How Cognitive is Psychomotor Slowing in Depression? Evidence from a Meta-Analysis*

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ABSTRACT

The current meta-analysis explores the hypothesis that many of the apparently specific deficits that depressed subjects show on speeded cognitive tasks are actually the result of general (i.e., task-independent) slowing. Results of three analyses provided strong support for this hypothesis. The reaction times (RTs) of the depressed groups were consistently slower than those of the control groups. Moreover, the degree of cognitive slowing was approximately the same regardless of the task or condition. Regression analyses revealed a proportional relation between the RTs of the two depressed and control groups, suggesting that depression slows sensory/motor and cognitive processes to approximately the same degree. The regression-based approach used in the present analyses has implications for the study of other neurological disorders and also may have important applications in the assessment of both general and specific cognitive deficits in individual patients.

Clinical depression is frequently accompanied by impairments in cognitive function. In a recent review of the extensive literature on the cognitive changes associated with depression, Hartlage, Alloy, Vázquez, and Dykman (1993) observed that the most consistently reported deficits have been in general intellectual ability, problem solving, learning and memory, reading comprehension, and speed of performance. Of these, some researchers assert that a speed deficit is the symptom most strongly associated with depression (e.g., Nelson & Charney, 1981).

Neuropsychologists refer to such speed deficits as psychomotor slowing or psychomotor retardation, which are usually assessed using speeded tasks such as the Digit Symbol Substitution Test. However, scores on many of the neuropsychological tests used to assess specific cognitive abilities (e.g., memory, attention, visuospatial ability) are also influenced by speed of performance, and the relative contributions of cognitive and motor speed to such are rarely evaluated. Thus, apparent deficits in specific cognitive abilities reported by neuropsychologists may be a result of a more general slowing affecting most or all cognitive processes.

This issue is not peculiar to depression. Some researchers (e.g., Cerella & Hale, 1994; Ferraro, 1996; Kail, 1991; Myerson, Wagstaff, & Hale, 1994) have suggested that what appear to be specific cognitive deficits in a variety of populations (e.g., elderly adults, children, individuals with closed head injury) may actually be the result of general (i.e., task-independent) slowing. Convincing evidence that general slowing may contribute to, or perhaps even completely account for, apparent deficits in specific cognitive abilities in a given population comes from meta-analytic studies using the method described by Brinley (1965). Following Brinley,
reaction times (RTs) from a target population (e.g., individuals with closed head injury) are plotted as a function of the RTs of controls (e.g., uncompromised individuals). The tasks from which RTs are obtained may assess different cognitive abilities, and in fact, including more diverse tasks provides a stronger test of general slowing. If regressing the RTs of a target population on those of controls reveals a sufficiently orderly relation between the two, this implies that differences in performance between the target population and controls may be predicted without taking into account the nature of the task (i.e., the specific cognitive processes involved).

One important advantage of this regression-based approach is that, in contrast to clinical tests for psychomotor slowing, the regression approach provides a technique for distinguishing sensory and motor slowing from cognitive slowing if the sensory and motor contributions to performance remain relatively constant across tasks (e.g., if all tasks involve undegraded visual stimuli, binary choices, and manual responses). If there is no cognitive slowing then sensory and/or motor slowing will result in a linear relation between the RTs of the two populations with a slope of 1 and a positive intercept. In this case, the intercept value indicates the constant difference between the RTs of the two populations on all tasks with similar sensory/motor requirements. Alternatively, general cognitive slowing will result in a linear function with a slope greater than 1, indicating that the difference in RTs between the two populations, rather than remaining constant, becomes progressively more pronounced as task complexity increases (Cerella, Poon, & Williams, 1980; Myerson & Hale, 1993).

If there is both sensory/motor and cognitive slowing, then their relative severity (i.e., whether cognitive processes are slowed more or less than sensory/motor process) will be revealed by the sign of the intercept. The significance of the intercept may be explicated by the following derivation, based on Cerella's (1985) multilayered slowing model of cognitive aging. Cerella suggested that both sensory/motor and cognitive processes might be slowed in older adults, but to different degrees. Myerson, Hale, Wagstaff, Poon, and Smith (1990) showed that if the composite duration of sensory/motor processing is approximately constant from task to task, then the relation between the RTs of older adults \((Y)\) and young adults \((X)\) is given by

\[
Y = m_c (X - a) + m_p a,
\]

where \(m_c\) represents the cognitive slowing coefficient, \(m_p\) represents the sensory/motor coefficient, \(a\) represents the composite duration of sensory/motor processes in the young adults, and thus \(X - a\) equals the portion of the RTs devoted to cognitive processing.

Rearranging the preceding equation yields \(Y = m_c X + a(m_p - m_c)\) and reveals that the intercept, \(a(m_p - m_c)\), depends on the difference between the cognitive and sensory/motor coefficients. If cognitive slowing is greater than sensory/motor slowing, the intercept term will be negative, whereas if sensory/motor slowing is greater, then the intercept term will be positive. If cognitive and sensory/motor processes are equally slowed (i.e., \(m_c = m_p\)), then the intercept term equals zero and the line passes through the origin. Although this equation was originally derived in the context of age-related slowing, in other applications \(Y\) and \(X\) may represent the RTs of any target and control groups (e.g., depressed and nondepressed), respectively.

The regression-based approach to slowing was first applied to meta-analytic investigations by Cerella et al. (1980), who found that across a wide variety of speeded tasks, the relationship between elderly and young RTs was well described by a linear function with a slope of 1.62, indicating general cognitive slowing. Subsequent studies examining the issue of general slowing in the elderly have generally verified these findings (for a recent review, see Cerella & Hale, 1994), although Lima, Hale, and Myerson (1991) found that general slowing was more pronounced in the nonlexical than the lexical domain. General cognitive slowing has also been identified using meta-analytic methods in children (Kail, 1991) as well as in a number of neurological disorders, including dementia of the Alzheimer type (Hale, Lawrence, Myerson, & Chen, 1995; Nebes & Brady, 1992; Nebes & Madden, 1988), multiple sclerosis (Kail, this
issue), mental retardation (Kail, 1992), and closed head injury (Ferraro, 1996).

In the current meta-analysis, we explored the extent to which general slowing underlies the cognitive deficits associated with depression. The question of the relative contributions of sensory/motor and cognitive deficits to psychomotor slowing in depression is also addressed.

**METHOD**

To acquire data for the current investigation, PsycINFO and Medline databases were searched for relevant journal articles published during the periods of 1984 to 1996 and 1986 to 1996, respectively. The search was conducted using the following subject headings and text words: depression in conjunction with reaction time, reaction speed, response time, response speed, processing time, processing speed, psychomotor time, psychomotor speed, and psychomotor slowing. Abstracts from the list of studies generated were examined and the 65 studies that appeared to include simple manual and vocal response latencies to visual stimuli from depressed individuals were further evaluated.

Examination of these studies revealed a large degree of variability in terms of diagnostic criteria and medication status. In addition, in many studies there was a significant discrepancy in the mean ages of the depressed group and the nondepressed control group. To maximize diagnostic consistency and minimize possible confounds, in Analysis 1 of the present investigation we only used data from those studies meeting the following requirements: (a) A diagnosis of major depression was conferred in accordance with criteria outlined in the Diagnostic and statistical manual of mental disorders-III or III-R (DSM-III, 1980; DSM-III-R, 1987); (b) the mean ages for control and depressed study groups were within five years of one another; and (c) subjects were unmedicated at the time of study. Examination of these studies revealed a large degree of variability in terms of diagnostic criteria and medication status. In addition, in many studies there was a significant discrepancy in the mean ages of the depressed group and the nondepressed control group. To maximize diagnostic consistency and minimize possible confounds, in Analysis 1 of the present investigation we only used data from those studies meeting the following requirements: (a) A diagnosis of major depression was conferred in accordance with criteria outlined in the Diagnostic and statistical manual of mental disorders-III or III-R (DSM-III, 1980; DSM-III-R, 1987); (b) the mean ages for control and depressed study groups were within five years of one another; and (c) subjects were unmedicated at the time of study. This method of selection yielded a total of five studies (see Table 1) with data that were amenable to our meta-analytic approach.

The number of studies that met the rigorous criteria for Analysis 1 was surprisingly small. Therefore, in order to test the generality of our findings without overly compromising the quality of the data for the current purposes, we selected a second set of studies from among those not included in the first analysis. The requirements for inclusion in Analysis 2 were: (a) A diagnosis of major depression was conferred either in accordance with the same criteria used for Analysis 1 (i.e., those outlined in the DSM-III or III-R) or in accordance with other rigorous criteria that appeared consistent with the DSM-III or III-R, and (b) the mean ages for control and depressed study groups were within ten years of one another (rather than the five years specified for Analysis 1). There was no requirement with respect to medication status, and as may be seen in Table 1, some of the depressed individuals were on medication in the six studies that met these criteria. (It should be noted that failure to include a study in our analyses does not necessarily reflect on the quality of the original research, which often addressed questions other than those of the present meta-analysis.)

**RESULTS**

Figure 1 (left panel) shows 15 data points representing the mean RTs of the depressed groups in Analysis 1 plotted as a function of those of the control groups in the same study condition. For the depressed groups, mean RTs ranged from 261 to 3660 ms; for the control groups mean RTs ranged from 221 to 2880 ms. In all conditions, the mean RTs of the control group were shorter than those of the depressed group. The data were well described by a linear function with a slope of 1.289 \((r^2 = .977)\). Because the intercept did not differ significantly from 0, the data were refit, forcing the line through the origin. The slope of this constrained regression was 1.320, indicating that the depressed were, on average across all conditions, approximately 30% slower than the controls.

Similar results were obtained in Analysis 2 (Figure 1, right panel). For the depressed groups, mean RTs ranged from 262 to 4257 ms; for the control groups mean RTs ranged from 237 to 3461 ms and were shorter than those of the depressed group in every condition. The 31 data points were well described by a linear function with a slope of 1.334 \((r^2 = .968)\). Because the intercept did not differ significantly from 0, the data were refit, forcing the line through the origin. The slope of this constrained regression was 1.31, again indicating that the depressed were on average approximately 30% slower than the controls. It may be noted that there was one point in the Analysis 1 data set that was more
Table 1. Studies, Subject Numbers, Mean Ages, Tasks, Number of Conditions, and Response Modes for Data included in the Meta-Analysis.

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>Age</th>
<th>Task (number of conditions)</th>
<th>Response mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANALYSIS 1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cornell, Suarez, &amp; Berent, 1984</td>
<td>14/26</td>
<td>31/34</td>
<td>Simple reaction time (1)</td>
<td>Button press</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Motor reaction time (1)</td>
<td>Key release, move, key press</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Letter classification (2)</td>
<td>Differential key press</td>
</tr>
<tr>
<td>Deijen, Orlebeke, &amp; Rijsdijk, 1993</td>
<td>12/12</td>
<td>48/48</td>
<td>Physical discrimination task (1)</td>
<td>Differential key press</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Choice reaction time (1)</td>
<td>Key press</td>
</tr>
<tr>
<td>Knott &amp; Lapiere, 1987</td>
<td>21/21</td>
<td>30/32</td>
<td>Choice reaction time (1)</td>
<td>Key release, move, key press</td>
</tr>
<tr>
<td>Lemelin et al., 1996</td>
<td>30/30</td>
<td>37/42</td>
<td>Standard Stroop task (3)</td>
<td>Joystick movement</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Stroop-like directional task (3)</td>
<td>Joystick movement</td>
</tr>
<tr>
<td>Min &amp; Oh, 1992</td>
<td>33/33</td>
<td>25/28</td>
<td>Physical discrimination task (2)</td>
<td>Differential key press</td>
</tr>
<tr>
<td>ANALYSIS 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>David, 1993&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23/12</td>
<td>34/41</td>
<td>Chimeric face discrimination (2)</td>
<td>Vocal response (sad/happy)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stroop color-strip task (2)</td>
<td>Vocal response (say color)</td>
</tr>
<tr>
<td>Moffoot et al., 1994&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20/20</td>
<td>42/47</td>
<td>Choice reaction time (2)</td>
<td>Touch finger to stimulus</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Delayed match-to-sample (8)</td>
<td>Touch one of 4 selections</td>
</tr>
<tr>
<td>Pirozzolo, Maturin, Loring, Appel, &amp; Maletta, 1985&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12/12</td>
<td>67/64</td>
<td>Choice reaction time (2)</td>
<td>Differential button press</td>
</tr>
<tr>
<td>Popescu, Ionescu, Jipescu, &amp; Popa, 1991&lt;sup&gt;b&lt;/sup&gt;</td>
<td>30/46</td>
<td>34/37</td>
<td>Simple reaction time (1)</td>
<td>Manual key press</td>
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<td></td>
<td></td>
<td></td>
<td>Move/Decide choice reaction time (1)</td>
<td>Key release and key press</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Go-No Go choice reaction time (1)</td>
<td>Key press and inhibit press</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Standard choice reaction time (1)</td>
<td>Differential key press</td>
</tr>
<tr>
<td>Segal, Gemar, Truchon, Guirguis, &amp; Horowitz, 1995&lt;sup&gt;b&lt;/sup&gt;</td>
<td>58/44</td>
<td>25/34</td>
<td>Emotional Stroop task (8)</td>
<td>Vocal response (name ink color)</td>
</tr>
<tr>
<td>Stip, Lecours, Chertkow, Elie, &amp; O'Connor, 1984</td>
<td>24/11</td>
<td>33/40</td>
<td>Lexical decision task (3)</td>
<td>Differential key press</td>
</tr>
</tbody>
</table>

<sup>a</sup> Some or all of the depressed individuals were medicated. <sup>b</sup> Medication status unknown.
than 250 ms greater than the value predicted by the regression line. This point corresponds to the Stroop interference condition in Lemelin et al. (1996). However, the data set for Analysis 2 also included a study (David, 1993) that used a Stroop task, and data from the interference condition in this study was more than 100 ms less than the value predicted by the regression line, suggesting that depression does not have a reliable effect on Stroop interference.

Finally, because the data points in the preceding two analyses were not independent (i.e., in all but one case, each group contributed more than one mean RT), Analysis 3 was conducted using one data point per study. Violation of the independence assumption can lead to underestimation of the standard errors of regression parameters, and including more than one point per study, although it improves parameter estimation by increasing the number of data points, may allow studies contributing more data points to overly influence the regression results. Because of the fact that including multiple points per study has both advantages and disadvantages, it may often be desirable in meta-analyses to analyze data sets using both approaches to see if consistent results are obtained (Lima et al., 1991).

For Analysis 3, we included all of the studies from the first two analyses, but focused on the task that produced the longest RTs for the controls on the assumption that this task involved the most cognitive processing. From this task, we selected the condition with the median RT for the control group unless there was an even number of conditions, in which case we selected the condition of the middle two that produced the longer RT for the controls. This was done so that, as in the first two analyses, each data point came from a single condition. As was the case for the data in the previous analyses, the data from Analysis 3 were well described by a linear function ($r^2 = .992$). When the line was forced through the origin (again because the intercept did not differ significantly from zero), the slope was 1.262 (Figure 2), a value similar to the slopes obtained in the previous analyses.
Whereas slopes consistently greater than 1.0 indicate that depression is associated with cognitive slowing, the fact that the intercepts did not differ significantly from 0 suggests that sensory/motor processes were slowed to approximately the same degree as cognitive processes. Thus, although the present findings are consistent with psychomotor slowing in depression, they provide a more precise description of that slowing. Although results of neuropsychological tests may indicate psychomotor deficits, they do not furnish information regarding the relative contributions of cognitive and sensory/motor processes to these deficits. That is, such test results do not reveal whether both cognitive and sensory/motor processes actually contribute to the observed slowing or if just one is responsible for the entire slowing effect.

Moreover, if both cognitive and sensory/motor processes are slowed, standard neuropsychological tests cannot indicate whether they are equally slowed or how much more one is slowed than the other. In contrast, the present approach permits comparison of cognitive and sensory/motor slowing. Although both were equivalent in the present case, if cognitive processes had been slowed more than sensory/motor processes, this would have been indicated by a negative intercept, whereas if sensory/motor processes had been slowed more than cognitive processes, this would have been indicated by a positive intercept. It should be noted that although the tasks used in the studies analyzed here varied greatly in their cognitive processing demands, the sensory/motor demands were generally minimal and relatively similar from task to task. Thus, although sensory/motor and cognitive processing appear to be equivalently slowed in the present data sets, this equivalence may not necessarily extend to tasks with other sensory/motor requirements. We would note, however, that the degree of slowing observed in the drawing times of a depressed group reported by Van Hoof, Hulstijn, Van Mier, and Pagen (1993) was very similar to that observed in the studies analyzed here, despite the more extensive motor requirements of the drawing task.

The present findings have important methodological implications for the study of cognitive
changes in depression. Typically, investigators use procedures such as analysis of variance (ANOVA) to examine possible differences in specific cognitive abilities between depressed and control groups. In such analyses, a group by condition interaction is interpreted as evidence of a specific deficit. As has been pointed out previously (e.g., Nebes & Brady, 1992; Salthouse, 1985), however, such interactions may be the result of general slowing which tends to magnify group differences as conditions become more complex. Thus, group by condition interactions are indicative of specific deficits only if between-group differences across conditions are larger than those predicted by a linear function describing general slowing (Madden, Pierce, & Allen, 1992).

Because of the ambiguity of ANOVA interactions for the analysis of group differences in RT, either supplementary or alternative statistical procedures are necessary. One possible approach is to use regression procedures analogous to those used in the present meta-analysis. Such procedures have been used to compare older and young adult RTs in multitask experiments, and make it possible to compare the magnitude of an observed group by condition interaction to that predicted by general slowing using a variety of statistical techniques (e.g., Hale, Myerson, Faust, & Fristoe, 1995; Madden et al., 1992; Myerson, Hale, Chen, & Lawrence, in press). Although such techniques have been pioneered in the area of cognitive aging, they are in principle applicable to other areas. Importantly, where the goal is to compare clinical populations (e.g., individuals with depression) and controls on speeded performance, some effort must be made to assess the degree of general cognitive slowing; if there is evidence of general cognitive slowing, then differences in particular tasks or conditions (used to infer specific deficits) must be assessed using procedures that take the observed general slowing into account.

Regression-based techniques may have other potentially significant applications beyond the study of group differences in cognition. Hale and Jansen (1994) reported that the RTs of an uncompromised individual performing a variety of tasks were an extremely orderly linear function of the average RTs for his or her age group, with very little evidence of task-specific strengths or weaknesses, suggesting that the slope and intercept of this line could be used to characterize the individual’s cognitive and sensory/motor speed. Such regression techniques may also be applicable to the assessment of individual neurological patients. Not only could one compare slowing of cognitive and sensory/motor processes, but these techniques also would allow performance on specific tasks or in specific conditions to be assessed relative to an individual’s general speed of performance. That is, one could measure an individual’s RTs on multiple tasks or in multiple conditions, and regress his or her RTs on those of controls. If the individual were impaired on a particular task or in a particular condition of that task, then the RT data from that task would lie significantly above the regression line. If there were no significant outliers, however, this would suggest that there was no task or condition in which performance was more impaired than would be predicted by general slowing.

The present conclusions regarding cognitive slowing in depression may be contrasted with those of Hartlage et al. (1993), who hypothesized that depression specifically interferes with the effortful aspects of cognition. That is, more profound deficits are demonstrated on tasks requiring effortful (e.g., recall) as opposed to automatic (e.g., recognition) cognitive processing. However, effortfulness is typically confounded with task difficulty or complexity. This confound raises the question of whether there is a specific deficit in effortful processing in depression, or whether the impaired performance of depressed individuals on effortful tasks simply represents another instance of a general effect of task complexity (e.g., Cerella et al., 1980; Myerson & Hale, 1993; Nebes & Brady, 1992).

The results of the present analyses demonstrate that the difference between the RTs of depressed and control groups may be predicted based on task complexity, where the complexity of a task condition is operationalized as the RT of a group of uncompromised individuals in that task condition. Regression-based techniques could provide a means of determining whether
the effortfulness of a task contributes to the difference between depressed and control groups’ performances, over and above the contribution of task complexity. In order for such techniques to be applied, future studies examining the effect of depression on speed of performance will have to assess task effortfulness independent of complexity. Although effortfulness measures may ultimately improve the prediction of performance by depressed groups, the present analyses indicate that much, if not all, of the variation in the size of group differences from task to task can be predicted without taking this factor into account.

Finally, we turn to the question posed in the title of this article regarding the relation between cognitive and psychomotor slowing in depression. The present findings suggest that both sensory/motor and cognitive processes are slowed to approximately the same degree in depression. Thus, when a task that is primarily sensory/motor in nature is used to assess psychomotor speed, the effect of depression that is observed will necessarily be attributable primarily to sensory/motor slowing. As the cognitive complexity of the tasks used to assess psychomotor speed increases, the contribution of cognitive slowing to the observed effect of depression will increase accordingly. Returning to the question, “How cognitive is psychomotor slowing in depression?” the answer would appear to be “As cognitive as the tasks used to assess it.”

REFERENCES

(An asterisk denotes a study included in the meta-analyses and listed in Table 1.)


inhibition or processing resource deficit? *Journal of Nervous and Mental Disease*, 184, 114-121.


