Experimental Evidence for Differential Slowing in the Lexical and Nonlexical Domains*

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ABSTRACT

Older and younger adults were tested on lexical and nonlexical tasks. When lexical and nonlexical processing were compared across equivalent ranges of task complexity, the degree of age-related slowing in the nonlexical domain was much larger than that observed in the lexical domain. To determine whether this nonlexical disadvantage is specific to older adults or whether it is characteristic of any slow individual, subgroups of fast older and slow young adults were matched on lexical processing speed. Older adults who were fast processors of lexical information were much slower at processing nonlexical information, but this was not true of slow young adults for whom the speed of processing lexical and nonlexical information was equivalent.

In the vast majority of studies of age-related differences in performance of speeded tasks, older adults have been found to process information more slowly than young adults. The ubiquity of this phenomenon has led some researchers to speculate that cognitive slowing during late adulthood may be global in nature. In fact, the degree of age-related slowing is remarkably consistent from task to task, suggesting that many, if not all, cognitive processes are equivalently slowed (for a recent review, see Cerella & Hale, 1994). More recently, however, a number of theorists have postulated that although all information processing may slow with advancing age, the degree of slowing may depend on the type of processing required to perform a task.

Three broad distinctions have been suggested that may differentiate between processing that is more age-sensitive and processing that is less age-sensitive: (a) Cerella (1985) proposed that sensory/perceptual processes show less age-related slowing than cognitive processes; (b) Mayr and Kliegl (1993) proposed that processing that involves a burden on working memory shows more age-related slowing than processing that puts a minimal load on working memory; and (c) Lima, Hale, and Myerson (1991) proposed that the processing of nonlexical information is far more slowed than the processing of lexical information. The present study focuses on one of these distinctions, specifically, the hypothesized difference between the effects of age on lexical and nonlexical processing.

Previous support for the lexical/nonlexical distinction comes primarily from meta-analyses (Hale, Myerson, & Wagstaff, 1987; Lima et al., 1991) and from the psychometric literature, where it has long been known that scores on the verbal subscales of the Wechsler Adult Intelligence Scale (WAIS) remain relatively constant with age whereas scores on the performance subscales show marked declines (Wechsler, 1955). However, objections may be raised to

* Support for this research was provided by a grant from the National Institute on Aging (R01 AG10197). We would like to thank Karen Topping, Bonnie Lawrence, and Dzung Nguyen for their assistance in data collection. Address correspondence to: Sandra Hale, Department of Psychology, Campus Box 1125, Washington University, One Brookings Drive, St. Louis, MO 63130, USA. E-mail: sshale@artsSci.wustl.edu. Accepted for publication: November 10, 1995.
both of these lines of evidence. A possible limitation of the meta-analytic studies is that they compare the lexical processing speed of one set of older and young adult groups with the nonlexical processing speed of a different set of groups. A possible limitation of the psychometric findings is that the verbal processing data involve primarily accuracy measures whereas the nonverbal processing data involve primarily speed measures (or measures that include extra points for speed), thus confounding the type of measure with the type of processing.

The major purpose of the current study was to conduct an experimental test of the lexical/nonlexical distinction in which the same older and young adults perform speeded tasks of both types. A related purpose grows out of recent reports that the response times (RTs) of slow young adults, like those of older adults, are an approximately linear function of average young adult RTs (Balota & Ferraro, 1992; Hale & Jansen, 1994). This finding led Balota and Ferraro to raise the question of whether age is similar to other individual difference variables with respect to processing speed. The current study examined the differential age sensitivity of lexical and nonlexical processing speed from this perspective. That is, the study sought to determine whether the hypothesized difference between nonlexical and lexical processing speed is unique to older adults, or whether it is common to all slow processors, regardless of age.

The tasks and analytic techniques for the present study were selected to address concerns raised in a recent debate regarding regression-based approaches to the analysis of RT data (Cerella, 1994; Fisk & Fisher, 1994; Myerson, Wagstaff, & Hale, 1994; Perfect, 1994). We selected tasks within each domain that previous results suggested would span roughly similar ranges of complexity. Then, based on preliminary analysis of the RTs of the young adult group, we eliminated data from tasks or conditions that were outside the obtained range of overlap. Thus, the final analyses of data from the present experiment compared lexical and nonlexical processing speed without any possible confound due to differences in task complexity. For purposes of statistical inference, we used an approach recently proposed by Lorch and Myers (1990) for analysis of repeated measures data that allows one to use a regression parameter such as slope as a processing speed index while still taking into account between-subject variability. We also carefully examined residuals for possible systematic deviations (e.g., all data from a particular task or type of condition on the same side of the regression line) and for significant outliers (Myerson et al., 1994; Salthouse, 1992b).

Using these methods, the current study tested three related hypotheses. First, we hypothesized that the degree of age-related slowing in the nonlexical domain is much greater than that in the lexical domain (Lima et al., 1991). This hypothesis predicts that the slope of the regression of older adults’ nonlexical RTs on the RTs of young adults in the same experimental conditions will be significantly greater than that obtained in the corresponding regression for lexical RTs. Second, we hypothesized that there is general slowing within specific processing domains (Lima et al., 1991). This hypothesis predicts that within each domain, the regression of older adults’ RTs on those of young adults will account for a large proportion of the variance in older adults’ RTs, and that there will be no significant outliers or systematic deviations from the regression line. Third and finally, we hypothesized that the differential slowing of lexical and nonlexical processing is unique to older adults, in that such domain-specific speed differences are not characteristic of slow young adults. If, when older and young adults are matched on processing speed, the older adults show a difference between the lexical and nonlexical domains but the young adults do not, such a finding would strongly suggest that nonlexical processes are more age-sensitive and that the age-related difference between the domains is not simply a consequence of the fact that older adults are, on average, slower processors.
METHOD

Subjects
The participants were 24 undergraduate students attending Washington University in St. Louis (M age = 19.7 years, SD = 1.0) and 24 older adults (M age = 69.7 years, SD = 3.5) selected from a pool of volunteers maintained by the Aging and Development Program at Washington University. All subjects reported themselves to be in good to excellent health. Verbal ability was assessed with the Shipley Institute of Living Scale, and scores were equivalent for the two groups (younger adult group M = 33.3, SD = 2.9; older adult group M = 33.7, SD = 3.5).

Apparatus
Stimuli were presented on a NEC MultiSynch 2A monitor controlled by a CompuAdd 286 computer. Stimulus presentation was synchronized with the refresh cycle for the monitor display, and times were recorded with greater than 1 msec accuracy. A wooden response panel housing three buttons, arranged in an inverted triangle, was used by the participants to indicate decisions (the upper two buttons) and to initiate trials (the lower button).

Tasks
Four tasks were selected from the lexical domain: single lexical decision, double lexical decision, category judgment, and synonym-antonym judgment. Four tasks were selected from the nonlexical domain: line-length discrimination, shape classification, visual search, and abstract matching. These tasks were selected because they each involved quite different component processes. This is not to say that all of the processes involved in a particular task were unique to that task. Rather, each task involved at least one component process unique to that task, and manipulation(s) of this unique process distinguished between experimental conditions. For example, one nonlexical task selected was visual search. This task may share encoding and response selection processes with many other tasks. However, the processes of examining the color and shape of successive items to determine whether the combination of features matches a specific target pattern, all the while keeping track of which items have been examined previously so as to avoid rechecking, is unique to visual search among the tasks used in the present study. In addition, this unique aspect of visual search (as well as the presence or absence of the target) was an aspect that was experimentally manipulated across conditions.

Procedure
Participants performed the four lexical tasks and the four nonlexical tasks in the following order: line-length discrimination, single lexical decision, visual search, category judgment, shape classification, synonym-antonym judgment, abstract matching, and double lexical decision. The order of conditions was selected so as to distribute the tasks from the two domains evenly across the session in order to prevent practice or fatigue effects from biasing the results. Each participant was administered the same order of tasks so that comparisons of individuals or subgroups of individuals (e.g., fast older adults and slow young adults) would not be confounded by order differences.

Prior to each task, 6 practice trials were administered. In addition, 2 buffer trials were inserted at the beginning of the experimental trials. Each experimental condition consisted of 16 trials, with the exception of the different-shapes condition of the shape classification task which consisted of 32 trials (16 same size but different shape and 16 different size and different shape). All participants used their dominant hand to signal the following responses: word (vs. nonword), two words (vs. one word + one nonword), same category (vs. different categories), synonym (vs. antonym), same shapes (vs. different), and target present (vs. absent). For the line-length discrimination task, participants pressed the key corresponding to the location of the longer line. For the abstract matching task, participants pressed the key corresponding to the location of the best match – upper left or upper right. As with task order, all subjects made the same responses with the dominant hand so as not to confound comparisons of individuals or subgroups.

Lexical Battery
In the single lexical decision task, participants decided whether or not a string of three letters (of the form consonant, vowel, consonant) was a word in English. The word stimuli were selected from Kucera and Francis (1967) to create three different conditions: high frequency words (e.g., top), lower frequency words (e.g., rib), and pronounceable nonwords created by replacing one letter of a word (e.g., ged). In the double lexical decision task, participants decided whether or not two strings of letters (presented one above the other) were both words in English. The word and nonword stimuli were selected from Shelton and Martin (1992, Experiments 3 and 4) to create four conditions: related word pairs (e.g., high and low), unrelated word pairs (e.g., bread and queen), nonword-word pairs (e.g., jarton and ink), and word-nonword pairs (e.g., flesh and biper). In the category judg-
ment task, participants decided whether or not two words were from the same semantic category. The stimuli were drawn from Battig and Montague (1969) to create four conditions: high-typicality word pairs from the same category (e.g., ruby and emerald), low-typicality word pairs from the same category (e.g., camel and buffalo), high-typicality word pairs from different categories (e.g., dog and carrot), and low-typicality word pairs from different categories (e.g., turnip and amethyst). In the antonym-synonym judgment task, participants decided whether the meanings of two related words were the same or opposite. The stimuli were generated using a variety of synonym/antonym dictionaries in order to create four conditions: synonym pairs made up of high frequency words (e.g., loud and noisy), synonym pairs made up of lower frequency words (e.g., grieve and mourn), antonym pairs made up of high frequency words (e.g., hard and soft), and antonym pairs made up of lower frequency words (e.g., domestic and foreign).

Nonlexical Battery
In the line-length discrimination task, participants decided which of two lines was longer. This task included two conditions: 10% and 20% difference in line length. In the shape classification task, participants decided whether or not two objects, regardless of any difference in size, shared the same form. This task included three conditions: same form and same size, same form and different sizes, and different forms. In the visual search task, participants decided whether a red square target was present in an array of red circles and green squares. This task included six conditions: target present and target absent conditions at each of three set sizes (i.e., 9, 15, and 25 items). In the abstract matching task, participants selected one of two arrays that was the best match to a third array displayed below the two upper arrays. Each array varied on four different dimensions (number, shape, and color of the elements, and orientation of the array) that could take on one of three values. Specifically, each array consisted of either two, three, or four shapes (circles, triangles, or squares) that were colored either red, yellow, or blue, and arranged either horizontally, vertically, or diagonally. On each trial, one and only one of the four dimensions was relevant to determining the best match. This task included four conditions: all three irrelevant dimensions held constant, two irrelevant dimensions held constant, one irrelevant dimension held constant, and no irrelevant dimensions held constant. Thus, a trial in which one irrelevant dimension (color) is held constant could be constructed as follows: one array of four blue circles arranged vertically at the bottom of the display (the sample), one array of two blue triangles arranged horizontally in the upper left of the display (the foil), and one array of three blue squares arranged vertically in the upper right of the display (the match based on the relevant dimension, in this case, orientation of the array).

RESULTS
For purposes of the present study, error rates were of interest only to the extent that age differences in accuracy could possibly confound interpretation of the RT data. From this perspective, it is reassuring to note that all participants were generally quite accurate on both the lexical and nonlexical tasks (see Table 1). Averaged across all tasks, both age groups' error rates were less than 5%. When each task is considered separately, averaging across all conditions for each task, error rates for both groups are still quite low: The greatest number of errors for the young adult group occurred on the synonym/antonym judgment task (5.5%), and the greatest number of errors for the older adult group occurred on the abstract matching task (6.5%). Importantly, no task showed an age difference in accuracy greater than 2.0%.

When an analysis of variance (ANOVA) was conducted on the errors for each task separately, there were no main effects of age on any of the nonlexical tasks, but older adults did make significantly fewer errors than younger adults on two of the lexical tasks (single lexical decision and category judgment). Even though older adults were significantly more accurate on two of the three lexical tasks, the age difference in errors averaged across all conditions of the lexical battery was only 1.9%. Thus, any age differences in RTs would appear to be relatively unbiased by differences in accuracy.

The mean RTs for each individual in each condition were calculated based on the untrimmed latencies of correct response, and then regression-based techniques, rather than ANOVAs, were used to analyze the RT data. Researchers in the cognitive aging area have long complained that the results of ANOVAs on RTs are potentially ambiguous (e.g., Cerella, 1991;
<table>
<thead>
<tr>
<th>Task</th>
<th>Young adult group</th>
<th>Older adult group</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>RT</td>
<td>SD</td>
</tr>
<tr>
<td>Lexical decision</td>
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<tr>
<td>High frequency word</td>
<td>0.639</td>
<td>0.092</td>
</tr>
<tr>
<td>Low frequency word</td>
<td>0.719</td>
<td>0.120</td>
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<tr>
<td>Nonword</td>
<td>0.774</td>
<td>0.151</td>
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<tr>
<td>Double lexical decision</td>
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<td></td>
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<tr>
<td>Related words</td>
<td>0.771</td>
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</tr>
<tr>
<td>Unrelated words</td>
<td>0.892</td>
<td>0.147</td>
</tr>
<tr>
<td>Word – nonword</td>
<td>1.077</td>
<td>0.184</td>
</tr>
<tr>
<td>Nonword – word</td>
<td>0.897</td>
<td>0.224</td>
</tr>
<tr>
<td>Category membership</td>
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<td></td>
</tr>
<tr>
<td>High typicality – same</td>
<td>0.940</td>
<td>0.179</td>
</tr>
<tr>
<td>Low typicality – same</td>
<td>1.016</td>
<td>0.183</td>
</tr>
<tr>
<td>High typicality – different</td>
<td>1.122</td>
<td>0.230</td>
</tr>
<tr>
<td>Low typicality – different</td>
<td>1.235</td>
<td>0.281</td>
</tr>
<tr>
<td>Synonym/antonym</td>
<td></td>
<td></td>
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<tr>
<td>High frequency synonyms</td>
<td>1.076</td>
<td>0.207</td>
</tr>
<tr>
<td>High frequency antonyms</td>
<td>1.057</td>
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<tr>
<td>Low frequency synonyms</td>
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<td>0.261</td>
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<td>Low frequency antonyms</td>
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<td>0.269</td>
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<tr>
<td>Line-length discrimination</td>
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<td></td>
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<tr>
<td>10% difference</td>
<td>0.473</td>
<td>0.147</td>
</tr>
<tr>
<td>20% difference</td>
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<td>0.127</td>
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<tr>
<td>Shape classification</td>
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<tr>
<td>Same shape – same size</td>
<td>0.549</td>
<td>0.112</td>
</tr>
<tr>
<td>Same shape – different size</td>
<td>0.583</td>
<td>0.108</td>
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<tr>
<td>Different shapes</td>
<td>0.621</td>
<td>0.142</td>
</tr>
<tr>
<td>Visual search</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 items – target present</td>
<td>0.638</td>
<td>0.120</td>
</tr>
<tr>
<td>9 items – target absent</td>
<td>0.698</td>
<td>0.148</td>
</tr>
<tr>
<td>15 items – target present</td>
<td>0.671</td>
<td>0.136</td>
</tr>
<tr>
<td>15 items – target absent</td>
<td>0.865</td>
<td>0.209</td>
</tr>
<tr>
<td>25 items – target present</td>
<td>0.750</td>
<td>0.171</td>
</tr>
<tr>
<td>25 items – target absent</td>
<td>1.019</td>
<td>0.230</td>
</tr>
<tr>
<td>Abstract matching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 1</td>
<td>0.918</td>
<td>0.175</td>
</tr>
<tr>
<td>Level 2</td>
<td>1.285</td>
<td>0.334</td>
</tr>
<tr>
<td>Level 3</td>
<td>1.469</td>
<td>0.389</td>
</tr>
<tr>
<td>Level 4</td>
<td>1.681</td>
<td>0.477</td>
</tr>
</tbody>
</table>

Note. RTs and SDs are in seconds.

Salthouse, 1985a), in part because superadditive interactions, although sometimes taken as evidence for task- or process-specific slowing, are also predicted by general slowing. However,
failures to observe such interactions are equally ambiguous because the sample sizes and designs used in most cognitive aging research do not provide the power necessary to detect them (Wahlin, 1991). As a consequence, various researchers have proposed regression-based techniques that may provide useful alternatives for the analysis of RT data from cognitive aging studies (e.g., Cerella, 1991; Fisk, Fisher, & Rogers, 1992; Myerson et al., 1994; Salthouse, 1992b).

Although regression-based techniques have their own limitations, careful application of the extensive knowledge regarding these techniques should enable researchers to avoid potential pitfalls. For example, the parameters of regressions based on data from individual subjects often provide a better basis for statistical inference than the parameters of regressions based on group means (Lorch & Myers, 1990). This is because tests based on group means may have an inflated rate of false positives in studies, such as the present effort, that use repeated measures designs. Therefore, the RTs of each older adult and each young adult were regressed separately on the mean young adult RTs from corresponding experimental conditions, and possible age differences in the individual regression parameters were evaluated using standard statistical tests. Because the parameters of regressions on the group means are equal to the means of the parameters estimated from the individual subject data (as pointed out by Lorch and Myers), regressions and fit statistics based on group means are presented as descriptive statistics that supplement the results of the statistical tests.

Initially, the mean RTs of the older adult group in each condition of each task were regressed on the corresponding RTs of young adults without distinguishing between lexical and nonlexical tasks. The regression line accounted for 74.4% of the variance in the older group's mean RTs for both lexical and nonlexical tasks, much less than that seen in previous analyses that examined only tasks from one domain or the other (e.g., Hale et al., 1987; Lima et al., 1991). Moreover, examination of the residuals revealed that all 15 of the residuals for the nonlexical tasks were positive (i.e., the older group's nonlexical RTs were larger than those predicted by the regression line) and 12 out of the 15 residuals for the lexical tasks were negative (i.e., most of the older group's lexical RTs were smaller than those predicted by the regression line). Therefore, further regression analyses were conducted on the lexical and nonlexical RTs separately.

In order to obtain comparable RT data from lexical and nonlexical tasks for these and subsequent analyses, the task conditions from each domain were matched on the range of young adult RTs so as to obtain complete overlap. The lexical RTs spanned a much shorter range, and therefore it was necessary to truncate the nonlexical data set. Excluded were the easiest and most complex nonlexical conditions: line-length discrimination, the two same-shape conditions from shape classification, and the two hardest conditions from abstract matching. Second, because truncating the nonlexical data set resulted in a preponderance of data from lexical tasks, the nonword conditions from the single and double lexical decision tasks were excluded so as to produce a better match on the number of conditions from each domain as well as a more valid measure of lexical processing speed. According to a number of researchers (e.g., Coltheart, Davelaar, Jonasson, & Besner, 1977; Madden, Pierce, & Allen, 1993), the RTs of no responses on nonword trials measure how long subjects will wait before giving up on recognizing a particular letter string, rather than the speed of a specific lexical process.

Figure 1 shows the older adult and young adult groups' mean RTs from lexical and nonlexical tasks across the range of overlap in task complexity. As may be seen, the regression line for the nonlexical data is much steeper and has a more negative intercept than the regression line for the lexical data. The linear function that best described the nonlexical data was $O = 3.11Y - 1.081$ sec; this function accounted for 97.1% of the variance in the older adult group's nonlexical RTs. The linear function that best described the lexical data was $O = 1.35Y - 0.006$ sec; this function accounted for 94.3% of the variance in the older adult group's lexical RTs.
There were no significant outliers from either the lexical or nonlexical regression lines. Data points from two of the nonword conditions from the lexical decision tasks fell above the lexical regression line fit to data from word conditions only, and the third nonword data point fell below the line. Similarly, there was no apparent evidence of systematic differences between yes and no responses on the nonlexical tasks. For visual search, one yes (target present) and one no (target absent) data point fell above the nonlexical regression line, and two yes and one no data points fell below the line; the third no data point was less than one ms from the predicted value. None of the other three tasks involved a yes/no decision. Although it might be argued that same and different responses on the shape classification task are functionally equivalent to yes and no responses, respectively, all three data points from this task (i.e., RTs for both same and different responses) alike fell above the regression line, presumably because of the positively accelerated relation between older and young adults’ RTs on nonlexical tasks (Hale et al., 1987).\(^1\)

In order to test whether there is greater slowing on nonlexical than lexical tasks when they are matched on complexity, the slopes of the

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\(^1\) Over the full range of the nonlexical data, the relation between the older and young adults’ mean RTs was positively accelerated, as indicated by a significant quadratic term in the best-fitting polynomial equation, \(r(12) = 5.54, p < .001\), and the data were extremely well described by a power function: \(O = 2.00Y^{1.56}, R^2 = .994\).
lexical and nonlexical regression lines from individual subjects were compared as suggested by Lorch and Myers (1990). For each individual older and young adult, lexical RTs were regressed on the corresponding mean lexical RTs for the young adult group, and nonlexical RTs were regressed on the corresponding mean nonlexical RTs for the young adult group. The older adults’ nonlexical slopes were significantly greater than their lexical slopes, $t(23) = 6.82, p < .001$. Case-by-case examination of the lexical and nonlexical regression slopes for individuals revealed the robustness of the domain-specific slowing phenomenon: All but one of the 24 older adult participants showed greater nonlexical than lexical slowing. In addition, older adults’ slopes for lexical and nonlexical tasks were both significantly greater than the corresponding slopes of young adults: for lexical tasks, $t(46) = 2.87, p < .01$; for nonlexical tasks, $t(46) = 7.66, p < .001$.

The fact that older adults show slowing on all tasks, but greater slowing in the nonlexical domain, raises the question of whether the difference in the speed with which they process lexical and nonlexical information occurs because they are old or whether it occurs because they are slow. That is, are slow young adults also especially slow at processing nonlexical information? To address this question, we selected a group of young adults and a group of older adults who, based on the slopes of their individual regression lines, processed lexical information at the same speed, and then compared the performance of the two groups on nonlexical tasks of equivalent complexity.

To obtain two groups of comparable lexical processing speed, we first divided each older and young adult’s RTs in each lexical condition by the corresponding mean RTs for the young adult group, and then calculated the mean ratio (individual RT to average young RT) for each individual. This procedure was used because it weights all conditions equally (a person slow on the easiest task but fast on the hardest task is equivalent in speed to someone fast on the easiest task and slow on the hardest task) and thus does not bias the form of the relation between the RTs of different groups. A median split of each age group based on individuals’ mean lexical RT ratios yielded a fast old group and a slow young group that did not differ in their lexical processing speed. The mean slope for the fast old group was 1.15 and the mean slope for the slow young group was 1.20, $t(22) < 1$.

Figure 2 shows the fast old and slow young adult groups’ mean lexical and nonlexical RTs across the range of overlap in task complexity. As may be seen, the regression line for the fast older adults’ nonlexical RTs is much steeper and has a more negative intercept than the regression line for their lexical RTs, but the nonlexical and lexical regression lines for the slow young adults hardly differ. What is suggested by visual inspection was confirmed by statistical analysis: The nonlexical regression slopes of individual fast older adults were significantly greater than their lexical slopes, $t(11) = 4.69, p < .001$, but there was no significant difference between nonlexical and lexical slopes of slow young adults, $t(11) < 1$.

DISCUSSION

The present results provide experimental validation of the hypothesis that in older adults, the processing of nonlexical information is slowed to a greater degree than the processing of lexical information (Lima et al., 1991). As the first stage in analysis of the present data, the RTs of older adults from both lexical and nonlexical tasks were regressed on the RTs of young adults, and the residuals were examined for evidence of separate regressions (Myerson et al., 1994). Inspection revealed that all of the nonlexical data points were above the regression line and most of the lexical data points were below the regression line. Subsequent separate regression analyses indicated that older adults took a little more than 3.0 times as long as young adults to perform nonlexical tasks but took a little less than 1.5 times as long on lexical tasks of equivalent complexity. Following the statistical approach advocated by Lorch and Myers (1990), analyses of the regression coefficients for individual older and young adults revealed that although older adults were slower than young adults on
both lexical and nonlexical tasks, nonlexical processing was significantly more slowed than lexical processing.

These results are consistent with the meta-analytic findings of Lima et al. (1991). Lima et al. analyzed published data from lexical and nonlexical tasks of equivalent complexity, as indexed by the RTs of the young adult groups. Using tests for separate regressions (Myerson et al., 1994), they found that the slope of the relation between the nonlexical RTs of older and young adult groups was significantly greater than the slope of the relation between lexical RTs. Similar results were obtained using all of the data, and using only one data point from each sample of older and young adults so as to avoid the increased probability of Type I error associated with comparing regressions on group means obtained from experiments with repeated measures designs (Lorch & Myers, 1990).

Similar results were also obtained by Myerson et al. (1994) when they reanalyzed two experiments on lexical and nonlexical visual and memory search by Fisk and Rogers (1991). Myerson et al. found that the lexical and nonlexical regression lines reported by Lima et al. (1991) accurately predicted the relation between the RTs of older and young adults reported by Fisk and Rogers, regardless of whether subjects were searching their memories...
or a visual display. However, both the Fisk and Rogers (1991) and Lima et al. (1991) data sets contain RTs from different groups of older adults for the lexical and nonlexical tasks, and the analyses of these data sets were post hoc. In contrast, the present study examined lexical and nonlexical processing in the same older adults, and tested the prediction of greater age-related slowing of nonlexical processing in an experiment specifically designed for that purpose. As a consequence, the present findings provide strong support for the hypothesis of differential slowing in the two domains through a clear experimental demonstration of the fact that nonlexical processing slows with age to a much greater extent than lexical processing.

Although the degree of slowing differs between the two domains, in the present study slowing appeared to be general within each domain as indicated by the absence of significant outliers from the lexical and nonlexical regression lines and the good fits of simple linear functions to the relationship between older and young adults’ RTs. That is, within each domain, older adults’ RTs could be accurately predicted from those of young adults without regard for the nature of the task or the processes specific to a particular experimental condition. According to Lima et al. (1991), this represents the operational definition of general slowing within a cognitive domain: If cognitive processes are equivalently slowed within a domain, then given similar levels of accuracy in both older and young adult groups, an equation in which young adult RTs are the only predictor can be used to predict older adults’ RTs on diverse tasks.

More rigorous statistical tests are possible (e.g., Hale, Myerson, Faust, & Fristoe, 1995) if the goal is not merely to demonstrate general slowing within a specific domain, but also to exclude the possibility of any task- or process-specific slowing. However, the goal of the present experiment was simply to show that there is general slowing within both the lexical and nonlexical domains, and that the degree of slowing is much less in the former than in the latter. We focused here on the large-scale structure of the information-processing system, as revealed by the effects of aging, and left questions of the fine-scale structure to studies specifically designed for that purpose.

It should be noted that the existence of general slowing is not incompatible with the existence of processes of slightly greater or lesser age-sensitivity within the same domain, even if on average, processes within one domain are much more affected by aging than those in another domain. However, as Salthouse (1992b) and others have pointed out, once general age-related changes become fairly well established then it is appropriate to treat such changes as the null hypothesis in order to test specific alternative hypotheses regarding uniquely age-sensitive or -insensitive processes. The present findings suggest that different null hypotheses will be needed, depending on the lexical or nonlexical process under investigation. That is, the effect of aging on a hypothetically unique task or process must be evaluated with reference to other tasks or processes within the same cognitive domain.

The differential slowing of lexical and nonlexical information processing has strong implications for Salthouse’s (1985b) processing rate theory of cognitive aging. According to this theory, age-related decreases in processing speed lead to working memory deficits. It follows that if there are differences in the effect of aging on lexical and nonlexical processing, then there should be corresponding differences in older adults’ memory for lexical and nonlexical information. Consistent with this prediction, we have recently found that when older adults’ memory for lexical and nonlexical information is compared using working memory tasks of approximately equal difficulty for young adults, the age difference in memory for lexical information is much smaller than the age difference in memory for nonlexical information (Hale, Myerson, & Rhee, 1994).

Salthouse (1991) has also hypothesized that slower processing leads to age-related differences in reasoning and higher cognitive abilities, presumably because of the effect of processing speed on working memory. Consistent with this hypothesis, a number of previous studies (e.g., Hertzog, 1989; Salthouse, 1992a; Schaie, 1989) have shown that when differences in processing speed are statistically controlled, age-related
differences in performance on mental ability tests are greatly reduced or even eliminated. In this context, the current finding of a greater age-related difference in the speed of nonlexical processing raises the possibility of a greater age-related difference in nonverbal reasoning and problem solving relative to verbal reasoning and problem solving. Moreover, the difference between the speed of lexical and nonlexical processing in older adults is rather large, suggesting that this differential sensitivity may have important consequences for older adults’ higher cognitive abilities.

Recent studies suggest that neither general slowing nor the relation of processing speed to working memory and higher cognitive abilities are unique to older adults. Slow young adults also show a form of general slowing in that they are approximately the same proportion slower than average on a wide variety of cognitive tasks (Balota & Ferraro, 1992; Hale & Jansen, 1994). Similar results have also been obtained in meta-analyses examining the regressions of the RTs of retarded persons (Kail, 1992) and individuals intoxicated with alcohol (Maylor & Rabbitt, 1993) on the RTs of appropriate control groups. Groups of children are also generally slower than young adults (Hale, 1990; Kail, 1991), and as in older adults, the effects of age-related changes (in this case improvements) in childrens’ processing speed on their higher abilities are entirely mediated by the effects of speed on working memory (Fry & Hale, in press). To date, however, there is no data to suggest that any of these groups shows the difference between lexical and nonlexical processing speeds characteristic of older adults. The uniqueness of this apparently robust cognitive aging phenomenon suggests that it may provide important clues as to how age affects information processing in adults.

REFERENCES


