Age, Variability, and Speed: Between-Subjects Diversity

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Two independent data sets were selected to examine the interrelations among reaction time (RT), between-subject variability or diversity (SD), and age. In both data sets, a strong correlation between RT and SD was obtained. This strong correlation was not affected when age was controlled in a partial correlation analysis. On the other hand, a weaker but significant correlation was obtained between age and SD. This correlation was eliminated when RT was controlled in a partial correlation analysis. Our analyses of the two data sets also indicated that the relation between RT and SD is identical for both young and elderly groups. Thus, the greater diversity often observed in performances of older groups is a direct consequence of slowing, rather than an independent effect of advancing age.

Two major generalizations emerge from the literature on age-related differences in speed of information processing. First, older adults are slower than younger adults in processing information (for recent reviews, see Birren, Woods, & Williams, 1980; Salthouse, 1982, 1985), and the age difference increases with the complexity of the information-processing task (Cerella, 1985; Cerella, Poon, & Williams, 1980; Hale, Myerson, & Wagstaff, 1987). Second, the reaction-time (RT) performances of older adults are more variable than those of younger adults (e.g., Botwinick & Thompson, 1968; Fozard, Thomas, & Waugh, 1976; Thomas, Waugh, & Fozard, 1978). A number of researchers have postulated that this increase in variability is an important consequence of aging (e.g., Birren et al., 1980; Rabitt, 1981; Welford, 1980).

Variability occurs both between (inter) and within (intra) subjects. We use the term diversity to refer to variability between subjects’ performances, in contrast to the dispersion of an individual’s performances. This article focuses on the nature of between-subject diversity in RTs of young and elderly groups; within-subject dispersion will be considered elsewhere (Poon, Smith, Myerson, & Hale, 1988). Our purpose is to examine age differences in response latencies in conjunction with the reported age differences in diversity, using a meta-analytic approach. Previous meta-analyses of age-related slowing have focused on the relation between the mean RTs of older adults and the mean RTs of younger adults (Cerella, 1985; Cerella et al., 1980; Hale et al., 1987). However, a meta-analytic approach has not been used to examine the increase in diversity that accompanies aging.

Many RT studies have reported greater diversity in older groups compared with younger groups. However, these same studies have reported slower RTs for older groups (e.g., Gaylord & Marsh, 1975; Halpern, 1984; Simon & Pouraghhabagher, 1978). Hence, the measure of diversity (SD of the group) is confounded with the measure of central tendency (group mean RT), and SDs are not compared under equivalent conditions (i.e., where RT is equal for both groups). Therefore, it is possible that the greater diversity among older adults’ RTs may be a direct result of slowing, rather than an independent consequence of aging.

The ideal test for whether older groups are truly more diverse than younger groups involves analyzing tasks on which the old and young groups have equal mean RTs. But, given the ubiquity of age-related slowing, this would be difficult to undertake. Another approach is to compare the relations between SDs and mean RTs of old and young groups across a wide range of latencies. If older and younger groups are equally diverse, then the SD of a group could be predicted on the basis of the mean RT, independent of the age of the group. Alternatively, if older groups are more diverse than younger groups, then both the age and the mean RT would be necessary in order to predict the SD of the group.

Using RT data from a wide variety of information-processing tasks that reported the mean RTs and SDs for both older and younger groups, two meta-analyses were conducted to determine whether older groups truly display greater diversity. In the first analysis, only studies that used a manual response were considered for inclusion in the data set. In the second analysis, only studies that used a vocal response were considered.

Method

Two separate meta-analyses were conducted. The data set for the first analysis was drawn from all of the articles published in the Journal of Psychology and Aging in 1988, Vol. 3, No. 4, 407-410. Copyright 1988 by the American Psychological Association, Inc. 0882-7974/88/$00.75.
Table 1
Experimental Data Sets

<table>
<thead>
<tr>
<th>Study</th>
<th>Task</th>
<th>No. of conditions</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis 1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cohen &amp; Faulkner (1983)</td>
<td>Rotated figures</td>
<td>4</td>
<td>Table 2</td>
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<tr>
<td>Howard, McAndrews, &amp; Lasaga</td>
<td>Sentence verification</td>
<td>4</td>
<td>Table 3</td>
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<tr>
<td>Nebes (1978)</td>
<td>Lexical decision</td>
<td>5</td>
<td>Table 3</td>
</tr>
<tr>
<td>Rabbitt &amp; Vyas (1980)</td>
<td>Simple reaction time</td>
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<td>Table 1</td>
</tr>
<tr>
<td>Simon &amp; Pouraghabagher (1978)</td>
<td>Choice reaction time</td>
<td>6</td>
<td>Table 2</td>
</tr>
<tr>
<td></td>
<td>Choice reaction time</td>
<td>3</td>
<td>Table 3</td>
</tr>
<tr>
<td>Analysis 2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Bowles &amp; Poon (1985)</td>
<td>Lexical decision</td>
<td>3</td>
<td>Table 1</td>
</tr>
<tr>
<td>Halpern (1984)</td>
<td>Pattern verification</td>
<td>4</td>
<td>Table 1</td>
</tr>
<tr>
<td>Nebes (1976)</td>
<td>Verbal-pictorial task</td>
<td>8</td>
<td>Table 1</td>
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<tr>
<td>Nebes (1978)</td>
<td>Simple reaction time</td>
<td>1</td>
<td>Text</td>
</tr>
<tr>
<td>Nebes, Boller, &amp; Holland</td>
<td>Category decision task</td>
<td>1</td>
<td>Table 1</td>
</tr>
<tr>
<td>Puglisi &amp; Morrell (1986)</td>
<td>Mental rotation</td>
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<td>Table 3</td>
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<td>10</td>
<td>Table 1</td>
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Gerontology during a 10-year span (1975–1984). This first data set consisted of all psychological studies that met the following three criteria: (a) The mean age of the older group fell within the range of 65–75 years and the mean age of the younger group fell within the range of 18–28 years, (b) The group mean RTs and SDs were both reported, (c) Participants signaled their response by pressing or releasing an RT key. The data set for the second analysis was drawn from all of the articles published in the Journal of Gerontology (1975–1986), Experimental Aging Research (1976–1986), and Psychology and Aging (1986). For the second data set, the same first two criteria were applied along with the following third criterion: Participants signaled their responses vocally by saying yes or no.

Data Sets

Application of these criteria produced the two data sets. The first data set consisted of the results of six experiments from five separate studies, providing a total of 23 different experimental conditions. The second data set included seven experiments from six studies, for a total of 30 different experimental conditions. (Whenever a condition did not yield a main effect—for example, left-hand versus right-hand—the data for those conditions were averaged.) As may be seen in Table 1, a wide variety of information-processing tasks are represented in both data sets.

Results

A comparison of the SDs of the older groups with the SDs of the younger groups for each of the experimental conditions yielded the typical finding that older groups have larger SDs. In fact, this was the case in 19 out of 23 conditions in the first data set and 26 out of 30 conditions in the second data set. However, plotting the SD as a function of the mean RT for each age group in each experimental condition is revealing (Figure 1 and Figure 2). In both data sets, the relation between the SD and mean RT is well described by a single linear function for both age groups ($r^2 = .872$ and $r^2 = .856$, for the first and second data sets, respectively). There were no significant differences between the parameters of the best-fitting lines for the two age groups (Table 2). This finding supports the hypothesis that SD can be predicted from mean RT without regard to the age of the group.

If age indeed exerts a minimum effect on the strong relation between RT and SD, then the correlation between RT and SD should not be affected when the age variable is controlled using a partial correlation. Moreover, the correlation between age and SD should be eliminated when RT is controlled. Consistent with this view, the correlation between SD and RT ($r = .93$, $p < .001$) in the first data set was unchanged with the influence...
of age controlled ($r = .93, p < .001$). The correlation between age and $SD$ in the first data set was smaller but significant ($r = .26, p < .05$). However, this correlation was eliminated when RT was controlled ($r = -.16, ns$). Thus, our first analysis of the relationship between age and RT was equivalent to the correlation between RT and $SD$ on RT, and the effect of age on $SD$ is via its effect on RT.

This finding was reinforced in our second analysis. The correlation between $SD$ and RT was equivalent to the correlation found in the first data set ($r = .93, p < .001$) and was virtually unchanged with the influence of age controlled ($r = .91, p < .001$). In addition, the correlation between age and $SD$ in the second data set was significant ($r = .43, p < .01$), but was eliminated with the influence of RT controlled ($r = .01, ns$).

Overall, the two data sets revealed similar findings. The only difference was that the intercept of the line for the second data set was significantly lower than the intercept for the first data set ($t = 3.23, p < .01$). Thus, although the diversity of group performances is apparently greater for manual RT than for vocal RT, in both cases the $SD$ of the group can be predicted independently of the age of the group and of the specific information-processing task.

### Discussion

The present effort attempted to establish whether the greater diversity observed in the RT performances of older groups is (a) a direct result of age-related slowing or (b) a consequence of individual differences in the rates of neurobiological changes due to aging as postulated by a number of prominent investigators (e.g., Birren et al., 1980; Rabbitt, 1981; Salthouse, 1982; Welford, 1980). The latter hypothesis is exemplified by the following quotation from Rabbitt (1981):

> The neurobiology of aging is not well understood but we know that people may 'age' at different rates and may exhibit a variety of different syndromes of aging associated with different pathologies. Performance measures support this picture of increased diversity in elderly populations. (p. 358)

The meta-analyses reported in this article on two independent data sets of published studies clearly support the hypothesis that the greater diversity in the aged is a direct result of age-related slowing. Invariance of diversity across age was demonstrated by showing that the relation between RT and $SD$ is the same for young and elderly samples. That is, both relations are well described by the same mathematical function. Partial correlations further clarified the findings: The high correlations between RT and $SD$ were virtually unaffected by the age variable, and thus increases in diversity appear to be directly associated with slowing rather than being an independent consequence of aging.

Our analyses lead directly to conclusions that run counter to established ideas about aging and the diversity of speeded performances in older groups. The data do not support the position that different rates of neurobiological change associated with aging are responsible for the apparently greater diversity of speeded performances in older groups. On the contrary, the present analyses show that diversity does not increase with age when the confound of differences in mean RT is removed.

### References


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The Publications and Communications Board of the American Psychological Association announces the appointment of Keith Rayner, University of Massachusetts, as editor of the *Journal of Experimental Psychology: Learning, Memory, and Cognition* for a 6-year term beginning in 1990. As of January 1, 1989, manuscripts should be directed to

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Manuscript submission patterns for *JEP: Learning, Memory, and Cognition* make the precise date of completion of the 1989 volume uncertain. The current editor, Henry Roediger, will receive and consider manuscripts until December 31, 1988. Should the 1989 volume be completed before that date, manuscripts will be redirected to Rayner for consideration in the 1990 volume.