of memory refers to knowing where one heard a piece of information – "Did my spouse tell me that, or was it a co-worker, or did I read it in the paper?" This has been shown to steadily decline between the ages of 21 and 80.[33,34]

Semantic memory, or memory for facts about the world (e.g. Canadian confederation happened in 1867, many leaves change color in the autumn), tends to be relatively preserved and, in some studies, even to improve into old age.

New learning may be measured by free recall, i.e. asking a subject to recall a list of words previously given. Free recall declines with age, declining relatively slowly until the age of about 60 and then declining a little more quickly.[35,36] Recognition memory (yes, that item was in the list you showed me earlier) tends to be better preserved with age.[37] As we age, retention of newly learned information tends to be preserved, but retrieval of that information may require cuing or a recognition task to recall it as recognition memory is better preserved than free recall.[35–37]

https://doi.org/10.1017/cjn.2023.259 Published online by Cambridge University Press

Procedural memory, i.e. memory of how to carry out physical tasks such as riding a bike or typing, is well preserved with age.[38]

Prospective memory or remembering to perform a task at a certain time (e.g. putting out the garbage on Monday evening) tends to decline with age.[36] Subjects in their twenties perform better than those in their sixties who perform better than those in their eighties.

Executive Functioning

This refers to the complex set of abilities that allow us to plan, focus our attention, manipulate information in working memory, inhibit inappropriate responses, shift mental set, exhibit cognitive flexibility, and multitask successfully, all skills that are important in a successful work and home life. With age we see a decline in the efficiency of carrying out novel tasks, as well as in those where we need to distinguish relevant from irrelevant information or stimuli, and in those where some responses must be inhibited but not others. These abilities typically begin to decline from the sixties onward.[4,26,39–43] There are few investigations of specific executive abilities. One study suggests that inhibition and updating may be more impaired in older subjects while flexibility is not.[42] Another suggests that inhibition and division of attention decline after age 60.[43] Crawford and Channon found that, while older subjects did more poorly on standardized neuropsychological tests of executive functioning, they performed as well as younger subjects in real-life situations.[44]

Language

Most language abilities tend to be well preserved with normal aging and some, such as vocabulary, may improve throughout the lifespan.[39,45–47] As noted above, verbal fluency may decline with age, but this does not necessarily reflect an underlying decline in language abilities and may reflect a decline in speed of processing. Similarly, auditory comprehension in noisy environments may decline, but this is generally related to age-related hearing loss.[47]

The tip-of-the-tongue phenomenon is a universally experienced inability to produce a word in a timely fashion accompanied by a feeling of partial knowledge of the word and that word retrieval is imminent. Its frequency has been reported to increase with age and may underlie poorer performance on naming tasks despite increasing vocabulary with age.[48,49] Some evidence suggests that age-related declines in processing speed and working memory may be contributors.[49]

Visuospatial functioning

These are variably affected by aging. Performance on Block Design, the ability to use colored blocks to replicate a presented pattern, declines steadily from about age 30–80.[50,51] Recognition of objects, shapes, and signs is well preserved into old age.[4] Copying a simple figure does not seem to be affected by age but copying a complex figure such as the Rey-Osterrieth figure may.[52] Judgment of spatial orientation of lines or objects becomes steadily more difficult with age.[51]

Conclusions

While we need to bear in mind the pitfalls discussed above, we can make some general conclusions about the way age affects cognitive abilities. Crystallized abilities such as vocabulary, general knowledge, reading comprehension, and the like are well-preserved with age. Most studies of these abilities show that they improve until about age 60 and then plateau until about age 80. As noted above, studies beyond the age of 80 become few and far between. Fluid abilities, those that require close attention to the environment and rapid processing of new information, are more affected by age and tend to decline between the ages of about 20 and 80.

In particular, processing speed, divided attention, working memory, attribution memory, free recall memory, retrieval of information, prospective memory, executive functioning for novel tasks, and some visuospatial tasks tend to show declines with age.

By contrast, simple attention, immediate memory, long-term memory, semantic memory, recognition memory, procedural memory, language, and some visuospatial tasks tend to be preserved and, in some cases, to improve with normal aging.

Those abilities affected by age are affected gradually over the years. None of them show a "falling off the cliff" effect at any particular age.

Various abilities are affected over different parts of the lifespan. Processing speed begins to decline in the twenties and does so for the rest of the lifespan. Performance on complex attentional tasks begins to decline after about the age of 80. Attribution memory declines steadily between the ages of 21 and 80. Free recall memory declines slowly until the age of about 60 and then declines more quickly for the rest of the lifespan. Prospective memory is stronger in the twenties than in the eighties. Complex attentional abilities decline from the sixties onward. Some visuospatial skills steadily decline from about the age of 30.

As we age, we tend to become poorer at activities that include rapid digestion of novel material and tend to be better preserved at tasks that include time to contemplate materials, consult references, and bring into play the benefits of our life experiences – our "wisdom," if you will.

All the results discussed above are based on averages of large groups of individuals. Just as individuals may be stronger in some areas of cognition than others (a sculptor may be very skilled at visuospatial tasks while a writer may have very strong language abilities, and these differences are not captured by talking about average levels of ability in the general population), changes in cognition over time vary between individuals too. As individuals age, they have more opportunity to acquire neuropathology affecting cognition. A 50-year-old who's had a head injury or who has frontotemporal dementia may have much poorer cognitive abilities than a 90-year-old who's remained healthy. We might thus expect between-person variability to increase with age. A group of 20-year-olds is likely to be more cognitively homogeneous than a group of 90-year-olds. The information we have considered above tells us much more about cognition of populations than about cognition of individuals.

While we can thus say a lot about how averages of cognitive performance change with age, these studies tell us a lot less about how any individual will change with age.[24,25]

Competing interests. The author has served as an expert witness for Saskatchewan Justice on a related topic.

References

1. Scahill RI, Frost C, Jenkins R, et al. A longitudinal study of brain volume changes in normal aging using serial registered magnetic resonance imaging. Arch Neurol. 2003;60:989–94. DOI: 10.1001/archneur.60.7.989.
2. Murman DL. The impact of age on cognition. Semin Hear. 2015;36: 111–5.
3. Harada CN, Natelson Love MC, Triebel KL. Normal cognitive aging. Clin Geriatr Med. 2013;29:737–52.
4. Lezak M, Howesen D, Bigler E, et al. Neuropsychological assessment 5th edition. New York: Oxford University Press; 2012.
5. Minder CE, Muller T, Gillmann G, et al. Subgroups of refusers in a disability prevention trial in older adults: baseline and follow-up analysis. Am J Public Health. 2002;92:445–60.

https://doi.org/10.1017/cjn.2023.259 Published online by Cambridge University Press

6. Ford JG, Howerton MW, Lai GY, et al. Barriers to recruiting under-represented populations to cancer clinical trials: a systematic review. Ann Ny Acad Sci. 2003;112:228–42.
7. Ross GW, Abbott RD, Petrovitch H, et al. Frequency and characteristics of silent dementia among the elderly Japanese-American men. Neuropsychology. 2010;24:563–72.
8. Abner EL, Dennis BC, Mathews MJ, et al. Practice effects in a longitudinal, multicenter Alzheimer's disease prevention trial. Trials. 2012;13:217.
9. Salthouse TA. Influence of age on practice effects in longitudinal neurocognitive change. Neuropsychology. 2010;24:563–72.
10. Van Beijsterveldt CE, van Boxter MP, Bosma H, et al. Predictions of attrition in a longitudinal cognitive aging study: the maastricht aging study. J Clin Epidemiol. 2002;55:216–23.
11. Salthouse T. Consequences of age-related cognitive declines. Annu Rev Psychol. 2012;63:201–26.
12. Doroudgar S, Chuang HM, Perry PG, et al. Driving performance comparing older versus younger drivers. Traffic Inj Prev. 2017;18:41–6.
13. Lloyd S, Cormack CN, Blais K, et al. Driving and dementia: a review of the literature. Can J Occup Ther. 2001;68:149–56.
14. Tefft BC. Rates of motor vehicle crashes, injuries and deaths in relation to driver age, United States, 2014-2015 (research brief). Washington, D.C: AAA Foundation for Traffic Safety; 2017.
15. Trites DK, Cobb BB. Problems in air traffic management, Fed aviat rep. Oklahoma City: FAA Civil Aeromed Inst; 1963.
16. Baker J, Deakin J, Horton S, et al. Maintenance of skilled performance with age: a descriptive analysis of professional golfers. J Aging Phys Act. 2007;15:300–17.
17. Davies DR, Sparrow PR. Effects of age, tenure, training, and job complexity on job performance. Psychol Aging. 1988;3:307–14.
18. Hunter J, Hunter R. Validity and utility of alternate predictors of job performance. Psychol Bull. 1984;96:72–98.
19. Hunter J, Schmidt FL. The validity and utility of selection methods in personell psychology: practical and theoretical implications of 85 years of research findings. Psychol Bull. 1998;124:262–74.
20. McEvoy GM, Cascio WF. Cumulative evidence of the relationship between employee age and job performance. J Appl Psychol. 1989;74:11–7.
21. Waldman DA, Avolio BJ. A meta-analysis or age differences I job performance. J Appl Psychol. 1986;71:33–8.
22. Rhodes SR. Age-related differences in work attitudes and behavior: a review and conceptual analysis. Psychol Bull. 1983;93:328–67.
23. Goman AM, Lin FR. Prevalence of hearing loss by severity in the United States. Am J Public Health. 2016;106:1820–2.
24. Salthouse TA. Trajectories of normal cognitive aging. Psychol Aging. 2019;34:17–24.
25. Shafto MA, Henson RN, Matthews FE, et al. Cognitive diversity in a healthy aging cohort: cross-domain cognition in the Cam-CAN project. J Aging Health. 2020;32:1029–41.
26. Salthouse TA. Selective review of cognitive aging. J Int Neuropsychol Soc. 2010;16:754–60.
27. Salthouse TA, Fristoe NM, Lineweaver TT, et al. Aging of attention: does the ability to divide decline. Mem Cognit. 1995;23:59–71.
28. Carlson MC, Hasher L, Zacks RT, et al. Aging, distraction, and the benefits of predictable location. Psychol Aging. 1995;10:427–36.
29. Gottsdanker R. Age and simple reaction time. J Gerontol. 1982;37:342–8.
30. Borkowski JG, Benton AL, Spreen O. Word fluency and brain damage. Neuropsychologia. 1967;5:135–40.
31. Salthouse TA, Mitchell DR, Skovronek E, et al. Effects of adult age and working memory on reasoning and spatial abilities. J Exp Pscyhol Learn Mem Cogn. 1989;15: 507–16.
32. Ronnlund M, Nyberg L, Backman L, et al. Stability, growth, and decline in adult life span development of declarative memory: cross-sectional and longitudinal data from a population-based study. Psychol Aging. 2005;20:3–18.
33. Meusel LA, Grady CL, Ebert PE, et al. Brain-behaviour relationships in source memory: effects of age and memory ability. Cortex. 2017;91:221–33.
34. Casino S, Torres-Trejo F, Estrada-Manilla C. Contributions of cognitive aging models to the explanation of source memory decline across the adult lifespan. Exp Aging Res. 2020;46:194–213.
35. Price L, Said K, Haaland KY. Age-associated memory impairment of logical memory and visual reproduction. J Clin Exp Neuropsychol. 2004;26:531–8.
36. Cargin JW, MaruffP Collie, etal A. Decline in verbal memory in non-demented older adults. J Clin Exp Neuropsychol. 2007;29:706–18.
37. Fraundorf S, Hourihan KL, Peters RA, et al. Aging and recognition memory: a meta-analysis. Psychol Bull. 2019;145:339–71.
38. Churchill JD, Stanis JJ, Press C, et al. Is procedural memory relatively spared from old age? Neurobiol Aging. 2003;24:883–892.
39. Allain P, Nicoleau S, Pinon K, et al. Executive functioning in normal aging: a study of action planning using the zoo map test. Brain Cognit. 2004; 57:4–7.
40. Andres P, Van Der Linden M. Age-related differences in supervisory attentional system functions. J Gerontol. 2000;23:225–39.
41. Libon DJ, Glosser G, Malamut BL, et al. Age, executive functions, and visuospatial functioning in healthy older adults.. Neuropsychology. 1994;8:38–43.
42. Etienne V, Marin-Lamellet C, Laurent B. Executive functioning in normal aging. Rev Neurol. 2008;164:1010–7.
43. Treitz FH, Heyder K, Daum I. Differential course of executive control changes during normal aging. Neuropyschol Dev Cogn B Aging. 2007;14:370–93.
44. Crawford S, Channon S. Dissociation between performance on abstract tests of executive function and problem solving in real-life-type situations in normal aging. Aging Ment Health. 2002;6:12–21.
45. Folia V, Liampas I, Ntanasi E. Longitudinal trajectories and normative language standards in older adults with normal cognitive status. Neuropsychology. 2022;36:626–39.
46. Del Prado Martin FM. Vocabulary, grammar, sex, and aging. Cogn Sci. 2017;41:950–75.
47. Verhaeghen P. Aging and vocabulary scores: a meta-analysis. Psychol Aging. 2003;18:332–9.
48. Facal-Mayo D, Juncos-Rabadán O, Alvarez M, Pereiro-Rozas AX, Díaz-Fernández F. Aging effects on lexical access. The tip-of-the-tongue phenomenon on proper names. Rev Neurol. 2006;43:719–23.
49. Facal D, Juncos-Rabadan O, Rodriguez MS, et al. Tip-of-the-tongue in aging: influence of vocabulary, working memory, and processing speed. Aging Clin Exp Res. 2012;24:647–56.
50. Klencklen G, Despres O, Dufour A. What do we know about aging and spatial cognition? reviews and perspectives Ageing Res Rev. 2012;11: 123–35.
51. Joung H, Yi D, Ahn H. Normative study of the block design test for adults aged 55 years and older in Korean aging population. Psychiatry Investig. 2021;18:539–44.
52. Gallagher C, Burke B. Age, gender, and IQ effects on the rey-osterrieth complex figure test. Br J Clin Psychol. 2007;46:35–45.

https://doi.org/10.1017/cjn.2023.259 Published online by Cambridge University Press