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Lexical vs. Nonlexical Cognitive Processing: Is General Slowing Domain-Specific?

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The results from several meta-analyses place new constraints on the general slowing hypothesis of age-related changes in the rate of cognitive processing. It was found that in the lexical domain, a linear function described the relationship between the response latencies of older (age 65 - 75) and younger (age 19 - 29) adults with great precision: $O = 1.48\ Y - .067$, where O and Y refer to older and younger latency, respectively, and the unit is the second; adjusted $\underline{r}^2 = .976$. This function was based on data from lexical decision experiments and accurately predicted performance in an independent set of experiments employing other lexical tasks. In contrast, performance in nonlexical tasks spanning the same range of task difficulty was described by a nonlinear, positively accelerated power function: $O = 1.60\ Y^{1.26}$, adjusted $\underline{r}^2 = .951$. It was concluded that although general slowing is observed in both the lexical and the nonlexical domains, latencies in the former are consistently shorter than would be predicted based on performance in the latter. These results are interpreted within the framework of the Information Loss Model, a mathematical model of age-related cognitive slowing (Myerson, Hale, Wagstaff, Poon, & Smith, in press).

One of the most striking observations of adult aging is that older adults perform cognitive tasks more slowly than younger adults. Is this age-related slowing a consequence of qualitative changes in cognitive processes, or is it more aptly characterized as a generalized quantitative slowing of cognitive processes that remain qualitatively stable with age? The purpose of this paper is to compare the quantitative and qualitative nature of age-related slowing in two cognitive domains, the lexical and the nonlexical, and to explain the findings within the framework of the Information Loss Model (Myerson, Hale, Wagstaff, Poon, & Smith, in press).

Age-related slowing has been found in experiments employing lexical tasks (e.g., lexical decision, category judgment, naming) as well as those employing nonlexical tasks (e.g., choice reaction time, memory scanning, mental rotation). The results of these experiments indicate that as task difficulty increases, so does the difference in response latencies between older and younger adult groups. The ubiquity of this "complexity effect" led to the development of the general slowing hypothesis, which states that all cognitive processes slow at the same rate with advancing adult age (e.g., Birren, 1965).

The existence of general slowing has been elegantly corroborated in meta-analyses in which the mean latencies of the older group were plotted as a function of the mean latencies of the younger group in the same experimental conditions, following the method of Brinley (1965). In the first major meta-analysis of this type, Cerella, Poon, and Williams (1980) suggested that the relation between old and young latencies was linear. An expanded and more systematic meta-analysis by Hale, Myerson, & Wagstaff (1987), which encompassed data from a remarkably wide variety of nonlexical tasks, demonstrated that the relation was actually a nonlinear, positively accelerated power function (the data are shown in Figure 1); this function accounted for 98.9% of the variance. Such precision of prediction suggests that general quantitative slowing was responsible for the greater latencies of the older adults. If it had instead been the case that task-specific cognitive processes differed between old and young, or that qualitatively stable cognitive processes slowed at different rates, then there would have been no single mathematical function relating old and young latencies across the

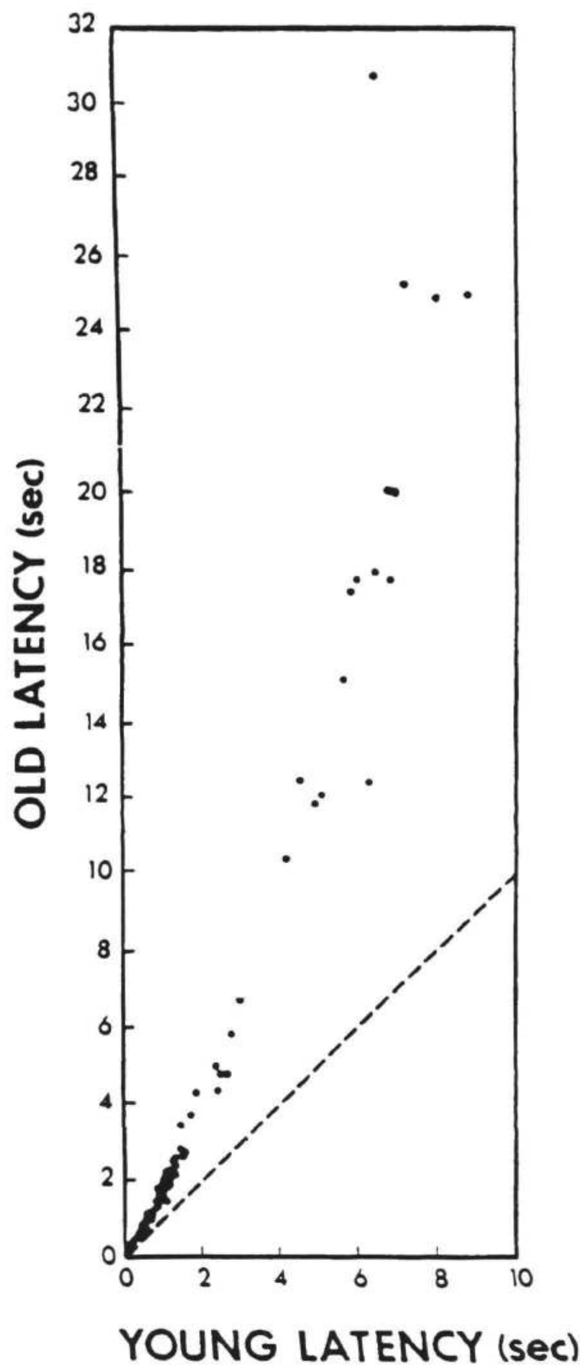

Figure 1. Old latency as a function of young latency (nonlexical tasks). The figure is taken from Hale et al. (1987).

entire data set. The significance of the single function is that the older group's latency in any nonlexical experimental condition can be reliably predicted from the younger group's latency in that condition without knowledge of the exact nature of the task. For example, if a young adult group performs a nonlexical task with a latency of 1.25 seconds, then an older adult group will perform that task with a latency of approximately 2.16 seconds, regardless of whether the task is choice reaction time, memory scanning, or mental rotation.

Evidence from psychometric testing indicates that verbal ability is less susceptible to age-related decline than nonverbal ability, suggesting the possibility that lexical slowing may be lesser in quantity than nonlexical slowing and that there will exist no single mathematical function that relates old and young latencies in both the lexical and the nonlexical domains. In order to compare lexical and nonlexical slowing, we conducted two meta-analyses in the lexical domain analogous to the one Hale et al. (1987) had conducted in the nonlexical domain. In their study, Hale et al. surveyed all issues of the Journal of Gerontology from 1975 to 1984; included in the meta-analysis were all experiments involving nonlexical reaction time tasks that required the pressing or releasing of a response key and that employed a younger group (mean age between 20 and 25 years) and an older group (mean age between 65 and 75 years). Nine studies met the inclusion criteria, yielding a data set consisting of results from 86 experimental conditions.

The data base for our two lexical meta-analyses included all issues of nine different journals from the years 1975 through 1987. The first meta-analysis was restricted to studies employing the lexical decision task, in which subjects decide as quickly as possible whether visually presented letter strings are words or nonwords. This task was by far the most prevalent reaction time task used in studies of word recognition and aging. Typically, the lexical decision response is signaled by pressing one of two response keys, making the motor component equivalent to that of the studies included in the nonlexical meta-analysis of Hale et al. (1987). Ten studies met the following inclusion criteria: the mean age of the younger group fell between 19 and 29 years and that of the older group fell between 65 and 75 years; the lexical decision response was based on one or two letter strings per trial; the authors reported both word and nonword response latencies; and error rates were similar for young and old subjects. The resulting data set consisted of results from 90 experimental conditions.

The mean latency of the older group in each experimental condition was plotted as a function of the mean latency of the younger group in the same condition; the results are shown in Figure 2, in which lexical decision response latencies are indicated by closed circles. Because word responses and nonword responses yielded statistically equivalent regression functions, functions based on all responses were calculated. The exponent of the best-fitting power function was not reliably different than 1.0, indicating that the relation between old and young latencies was essentially linear. The linear regression equation that best fit the data was

$$O = 1.48\ Y - .067$$

(represented by the solid line in Figure 2); O and Y represent the latencies of old and young groups respectively and the unit of time is the second. The adjusted $\underline{r}^2$ was .976.

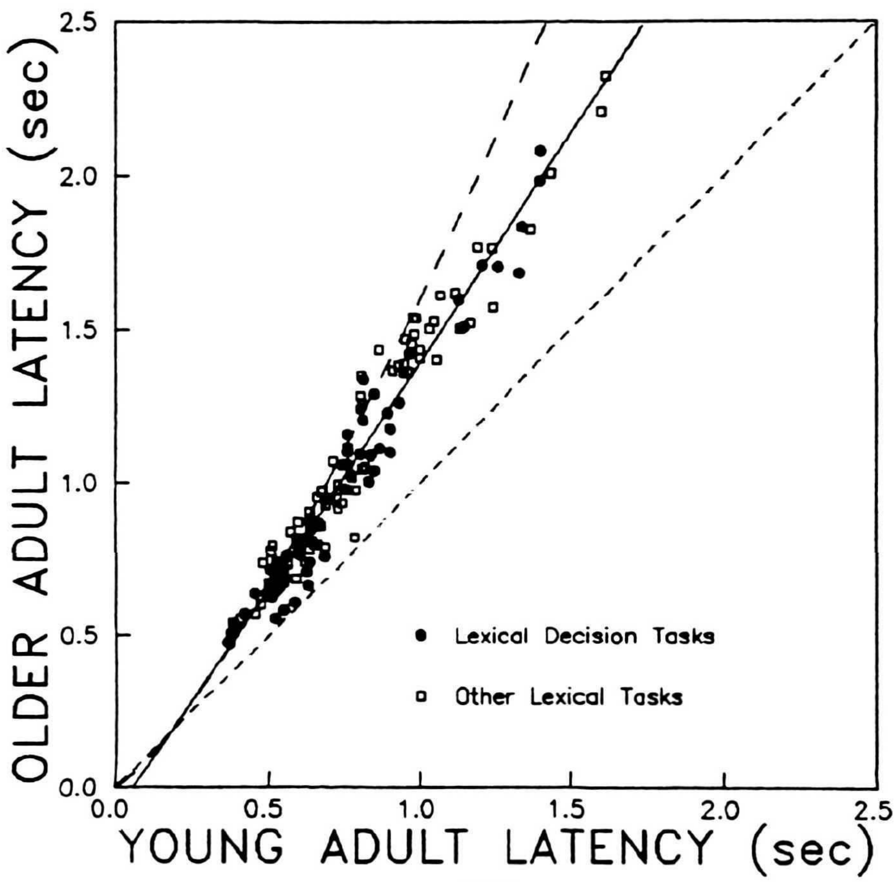

Figure 2. Old latency as a function of young latency (lexical tasks). If the performances of older and younger adult groups were equal, the data points would fall along the dashed diagonal line.

Because the younger adult latencies in the nonlexical meta-analysis of Hale et al. (1987) spanned a much wider range (0.2 s to 9.0 s) than those in our lexical decision meta-analysis (0.4 s to 1.6 s), we computed a best-fitting function for the 62 nonlexical conditions in which the younger adult latency fell between 0.4 s and 1.6 s; the equation of this function was

$$O = 1.60\ Y^{1.26}$$

with an adjusted $\underline{r}^2$ of .951. This positively accelerated function is indicated by the dashed curve in Figure 2. (The function is very similar to that found by Hale et al., 1987, across their entire data set: $O = 1.62\ Y^{1.29}$.) A comparison of the lexical decision data and the nonlexical function makes it apparent that lexical decision performance shows less age-related slowing than nonlexical performance; 74.4% of the lexical decision data points fall below the nonlexical curve.

Are the results from the lexical decision meta-analysis unique to the lexical decision task, or do they capture a general slowing trend common to the entire domain of lexical processing? To answer this question, we conducted a second lexical meta-analysis by surveying our nine-journal data base for all lexical experiments that employed reaction time tasks other than lexical decision. This survey yielded a data set of 76 conditions from nine studies employing four tasks: naming, same-different judgment, category membership judgment, and relatedness judgment. When older latencies were plotted as a function of younger latencies, the resemblance to the lexical decision function was striking. The results can be seen in Figure 2, in which latencies from the second lexical meta-analysis are indicated by open squares. The regression equation that best fit this second set of lexical data was

$$O = 1.47\ Y - .100$$

with an adjusted $\underline{r}^2$ of .960. The close similarity of this equation and the the equation from the lexical decision meta-analysis implies that essentially one rate of cognitive slowing characterizes lexical processing. It cannot be argued that the results from the lexical decision meta-analysis were attributable to age-related changes in post-access decision processes unique to the lexical decision task.

The results of the two lexical meta-analyses thus indicate that although older subjects process words more slowly than younger adults, the degree of age-related decrement is less than that found in nonlexical processing. The finding that the lexical domain is associated with a different function than the nonlexical domain indicates that age-related cognitive slowing is not so general that one rate of slowing characterizes performance in both domains. On the other hand, the existence of a precise mathematical relationship between old and young latencies within each domain indicates that the rate of cognitive slowing is general across experimental conditions within that domain. It appears, then, that the rate of general slowing is domain-specific, with a lesser rate of slowing in the lexical domain than in the nonlexical domain.

The meta-analysis of Hale et al. (1987) showed that complexity effects in performing nonlexical tasks are nonproportional; not only does the difference between old and young latency increase as a function of task difficulty, but the ratio of old latency to young latency also increases as task difficulty increases. Recently, Myerson et al. (in press) developed the Information Loss Model of age-related slowing, a mathematical model that rests on three assumptions:

(a) the more complex the task, the more information processing steps required to complete the task;

(b) the duration of each processing step is inversely proportional to the amount of information available at that step; and

(c) a constant proportion of information is lost at each processing step.

Based on these assumptions, the equation for the relation between latencies of older and younger adults is

$$O = \{[1 + Y \cdot P_y / D_y (1-P_y)]^b - 1\} D_o (1-P_o)/P_o$$

where

$$b = \underline{\ln}(1-P_o)/\underline{\ln}(1-P_y),$$

D_o and P_o are, respectively, the duration of a processing step without information loss and the proportion of information loss per step for the older group, and D_y and P_y are the corresponding parameters for the younger group. If P_o is greater than P_y, then b is greater than 1.0, and the relation between older and younger latencies is positively accelerated. However, if P_o equals P_y, then the equation for the relation between latencies of older and younger adults simplifies to

$$O = Y \cdot D_o/D_y.$$

In this case, all processing steps in the older adults are proportionally greater than those of the younger adults by the general speed factor D_o/D_y, and the relation between the latencies of older and younger adults is linear.

Thus, according to the Information Loss Model, the linearity of the relation between old and young lexical latencies can only arise if the information loss proportion does <u>not</u> increase with advancing age. If the information loss proportion does increase, then the prediction is that the relation between old and young latencies will be positively accelerated. Therefore, in the lexical domain, the rate of information loss during cognitive processing appears to remain stable as an adult ages, whereas in the nonlexical domain, it appears to increase with age.

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