Implicit and Explicit Learning in Young Adults With Mental Retardation

Julie A. Atwell, Frances A. Conners, and Edward C. Merrill
The University of Alabama

Abstract

We examined intelligence-related differences in explicit and implicit learning using an artificial grammar paradigm. Young adults with and without mental retardation completed a sequence-learning and identification task. For some participants, sequences were constructed following an artificial grammar; for others, sequences were random. Explicit learning was determined by ability to learn and later identify random sequences. Implicit learning was determined by the tendency to incorrectly identify new grammatical sequences as seen before, relative to new nongrammatical sequences. Participants with mental retardation did more poorly than participants without mental retardation on explicit learning but just as well on implicit learning. Results suggest that learning of complex materials, when accomplished through implicit processing, is functionally equivalent in individuals with and without mental retardation.

Persons with mental retardation exhibit widespread difficulty in performance on cognitive tasks. In recent years, however, several important distinctions have been made between types of cognitive processes and types of learning. These distinctions have prompted a re-evaluation of the cognitive performance of persons with mental retardation and an attempt to identify the processes and mechanisms that operate similarly for persons with and without mental retardation relative to those that operate differently. In general, researchers have demonstrated that cognitive tasks that require the conscious, explicit, and effortful use of information typically yield much larger differences in performance between persons with and without mental retardation (in favor of persons without mental retardation) than do tasks that are performed with relatively automatic and implicit use of information (e.g., Carlesimo, Marotta, & Vicari, 1997; Ellis & Allison, 1988; Ellis, Katz, & Williams, 1987; McFarland & Sandy, 1982; Meador & Ellis, 1987; Sperber, Ragain, & McCauley, 1976; Vicari, Bellucci, & Carlesimo, 2000; Wyatt & Conners, 1998).

In the 1970s, a classic distinction between automatic and effortful processing became the focus of a great deal of research in general cognitive psychology (see Hasher & Zacks, 1979; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Several researchers evaluated performance differences between persons with and without mental retardation in terms of this distinction. For example, Sperber et al. (1976) found that adolescents with mental retardation failed to exhibit knowledge of category relationships when they were required to explicitly retrieve and use category knowledge, but the same adolescents exhibited knowledge of category relationships when tested using a semantic priming procedure that relied more heavily on relatively automatic processes. In the semantic priming task, category knowledge is inferred from how the processing of one stimulus facilitates or interferes with the processing of a semantically related or unrelated stimulus (see also Cody & Borkowski, 1977; McFarland & Sandy, 1982). It does not require the explicit use of the category information for category knowledge to influence processing.

During the 1980s, researchers focused on the

 © American Association on Mental Retardation

extent to which new memories could be acquired without conscious attention (e.g., Ellis, 1990; Hasher & Zacks, 1979, 1984). Ellis and Hasher and Zacks suggested that certain stimulus features, particularly location and frequency of occurrence, could be remembered even without conscious attention being paid to those features during presentation. Although there is some disagreement about whether memory for these features is acquired *entirely* without attention (see Greene, 1986; Jonides & Naveh-Benjamin, 1987; Naveh-Benjamin, 1987, 1988), it is reasonable to conclude that memory for these features is acquired with less effort than memory for features such as object identity. Ellis and colleagues conducted a series of studies evaluating performance differences between persons with and without mental retardation on memory for location and frequency of occurrence. In the typical task, participants attend to some feature of the stimuli other than location or frequency of occurrence (e.g., identity or color) and are given an unexpected test of location or frequency at the end of the procedure. It is generally assumed that participants do not focus on location or frequency of occurrence when attention is directed to other aspects of the stimuli. Ellis and colleagues found large differences between participants with and without mental retardation in effortful memory for studied items but generally found small or no differences in relatively automatic memory for location or frequency of occurrence (Dulaney & Ellis, 1991; Ellis & Allison, 1988; Ellis, Katz, & Williams, 1987; Ellis, Palmer, & Reeves, 1988; Ellis, Woodley-Zanthos, & Dulaney, 1989; Nigro & Roak, 1987; Woodley-Zanthos & Ellis, 1989).

Wyatt and Conners (1998) recently evaluated the performances of persons with and without mental retardation on tasks that reflect noneffortful retrieval of information from memory. This form of memory retrieval that does not require intentional or conscious recollection of experience has been termed *implicit memory* (see Roediger, 1990; Schacter, 1987; Schacter, Chui, & Ochsner, 1993). In implicit memory studies, participants actively process a set of stimuli in one task and, following some intervening procedure, perform a second task that can be influenced by the unintentional retrieval of stimuli encountered in the first task. For example, in a common version of an implicit procedure, participants study a list of words and are later asked to perform a word-fragment completion task. In this completion task, they are provided some but not all letters in a word and are asked to complete the fragment with the first word that comes to mind (e.g., C _ _ T _ N might be completed with *carton* or *cotton*). No mention is made of any relation between the study list and the word-fragment completion task, although some of the word fragments in the second task can be completed by words in the original study list. Implicit memory is evidenced by participants' use of previously studied words to complete the word fragments, as indexed by a comparison of participants who had previously studied the word list versus those who had not. Picture fragment completion tasks are also used to measure implicit memory, particularly when reading and spelling ability cannot be assumed (see Greene, 1992, for a review of implicit memory paradigms).

Wyatt and Conners (1998) used Snodgrass's Picture Fragment Completion Task (Snodgrass, Smith, Feenan, & Corwin, 1987) to examine implicit memory performance in three age groups of children with and without mild mental retardation. Participants viewed pictures of varying degrees of fragmentation produced by randomly removing a percentage of picture segments. The first picture presented had the greatest percentage of the picture missing, with each subsequent picture introducing more and more of the picture segments until a complete picture was presented. Participants tried to identify the picture. The level of fragmentation at which a picture was correctly identified was the measure of interest. Two days later, participants returned for a second testing session. They viewed the same pictures from the first session mixed with a set of new pictures and performed the identification task again. Implicit memory was indexed by the degree of improvement in identifying the pictures observed when the picture was presented the second time. Explicit memory was measured by having participants free recall the original test pictures during the second testing session. Wyatt and Conners found that explicit memory varied with both age and IQ, whereas implicit memory varied with age but not IQ. Their results were generally consistent with other implicit memory research involving persons with and without mild mental retardation (Carlesimo et al., 1997; Komatsu, Naito, & Fuke, 1996; Vicari et al., 2000).

Several lines of research have recently been developed indicating that individuals may learn to perform complex skills without the involvement

© American Association on Mental Retardation

of an explicit learning system (e.g., Lewicki, Hill, & Czyzewska, 1992; Mathews et al., 1989; Reber, 1989a; see Seger, 1994). Reber (1989a, 1989b, 1990) has generally characterized implicit learning as a process of learning in which complex, rule-governed knowledge is acquired without explicit awareness of the rules that have been learned or the processes and mechanisms involved in learning the rules. One task that exemplifies implicit learning is the artificial grammar learning task (see Reber, 1989a, 1989b). In this procedure, participants view sets of letter strings that were generated according to the rules of a finite-state grammar. At this point, no mention is made of the grammatical nature of the strings, and participants may be required, for example, to memorize the strings and recall them verbatim. Following this *acquisition phase* in which participants are unknowingly being familiarized with the grammar, they are informed of the grammatical nature of the letter strings. Then, their knowledge of the rules of the grammar is evaluated by asking them to determine the grammaticality of new sets of letter strings, some of which conform to the rules of the grammar and some of which do not. Although they are not able to state the rules upon which their decisions were based, they are able to determine which strings are grammatical at a level well above chance. Using the artificial grammar paradigm and an explicit learning task with college students, Reber, Walkenfeld, and Hernstadt (1991) found that explicit learning correlates with IQ, but implicit learning does not.

Research using other implicit learning paradigms has also shown that whereas intelligence is strongly related to explicit learning, it is, at best, weakly related to implicit learning (Maybery, Taylor, & O'Brien-Malone, 1995; McGeorge, Crawford, & Kelly, 1997; Vicari et al., 2000). Maybery et al. (1995) tested children with low, medium, and high IQ in two age groups (5 to 7 years old and 10 to 12 years old) using a covariation learning procedure. Participants were presented a matrix of 16 pictures, with 4 pictures in each of four quadrants on the picture board. During the learning phase, participants were asked to look at all of the pictures and to point to the picture of the house. The quadrant in which the house was presented could be predicted by two presentation cues. The color of the picture board cover (red or blue) predicted left or right half and whether the experimenter approached from the left or right predicted top or bottom half. During the test phase, the cues remained the same and participants had to guess where the house would be. Correct guessing above chance indicated implicit learning of the covariation between the cues and the location of the house. Maybery et al. (1995) reported that although older children showed better implicit learning than did younger children, there was no difference across IQ groups. Using the same procedure, but more extreme IQ groups, however, Fletcher, Maybery, and Bennett (2000) found better implicit learning in children with high IQ than in children with mental retardation.

One difficulty with the Fletcher et al. (2000) findings is that children with mental retardation scored below chance on the measure of implicit learning. Apparently, the task constraints were adequate to foster implicit learning in the group with high IQ but not in the group with mental retardation. There may be many reasons for this, among them the fact that the cue stimuli involved in the covariation (color of cover and side of approach) were not integrated into the participants' task. In order to learn the covariation, participants had to encode cues that were not part of the task or task materials, per se. With more limited information-processing capacity, children with mental retardation may not have encoded these cues.

In the present study, we used a paradigm in which the material to be implicitly learned was integrated into the task materials. We used an artificial grammar paradigm in which participants first examined grammatical or random sequences (acquisition phase), and later judged whether they had seen them before (test phase). In the acquisition phase, we required participants to reconstruct sequences from memory and allowed repetitions if necessary, thereby ensuring that all participants had fully processed the stimulus materials. We expected that young adults with and without mental retardation would demonstrate implicit learning significantly above chance. If so, we could compare the levels of implicit learning across groups. One additional difference between the present study and the Fletcher et al. (2000) study is that in the present study the material to be implicitly learned was more complex. The covariations to be learned in the Fletcher et al. study involved only two cues, which in combination predicted perfectly the correct quadrant. In contrast, the artificial grammar in the present study involved a set of rules that can be described verbally only with great effort.

Young adults with and without mental retar-

 © American Association on Mental Retardation

dation participated in one of two conditions. Half were exposed to grammatical sequences and half, to random sequences. After viewing the sequences, participants completed a recognition test in which they said whether they had previously viewed each sequence. Explicit learning was measured in the random sequence condition by the degree to which participants correctly identified old sequences. We expected participants without mental retardation to do better in explicit learning than those with mental retardation. Implicit learning was measured in the grammatical sequence condition by the degree to which participants mistook new grammatical sequences for old, relative to the degree to which they mistook new *non*-grammatical sequences for old. We expected that implicit learning of complex relations would be relatively intact in individuals with mental retardation; thus, we expected that our measure of artificial grammar learning would be similar for groups with and without mental retardation. We also examined explicit and implicit learning across groups in a few other ways, with the expectation that there would be large group differences in explicit learning measures and smaller or no group differences in implicit learning measures.

Method

Participants

Forty-three young adults with mental retardation were recruited from area service providers and high schools and were paid $5 for their participation. They were identified by supervisors or teachers as having IQs between 50 and 75. Eligibility for the study was not dependent on etiology of mental retardation. Although there were no participants with readily identifiable syndromes, the sample was regarded as mixed in etiology. Nine of the 43 participants with mental retardation were not included in the final sample because of failure to complete the acquisition phase of the study ($n = 5$), failure to complete all phases of the study in the time allotted ($n = 2$), schedule conflict ($n = 1$), or yes-only responding ($n = 1$).

Forty-two young adults without mental retardation were recruited through the introductory psychology student participant pool at the University of Alabama and through a campus church organization. They received either course credit (psychology students) or $5 (one nonpsychology student) for their participation. One participant was not included in the final sample because of failure to complete the task according to instructions. Thus, there were 34 participants with mental retardation and 41 participants without mental retardation included in the final sample.

Of the final 34 participants with mental retardation, 56% were Caucasian (remainder African American); 71% were male; their mean age was 17.0 years (standard deviation [*SD*] = 1.7), and mean Kaufman Brief Intelligence Test—K-BIT (Kaufman & Kaufman, 1990) IQ was 60.1 (*SD* = 9.8). Of the final 41 participants without mental retardation, 78% were Caucasian (remainder African American or Asian Indian); 22% were male; their mean age was 19.5 years (*SD* = 1.6); and mean K-BIT IQ was 104.0 (*SD* = 8.5). Half of the participants in each intelligence group were randomly assigned to the grammatical sequence condition and half to the random sequence condition. There was no significant difference in IQ between sequence conditions for participants with or without mental retardation.

Materials

Intelligence test. The K-BIT was used to estimate IQ. The three K-BIT subtests were interspersed between tasks in the testing session. One subtest was administered after the first acquisition phase, another after the first recognition test, and the third after the second acquisition phase.

Artificial grammar. An artificial grammar uses symbols that are made into "sentence" sequences. The specific sequences are composed by the experimenter, following the rules of the artificial grammar. The rule set used to compose the grammatical sequences for the present study (see Figure 1) is a modification of the traditional type of finite-state grammar commonly used in the literature (see Roter, 1985). The diagram represents a grammar that consists of four elements (A–D) that can be combined in certain ways. Grammatical sequences can be composed by beginning at "IN" and choosing paths depicted in the diagram. For example, if A is chosen first, D or B must follow. If D follows, it may be repeated but then must be followed by B; B may be followed by D to finish or may be repeated once and followed by A or C, etc. Thus, sequences CCA, ABBAC, and ADDDBD are grammatical, but sequences AAC, ABACC, and DDDABD are not grammatical. This grammar is less complex and contains more redundancy than grammars typically used in the literature. Also, in the present study we used col-

© American Association on Mental Retardation

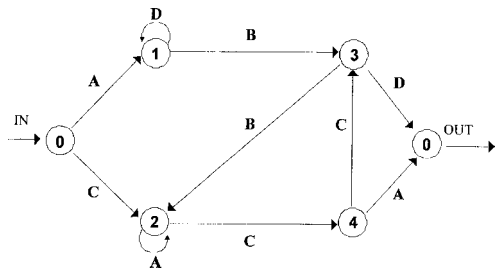

Figure 1. The finite-state artificial grammar used for the current study (after Roter, 1985). Sequences are generated by entering the diagram at IN and choosing paths that are depicted by the arrows. Grammatical sequences include CCA, ABBAC, and ADDDBD. Nongrammatical sequences include AAC, ABACC, and DDDABD. In the present study, letters were replaced by colored shapes.

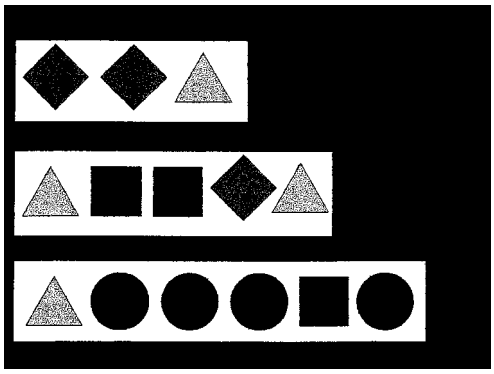

Figure 2. Sample of grammatical sequences used in the present study.

ored geometric shapes in place of letters when making up the stimulus sequences (see Figure 2). We did this to avoid using word-like stimuli that might confuse the participants with mental retardation.

Sequences. We constructed two pools of sequences. One consisted of grammatical sequences and the other contained random sequences. Grammatical sequences followed the rules of the artificial grammar. Random sequences did not follow a rule set and were random within certain control constraints. They were equated with grammatical sequences on length; number of shapes per sequence; and number of double, triple, and quadruple repeats of shapes. From these two pools of sequences, we chose 15 grammatical and 15 matched random sequences to be used in the acquisition phases of the study.

For each of these sets, we constructed a 30-item recognition test, each of which consisted of 10 old and 20 new sequences. The old sequences were identical to 10 sequences used in the acquisition phase. The new sequences were not used in the acquisition phase—10 of them were drawn from the same pools as the sequences used in acquisition and 10 were modified from the old and new sequences drawn from the pools. These were modified with one or two changes in each sequence. For grammatical sequences, the changes made the sequences nongrammatical (i.e., they violated the rules of the grammar). For random sequences, the changes resulted in additional nongrammatical sequences. The number of changes and the position of those changes within the sequence was the same for grammatical and random sequences. Thus, in the grammatical sequence condition, the three types of test items were (a) *old grammatical,* generated from the artificial grammar and shown to participants in acquisition; (b) *new grammatical,* generated from the artificial grammar but *not* shown in acquisition; and (c) *new nongrammatical,* changed in one or two features from old grammatical or new grammatical sequences so as to violate the artificial grammar. In the random acquisition sequence condition, the three types of test sequence were (a) *old random,* nongrammatical sequences shown to participants in acquisition; (b) *new random,* nongrammatical sequences generated in the same way as in the random sequences shown in acquisition, but *not* shown in acquisition; and (c) *new/changed random,* changed in one or two features from old random or new random sequences.

Sequences were presented on 7- × 28-cm posterboard cards. In the acquisition phase, participants used 6- × 8-cm posterboard cards with individual shapes on them to reproduce the sequences.

Procedure

Acquisition phase. Each participant was tested individually. In the acquisition phase, participants viewed sequences and tried to reproduce them with individual shape cards. Participants in the grammatical sequence condition viewed grammatical sequences, whereas those in the random sequence condition viewed random sequences. To ensure that participants had fully processed each sequence, we required them to reproduce each of them from memory.

The experimenter showed participants the task materials and gave instructions while dem-

 © American Association on Mental Retardation

onstrating the task. She asked participants to look at each sequence when it was shown, try to memorize it, and say when they were ready. Next, with the sequence removed from view, the experimenter asked them to put the shape cards in the right order to match the sequence. They were told to hurry but not so much that they would make mistakes. After a practice trial, participants completed 15 experimental trials in the acquisition phase. The first experimental trial was always a 3-item sequence and the second was always a 4-item sequence. The remaining experimental trials were presented in random order for each participant.

For all trials, participants were allowed up to four attempts to reproduce the sequence. The task was discontinued if they failed the four attempts on either the practice or the first or second experimental trial, and the participant was excluded from the study. Five participants with mental retardation were excluded for this reason. After 4 failed attempts on subsequent trials, the task simply continued with the next trial. This happened on 6% of trials for participants with mental retardation and 1% of trials for participants without mental retardation. After completing the acquisition phase, participants completed the first subtest of the K-BIT.

Recognition testing phase. The recognition test followed the acquisition phase. Participants viewed sequences one at a time and judged whether they had appeared in acquisition. They completed one practice trial (the same sequence used for practice in acquisition) and 30 experimental trials presented in random order for each participant.

In the typical artificial grammar paradigm, a grammaticality judgment rather than a recognition decision is made. Following Roter (1985), we used a recognition task because it would (a) be easier to understand and (b) provided measures of both explicit and implicit learning. Explicit learning was determined by the accuracy of recognition by participants who viewed random sequences in acquisition. Implicit learning was determined based on false-positive responses by participants who viewed grammatical sequences in acquisition. If these participants used a grammar-based prototype to recognize sequences, then they would find it difficult to differentiate between new grammatical and old grammatical sequences and would make more false positive errors on new grammatical sequences than on new nongrammatical sequences.

Repetition. After a short break, participants completed the second subtest of the K-BIT. Then they repeated the acquisition and recognition test phases using the same sequences as before. They completed the third K-Bit subtest between the acquisition phase and the recognition test phase. The repetition was included in the study to test the idea that with repeated exposure to grammatical sequences, evidence for implicit learning would be even stronger.

Results

Preliminary Analyses

We conducted within-group correlations between demographic variables (gender, race, and age) and measures of implicit and explicit learning. There were no consistent patterns suggesting that any small group differences in gender, race, or age affected the group comparisons in implicit or explicit learning. Of 30 correlations, only 2 were significant, and these appeared to be idiosyncratic. Mean number of trials to learn sequences in the acquisition phase correlated significantly with gender in the group without mental retardation in the grammatical sequence condition, $r(19) = .55$, $p < .02$, with males performing better than did females. It also correlated significantly with race in the group with mental retardation in the random sequence condition, $r(16) = .63$, $p < .01$, with African Americans performing better than Caucasians. An alpha level of .05 was used for these analyses as for all analyses in this report. Covarying out race and gender in the main analyses did not change the pattern of results.

Acquisition

To determine the effects of grammaticality on learning in the acquisition phase, we analyzed participants' mean number of trials needed to successfully reproduce the 15 sequences. The possible range of this variable was 1 to 4, and the cell means ranged from 1.20 and 2.12 (see Figure 3). Thus, participants generally learned the sequences quickly and easily. This learning was explicit because participants were intentionally trying to remember and reconstruct the sequences. However, when the sequences followed an artificial grammar, there was an opportunity for implicit processing to enhance learning.

We performed a 2 (IQ group) × 2 (sequence condition) × 2 (repetition) ANOVA, with repeat-

© American Association on Mental Retardation

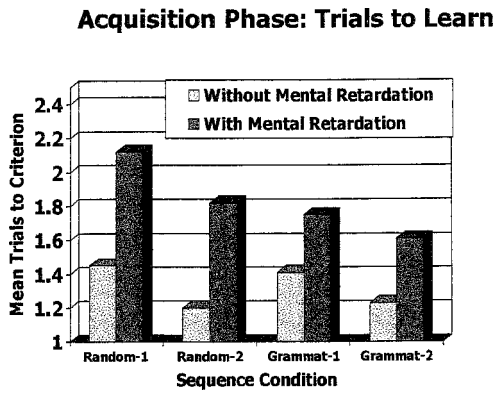

Figure 3. Mean number of trials needed to successfully reproduce the sequences from memory in the first and second acquisition phases of the study. Random = random sequence condition. Grammat = grammatical sequence condition. Numbers 1 and 2 refer to first and second acquisition phases.

ed measures on the third factor. If the artificial grammar helped participants learn the sequences, there should be fewer trials required in the grammatical sequence condition than in the random sequence condition. This effect should become stronger on the second repetition, due to more exposure to the grammar. The group with mental retardation should require more trials to learn the sequences than should the group without mental retardation; however, if the two groups are fairly comparable in implicit learning, they should have about the same degree of *advantage* afforded by the underlying grammar.

There was a main effect of IQ group, $F(1, 71) = 50.33$, $p < .001$, $MSE = .18$, with participants who did not have mental retardation requiring fewer trials to produce sequences than did participants with mental retardation. There was also a main effect of repetition, $F(1, 71) = 99.01$, $p < .001$, $MSE = .02$, with fewer trials needed in the second acquisition phase than in the first. Also, as expected, there was a main effect of sequence condition, $F(1, 71) = 4.43$, $p < .05$, $MSE = .18$, with participants in the grammatical condition requiring fewer trials to produce sequences than participants in the random condition.

The main effect of sequence condition, however, was present only in the group with mental retardation. The IQ Group × Sequence condition interaction was significant, $F(1, 71) = 4.19$, $p < .05$, $MSE = .18$, with participants who had mental retardation showing an advantage of the grammatical sequence condition over the random sequence condition, $t(32) = 2.09$, $p < .05$, $SE = .14$, but participants without mental retardation not differing between sequence conditions. The group with mental retardation had a larger advantage afforded by the grammar than did the group without mental retardation, but this could have been due to the high level of performance overall of participants without mental retardation. The IQ Group × Sequence condition interaction also indicated that the IQ group difference was larger in the random sequence condition than in the grammatical sequence condition. This suggests that the performance of the two IQ groups is more similar when it is more susceptible to influence by implicit learning processes.

Finally, there was an interaction between sequence condition and repetition, $F(1, 71) = 5.97$, $p < .01$, $MSE = .02$, indicating (contrary to expectations) that the effect of sequence condition was larger in the first acquisition phase, $t(73) = 1.82$, $p < .08$, $SE = .10$, than in the second, $t < 1$. This appears to be due to improvement with repetition by participants with mental retardation in the random sequence condition. However, the three-way interaction was not significant.

In sum, grammatical sequences were easier to learn than were random sequences, particularly on the first encounter and particularly for the participants with mental retardation. These participants required more exposure to the sequences than did participants without mental retardation but benefited more from the underlying grammar than did the group without mental retardation. Further, the IQ groups differed less when an underlying grammar was present, allowing for implicit learning, than when it was not. Finally, repetition of the acquisition-test procedure improved performance but did not yield the expected advantage for grammatical sequences. Apparently, the benefits associated with the grammatical sequences accrued relatively early in the acquisition phase.

Recognition Testing

Implicit and explicit learning measures from the recognition test were expressed using the sensitivity indicator A' (A-prime). A' is a nonparametric analog of d' (d-prime) and is used to express hits in relation to false alarms without requiring the assumption of normal distribution. Following Grier (1971), we used the formula:

 © American Association on Mental Retardation

$$A' = \frac{1}{2} + \frac{(y - x)(1 + y - x)}{4y(1 - x)}$$

where x is the proportion of false alarms and y is the proportion of hits.

In the statistical analyses, A' measures were computed for each participant, and analyses were completed on the A' measures. In preliminary analyses, the Repetition factor produced no main effects and did not interact with any other variables, and so data were collapsed across repetition condition. Means of A' measures are shown in Figure 4. Means of proportions used to calculate A' measures are shown in Table 1.

Explicit learning. For the primary measure of explicit learning, we calculated A' on data from the random sequence condition, with the proportion of (correct) yes responses to old random items as hits and the proportion of (incorrect) yes responses to new/changed random items as false alarms. To achieve a high score on this measure, a participant would have to be accurate at both recognizing specific sequences seen before and at rejecting specific sequences that were similar but not seen before. In other words, the participant must have learned the specific sequences in the acquisition phase. Although any learning task is likely to recruit both explicit and implicit processes, this measure is primarily explicit at least in regard to artificial grammar learning. We expected participants without mental retardation to have higher scores on this measure than participants with mental retardation.

We also calculated an analogous A' on data from the grammatical sequence condition, using the proportion of (correct) yes responses to old grammatical items as hits and the proportion of (incorrect) yes responses to new/nongrammatical items as false alarms. This A' reflects explicit learning as enhanced by implicit learning. To achieve a high score, a participant would have to be good at recognizing specific sequences seen before and rejecting sequences that are similar but not seen before, just as for the explicit learning A' measure. However, because the sequences seen before share an underlying grammar, implicit learning should benefit the ability to recognize specific sequences seen before. Further, because the sequences not seen before do not share the underlying grammar, implicit learning should benefit the ability to reject them. Therefore, we called this A' *implicit-enhanced learning.* We expected that participants would score higher on im-

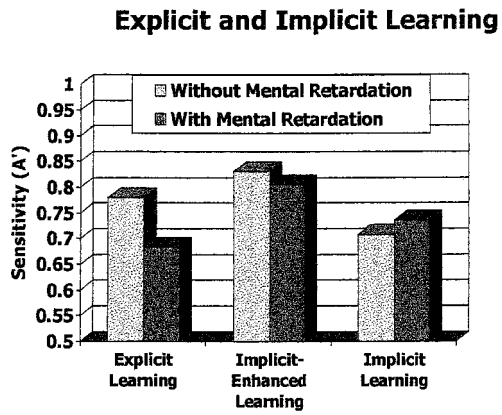

Figure 4. A' sensitivity measures reflecting explicit learning, implicit-enhanced learning, and implicit learning. Random sequence groups provided the measures of explicit learning, and grammatical sequence groups provided the measures of implicit-enhanced learning and implicit learning.

Table 1. Means and *SD*s of Proportion of "Yes" Responses by Sequences Appearing in Recognition Test

Sequence type	Without mental retardation				With mental retardation			
	Random		Grammatical		Random		Grammatical	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Old	.72	.16	.73	.14	.65	.15	.70	.13
New	.29	.18	.50	.12	.34	.19	.56	.11
Changed	.35	.16	.25[a]	.18[a]	.42	.15	.23	.16

Note. In the grammatical sequence condition, old and new sequences were grammatical, and changed sequences were nongrammatical.
[a]Figures given were used to calculate A' for implicit learning. Those used to calculate A' for implicit-enhanced learning were .24 and .17, respectively. They are slightly different because of treatment of outliers.

© American Association on Mental Retardation

plicit-enhanced learning than on explicit learning. We also expected that the difference between IQ groups would be smaller for implicit-enhanced learning than for explicit learning.

Three outliers were excluded from this analysis (2 in the random sequence condition and one in the grammatical sequence condition, all participants without mental retardation). Mean A' for both explicit learning and implicit-enhanced learning were significantly above chance for both IQ groups, all ps $< .001$. We performed a 2 (sequence condition) $\times$ 2 (IQ group) ANOVA on the A' measures described above. In the random sequence condition, the A' reflected explicit learning. In the grammatical sequence condition, the A' reflected implicit-enhanced learning. As expected, there was a main effect of sequence condition, $F(1, 68) = 27.11$, $p = .000$, $MSE = .005$, showing higher scores on implicit-enhanced learning than on explicit learning. In other words, participants who viewed grammatical sequences were more accurate in recognizing sequences they had seen before than were participants who viewed random sequences. Also, there was a main effect of IQ group, $F(1, 68) = 11.94$, $p < .001$, $MSE = .005$, in which participants without mental retardation were more accurate overall than participants with mental retardation. The Sequence Condition $\times$ IQ Group interaction was also significant, $F(1, 68) = 4.17$, $p < .05$, $MSE = .005$, and further comparisons showed an IQ group difference in explicit learning, $t(34) = 3.62$, $p < .001$, $SE = .026$, but not in implicit-enhanced learning. Thus, as expected, participants with mental retardation did less well than participants without mental retardation in explicit learning. Yet they did just as well when they were able to use implicit learning to enhance explicit learning.

Implicit learning. For the primary measure of implicit learning, A' was calculated on data from the grammatical sequence condition, with the proportion of (incorrect) yes responses to new grammatical items as hits and the proportion of (incorrect) yes responses to new/nongrammatical items as false alarms. Although yes responses to new grammatical items were technically incorrect, they can be considered hits for sensitivity to the artificial grammar, especially when set relative to yes responses to new nongrammatical items. To achieve a high score on this implicit learning measure, participants would have to have learned the underlying grammar well enough to be tricked *often* into thinking that never-seen sequences that are grammatical are sequences seen before. At the same time, they would have to be accurate at rejecting never-seen sequences that are not grammatical. We expected participants with and without mental retardation to score similarly on this measure.

Because the analogous A' measure in the random sequence condition has little meaning, we simply compared the groups with and without mental retardation in the grammatical condition on the implicit learning measure. For each group, one outlier was eliminated from analyses. Both groups showed implicit learning above chance, ps $< .001$. The group means were very similar (see Figure 4), and there was no significant difference between groups.

Discussion

Previous research showed large intelligence-related differences in tasks requiring primarily effortful processing and small or no differences in tasks requiring primarily automatic processing. Thus, we expected to see large differences between participants with and without mental retardation in explicit learning, but small if any differences in implicit learning. The results of the study supported this expectation. Participants with mental retardation performed more poorly than did participants without mental retardation on two largely explicit learning measures, but the two groups performed equally on an implicit learning measure. Further, the two groups performed similarly in explicit learning as long as there was ample opportunity for influence of implicit learning, by virtue of the artificial grammar.

In the acquisition phase of the study, participants with mental retardation required more trials before they could repeat back the sequences, particularly when the learning was primarily explicit (i.e., the random condition). When there was an opportunity for sequence learning to be assisted by implicit processes (i.e., in the grammatical condition), the IQ group difference was smaller. Later, when asked to recognize the sequences previously seen, participants with mental retardation who had viewed random sequences were less able than were participants without mental retardation to discriminate between old and new sequences. However, those who had viewed grammatical sequences were just as able to discriminate between old and new sequences as participants without mental retardation. The underlying grammar pre-

 © American Association on Mental Retardation

sumably fostered implicit learning, which enhanced the ability to identify old sequences. Participants with mental retardation benefited substantially more from the availability of an implicit rule system, and the result was that they performed the task equally as well as participants without mental retardation.

The main measure of implicit learning in the present study reflected the tendency to mistakenly identify new grammatical sequences as old, relative to the tendency to mistakenly identify new nongrammatical sequences as old. On this measure, participants with mental retardation performed as well as those without mental retardation. Thus, all of the comparisons in the study point strongly to the same conclusion—that implicit learning is intact and fully functional in young adults with mental retardation.

The results of the present study are consistent with those of Maybery et al. (1995), who found that incidental covariation learning was equal across groups of children with low, medium, and high IQ. The present results go one step further by showing that individuals with low IQ may be just as good as those with higher IQs at implicit learning of complex relations. The results seem at odds, however, with the results of Fletcher et al. (2000), who found that children with mental retardation performed more poorly in covariation learning than did children with high IQ. A number of different possible explanations exist for this discrepancy. First, IQ-related differences in implicit learning may be small, and in the present study we did not have a wide enough IQ range or adequate sample size to show the effect. The IQ range was smaller in this study than in the Fletcher et al. study, and there were 3 to 4 fewer participants with mental retardation. If this argument were valid, however, there would be a trend in the data of the present study, with participants who have mental retardation scoring somewhat lower than participants without mental retardation, even if the difference were not significant. To the contrary, the implicit learning means in the two IQ groups were extremely similar, with the mean of the group with mental retardation slightly *higher*.

Second, Fletcher et al. (2000) provided equivalent exposure to stimulus materials across IQ groups, but in the present study participants with mental retardation generally had more exposure to the stimulus materials than did participants without mental retardation. Those with mental retardation required more trials to reconstruct the sequences in acquisition. One might argue that the additional exposure gave these participants an advantage in implicit learning by allowing them more opportunity to internalize the grammatical rule set. If this were true, however, trials to learn sequences would have correlated positively with implicit learning, and this was not the case. Thus, the fact that participants with mental retardation showed just as much implicit learning as did participants without mental retardation in the present study cannot be explained by differences in initial exposure to sequences.

A third difference between the two studies is the nature of the implicit learning task used. The covariation learning task employed by Fletcher et al. (2000) required association between stimulus location and two cues that were external to the task; the artificial grammar learning task used in the present study required internalization of a complex set of rules for what elements precede and follow other elements. Possibly, intelligence is more closely related to relatively simple implicit association learning than it is to relatively complex rule set learning. This argument, however, is weakened by the fact that Maybery et al. (1995) found no IQ-related differences using the covariation task. Still, more research is needed to examine task as a moderator of the relation between implicit learning and intelligence.

Finally, as we suggested in the introduction, children with mental retardation in the Fletcher et al. (2000) study may not have adequately processed the information needed to learn the covariances. Because the cues that were critical to covariance learning were not integrated into the task stimuli, participants with mental retardation may not have processed them adequately. Their covariance learning was below chance as well as below that of the group with high IQ. In the present study, we ensured that participants did process the stimulus sequences by requiring criterion performance, and there were no IQ-group differences.

One important issue raised by Fletcher et al. (2000) is whether implicit learning varies primarily with mental age (MA) rather than either chronological age (CA) or IQ. When they combined results from various age and IQ groups, Fletcher and colleagues concluded that it was in fact MA that contributed most to covariance learning. After MA, neither CA nor IQ contributed significantly to covariance learning. Although this idea has

© American Association on Mental Retardation

much merit, it would predict a difference between the IQ groups in the present study. Because the two groups were roughly similar in CA and different in IQ, they were different in MA; yet, they were not different in implicit learning.

We suggest that the role of MA may be slightly different from what Fletcher et al. (2000) described. Perhaps beyond a certain MA (6 or 7 years), there are no differences in implicit learning due to intelligence. However, when comparisons are made that span this threshold, differences are apparent. This would explain the discrepancy between the present study, in which we compared MAs beyond this threshold (about 11 vs. about 19) and the Fletcher et al. (2000) study, in which they compared MAs across this threshold (about 6 vs. about 12). The threshold notion is also consistent with the nature of IQ-group similarities and differences present in the location memory literature. This literature shows that as long as IQ is in the mild range and age is above 12 years, there is no difference between groups with and without mental retardation. However, when MA is low either because of IQ in the moderate or severe range or because of young age, there are differences between IQ groups (see Dulaney, Raz, & Devine, 1996; Ellis et al., 1989; Katz & Ellis, 1991; Nigro & Roak, 1987). More research is needed to explore this hypothesis.

Developmental level may define a boundary for whether implicit processing is intact and fully functional in individuals with mental retardation. It is important to further investigate this potential boundary as well as others, including delay between study and test, degree of semantic relative to perceptual processing of stimuli, and etiology of mental retardation. Dulaney et al. (1996) and Katz and Ellis (1991), for example, found smaller IQ-related differences in location memory for immediate tests than for delayed tests. Komatsu et al. (1996) found IQ-related differences for implicit memory of items processed semantically, but not for items processed perceptually. Researchers studying etiology-defined groups have found that for individuals with fetal alcohol syndrome, location memory seems impaired (Uecker & Nadel, 1998), whereas implicit memory does not (Mattson & Riley, 1999). For people with Down syndrome, a variety of measures of automatic processing seem impaired relative to CA (Dulaney et al., 1996; Ellis et al., 1989; Mattson & Riley, 1999), but consistent with MA (Carlesimo et al., 1997; Vicari et al., 2000). These and other factors affecting the relation between IQ and automatic processing ability need further investigation.

The results of the present study suggest that, generally, implicit learning is a relative strength for young adults with mild mental retardation. As such, there should be ways to make use of this strength in educational and training settings. The first step is for instructors to understand that they can expect a high level of learning from adults with mild mental retardation, provided that the learning is implicit. Second, researchers and instructors should identify useful practical tasks that have strong implicit learning components. Learning sorting sequences, relations among machinery components, and rule-based codes for different types of inventory, for example, might have strong implicit learning components and might be tasks that could be done well by adults with mild mental retardation. Next, instruction for these tasks should be designed in such a way as to foster implicit learning. This would likely involve active exposure to a variety of examples of the set of relations to be learned. Finally, instructors should bear in mind that although implicit processes may work well, the supporting explicit processes may not. For example, learning to distinguish types of rule-based codes may be easy, but intentionally remembering exactly which codes were used may be difficult. Thus, supports for the explicit components of tasks would be required. The results of the present study and those preceding it suggest that there indeed may be quite a lot to gain in the careful design of implicit-based learning systems for individuals with mental retardation.

References

Carlesimo, G. A., Marotta, L., & Vicari, S. (1997). Long-term memory in mental retardation: Evidence for a specific impairment in subjects with Down's syndrome. *Neuropsychologia, 35,* 71–79.

Cody, W. J., & Borkowski, J. G. (1977). Proactive interference and its release in short-term memory of mildly retarded adolescents. *American Journal of Mental Deficiency, 82,* 305–308.

Dulaney, C. L., & Ellis, N. R. (1991). Long-term recognition memory for items and attributes by retarded and nonretarded persons. *Intelligence, 15,* 105–115.

Dulaney, C. L., Raz, N., & Devine, C. (1996). Effortful and automatic processes associated with Down syndrome and nonspecific mental

 © American Association on Mental Retardation

retardation. *American Journal on Mental Retardation, 100,* 418–423.

Ellis, N. R. (1990). Is memory for spatial location automatically encoded? *Memory and Cognition, 18,* 584–592.

Ellis, N. R., & Allison, P. (1988). Memory for frequency of occurrence in retarded and nonretarded persons. *Intelligence, 12,* 61–75.

Ellis, N. R., Katz, E., & Williams, J. E. (1987). Developmental aspects of memory for spatial location. *Journal of Experimental Child Psychology, 44,* 401–412.

Ellis, N. R., Palmer, R. L., & Reeves, C. L. (1988). Developmental and intellectual differences in frequency processing. *Developmental Psychology, 24,* 38–45.

Ellis, N. R., Woodley-Zanthos, P., & Dulaney, C. L. (1989). Memory for spatial location in children, adults, and mentally retarded persons. *American Journal on Mental Retardation, 93,* 521–526.

Fletcher, J., Maybery, M. T., & Bennett, S. (2000). Implicit learning differences: A question of developmental level? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 246–252.

Greene, R. L. (1986). Effects of intentionality and strategy on memory for frequency. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 489–495.

Greene, R. L. (1992). *Human memory: Paradigms and paradoxes.* Hillsdale, NJ: Erlbaum.

Grier, J. B. (1971). Nonparametric indexes for sensitivity and bias: Computing formulas. *Psychological Bulletin, 75,* 424–429.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General, 108,* 356–388.

Hasher, L., & Zacks, R. T. (1984). Automatic processing of fundamental information: The case of frequency of occurrence. *American Psychologist, 39,* 1372–1388.

Jonides, J., & Naveh-Benjamin, M. (1987). Estimating frequency of occurrence. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 230–240.

Katz, E. R., & Ellis, N. R. (1991). Memory for spatial location in retarded and nonretarded persons. *Journal of Mental Deficiency Research, 35,* 209–220.

Kaufman, A. S., & Kaufman, N. L. (1990). *Kaufman Brief Intelligence Test.* Circle Pines, MN: American Guidance Services.

Komatsu, S., Naito, M., & Fuke, T. (1996). Age and intelligence-related differences in implicit memory: Effects of generation on a word-fragment completion test. *Journal of Experimental Child Psychology, 62,* 151–172.

Lewicki, P., Hill, T., & Czyzewska, M. (1992). Nonconscious acquisition of information. *American Psychologist, 47,* 796–801.

Mathews, R. C., Buss, R. R., Stanley, W. B., Blanchard-Fields, F., Cho, J. R., & Druhan, B. (1989). Role of implicit and explicit processes in learning from examples: A synergistic effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 1083–1100.

Mattson, S. N., & Riley, E. P. (1999). Implicit and explicit memory functioning in children with heavy prenatal alcohol exposure. *Journal of the International Neuropsychological Society, 5,* 462–471.

Maybery, M., Taylor, M., & O'Brien-Malone, A. (1995). Implicit learning: Sensitive to age but not IQ. *Australian Journal of Psychology, 47,* 8–17.

McFarland, C., & Sandy, J. (1982). Automatic and conscious processing in retarded and nonretarded adolescents. *Journal of Experimental Child Psychology, 33,* 20–38.

McGeorge, P., Crawford, J. R., & Kelly, S. (1997). The relationships between psychometric intelligence and learning in an explicit and implicit task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 239–245.

Meador, D. M., & Ellis, N. R. (1987). Automatic and effortful processing by mentally retarded and nonretarded persons. *American Journal of Mental Deficiency, 91,* 613–619.

Naveh-Benjamin, M. (1987). Coding of spatial location information: An automatic process? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 595–605.

Naveh-Benjamin, M. (1988). Recognition memory of spatial location information: Another failure to support automaticity. *Memory and Cognition, 16,* 437–445.

Nigro, G. N., & Roak, R. M. (1987). Mentally retarded and nonretarded adults' memory for spatial location. *American Journal of Mental Deficiency, 91,* 392–397.

Reber, A. S. (1989a). Implicit learning and tacit knowledge. *Journal of Experimental Psychology: General, 118,* 219–235.

Reber, A. S. (1989b). More thoughts on the unconscious: Reply to Brody and to Lewicki and

Hill. *Journal of Experimental Psychology: General, 118,* 242–244.

Reber, A. S. (1990). On the primacy of the implicit: Comment on Perruchet and Pacteau. *Journal of Experimental Psychology: General, 119,* 340–342.

Reber, A. S., Walkenfeld, F. F., & Hernstadt, R. (1991). Implicit and explicit learning: Individual differences and IQ. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 888–896.

Roediger, H. L., III. (1990). Implicit memory: Retention without remembering. *American Psychologist, 45,* 1043–1056.

Roter, A. (1985). *Implicit processing: A developmental study of the effect of instruction, underlying structure, and materials.* Unpublished doctoral dissertation, City College of New York.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 501–518.

Schacter, D. L., Chiu, C.-Y. P., & Ochsner, K. N. (1993). Implicit memory: A selective review. *Annual Review of Neuroscience, 16,* 159–182.

Schneider, W., & Shiffrin, R. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review, 84,* 1–66.

Seger, C. A. (1994). Implicit learning. *Psychological Bulletin, 115,* 163–196.

Shiffrin, R., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84,* 127–190.

Snodgrass, J. G., Smith, B., Feenan, K., & Corwin, J. (1987). Fragmenting pictures on the Apple Macintosh computer for experimental and clinical applications. *Behavior Research Methods, Instruments, and Computers, 19,* 270–274.

Sperber, R., Ragain, R., & McCauley, C. (1976). Reassessment of category knowledge in retarded individuals. *American Journal of Mental Deficiency, 81,* 227–234.

Uecker, A., & Nadel, L. (1998). Spatial but not object memory impairments in children with fetal alcohol syndrome. *American Journal on Mental Retardation, 103,* 12–18.

Vicari, S., Bellucci, S., & Carlesimo, G. A. (2000). Implicit and explicit memory: A functional dissociation in persons with Down syndrome. *Neuropsychologia, 38,* 240–251.

Woodley-Zanthos, P., & Ellis, N. R. (1989). Memory for frequency of occurrence: Intelligence level and retrieval cues. *Intelligence, 13,* 53–61.

Wyatt, B. S., & Conners, F. A. (1998). Implicit and explicit memory in individuals with mental retardation. *American Journal on Mental Retardation, 102,* 511–526.

Received 10/2/01, accepted 2/21/02.

This research was part of a master's thesis submitted to the Department of Psychology at the University of Alabama by the first author. It was presented at the Gatlinburg Conference on Research and Theory in Mental Retardation and Developmental Disabilities in March 1998. It was supported by a grant from the Student Government Association and the Psychology Department of the University of Alabama. We thank Will Shivers and Stephanie Wright for their help in data collection and entry. We also thank the Tuscaloosa County Schools, The Arc of Tuscaloosa, and Resources for Independence for helping identify participants for the study. We are grateful to Mark R. Klinger and Beverly Roskos-Ewoldsen for their helpful comments related to theoretical issues and data analysis. Requests for reprints should be sent to Frances A. Conners, Box 870348, The University of Alabama, Tuscaloosa, AL 35487-0348. E-mail: fconners@bama.ua.edu.

 © American Association on Mental Retardation