How General Is General Slowing? Evidence From the Lexical Domain

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Three analyses are reported that are based on data from 19 studies using lexical tasks and a reduced version of the Hale, Myerson, and Wagstaff (1987) nonlexical data set. The results of Analysis 1 revealed that a linear function with a slope of approximately 1.5 described the relationship between the lexical decision latencies of older (65–75 years) and younger (19–29 years) adults. The results of Analysis 2, based on response latencies from 6 lexical tasks other than lexical decision, revealed a virtually identical linear relationship. In Analysis 3, it was found that performance on nonlexical tasks spanning the same range of task difficulty was described by a significantly steeper regression line with a slope of approximately 2.0. These findings suggest that although general cognitive slowing is observed in both domains, the degree of slowing is significantly greater in the nonlexical domain than in the lexical domain. In addition, these analyses demonstrate how the meta-analytic approach may be used to determine the limits to the external validity of experimental findings.

When older adults and younger adults perform the same cognitive task, the older group tends to perform more slowly than the younger group. This age-related decline in the speed of information processing has been found in experiments using a wide variety of experimental paradigms (for a review, see Salthouse, 1985). Although age differences are greater on some tasks than on others, it has been argued that this is not because the information-processing components used in some tasks have been more affected by aging, but rather because some tasks simply require more processing (Cerella, Poon, & Williams, 1980; Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse & Somberg, 1982). If there is a *general cognitive slowing* with advancing age, that is, if all information processing proceeds more slowly (Birren, 1965; Birren, Woods, & Williams, 1980), then tasks that require more processing should show greater age differences, regardless of the particular components involved.

The evidence supporting the general slowing hypothesis comes primarily from meta-analyses that integrate the data from studies using a wide range of information-processing tasks (Cerella, 1985; Cerella et al., 1980; Hale, Myerson, & Wagstaff, 1987; Nebes & Madden, 1988), although similar results have been obtained when multiple tasks have been used in a single study (Smith, Poon, Hale, & Myerson, 1988) and when a

single task has been made more difficult in a variety of ways (Salthouse & Somberg, 1982). The nature of this evidence is as follows: When the mean latencies of older adults are plotted as a function of the mean latencies of younger adults in the same experimental condition, simple mathematical equations (e.g., linear and power functions) accurately ($r^2 > .90$) describe the relationship between the performances of the two age groups. These results imply that the older adults' latencies may be predicted directly from the younger adults' latencies without taking into consideration the componential makeup of the tasks being performed. If processing components were differentially affected by aging, then accurate prediction of the latencies of older adults would not be possible without taking the nature of the task into consideration.

In their pioneering meta-analysis, Cerella et al. (1980) found that the latencies of older adults could be predicted from those of younger adults by using a linear function. Although the data set analyzed by Cerella et al. consisted of results from both lexical and nonlexical tasks, a subsequent meta-analysis by Hale et al. (1987) included only results from nonlexical tasks, that is, tasks that did not use words as stimuli. Hale et al. reported that the relationship between the latencies of older and younger adults on nonlexical tasks was nonlinear and best described by a positively accelerated power function. In contrast, Madden (1989) reported that a linear function described the relationship between older and younger adults' latencies on lexical decision tasks based on several studies performed in his laboratory. Taken together, these findings suggest that there are two domains, one lexical and the other nonlexical, which are differentially affected by aging. The existence of two domains would provide an important constraint on the generality of general slowing.

The distinction between lexical and nonlexical domains is not based simply on the form of the relationship between older and younger adults' latencies: The power function describing nonlexical performance (Hale et al., 1987) predicts a much greater age difference in latencies on difficult tasks than does the linear function describing lexical performance (Madden,

1989). The psychometric literature also provides evidence that nonverbal abilities show much greater age differences than verbal abilities (for reviews, see Salthouse, 1982, 1989). However, speed of response plays a much smaller role in the Verbal scale of the Wechsler Adult Intelligence Scales (WAIS) than in the Performance scale. Thus, the differential effect of aging on these psychometric tests, although consistent with the existence of two domains, does not directly address the question of whether lexical processing speed and nonlexical processing speed show two different developmental trends.

Our investigation *does* directly address the issue of different developmental trends for processing speed in the lexical and nonlexical domains. In Analysis 1 we integrate data from lexical decision experiments conducted in a variety of laboratories, and compare our results with Madden's (1989) analysis of data from his laboratory to test the inter-laboratory generality of his findings. In Analysis 2 we compare data from lexical decision experiments with data obtained from a variety of other tasks using lexical stimuli to test for general slowing on lexical tasks. Finally, in Analysis 3 we compare lexical data from Analyses 1 and 2 with nonlexical data spanning a comparable range of latencies to test for the existence of two separate domains.

Analysis 1

Method

All articles published in 11 different journals from 1975 through 1987 (see Appendix) were examined, and all lexical decision experiments (in which subjects were required to indicate as quickly as possible whether a string of letters is a word or a nonword) were considered. Data from a lexical decision experiment were included if the experiment met the following criteria:

1. 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.

2. Subjects were in good health.

3. Error rates were similar for younger and older subjects.

4. Subjects made lexical decisions based on one or two visually presented letter strings, and the authors reported both word and nonword response latencies. Prior sentence context may or may not have been provided.

The 10 studies that met all the inclusion criteria yielded a data set consisting of results from 90 experimental conditions (Table 1).

Table 1
Studies Included in the Meta-Analysis of Lexical Decision Data

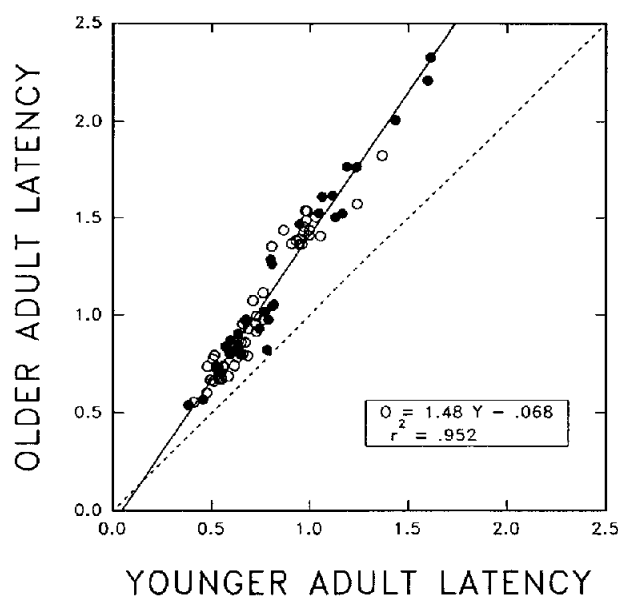| Study	No. conditions		
	Words	Nonwords	Source
Bowles & Poon (1981)	3	3	Table 1
Burke, White, & Diaz (1987)	8	2	Table 4
Burke & Yee (1984)	9	2	Table 3
Cohen & Faulkner (1983b)	4	2	Table 2
Howard (1983)	4	3	Table 3
Howard, McAndrews, & Lasaga (1981)	2	3	Table 3
Howard, Shaw, & Heisey (1986)	9	6	Table 3
Madden (1986)	6	2	Table 2
Madden (1988)	6	4	Table 1
Madden & Greene (1987)	6	6	Table 1

Figure 1. Data from lexical decision tasks. (The latencies, in seconds, of older adults are plotted as a function of the latencies of younger adults in the same experimental condition. Open circles represent word responses, and closed circles represent nonword responses. The solid line represents the best fitting linear regression function for word and nonword responses combined. The dashed line represents the equal performance diagonal.)

Results and Discussion

Following the method of Brinley (1965), the mean latency of the older group in each of the 90 experimental conditions was plotted as a function of the mean latency of the younger group in the same condition. The results are shown in Figure 1. Had the older adults performed as quickly as the younger adults, all the data would have fallen along the diagonal (indicated by the dashed line). In fact, older adults were always slower than younger adults in the same experimental condition, as indicated by the fact that all data are above the diagonal. The relationship between older adults' latencies (O) and younger adults' latencies (Y) is well described ($r^2 = .952$) by a linear function,

$$O = 1.48Y - .068, \qquad (1)$$

where the units are seconds. Because word responses (indicated by open circles) and nonword responses (indicated by closed circles) yielded regression functions that did not differ significantly in their slopes and intercepts based on a simultaneous comparison of the regression coefficients using multiple regression (see Netter, Wasserman, & Kutner, 1985, for a description of this technique), all lexical decision responses were combined in this and subsequent analyses of this data set.

Our results are similar to those obtained by Madden (1989) when he analyzed lexical decision data from several of his own studies. In both cases, the relationship between the latencies of older and younger adults was well described by a linear function with a slope of approximately 1.5. To determine whether data obtained in Madden's laboratory differ significantly from

data obtained by other investigators, we conducted two statistical tests. To conduct these tests, we divided our data set into two subsets, one consisting of the three studies by Madden and the other consisting of the seven remaining studies by other investigators. In the first test we used multiple regression to compare the regression coefficients, which revealed that the slope and intercept parameters of the regression lines for the two subsets did not differ significantly. The second test revealed that the 1.56 slope and the 99 ms intercept reported by Madden (1989) did not differ significantly from the slope and intercept for the seven studies conducted by other investigators based on the t values for the parameters (Chatterjee & Price, 1977).

In these analyses, as in previously published meta-analyses in this area (Cerella, 1985, 1990; Cerella et al., 1980; Hale et al., 1987; Madden, 1989; Myerson et al., 1990), the data from each experimental condition were treated as equally reliable estimates. However, this may not be the case; in particular, data from larger samples may be more reliable than those from smaller samples. Therefore, weighted regression (in which each point was weighted according to the square root of the sample size) was also used to provide alternative estimates of regression parameters. Weighted regression of the lexical decision data set yielded estimates of 1.47 and −0.068 for the slope and intercept parameters, respectively, values that are virtually identical to those for Equation 1. Nevertheless, the concern that analyses might be unduly influenced by less reliable data is a reasonable one and, in the analyses that follow, results obtained from both weighted and unweighted regression procedures are reported.

Another methodological point concerns the fact that these analyses, like previous meta-analyses in this area (Cerella, 1985, 1990; Cerella et al., 1980; Hale et al., 1987; Madden, 1989; Myerson et al., 1990), were based on the data from all of the experimental conditions from each of the included studies. Although this approach uses the maximum amount of information available, some subjects, those who participated in more conditions, contribute more data and thus exert more influence than other subjects who participated in fewer conditions, potentially biasing the results. Therefore, additional analyses were conducted in which a single, representative condition was selected for each pair of groups (elderly and young adults) from each study. Each representative condition was selected so as to be of median complexity in relation to all of the conditions in which a given pair of groups participated. Median complexity was determined on the basis of the latencies of the young adult group.

Analyses based on one representative condition per pair of groups yielded the same pattern of results as those based on all of the experimental conditions. That is, there was no significant difference between the slopes or intercepts of the regression equation describing data from word responses and the regression equation describing data from nonword responses. Although the two approaches to meta-analysis used here, one based on representative conditions and the other based on all conditions, lead to the same conclusions in this instance, the possibility that results might be biased when some samples contribute more data than others is an issue that should be considered in subsequent meta-analytic studies; we include the results of both approaches in all possible analyses in this study. Unfortunately, despite the large number of experimental conditions (90), the number of different pairs of subject groups in lexical

decision studies from Madden's laboratory and other laboratories (three and seven, respectively) was insufficient for an analysis based on representative conditions. For the purpose of comparison, regression functions from all analyses are given in Table 2 and the results of all comparisons of regression coefficients are given in Table 3.

Analysis 2

Are the preceding results unique to the lexical decision task or are they common to the entire domain of lexical processing? Do older adults always take approximately 1.5 times longer than younger adults to process lexical information? Recently, the lexical decision task has been the target of criticism. Balota and Duchek (1988), for example, argued that lexical decision latency is unduly influenced by decision processes that occur after the mental lexicon has been accessed. Such processes are unique to the lexical decision task because it, unlike other lexical tasks, requires a discrimination between words and nonwords. In the light of such concerns, it might be argued that the results of the lexical decision meta-analysis reflect the age-related slowing of a post-access decision process unique to experiments requiring subjects to discriminate words from nonwords. If this were the case, age-related slowing should be less evident in the performance of lexical tasks that use only actual words of English as target stimuli. Such tasks provided the data for our second meta-analysis.

Method

The 11-journal data base listed in the Appendix was surveyed, and all lexical experiments that used reaction time tasks other than lexical decision were considered. Data from these experiments were included if the experiment met the first three criteria (age, health, and error rate) used in Analysis 1 as well as the following additional criteria:

4. Subjects made vocal pronunciation responses (naming) or vocal or manual binary choice responses (same–different judgment, category membership judgment, relatedness judgment, case judgment, or animate–inanimate judgment) on the basis of one or two visually presented words per trial. Prior sentence context may or may not have been provided.

5. Subjects were *not* instructed to memorize the stimuli for a later recall or recognition test. Experiments or conditions using such instructions were excluded to eliminate any influence of possible age-related differences in the strategies employed to enhance long-term retention.

The nine studies that met all the inclusion criteria yielded a data set consisting of results from 76 conditions (Table 4). Six tasks were represented: naming (simple pronunciation), same–different judgment, category membership judgment, relatedness judgment, case judgment (uppercase or lowercase), and animate–inanimate judgment. In contrast to the lexical decision task, none of the tasks included in the second lexical data set required the processing of nonwords.

Results and Discussion

When the latencies of older adults were plotted as a function of the latencies of younger adults in the same experimental condition, as shown in Figure 2, a close resemblance to the lexical decision data was apparent. As before, the relationship

Table 2
Parameter Estimates for Unweighted and Weighted Linear Regression Functions

	Unweighted regression		Weighted regression	
	Formula	r^2	Formula	r^2
Analysis 1				
Lexical decision tasks	O = 1.48Y − .068	.952	O = 1.47Y − .068	.951
Word responses only	O = 1.52Y − .093	.936	O = 1.51Y − .092	.934
Nonword responses only	O = 1.45Y − .055	.963	O = 1.45Y − .054	.961
Studies not by Madden	O = 1.47Y − .067	.947	O = 1.47Y − .073	.945
Madden studies only	O = 1.62Y − .149	.914	O = 1.62Y − .149	.914
Analysis 2				
Other lexical tasks	O = 1.47Y − .101	.961	O = 1.45Y − .091	.970
Analysis 3				
Nonlexical tasks	O = 2.05Y − .385	.908	O = 2.03Y − .361	.919

between the latencies of older and younger adults was well described (r^2 = .961) by a linear function,

$$O = 1.47Y - .101. \qquad (2)$$

Weighted regression yielded similar parameter estimates (see Table 2). Moreover, no significant differences between the slope and intercept of this equation and those of Equation 1 (the regression equation describing the lexical decision data from Analysis 1) were found using either all conditions or a set of representative conditions (see Table 3). Our results imply that as the latencies on lexical tasks increase, the difference between the latencies of older and younger adults increases, but the size of this *complexity effect* is largely independent of the nature of the task or the manipulation leading to the increased latencies.

Perhaps the most striking aspect of these results, and the most theoretically significant, is the precise correspondence between the slopes obtained for lexical decision tasks and for a variety of other lexical information-processing tasks. For pur-

poses of interpreting these slopes, the performance of younger adults may be thought of as a benchmark or standard, and their latencies as an index of task difficulty, operationally defined as the amount (measured as duration) of processing required for task performance. If all lexical information processing were approximately 1.5 times slower in older (65–75 years) adults, then any manipulation that increased the amount of processing required to perform a task would increase the latencies of older adults 1.5 times more than it would increase the latencies of younger adults, regardless of the nature of the manipulation or the size of the increase in younger adults' latencies. Indeed, this is what Analyses 1 and 2 reveal. Thus, our results imply that essentially one age-related cognitive slowing factor characterizes all lexical processing, regardless of the specific lexical task, regardless of whether the task involves words only or both words and nonwords, and regardless of the specific variables manipulated in the experiment.

Analysis 3

How does age-related slowing of lexical information processing compare with age-related slowing of nonlexical processing? In contrast to the linear relationships observed in our analyses of data from lexical tasks, Hale et al. (1987) reported that the relationship between the latencies of older and younger adults performing nonlexical tasks was nonlinear and well described by a positively accelerated power function. In addition, the power function reported by Hale et al. predicts larger differences between the latencies of older and younger adults than are predicted by Analyses 1 and 2. However, data from lexical and nonlexical experiments have not been compared directly, and this was the purpose of Analysis 3.

Method

Three data sets were included in Analysis 3: the lexical decision data and the data from other lexical tasks that provided the bases for Analyses 1 and 2, and those data from the Hale et al. (1987) data set that spanned the same range of young adult latencies as the two lexical data sets. This reduced nonlexical data set was needed because the younger adult latencies in the Hale et al. (1987) analysis included much longer latencies than those included in Analyses 1 and 2. Thus, reducing the Hale et al. data set should avoid the possibility that any difference

Table 3
Results of Comparisons of Regression Coefficients

	All conditions		Representative conditions	
Data sets compared	Slope	Intercept	Slope	Intercept
Analysis 1				
Word responses vs. nonword responses	−0.86	0.63	−0.13	0.03
Three Madden studies vs. seven other studies	1.02	−0.88	—[a]	—[a]
Analysis 2				
Lexical decision tasks vs. other lexical tasks	0.13	0.86	−0.72	1.04
Analysis 3				
Lexical decision tasks vs. nonlexical tasks	−6.58***	4.18***	−4.22***	3.19**
Other lexical tasks vs. nonlexical tasks	−6.09***	3.64***	−2.36*	1.86*

Note. All values are expressed as *t*-test results.
[a] These tests were not conducted because of the small number of studies by Madden.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 4
Studies Included in the Meta-Analysis of Data From Other Lexical Tasks

Study	Task	No. conditions	Source
Balota & Duchek (1988)	Naming	28	Figures 1 & 4
Byrd (1984)	Relatedness judgment	6	Figures 1 & 2
Cerella & Fozard (1984)	Naming	4	Table 1
Eysenck (1975)	Category membership judgment	3	Table 1
Madden (1985)	Same–different judgment	3	Page 209
Mitchell & Perlmutter (1986)	Case judgment	4	Table 1
	Animate–inanimate judgment	4	Table 1
Mueller, Kausler, & Faherty (1980)	Same–different judgment	6	Table 1
Nebes, Boller, & Holland (1986)	Category membership judgment	3	Table 2
	Naming	3	Table 2
Petros, Zehr, & Chabot (1983)	Same–different judgment	12	Table 2

between the relationships reported for nonlexical and lexical latencies could be due to the fact that the nonlexical data set reported by Hale et al. included tasks of much greater difficulty. The reduced nonlexical data set consisted of results from those experimental conditions in the original data set that met the first three criteria (age, health, and error rate) as well as the following additional criteria:

4. Subjects responded to nonlexical stimuli by making a manual, binary-choice response, and the mean latency for the younger adult group was between 0.35 and 1.65 s.

These criteria yielded a data set of the results from 59 conditions from seven studies (Table 5), and a variety of experimental paradigms were represented: choice reaction time, cued reaction time, memory scanning, and mental rotation.

Results and Discussion

For the reduced Hale et al. (1987) data set, the relationship between the latencies of older and younger adults was well described ($r^2 = .913$) by a positively accelerated power function,

Figure 2. Data from lexical tasks other than lexical decision. (The latencies, in seconds, of older adults are plotted as a function of the latencies of younger adults in the same experimental condition. The solid line represents the best fitting linear regression function.)

$$O = 1.63 \, Y^{1.31}. \tag{3}$$

It is reassuring that this function is remarkably similar to that reported by Hale et al. for their entire nonlexical data set: $O = 1.62 \, Y^{1.29}$. However, a linear function,

$$O = 2.05 \, Y - .385, \tag{4}$$

accounted for only slightly less of the variance ($r^2 = .908$) of the reduced data set. Thus, over a truncated range, a straight line provides a good approximation of the relationship between older and younger adults' nonlexical latencies (see Figure 3). Moreover, similar parameter estimates were obtained by using both unweighted (Equation 4) and weighted linear regression (see Table 2).

Linear regression provided a basis for comparing the truncated nonlexical data set with the data sets from the previous analyses. As shown in Table 3, the slope of the nonlexical regression line was significantly greater than the slopes of the regression lines for both of the lexical data sets, which did not differ from each other. It should be noted that the same pattern of results was obtained with analyses based on all the experimental conditions and with analyses based on representative conditions only. (The criterion for selecting a representative condition for each pair of groups in the nonlexical studies falling within the truncated range was the same as that used in the previous analyses.)

Thus, the general slowing of lexical information processing associated with advancing age is significantly less than the general slowing of nonlexical information processing. In fact, 82% of the lexical decision data points and 79% of the data points from other lexical tasks fall below the regression line for the nonlexical data set (Equation 4); in other words, most of the observed lexical latencies of older adults are faster than would be predicted on the basis of nonlexical performances. Moreover, as may be seen in Figure 4, the discrepancy between the observed lexical latencies and those predicted by the nonlexical regression line increases with task difficulty ($r = .871$), such that nonlexical latencies are increasingly slower than comparable lexical latencies.

Further evidence of the distinction between lexical and nonlexical slowing is found in the significantly different intercepts of the regression lines. However, if the linear fit to the nonlexical data is only an approximation of a relationship that is actu-
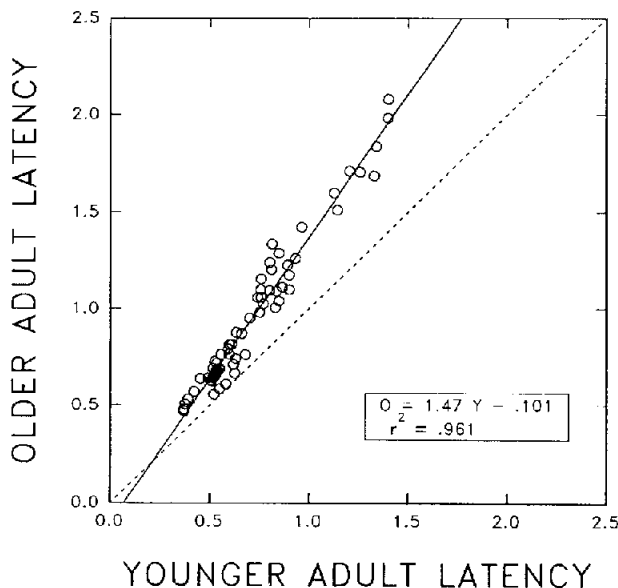
Table 5
Studies Included in the Reduced Nonlexical Data Set From Hale, Myerson, & Wagstaff (1987)

Study	Task	No. conditions	Source
Cerella, Poon, & Fozard (1981)	Mental rotation	20	Table 1
Cohen & Faulkner (1983a)	Rotated figures	4	Table 2
Gaylord & Marsh (1975)	Mental rotation	1	Figure 2
Madden (1984)	Cued reaction time	10	Figure 2
Rabbitt & Vyas (1980)	Multiple-choice reaction time	6	Table 2
	Four-choice reaction time	1	Table 3
Salthouse & Somberg (1982)	Sternberg memory scanning	8	Figure 2
Simon & Pouraghabagher (1978)	Choice reaction time	9	Figure 1 & Table 2

ally positively accelerated, then the difference in intercepts has no theoretical interpretation other than providing additional support for the lexical–nonlexical distinction. Unfortunately, the limited range of latencies in the three data sets do not provide a basis for distinguishing between linear and power functions as descriptions. Note, however, that over the larger range of the complete nonlexical data set, both the pattern of the residuals and the results of polynomial regression are consistent with nonlinearity (Myerson et al., 1990).

General Discussion

Our findings suggest that although older adults process visually presented words more slowly than younger adults, the degree of age-related decrement is less than would be expected on the basis of performance on nonlexical tasks. To make the implications of this more concrete, consider the following example. Suppose that a group of younger adults performs two tasks, one lexical and the other nonlexical, and their mean latency on

both tasks is 1.5 s. Our results imply that if an older adult group is given the same two tasks, the age difference for the nonlexical task will be twice that for the lexical task. That is, the older adults' mean latency on the lexical task will be approximately 2.1 s (estimated from the lexical regression line of Analysis 2), but their mean latency on the nonlexical task will be approximately 2.7 s (estimated from the nonlexical regression line of Analysis 3). Thus, an older adult may perform a nonlexical task much more slowly than a lexical task even though a younger adult performs both tasks equally quickly.

The general slowing hypothesis states that all information processing is similarly affected by age (e.g., Birren, 1965; Birren et al., 1980). This hypothesis is supported when a mathematical relationship exists between the latencies of older and younger adults such that the performance of one age group can be pre-
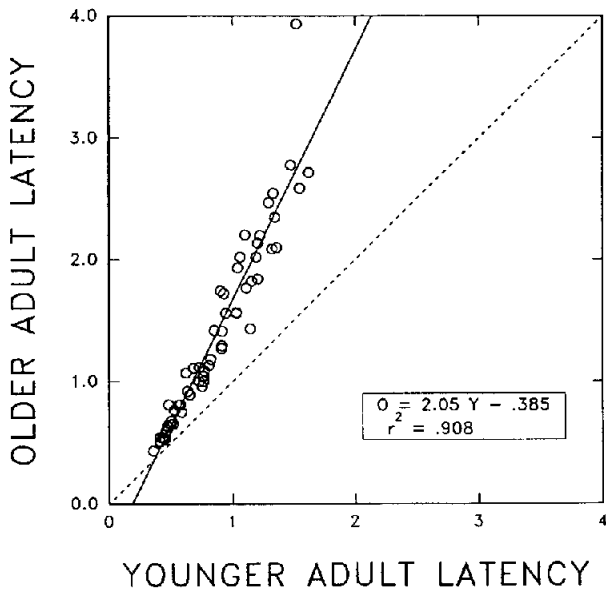

Figure 3. Data from nonlexical tasks. (The latencies, in seconds, of older adults are plotted as a function of the latencies of younger adults in the same experimental condition. The solid line represents the best fitting linear regression function.)
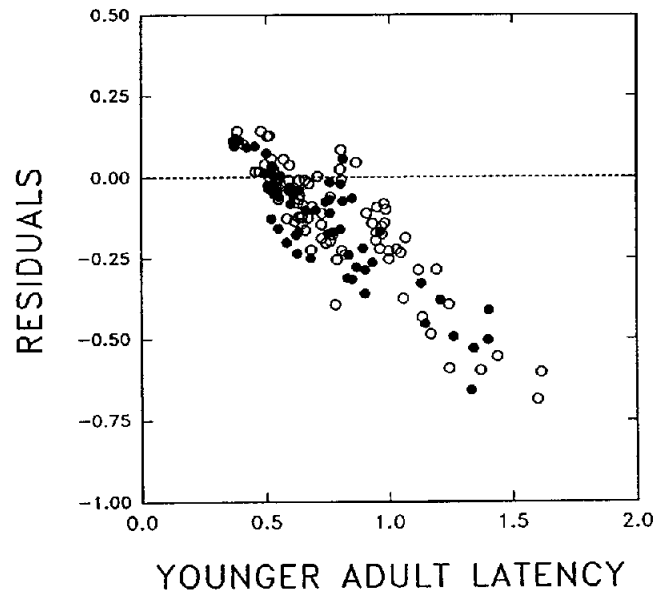

Figure 4. Lexical residuals about the nonlexical regression line. (The difference between the observed latencies, in seconds, of the older adults on lexical tasks and the latencies predicted by the nonlexical regression function is plotted as a function of the younger adults' lexical latencies. The open circles represent data from lexical decision tasks, and the closed circles represent data from other lexical tasks. The dashed line represents no deviation from the nonlexical regression line.)

dicted from that of the other group without taking into consideration any information about the specific nature of the tasks (e.g., Cerella et al., 1980; Hale et al., 1987). Our finding that the lexical domain is associated with a different mathematical function than the nonlexical domain indicates that age-related cognitive slowing is not so general that a single slowing factor characterizes performance in both domains. On the other hand, the existence of a precise mathematical relationship between the latencies of older and younger adults within each domain indicates that the amount of slowing is general across the different experimental tasks and conditions within that domain. It appears, therefore, that the degree of general slowing is domain-specific, with the amount of slowing in the lexical domain being less than that in the nonlexical domain.

The evidence for two distinct domains raises several interesting questions. For example, why should the degree of cognitive slowing be different in the lexical and nonlexical domains? Are there better ways to characterize these two domains? Are there more than two domains? These questions are similar to those traditionally asked regarding age-related changes in performance on psychometric tests (for reviews, see Salthouse, 1982, 1989), and the distinctions made in that area may prove relevant here. For example, it is possible that the lexical tasks surveyed in our analyses depended primarily on crystallized abilities, whereas the nonlexical tasks depended primarily on fluid abilities (Horn & Cattell, 1967). Certainly, the greatest difference between lexical and nonlexical domains was observed in the latency range in which the lexical tasks unarguably tapped background knowledge (e.g., category and relatedness judgments), whereas the nonlexical tasks did not (e.g., mental rotation and memory scanning).

Evidence relevant to the characterization of the two domains comes from studies of picture naming by younger and older adults (Bowles, 1990; Thomas, Fozard, & Waugh, 1977). The picture-naming latencies of older adults reported by both Bowles and Thomas et al. were much shorter than would be predicted by Equation 4, despite the fact that the use of Equation 4 would be consistent with the nonlexical nature of the stimuli. It is interesting that the older adults' latencies were not much different from what would be predicted on the basis of Equation 2, suggesting that name retrieval might be better classified as a lexical task, despite the pictorial nature of the stimuli. Alternatively, picture naming might be considered to tap background knowledge and thus to be a test of crystallized abilities.

Our findings also pose interesting problems for formal models recently developed to explain general cognitive slowing, for example, the multilayered slowing model (Cerella, 1985), the overhead model (Cerella, 1990), and the information-loss model (Myerson et al., 1990). For example, the multilayered slowing model posits two general slowing layers: a peripheral, sensorimotor layer associated with a lesser degree of slowing; and a central, cognitive layer associated with a greater degree of slowing. In our three data sets, almost all of the stimuli were high contrast visual displays, and the motor components were minimal. Nevertheless, despite the similarity of the sensorimotor aspects of the tasks, two distinct relationships emerged, depending on whether the cognitive aspect of the task was lexical or nonlexical.

Thus, in the context of the multilayered slowing model, our findings suggest that the cognitive layer may actually consist of two layers: one associated with a moderate degree of slowing (older adults requiring approximately 50% more time for processing lexical information than younger adults), and another associated with a high degree of slowing (older adults requiring approximately 100% more time for processing nonlexical information). The current estimate of the relationship between older and younger adults' nonlexical processing speeds agrees with the 2.0 cognitive slowing coefficient estimated by Cerella (1985) on the basis of data from experiments on mental rotation (Cerella, Poon, & Fozard, 1981), a nonlexical task. Note that Cerella considered the possibility that lexical access might represent a separate layer, but one in which processing was not slowed, in contrast with the 1.5 lexical slowing coefficient estimated here.

Cerella's (1990) overhead model, like Myerson et al.'s (1990) information-loss model, treats information processing as a sequence of generic processing steps, and more difficult tasks as simply consisting of more steps than easier tasks. However, the two models differ in that the former model attributes the larger age difference in latencies on more difficult tasks to age differences in the rate at which information-processing *overhead* accumulates, whereas the latter model attributes it to age differences in the rate of *information loss* during processing. In the context of the overhead model, on the one hand, our findings suggest that the overhead associated with nonlexical processing in older adults is greater than that associated with lexical processing. In the context of the information-loss model, on the other hand, our findings suggest that older adults lose nonlexical information at a greater rate than lexical information. It is not clear, however, why either overhead or information loss should be different for lexical and nonlexical processing. Future research that leads to better characterization of the two domains may also lead to needed clarification of the concepts of overhead and information loss.

Our findings have methodological as well as theoretical implications. Meta-analyses can be viewed as preliminary surveys that may generate interesting hypotheses, and along with this view goes the expectation that experimental investigations will be required to test these meta-analytically derived hypotheses. Although it is true that meta-analyses may serve such a hypothesis-generating role, this study suggests that the roles of experimentation and meta-analysis may sometimes be reversed. That is, given a finding from one laboratory, such as Madden's (1989) discovery of a linear relationship between older and younger adults' lexical decision latencies, the generalizability of that finding may be assessed through the use of meta-analyses. In our study, meta-analyses established that the value of the slope of the linear regression line is statistically reliable across laboratories using lexical decision tasks. Moreover, the generalizability of these findings extended not just to other laboratories using similar procedures but also to studies in other laboratories using quite different lexical tasks.

However, the generalizability of these findings did not extend to studies using nonlexical tasks, although an orderly relationship between older and younger adults' nonlexical latencies did exist. The fact that the meta-analytic approach may play a role in assessing external validity or generalizability also speaks

to the issue of whether meta-analyses attempt to integrate the incommensurable, a recurring question that seems to arise whenever meta-analytic techniques are applied in a new area (Glass, 1978; Rosenthal, 1984). In our study, statistical tests for possible differences between regression coefficients (both slopes and intercepts) established that results obtained in different laboratories and using different procedures could be integrated, but only so long as those procedures all involved responses to lexical stimuli. Thus, our effort did not simply combine data from diverse sources without any concern for whether it was meaningful or reasonable to do so. Rather, our study exemplifies how meta-analyses may be used as a tool for determining objectively what data may be integrated and what data may not.

In terms of the hypothesis-generating role served by meta-analyses, one hypothesis generated by our study, as by most meta-analyses, is that the meta-analytic results can be replicated in the context of a single experimental investigation. In this case, that means that if the same older and younger adults are tested on multiple tasks, some lexical and some nonlexical, the degree of age-related slowing observed on the lexical tasks should be consistently less than that observed on the nonlexical tasks. If this hypothesis is supported, the existence of two differentially slowed domains potentially constitutes a major constraint on models of cognitive slowing. The critical issue to be explicated then becomes the nature of the distinction between the lexical and nonlexical domains. That is, why are responses to lexical stimuli less affected by aging than are responses to nonlexical stimuli?

As indicated previously, the results of picture-naming studies (Bowles, 1990; Thomas et al., 1977) argue against the hypothesis that the critical distinction concerns the lexical versus nonlexical nature of the stimuli. However, this hypothesis has not been directly tested experimentally, and further tests in which the same subjects must make similar decisions in response to different types of stimuli (e.g., classification of words and pictures) are desirable.

Alternative hypotheses regarding the distinction between the two domains focus not on the nature of the stimuli but on the nature of the processing required by different types of tasks. Specific examples of differences in the nature of processing that might be responsible for our findings include the verbal/nonverbal (or verbal/spatial) and crystallized/fluid distinctions. Confounds between these distinctions constitute the major problem in developing good experimental tests to discern which distinction best captures the observed pattern of differential slowing. That is, experiments are needed that unconfound the typical associations between fluid and spatial abilities, on the one hand, and between crystallized and verbal abilities, on the other. For example, such experiments might compare tasks that test verbal versus spatial background knowledge, or they might compare tasks that test fluid versus crystallized verbal abilities (e.g., verbal analogies that rely more on the ability to see relationships vs. those that rely more on vocabulary; Horn, 1987). It is also possible that simple attempts to replicate our findings in a single experiment may reveal task differences, confounded with sample and procedural differences in the context of a meta-analysis, that suggest new hypotheses regarding the differential slowing in the lexical and nonlexical domains.

In conclusion, our findings suggest that there are at least two domains, provisionally characterized as lexical and nonlexical, which differ in the degree of general age-related cognitive slowing. These findings are consistent with results from the psychometric literature, which show greater age-related declines on the WAIS Performance scales than on the Verbal scales as well as with similar results obtained with other tests of verbal and nonverbal abilities. It is important to note that nonverbal test scores typically are more influenced by response speed; however, the pattern of results often does not change when scoring or time limits are altered so as to minimize the role of speed when testing nonverbal ability (e.g., Heron & Chown, 1967; Storandt, 1977). These findings imply that the different patterns of age-related decline in these two domains are not due to a greater decline in speeded as compared to unspeeded performances. Our results strengthen this interpretation: Greater age differences in the performance of nonlexical as compared with lexical tasks are also found when the two types of tasks are made comparable not by minimizing the influence of speed, but by making speed the dependent variable for both types of tasks. The converging evidence for the differential age sensitivity of two cognitive domains underscores the long-recognized need to accurately characterize these domains in order to better understand their implications for cognitive aging (Horn & Cattell, 1967).

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Appendix

Journals Surveyed for the Lexical Meta-Analyses

British Journal of Psychology
Cognitive Psychology
Developmental Psychology
Experimental Aging Research
Journal of Gerontology
Journal of Experimental Psychology: General
Journal of Experimental Psychology: Human Perception and
  Performance
Journal of Experimental Psychology: Learning, Memory, and
  Cognition (formerly *Human Learning and Memory*)
Journal of Memory and Language (formerly *Journal of Verbal*
  Learning and Verbal Behavior)
Memory & Cognition
Psychology and Aging (1986–1988)

Note. Years surveyed were 1975–1987, unless otherwise noted.