Abstract: This paper shows how the results of research on cognitive aging converge to support the theory that slowing with age is centralized and systematic. Based on this observation, a technique for detecting early differences between normal and pathological change in cognition is proposed.

The term cognitive aging has been used in recent years to denote cross-sectional differences and longitudinal changes in cognitive functioning in old age. A review of findings of cognitive aging research contained in the Handbook of the Psychology of Aging (e.g., Craik, 1977, Poon, 1985; Hultsch & Dixon, 1990, Smith, 1996) shows three general clusters of results: (1) most cognitive functions decline in old age. The speed of information processing slows down with age; (2) for persons of the same age, there is vast individual difference in cognitive performances; (3) although many postulations have been put forward to describe cognitive aging phenomena, no extant theories adequately explain the causes of observed age-related decline in cognition.

Jenkins (1979) proposed a conceptual model for understanding cognitive performances. The model noted four major interacting factors that are relevant to cognitive performances: (1) characteristics of the individual (e.g., age, skills, knowledge), (2) cognitive strategies (e.g., organization, elaboration), (3) criterial tasks (e.g., recognition, recall, problem solving.), and (4) nature of the material (e.g., organizational structure, difficulty). The observed cognitive performance is the sum of, or interaction among, these four factors. While the criterial task and nature of the material may be kept constant in an experiment, variation in the characteristics and cognitive strategies of the individuals is sufficiently large that a diversity of performances is usually observed.

In cognitive aging research, an individual's characteristics and cognitive strategies are of primary interest. Chronological age represents not only a person's physiological function or dysfunction but also reflects the person's level of development, maturity, and experience. Information processing performance would be enhanced when a person's experience is consonant with the nature of the experimental stimuli or criterion task.

FIGURE 1 represents an example of such interaction in a naming latency experiment that evaluated the speed of retrieval from memory of very familiar information (Poon & Fozard, 1978). Young, middle-aged, and older adults named pictures of objects. Some of...
the objects were everyday common items used in the 1970s and 1920s (e.g., shoe and shirt.) Some are unique objects used in the 1970s (e.g., digital clock) or 1920s (e.g., churn). Figure 1 shows the latencies of the correct responses ; there is no age difference in the response latencies of common objects. A classic aging function was observed when young, middle-aged, and older adults were asked to name objects that were representative of the 1970s. Older persons were slower. However, the direction of the function was reversed when the stimuli that were more familiar to the older adults were employed. It is interesting to note that middle-aged adults' naming latencies were the same for the naming of objects from the 1970s and 1920s.

The results from Figure 1 illustrate several design-related points in cognitive aging research : (1) the results underline Jenkins's (1979) postulation regarding the importance of the interaction between subject characteristics and experimental stimuli ; (2) the type of stimuli used in aging research can dictate different types of aging functions, (3) one must not automatically deduce that older people's cognitive speed is slower. The implication of the observed individual and group differences in cognitive aging research is that context of the question or experimental condition is important. The experimenter and clinician must understand the context from which to interpret the observed aging changes and age differences (Poon et al., 1986).

Finally, Jenkins's model also helps us to better understand the observed increased performance variability in older adults. In most cognitive aging studies reported in the literature, the control groups are college students who tend to be homogeneous in the characteristics of interest. The experimental groups tend to be community-dwelling, older adults whose life, occupational, and educational experiences are richer and more diverse. Conversely, the older groups tend to be poorer in health and to have less cognitive ability. The combination of these individual characteristics tend to produce larger within-group variability in the older experimental group. Owing to the large performance variability in "normal" community-dwelling, older adults, departure from normality (e.g., early stages of dementia) is difficult, if not impossible, to detect (Poon, 1992). From a clinical perspective, detection of early dementia is a formidable challenge to clinicians and researchers alike.

The Search for Basic Cognitive Aging Mechanisms

As noted earlier, few postulations explain the age-related mechanisms that underlie the observed cognitive performances in older adults. However, one postulation put forward by James Birren (e.g., Birren, Woods, & Williams, 1980) forms the basis for development of a technique-to be described in this paper-that has the potential for characterizing the integrity of the cognitive system of an individual or a group of individuals (Poon, 1983, 1989, 1993).

Birren observed that the most ubiquitous finding in aging research is that older adults are generally slower in both psychomotor and cognitive speed. With the exception of the findings from the naming latency experiment noted earlier, the observation is robust.

Birren further postulated that the observed cognitive slowing in older adults is a result of the slowing of the central nervous system. Evidence used in this line of deduction came from experimental data collected from patients with different types of central nervous system deficits.
FIGURE 2 Relationship of reaction times from young and old adults across the same attention, memory retrieval, decision-making, verbal, and spatial processing tasks. Adapted from Cerella, Poon, & Williams (1980) by permission.

Two lines of research extended the concepts postulated by Birren. A meta-analysis by Cerella, Poon, and Williams (1980) showed that in 99 experimental conditions ranging from choice reaction to memory scanning when speed was the dependent measure, an orderly, multiplicative relationship between the cognitive speed of young and old adults is apparent. FIGURE 2 shows this relationship. Older adults in their 60s and 70s were 1.36 times slower than younger adults in their 20s. Since the relationship between young and older adults in cognitive speed is a linear mathematical function, the implication is that if the cognitive speed of a younger person is known, the cognitive speed of an older person can be predicted with a high degree of confidence.

In a second line of research, young, middle-aged, and older adults were given the same series of tasks in which the speed of cognition was measured (Poon, 1993). The results are shown in FIGURE 3. Using the young subjects as controls, middle-aged adults were 1.12 times slower. In contrast, older adults were 1.29 times slower than the younger controls. Again, an orderly function that could account for a large amount of data variance was obtained.

FIGURE 3 Relationship of reaction times between young, middle-aged, and elderly adults. Adapted from Poon (1993) by permission.

In summary, three lines of research converge to identify a basic mechanism for producing age-related differences in cognition. First, Birren noted that older adults' cognition is slower because of the slowing of the central nervous system with aging. Second, we found a systematic, multiplicative relationship in the slowing of cognition in older as compared to younger adults. Finally, we found that cognitive slowing is evidenced in middle-aged adults and that the slowing is further exacerbated in older adults; the results suggest that the systematic slowing of a centralized mechanism may be involved in the observed cognitive performances from young, to middle-aged, to older adults.

Implications for the Diagnosis of Cognitive Functions

If this centralized slowing notion in normal aging is viable, could it be used to differentiate normal from pathological aging, that is, to detect the beginning stages of dementia? As noted earlier, the increased performance variability in normal older adults makes
the differentiation from normality difficult. However, if cognitive ability can be represented by performance on an array of cognitive tasks (such as the performance depicted in Figure 3), then it may be possible to differentiate small departures from normality or small changes due to an intervention.

**FIGURE 4** Relationship of reaction times between control, early demented, and major depressive patients. Adapted from Poon (1989) by permission.

![Figure 4](image1.png)

**FIGURE 5** Reaction time profiles of six subjects. The top two panels represent healthy adults. The middle two panels represent major depressive patients. The bottom two panels represent early demented patients. Adapted from Poon (1989) by permission.

**FIGURE 4** shows a comparison of cognitive speed in patients with early dementia of the Alzheimer's type (but not depressed) and patients who are major depressives (but not demented) with age-matched controls (Poon, 1989) on four cognitive tasks (simple reaction time, semantic processing, recognition memory, and mental rotation). The Figure shows that patients in early dementia are 1.45 times slower than their normal controls.

Depressed but not demented patients are very similar to normal controls in cognitive speed, only 1.12 slower.

**FIGURE 5** shows the performance of individual subjects. The subjects in the top two panels were normal control subjects (vertical axis), as they were compared to the same cognitive tasks completed by their own peers (horizontal axis). Their performance were very similar to the average of the control group. The middle two panels show the performances of two depressed but not demented subjects, as compared to the control group. The subject represented in the left panel performs as well as a normal control, and the subject represented on the right panel is slightly faster than control. The bottom two panels show the performances of demented but not depressed patients. Visual inspection of the cognitive profiles reveals that cognitive performances of the early demented subjects are different from normals and from depressed subjects. Their performance profiles are slower and more variable when compared to normal controls.

A picture is worth a thousand words. When the cognitive speed performances of an individual or group are plotted and compared with data from a control group on identical cognitive tasks, a picture emerges of (1) the relative speed of the experimental group or individual compared to the control and (2) the consistency and variability of the performances. Data collected so far show that there is systematic slowing with aging. And patients with early dementia are slower and more variable than age-matched controls. Could this technique be employed to show changes over time or changes due to an intervention such as a drug trial? Theoretically, the technique would be ideally suited for measuring cognitive changes over time. Instead of relying on one or two cognitive tasks to measure change (which is often done in intervention research), this technique exam-
ines a composite of tasks. The relationship among the tasks (slope of the regression) is used as a more stable measure of the integrity of the central processor of an individual. If a particular cognitive intervention works, it should have the effect of changing the slope of the processing function.

The technique has not often been employed in intervention trials. However, in one intervention trial to evaluate the effects of long-term, regular aerobic exercise on cognition in older adults, the improvement in the speed of the central processor (regression slope) after the exercise program was found to relate positively and significantly to the amount of improvement in oxygen consumption (VO2-Max) (Noble & Poon, 1995). More intervention trials are needed to determine the viability of this technique for assessing intervention and the resulting changes in cognition.

**Summary and Conclusion**

Greater variability in cognitive performance is observed in older adults than in younger adults, which could be due to the more diverse life experiences, occupations, education, and health of older adults. The wider range of cognitive functioning in normal older adults makes the diagnosis of early pathology difficult.

Cognitive speed, or reaction time, has the convenient measurement property of a ratio scale. Further, cognitive speeds obtained from different tasks can be analyzed and compared with a control group through regression techniques. The regression equation, or the scatter plot, offers the advantage of producing a profile from which the relative slowing and variability of the processor can be assessed. Further trials are needed to establish the efficacy of this method for diagnosing early dementia and for measuring the effectiveness of interventions.

**References**


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