Brief Report: Speed of Information Processing in Children With Insulin-Dependent Diabetes Mellitus

Robert Kail,¹ PhD, Christopher A. Wolters,² PhD, Shirley L. Yu,² PhD, and John W. Hagen,³ PhD
¹University of Maryland, ²University of Houston, and ³University of Michigan

Objective: To determine whether children with insulin-dependent diabetes mellitus (IDDM) process information more slowly than children who do not have diabetes.

Methods: We tested 31 children with early onset and longer duration of IDDM, 35 with later onset and briefer duration of IDDM, and 36 comparison children without diabetes. They were administered five tasks requiring rapid responding that assessed a range of cognitive processes.

Results: On most tasks, children in the three groups were quite similar in the accuracy and speed of performance. Furthermore, for children in the diabetic groups, disease-related variables were unrelated to accuracy and speed of performance.

Conclusions: The results suggest that children with IDDM do not have a pervasive deficit in speed of information processing, although more circumscribed deficits in processing speed are possible.

Key words: diabetes; processing speed; cognitive development.

Children who develop insulin-dependent diabetes mellitus (IDDM, also known as Type 1 diabetes) before 5 years of age often have impaired performance on cognitive tasks. For example, children who develop IDDM before age 5 often have lower scores on measures of intelligence, attention, learning, memory, and visual spatial processing (Hagen et al., 1990; Ryan, Vega & Drash, 1985). This impaired performance in children with IDDM might reflect slower speed of cognitive processing because, in children without IDDM, increased processing speed is associated with more accurate retention and more effective reasoning and problem solving (Fry & Hale, 1996). If children who develop IDDM before age 5 process information more slowly than children without IDDM, their performance on memory and cognitive tasks may be sometimes impaired.

In fact, the extant literature on speed of processing in children with IDDM is sparse and inconsistent. In the most extensive study (Ryan et al., 1985), children who developed IDDM before age 5 responded more slowly on two tasks: (1) a symbol substitution task in which a code consisting of digits paired with unique symbols appeared at the top of the page and children printed the digit adjacent to symbols at the bottom of the page, and (2) a pegboard task in which children moved pegs between two sets of holes. Children with IDDM did not, however, respond more slowly on a third task, trails,
in which they quickly drew lines linking letters and numbers in a specified order.

Two other studies included a single measure of processing speed. On the one hand, Sansbury, Brown, and Meacham (1997) found that, among a group of children with IDDM, those who developed IDDM early tended to respond more slowly on a visual search task. On the other hand, Holmes, Dunlap, Chen, and Cornwell (1992) found that children with IDDM did not respond more slowly than children without IDDM on a symbol substitution task like that used by Ryan et al. (1985).

Given these inconsistent findings and the critical role that processing speed plays in memory and cognitive functioning in healthy children (Kail, 1995), this study was designed to provide a comprehensive evaluation of speed of processing in children with IDDM. Our sample included children who developed IDDM before age 5, a separate group of children who developed IDDM at age 5 or older, and a comparison group of children who did not have IDDM. Because a deficit in processing speed may appear in some but not all speeded tasks, we used five tasks that tap different cognitive processes and that reveal age differences in processing speed (Kail, 1995). Three tasks (mental rotation, form board, analogies) relied heavily on visual-spatial processing; these were chosen because investigators have reported impaired performance by children with IDDM in the visual-spatial domain (Ryan et al., 1985). The other tasks (addition and visual search) relied more on verbal skills. We hypothesized that, if processing speed is impaired in children who develop IDDM early (and thus have had the disease for a longer duration), they should respond more slowly on some if not all these speeded tasks.

Method

Participants

The results described here were obtained from children participating in a comprehensive study of psychological and behavioral characteristics of children with IDDM (Wolters, Yu, Hagen, & Kail, 1996). We tested 77 children with IDDM and 36 children without IDDM. However, 11 children with IDDM were excluded because they did not meet the age of onset and duration of illness requirements described below. Thus, 66 children with IDDM and 36 comparison children were included. The 49 boys and 53 girls ranged in age from 9.1 to 16.7 years, with a mean of 12.6 years ($SD = 2.24$ years). Children with IDDM were categorized into two groups: 31 children diagnosed before their fifth birthday and at least seven years before testing constituted the earlier onset/longer duration group; 35 children diagnosed after their fifth birthday and no more than seven years before testing constituted the later onset/briefer duration group. (Hereafter, for simplicity these are referred to as early and late onset groups, respectively.) All children with IDDM were diagnosed at least two years before testing. The early onset, late onset, and comparison groups included 1, 1, and 6 African American children, respectively; all remaining children were white. Details concerning the sample can be found in Wolters et al. (1996).

Procedure

Children and at least one parent came to our laboratory for two 1½- to 2-hour sessions separated by at least 30 days. The general procedures, described in Wolters et al. (1996), included cognitive and memory tasks and a parental interview. Blood glucose was assessed in children with IDDM; children were not tested if they were hypoglycemic or hyperglycemic.

Stimuli were presented on a computer monitor (mental rotation, addition, visual search) or were prepared as slides and projected onto a 8½×10 in. screen (analogies, form board). Children responded by pressing one of two keys on a keyboard with their right index finger. Due to space limits, details of specific tasks are not presented here; they are available upon request from the authors. The order of tasks was rotation, addition, and visual search in session 1 and analogies and form board in session 2.

Mental Rotation. On each of 80 trials, children judged whether a stimulus presented in different orientations was a letter or the mirror image of a letter.

Analogies. On each of 48 trials, there were two pairs of rectangles, with geometric figures inside each rectangle. Children determined the relation between the figures in the first pair of rectangles, then decided whether the figures in the second pair were related in like manner.

Form Board. On each of 64 trials, a problem con-
these conditions, a mean RT was computed from times on correct responses. To reduce the impact of outlying RTs, any RT within a condition that was twice the mean was deleted and the mean was re-computed. Fewer than 1% of RTs were deleted in this fashion. To account for age-related variance in performance, the samples were divided at the median chronological age to create “younger” and “older” groups. The data from each task were analyzed with analysis of variance (ANOVA) in which there were two between-group factors (group, age) and two within-group factors that defined the structure of the task (e.g., for mental addition, size of the stated sum and whether the stated response was true or false).

Results

Children performed quite accurately. Children in the early onset and comparison groups tended to perform at about the same level of accuracy, and children in the late onset group tended to be slightly less accurate. This difference in accuracy was significant on the rotation and analogies tasks, $F_{5} = 3.21, p < .05$ (rotation: early onset, 94.4%; late onset, 89.5%; comparison, 94.9%; analogies: early onset, 86%; late onset, 81%; comparison, 87.7%).

Each task included several within-subject conditions, each of which included 6–8 response times (RTs). For example, mental rotation included 10 within-subject conditions, reflecting orthogonal combination of 5 stimulus orientations and 2 responses (identical, mirror image). Within each of these conditions, a mean RT was computed from times on correct responses. To reduce the impact of outlying RTs, any RT within a condition that was twice the mean was deleted and the mean was re-computed. Fewer than 1% of RTs were deleted in this fashion. To account for age-related variance in performance, the samples were divided at the median chronological age to create “younger” and “older” groups. The data from each task were analyzed with analysis of variance (ANOVAs) in which there were two between-group factors (group, age) and two within-group factors that defined the structure of the task (e.g., for mental addition, size of the stated sum and whether the stated response was true or false).

Results of primary importance were the main effects of groups (early onset, late onset, comparison) and interactions between groups and other variables. On four tasks, these effects were all nonsignificant, $F_{5} < 1$ for main effects; $F_{5} = 2.18, p > .05$ for interactions. As shown in the left panel of Figure 1, on the analogies, form board, mental addition, and visual search tasks, children in the three groups responded in approximately the same amount of time. On mental rotation, the main effect of group was not significant, but the interaction of age, group, and orientation was, $F(8, 174) = 2.19, p < .05$. As shown in the right panel of Figure 1, for older children, RTs increased as a function of orien-
tation at about the same rate for all groups. For younger children (Figure 1, center panel), this was true for orientations between 0 and 90 degrees. However, at 120 degrees, the mean RT for children in the early onset group was unexpectedly less than the mean at 90 degrees, whereas the mean RTs at 120 degrees for children in the late onset and comparison groups were greater than the corresponding means at 90 degrees.

In a final analysis, we computed correlations between performance on speeded tasks and several diabetes-related variables: age of onset of IDDM, parent’s rating of control (as a global measure of the child’s long-term control of the disease), and blood glucose levels at each testing session (as a measure of the child’s current level of control). In these analyses, mean level of accuracy and mean RT for each task were calculated separately for each child. In addition, overall measures of accuracy and RT were determined by calculating, for each child, a standard score on each task and summing these standard scores across tasks. For example, the overall measure of accuracy was simply the sum of each child’s standard scores for accuracy on the five tasks. Of the 48 rs between diabetes-related variables and the 12 performance measures, only one was significant, approximately the number expected by chance.

**Discussion**

The primary outcome of the current study was that, contrary to our hypothesis, children who developed IDDM early (and thus had the disease for a longer duration) performed at a similar rate as children in the late onset group and children without IDDM. Because group differences were not significant, it is important to show that our study was sufficiently sensitive to find such differences had they existed. Four factors suggest that the tasks and design were sufficiently sensitive. First, tasks such as these have been used previously to reveal deficits in clinical groups, such as children with specific language impairment (Kail, 1994). Second, we found the usual pattern of age differences. Consistent with previous research on developmental change in speed of cognitive processing, older children responded more rapidly than younger children on each task, and the magnitude of these age differences resembled those found previously (Kail, 1995). Third, within each task, we found the usual effects of task complexity or difficulty. Children responded more slowly when completing the more complex portions of each task. For instance, on mental addition, children responded more slowly on trials with greater sums. Fourth, power analyses indicate that our study would have detected differences of the size found previously. Specifically, the differences reported by Ryan et al. (1985) and by Sansbury et al. (1997) ranged from “medium” to “large” effects (as defined by Cohen, 1979). The power of this design to detect such differences between children with IDDM and those without IDDM was .71 and .98, respectively. Thus, it is unlikely that clinically important differences between groups would have gone undetected in this design.

Although most analyses showed no differences between groups, in three instances children with IDDM had impaired performance. There were group differences in accuracy on two of the tasks, with the late onset group less accurate than the other two. This outcome was unexpected based on previous work, in which impaired performance is more likely when onset of IDDM is early rather than late. However, overall accuracy was reasonably high, especially on the rotation task. More important, given the special interest in the early onset group, it is noteworthy that children in this group were just as accurate as children in the comparison group; children in the early onset group did not sacrifice accuracy to achieve processing speed comparable to children in the comparison group.

The third instance of a group difference occurred on the rotation task. The interaction of age, group, and orientation was significant, reflecting the fact that children in the early onset group responded more rapidly when stimuli appeared at 120 degrees than at 90 degrees. This result is unusual on this task and we have no obvious explanation. More important, however, is that at both ages children in the early onset groups responded more rapidly on the rotation task than children in the comparison group (though not significantly so). Thus, none of the findings of group differences suggests a pattern of serious impairment in children with IDDM.

These findings of unimpaired processing speed in children with IDDM differ from those of Ryan et al. (1985). One explanation is that the tasks used by Ryan et al. included a more demanding response component than the tasks we used. In symbol substitution, children moved the pencil from one symbol to the next, then printed the correct digit; in
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1985). Furthermore, although each of these deficits may be relatively small, in aggregate they can lead to below-average achievement, particularly when children are exposed to other risk factors unrelated to diabetes.

Finally, there was no evidence that metabolic control–related aspects of IDDM were related to children's speed of cognitive processing. Neither metabolic history (age at onset, parental report of control) nor current control (blood glucose levels) was related to performance. At first glance, these findings may appear inconsistent with previous work showing that (1) individuals with a history of poor metabolic control complete speeded tasks more slowly than those with better control (Ryan & Williams, 1993) and (2) speed of processing is slower during hypoglycemic states (Holmes, Hayford, Gonzalez, & Weydert, 1983). However, our measures of metabolic history were limited (e.g., parents' ratings of overall metabolic control may be inaccurate or unreliable). Furthermore, because children were not tested if they were either hyperglycemic or hypoglycemic, our results simply show that blood glucose levels within the normal range are unrelated to speeded performance.

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