Abstract: This microgenetic study investigated similarities and differences in use and discovery of addition strategies in children with and without mild mental retardation across 24 sessions. Nine children with mild mental retardation in third through fifth grade classrooms and 14 children without mental retardation in kindergarten classrooms were tested individually over 12 weeks (two sessions per week with 12 addition problems per session) and were given no strategy instruction. Overall, children with and without mental retardation showed strategy change across session, progressing from less to more sophisticated strategies and did not differ in the range of strategies, with one to six different strategies used in both groups. Pretests measures of conceptual understanding of number, including highest number counted to and magnitude estimation problems were the best predictors of accuracy during testing sessions. These results have important implications for educational practices for children with disabilities.

Much of the cognitive research conducted with children with mental retardation (MR) has focused on deficits. This research indicated deficits in many cognitive domains such as memory (Ellis, 1978), attention (Zeaman & House, 1963), and problem solving (Ferretti, 1989; Ferretti & Cavalier, 1991) that often hinder academic task performance. In contrast, recent research has shown that children with MR have cognitive competencies as well in both academic and nonacademic tasks (Baroody, 1999; Bray, Fletcher & Turner 1996). However, adopting this view in the field of special education has been slow (Baroody, 1999). Research across numerous domains to document both competencies and deficiencies is crucial to obtain a comprehensive view of capabilities of children with MR.

In the domain of mathematics (Baroody, 1999), children with mild or moderate MR have been shown to exhibit evidence of early math knowledge such as counting principles (Baroody, 1986b; Gelman, 1982; Gelman & Cohen, 1988), number concepts (Baroody & Snyder, 1983), and strategy use to solve simple addition problems (Baroody, 1986a, 1986b, 1988, 1995, 1996; Bray, Huffman, Hawk, & Ward, 1994). Research has shown that children with and without MR use a variety of observable strategies to solve addition problems (Carpenter & Moser, 1984; Goldman, Mertz, & Pellegrino, 1989; Siegler & Jenkins, 1989; Siegler & Shrager, 1984), and even spontaneously invent new strategies (Baroody, 1995, 1996). Children’s addition strategies change rapidly over a relatively short period of time (Fuson, 1982; Siegler, 1987). In addition, some researchers have suggested studying children with MR because their development is often slower and may allow researchers to more clearly view change as it occurs (Baroody, 1995; 1999).

large age range (6 - 20 years) over 51 experimental addition sessions during an academic year. Fifteen children also were in a control condition that did not receive sessions solving simple addition problems. Initially, researchers modeled the “concrete counting all” strategy (i.e., each addend is counted out and then the child recounts each addend to arrive at the sum) during pretest sessions when individual children failed to use a legitimate strategy to solve a problem. Across the pretest, children with mild and moderate MR readily learned the basic strategy of concrete counting all. During experimental sessions, children also spontaneously modified their strategy use to reduce number of counts needed to arrive at the sum. It is important to note that the researcher did not demonstrate these strategies, but instead children discovered them. Discovery of these modified strategies was only observed in the experimental group that had multiple sessions solving simple addition problems.

Other studies have noted that young typical children also modify their strategy use over multiple sessions involving solving simple addition problems. Siegler and Jenkins’ (1989) and others (Bray, et al., 1994) examined young children’s addition strategies using a microgenetic method (a longitudinal study in which children are intensively observed over an extended period of time followed by a trial-by-trial analysis of what occurred when the child solved the addition problem). In general, these studies also reported that many children without any training discovered a variety of new strategies. Similar to findings of Baroody (1995, 1996), the new strategies economize the number of counts needed to arrive at the sum. Thus, both children with and without MR appear to discover and use sophisticated strategies to solve addition problems. However, there have been no direct comparisons between children with and without MR in the discovery and use of these sophisticated addition strategies.

The present study compared the use and change of strategies to solve simple addition problems, with no training, in children with and without MR. The following questions were addressed: Do children with and without MR 1) achieve the same level of accuracy when solving simple addition problems? 2) use the same types of strategies, and with the same frequency to solve simple addition problems? 3) show the same change in strategy use? 4) have the same relationship between initial number knowledge (magnitude estimation or highest number counted) and accuracy in subsequent sessions?

Method

Participants

Participants were 10 children with mild MR ($M = 8.9$ years; $SD = 5.9$) and 14 children without MR from kindergarten classrooms ($M = 6.4$ years; $SD = 3.7$). One of the children with MR was excluded from data analysis because he guessed the same answer, i.e., “6”, on each of 288 trials, even with the researcher prompting him to try as hard as he could. Thus, 9 children with MR were included in all data analyses. All children were ambulatory, had normal vision (corrected or uncorrected) and hearing. All children attended schools in a large metropolitan area in the southeast. The IQ scores of the children without MR were not available, but all children were in their age-appropriate grade placement. Mean IQ for children with MR was 68 ($SD = 4.7$). All IQ scores were provided by the school district. Based on pretests, the two groups were not different from each other with respect to addition accuracy and strategy use on single-digit addend problems.

Materials

A laptop computer generated problems, which the children viewed on a 22 cm monitor. A video camera placed to the right of the child, providing a view of the child, the table, and the computer screen recorded all sessions. A microphone was attached to the side of the monitor to record all verbalizations. Sessions lasted approximately 10 to 15 minutes each.

Pretest and subsequent testing sessions involved number-fact (“How much is $5 + 3$?”) problems using small addends. The testing sessions also included large addend and challenge problems. The small addend problems
consisted of all possible pairs of digits from 1 to 5 (excluding ties such as 2 + 2); the large addend problems consisted of all pairs, with the digits 1 to 5 for one addend and the digits 6 to 9 as the other. The challenge problems consisted of pairs with digits 1 to 4 as one addend and the digits 12 to 29 as the other addend.

Procedure

Pretest sessions. All potential participants were screened during four pretest sessions. Participants were told they were going to play a “sticker game” and that by answering math problems correctly they could receive stickers. Participants were told, “You can do anything you want to get the right answer. You can just say the right answer if you know it, or you can count or use your fingers or do whatever you want to do.” Participants were also told they did not have to answer the same way every time as long as they tried their best.

During pretest sessions 1 and 2, small addend problems appeared on a computer screen for 2.5 seconds while the tester read the problem aloud (e.g., “How much is 3 + 5?”). All problems consisted of digits from 1 to 5 (excluding ties such as 2 + 2) called small addend problems. The length of time it took to answer each problem (latency) and how the child responded to the problem was recorded. Participants were given a colorful “sticker” after each correct response. A sticker was also given after three consecutive missed trials to keep the participants motivated and interested in the game. After each response was given, accuracy feedback was given to the participant. Participants were then asked, “How did you figure out the answer to that problem?” If the answer was scorable, the tester proceeded to the next problem. However, if the answer was ambiguous, the tester asked, “Did you already know it, did you count, or did you use another way to figure out the answer?” If the participant responded with “already knew it,” the tester continued with the next problem. If the participant responded with “I counted,” the tester asked how he/she counted. If the tester had observed the participant counting on his/her fingers, but the participant failed to report finger counting, the tester asked, “What were you doing with your fingers?” If the participant used another way to figure out the answer, the tester asked, “What way did you use?” After this probe the tester continued with the next problem regardless of the participant’s response.

Pretest session 3 began with the “sticker game” after which followed an introduction to “Lance,” a cabbage patch doll. Participants were told to pretend he was a younger kid just learning to add and were asked to explain to “Lance” a way to figure out the answer to 2 + 4. Following the first response, participants were asked to tell “Lance” another way to figure out the answer. “Lance” provided a pretest index of each child’s level of strategy knowledge.

In pretest session 4, participants were told they were going to play the “sticker game” a little differently. First, participants were asked 36 magnitude estimation questions by the tester (e.g., “Which is larger 5 or 3?”). Participants earned a sticker after every four correct responses. Second, participants were asked to count as high as they could.

Responses to “Lance,” magnitude estimation, and the highest number counted to were recorded during the pretest to be used as possible predictors of later performance.

Based on number of errors made and level of strategy knowledge demonstrated during the pretest, participants were selected to participate in additional sessions. All available children with mild MR who had not yet mastered addition were included in the study. Regular education kindergarten children who were comparable to children with mild MR on pretest accuracy were also selected. This was to ensure the two groups were similar before additional sessions.

Additional sessions. These sessions began approximately two weeks after completion of the pretest. All participants were tested individually in a room at their school and were given no strategy instruction. There were two sessions per week for 12 weeks with 12 addition problems per session for a total of 288 problems. Each session began with a review of instructions (identical to those used in pretest sessions 1, 2, and 3). Problems appeared on a computer screen while the tester read them aloud (e.g., “How much is 3 + 5?”). Stickers
were awarded as they had been in pretest sessions. After participants responded to each problem, probe questions identical to those in the pretest (regarding how they solved the problem) were asked.

During the first 12 sessions, children received 10 small addend problems (both addends less than or equal to 5) and two large addend problems (one addend less than or equal to 5 and one greater than 5 but less than 9). During the last 12 sessions, participants received eight small addend problems, two large addend problems and two challenge problems (one addend greater than 10, the other less than 5). The 24 sessions were divided into four blocks of six sessions each.

**Data Reduction**

Pretest responses to “Lance,” magnitude estimation, and highest number counted to were recorded during each session.

For each addition problem presented during pretest and additional sessions a microgenetic analysis was conducted, focusing on detailed trial-by-trial analyses of videotapes. Accuracy, strategy use, answers to interview questions, and latency on each of the addition problems were scored for each participant. Categorization of strategies (Table 1) was adopted from Siegler and Jenkins (1989).

As in Siegler and Jenkins (1989), when children’s strategies could be observed via videotape, strategies were scored based on observed strategy. When strategies were unobservable, strategies were scored based on the child’s report of strategy use. All videotapes were scored by one of four raters. Reliability among raters was greater than .90 on all measures for both pretest and additional sessions.

**Results**

*Do children with and without MR achieve the same level of accuracy?* Overall, children with (55%) and without MR (72%) did not differ in accuracy across the additional sessions, $t(21) = 1.25, p = .23$. Because of this, we re-examined the pretest data. Although we were interested in a general mean comparability in pretest accuracy in the two IQ groups, we noted that the groups dichotomously broke into either low (<35% correct) or high accuracy (>85% correct) subgroups when pretest accuracy was examined. The high accuracy group consisted of nine children without MR ($M = 90\%$ correct) and four children with MR ($M = 94\%$ correct). The low accuracy group consisted of five children without mental retardation ($M = 28\%$ correct) and five children with MR ($M = 23\%$ correct). Moreover, there were no differences in pretest measures between children with and without MR, whereas each measure, with the exception of Lance 2, differed significantly between the two accuracy groups (Table 2). In light of this finding, further analyses considered low and high pretest accuracy group as well as intelligence group.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Typical Use of Strategy to Solve “3 + 5”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum</td>
<td>Put up 3 fingers, count “1,2,3”. Put up 5 fingers, count “1,2,3,4,5”. Begin counting again at 1, “1,2,3,4,5,6,7,8”.</td>
</tr>
<tr>
<td>Shortcut Sum</td>
<td>Count “1,2,3,4,5,6,7,8”, perhaps while putting up one finger for each count.</td>
</tr>
<tr>
<td>Count from first addend</td>
<td>Say “3,4,5,6,7,8” or “4,5,6,7,8”, perhaps while putting up one finger for each count.</td>
</tr>
<tr>
<td>Min</td>
<td>Count from larger addend by saying, “5,6,7,8” or “6,7,8”, perhaps while putting up one finger for each count.</td>
</tr>
<tr>
<td>Finger Recognition</td>
<td>Put up 3 fingers, put up 5 fingers, say “8” without counting.</td>
</tr>
<tr>
<td>Retrieval</td>
<td>Say an answer and explain it by saying, “I just knew it”.</td>
</tr>
</tbody>
</table>
Do children with and without MR use the same type of strategies and with similar frequencies? Of the six strategies observed, children with and without MR did not differ overall in types of strategies used. Children in both groups used from one to six different strategies. Children in the high pretest accuracy group used more strategies than children in the low pretest accuracy groups (see Table 3).

Frequency of strategy use for the two intelligence groups did not significantly differ from one another on four of the six strategies observed (sum, count from first, finger recognition, and retrieval). It is especially interesting that groups did not differ on use of retrieval, with this strategy used more than half the time in both intelligence groups. Children with and without MR used the min strategy more frequently (see Table 3). In the low pretest accuracy group, children with and without MR were only significantly different in their use of the shortcut sum strategy, $t(8) = 2.40$, $p < .05$, with children without MR using shortcut sum more frequently (see Table 3).

Because retrieval was used more often than any other strategy, it merits closer analysis. Use of retrieval was similar for children with and without MR ($M = 54.4\%$ and $52.6\%$, respectively). Within the high pretest accuracy group, eight children without MR used retrieval more than 40% of the time, with four of those using retrieval more than 80% of the time. All four children with MR in the high pretest accuracy group used retrieval more.

### TABLE 2
Pretest Measure Results for Children With and Without Mental Retardation and for High/Low Pretest Accuracy Groups

<table>
<thead>
<tr>
<th></th>
<th>Children with Mental Retardation</th>
<th>Children without Mental Retardation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$ (SD)</td>
<td>$M$ (SD)</td>
</tr>
<tr>
<td>Pretest Accuracy</td>
<td>.54 (.38)</td>
<td>.67 (.32)</td>
</tr>
<tr>
<td>Lance 1</td>
<td>6.44 (4.77)</td>
<td>8.46 (5.32)</td>
</tr>
<tr>
<td>Lance 2</td>
<td>7.56 (4.82)</td>
<td>7.15 (5.43)</td>
</tr>
<tr>
<td>Highest Count</td>
<td>31.56 (19.24)</td>
<td>52.77 (26.63)</td>
</tr>
<tr>
<td>MagnitudeEstimation</td>
<td>.81 (.23)</td>
<td>.95 (.11)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Low Pretest Accuracy (&lt;35% correct)</th>
<th>High Pretest Accuracy (&gt;85% correct)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$ (SD)</td>
<td>$M$ (SD)</td>
</tr>
<tr>
<td>Pretest Accuracy</td>
<td>.25 (.08)</td>
<td>.91 (.07)</td>
</tr>
<tr>
<td>Lance 1</td>
<td>5.30 (5.31)</td>
<td>9.58 (4.14)</td>
</tr>
<tr>
<td>Lance 2</td>
<td>6.40 (5.68)</td>
<td>8.08 (4.62)</td>
</tr>
<tr>
<td>Highest Count</td>
<td>31.22 (14.96)</td>
<td>53.00 (28.22)</td>
</tr>
<tr>
<td>Magnitude Estimation</td>
<td>.80 (.23)</td>
<td>.97 (.06)</td>
</tr>
</tbody>
</table>

The same general pattern holds even when the two intelligence groups are broken down into high and low pretest accuracy groups. In the high pretest accuracy group, children with and without MR differed significantly in frequency of using shortcut sum, $t(11) = 1.99$, $p < .05$, and min, $t(11) = -1.65$, $p < .05$, with children without MR using shortcut sum more frequently, and children with MR used the min strategy more frequently (see Table 3). In the low pretest accuracy group, children with and without MR were only significantly different in their use of the shortcut sum strategy, $t(8) = 2.40$, $p < .05$, with children without MR using shortcut sum more frequently (see Table 3).
than 30% of the time, with two using retrieval more than 90% of the time. Within the low pretest accuracy group, two children without MR used retrieval over 88% of the time, while the other three used it less than 20% of the time. Three of children with MR in low pretest accuracy group used retrieval more than 95% of the time, while the other two used it on less 1% of the problems.

Although frequencies significantly differed between the intelligence groups for the shortcut sum and min strategies, patterns of strategy use by children with and without MR were remarkably similar. Figure 1 shows examples of representative children with and without MR in the low and high accuracy pretest groups. There was no one particular strategy predominantly used by children with or without MR.

Do children with and without MR show the same change in strategy use over time? Strategy evolution is defined as change in strategy use over time from using less sophisticated to more sophisticated strategies. Strategies listed in Table 1 can be thought of as a progression from least to most sophisticated. Consistent with Baroody (1996), across the continuum of strategies, children’s behaviors to count and recount addends diminish over time. Over the course of the study, 10 children without MR showed strategy change (71%) while four did not (29%). Of the 10 children who showed strategy change, all used counting strategies of some type, and none used retrieval only. Of these 10 children, seven children performed with high accuracy, while three performed at a low accuracy level. Four children showed no strategy change, two children used counting strategies of some type, and two children used retrieval only.

Similarly, all nine children with MR used one of the observed strategies. Over the course of the study, six children showed strategy change (61%) while three children did
not (40%). Similar to the sample without MR, the six children showing strategy change used counting strategies of some type, and none used retrieval only. Of these six children, five performed with high accuracy, while one performed at a low accuracy level. The three children who showed no strategy change used retrieval only and performed at a low accuracy level.

Does number knowledge during pretest predict accuracy during the additional sessions? Accuracy across the study sessions was significantly correlated to conceptual understanding of number, which was based on pretest measures of highest number counted to \( (r = .50, p < .02) \) and magnitude estimation problems \( (r = .54, p < .01) \). Lance, which represented an ability to describe effective addition strategies, was not related \( (r = .27, p = .22) \). Thus more advanced conceptual number knowledge in the pretest sessions was related to higher accuracy levels in additional sessions.

Discussion

Both children with and without MR used a similar range of strategies to solve addition problems. Our analysis also revealed that children with and without MR progressed along a continuum of sophistication in their addition strategy use. Both children with and without MR used less to more sophisticated strategies over a relatively brief period of time in the absence of direct instruction. Accuracy during additional trials was predicted by measures of conceptual number knowledge during pretests. Children who demonstrated more advanced conceptual number knowledge in pretest sessions achieved higher accuracy levels regardless of classification in the additional sessions.

These findings support previous theoretical and educational implications. Theoretically, results support the notion of Baroody (1999) and Bray, et al. (1996) that children with MR have more cognitive competence than previously believed. Our direct comparison of children in these two groups indicated many more similarities across IQ group than differences. Underlying number competence in both children with and without MR is important for learning mathematics. Further, labels have not been shown to be good predictors of individual children’s skills and abilities (Ba-
roody, 1986b; Baroody & Ginsberg, 1982). Even in our very restricted sample of children with MR (limited age and IQ range), we found substantial individual variability in pretest number knowledge and strategy use. This was also evident in our sample of typical children. These individual differences may be related to the wide variety of informal math experiences provided in home and preschool settings (Ginsburg, Klein, & Starkey 1998).

Children with MR are active learners (Baroody, 1999). In fact, those children who tried counting strategies and did not rely on retrieval were more likely to show strategy change. These results have implications not only for understanding the use of math addition strategies, but also for the apparently limited view of general strategy use in children with mild MR. Strategy use and change was not related to classification. Thus, limited views regarding potential academic strategy abilities of children with MR needs to be re-examined.

According to Baroody (1999), “It is essential that special educators assess the entry knowledge of children classified as mentally handicapped. Study after study indicates that special education teachers cannot take for granted that children with MR just beginning school will have the same level of mathematical knowledge that NMH children bring to school” (p. 89). Our results do suggest, however, if children with and without MR have similar levels of number knowledge and concepts, they will have similar accuracy in solving addition problems. Consequently, once basic number knowledge is learned children with MR can be expected to solve simple addition in a similar manner as typical children.

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324 / Education and Training in Developmental Disabilities-December 2004


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