COMMENTARY

Cognitive ability in old age is predetermined by age 20 y

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Determinants of Successful Neurocognitive Aging

One of the major scientific problems of the 21st century is determining how to maintain cognitive vitality in late adulthood and prevent age-related cognitive decline. There is considerable evidence that adults age 60 y and older have better cognition in late adulthood when they maintain an active lifestyle, engage in cognitively stimulating leisure activities, and have advanced education and occupations of high complexity. It appears that a lifetime of such engagement builds a neurocognitive reserve (1, 2) or creates additional neural circuitry that protects cognitive function in later years (3). Other studies have shown that an overall level of high cognitive ability (intelligence) is an important component of late-life cognitive resilience and may even delay a diagnosis of Alzheimer's disease by months or years (4).

In PNAS, longitudinal findings by Kremen et al. (5) challenge the role that enriching life experiences play in supporting cognition in late adulthood and indicate that cognitive function in old age is largely predetermined by general cognitive ability (GCA) measured in young adulthood. Others have reported that even adolescent GCA has high predictive value of GCA in late life (6). The Kremen et al. (5) study utilized data from American military recruits between 1965 and 1975 who were part of the Vietnam Era Twin Study of Aging (7). Available data included GCA scores at both an average age of 20 y and an average age of 62 y, as well as self-reported measures of job complexity, lifetime education, and lifetime engagement. In an initial mixed model, years of education, occupational complexity, and lifetime cognitive engagement significantly predicted GCA at age 62 y and predicted performance on six of seven individual cognitive measures (speed, reasoning, memory, etc.), thus replicating the effects of experience on cognition in late adulthood reported by others. (Note that appropriate control variables were also included.) Importantly, when GCA measured at age 20 y was added to this model, results showed that age 20 GCA accounted for over 10% of the variance in GCA at age 62 y, and the variance explained by the three experience-based predictors (education, engagement, and job complexity) was sharply curtailed, with each accounting for less than 1% of variance. Additional analyses supported the centrality of GCA at age 20 y and the minor role of experience in predicting GCA at age 62 y.

Limits of Late-Life Experiences

These findings provide compelling evidence that cognitive ability in late adulthood appears to be fixed relatively early in life and that experiential variables, including education, contribute relatively little to GCA in old age. Kremen et al. (5) suggest that this pattern of findings reflects reverse causality—that is, a high GCA at a young age drives those individuals to seek additional education and enriching life experiences. Hence, the effects of education and other enriching experiences are limited and almost wholly accounted for by intellectual ability at youth. These are important findings that have implications for public policy; the authors suggest that the results indicate that scarce public resources could be best invested in cognitive enrichment and better education during childhood and adolescence to achieve the greatest societal gains.

There are a number of findings from other research domains that add some support to this "youth-determined ability model" of cognitive aging. The burgeoning literature on behavioral interventions designed to facilitate late-life cognitive function has yielded promising but relatively small gains in cognitive function. Cognitive training interventions tend to increase specific skills but have modest to negligible effects on GCA (8), so these studies are generally consistent with the finding that experience plays a modest role in late-life GCA. However, the quantity of time devoted to training, relative to the totality of experiences that occur from young to late adulthood, is quite modest, so possibly, intervention effects would be larger with long-term exposure. Studies that have included sustained intervention experiences that were designed to effect lifestyle changes for an extended period and increase cognitive engagement and complexity, such as the

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Experience Corps Project and the Synapse Project, have yielded significant improvements in memory function (9) or related brain activity (10, 11) but, again, no evidence for an increase in global GCA. Memory improvements in the Synapse Project relative to active controls were attributed to individuals "learning to learn" and becoming more skilled at using existing cognitive resources effectively to develop better learning strategies. Such intervention effects may be a parallel to the impact of an intense Scholastic Aptitude Test (SAT) training course that is designed to improve performance rapidly on a test that measures GCA. The SAT course is not designed to improve the student's intelligence (GCA) in a matter of 15 or 20 h, but is instead focused on enhancing test-taking skills and training students to utilize their existing neurocognitive hardware to enhance their performance on the SAT. Similarly, cognitive interventions may not improve GCA, but they nevertheless may significantly optimize effective use of cognitive mechanisms in everyday life.

Implications for Models of Neurocognitive Reserve

The evidence that cognitive ability in late life is, at best, only modestly affected by additional education and other stimulating late-life experience brings into question the notion that such experiences can be a ticket to increased neurocognitive reserve in late life. One approach to address this issue might be to focus study on two categories of individuals whose lifetime experiences are inconsistent with the reverse-causation explanation as the basis for the predetermining impact of early GCA on late adulthood GCA: (*i*) those with high early GCA whose subsequent lifetime was characterized by low levels of education and engagement, and (*ii*) those with early low GCA who had a lifetime of high education. If early GCA trumps subsequent life experiences in predicting late GCA in even these cases, then the inference that early GCA (and not life experiences) plays a central role in predicting late-life GCA would be greatly strengthened.

The findings of Kremen et al. (5) also suggest that the concept of reserve may not be necessary to understand late-life cognitive ability, as it operates largely through youthful GCA. Even the finding that high-ability older adults are diagnosed later with Alzheimer's disease may not be related to reserve. High ability could mask disease symptoms early on: Because it may simply take longer for highly able older adults to become unable to function effectively in a familiar environment compared with those of lower ability, diagnosis is delayed.

One caveat in interpreting the results relates to measurement issues. The weak effects of experiences to predict age 62 GCA could be related to the use of relatively crude measures to calibrate complex experiences. The lifetime engagement and lifetime education measures rely substantially on self-report. The simple scales used to quantify decades of behavior also have a limited range of measurement and do not share the response characteristics that were used to measure GCA. Based on only the psychometric properties of the different measures used to predict age 62 GCA, it seems almost certain that age 20 GCA would be the variable most likely to share variance with age 62 GCA. The GCA measures are continuous and were designed to be reliable and sensitive measures of intelligence that should be relatively stable over time. The measurement properties of life experiences, however, are mainly checkoff scales that are badly in need of revision and expansion to enhance validity and sensitivity.

Longitudinal findings by Kremen et al. challenge the role that enriching life experiences play in supporting cognition in late adulthood and indicate that cognitive function in old age is largely predetermined by general cognitive ability (GCA) measured in young adulthood.

Related to this issue, if the concept of reserve accrued through experience is to persist, it is equally important to recognize that experiences can deplete neurocognitive resources as well as enrich them (12). The development of a companion neurocognitive depletion index (to be used in tandem with an index of enrichment that leads to reserve) would be useful. Although researchers screen for major depletion events (e.g., 10 min of unconsciousness or major psychopathology), there are many additional experiences that have the potential to exert a negative effect on late adulthood cognition (e.g., participation in varsity football, number and duration of surgical anesthetics administered, traumatic experiences of combat, automobile accidents, etc.). To understand the variables affecting cognition in late adulthood, development of psychometrically sophisticated instruments to measure both reserve and depletion factors across the life span would be highly desirable.

Finally, although the case for lifetime experiences (including years of education) improving cognitive function in late adulthood is relatively weak at present, it is important to consider that education is actually not designed to increase intelligence systematically. Individual differences in intelligence remain among students as they become increasingly educated. Cognitively complex experiences, including education, may not only increase knowledge, but also enable maximally effective use of each individual's own cognitive toolbox rather than improve his or her intelligence.

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