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Implicit Learning in Children and Adolescents With Mental Retardation

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Abstract

The literature on implicit learning in persons with mental retardation is scarce and contradictory with respect to the relationship between degree of intellectual disability and impact of implicit-learning processes on performance. We examined children and adolescents with mild or moderate mental retardation and typically developing children matched on MA with regard to their implicit learning. Individuals with mental retardation modified their behavior after an implicit training procedure in a way similar to MA- or CA-matched controls. The impact of implicit learning did not vary as a function of IQ or age. However, some differences appeared between groups in their explicit remembering of the training conditions. The theoretical implications of these results are discussed.

A promising area of research has been opened by investigating whether the implicit forms of information-processing, such as implicit memory or implicit learning, are intact in individuals with mental retardation (Fletcher, Maybery, & Bennett, 2000; Maybery, Taylor, & O'Brien-Malone, 1995; Wyatt & Conners, 1998). In the present study we examined implicit learning, which covers all forms of unintentional learning in which, as a consequence of repeated experience, an individual's behavior becomes adapted to the relevant characteristics of a situation without, at any time, being told to learn anything about this situation; therefore, the individuals do not feel that anything has been learned. Implicit learning is opposed to explicit learning, which relies heavily on effort-driven and intentional learning processes that are known to be a deficit for individuals with mental retardation (e.g., Bebko & Luhaorg, 1998; Bray, 1979; Meador & Ellis, 1987). What appears attractive about implicit learning is that relatively complex information may seem to be learned in this way. Some researchers have suggested that this mode of learning may even be more efficient than the explicit mode in coping with complex information (e.g., Lewicki, 1986). Thus, the better our understanding of how the implicit processes operate in persons with mental retardation, the more likely we will be able to develop educational methods that are most suitable for them.

Although experimental studies of implicit learning in persons with mental retardation are still scarce, this area of inquiry is dominated by an influential postulate formulated by Reber (1993). Considering that from the phylogenetic viewpoint, the implicit mode of learning precedes the explicit mode, Reber (1992, 1993) claimed that implicit learning should be able to withstand neurological or psychological damage and that it should be independent of IQ and age. To date, four reports provide support for the Reber postulate of interest here, namely, the IQ-independence postulate (Reber, Walkenfeld, & Hernstadt, 1991; Myers & Conner, 1992; Maybery et al., 1995; McGeorge, Crawford, & Kelly, 1997). Results of the most recent study contradicts this postulate (Fletcher et al., 2000).

Reber et al. (1991) found a nonsignificant correlation between IQ and implicit performance in an artificial grammar task in a sample of 20 undergraduates and a significant correlation between IQ and an explicit-learning performance score.

The same conclusion was reached by Myers and Conner (1992) in a computer-control task and by McGeorge et al. (1997) in an artificial grammar task. The implicit performances did not vary as a function of age in the two latter experiments, in which the researchers explored a large range of ages—between 16 and 18 years and 59 and 70 years, respectively.

However, the range of IQs included in these studies did not involve any cases of people with mental retardation. Using a covariation task, Maybery et al. (1995) did not find any relationship between IQ and implicit performances in children with an average age of 6 to 11 who were divided into low IQ (78 to 97), medium IQ (100 to 110), and high IQ (110 to 125) groups. They reported that implicit learning improved with age, and explicit learning, assessed through a task presenting a logical structure similar to the implicit task, improved with age and with intelligence. Fletcher et al. (2000) repeated the experiment, comparing a group of gifted children 9 through 10 years of age (average mental age [MA] of 12.4 years, IQ approximately 120) with a group of children with mental retardation (average MA of 5.8 years, IQ of around 60). The implicit performances were below chance in the children with mental retardation and above chance in those who were gifted. These results suggest that implicit-learning processes should be inoperative in children with mental retardation, or least in those presenting an IQ close to 60. Such a conclusion goes well beyond the fact that implicit learning may vary as a function of MA, which does not exclude the possibility that implicit processes could nevertheless be efficient in low-MA individuals. It also seems to contradict results concerning implicit memory in children with mental retardation, which appears to be efficient (Burack & Zigler, 1990; Perrig & Perrig, 1995; Takegata & Furutuka, 1993; Wyatt & Conners, 1998). In a recent study dealing with implicit memory in children who have mental retardation, Vicari, Bellucci, and Carlesimo (2000) included a classical implicit-learning task (the serial reaction-time task). In this task, as well as in the implicit-memory tasks, they reported similar implicit-processing abilities when persons with mental retardation were compared to MA-matched children.

Because the current literature tends to indicate that implicit processes are resistant to a series of factors, such as aging, memory deficits (e.g., Alzheimer's disease), or dual-task experimental conditions (see Stadler & Frensch, 1998, for a review), the negative result reported by Fletcher et al. (2000) suggests that further investigation is needed. These authors suggested that the association found in their study between explicit and implicit learning could stem from the fact that both types of learning could be based on a common conceptual structure for representing spatial locations, given that this skill was involved in their implicit and explicit tasks. If this explanation is justified, it seems reasonable to suggest that implicit learning in persons with mental retardation should be assessed using a simpler task, in which no effect of conceptual components can be imputed, given that such components are generally lacking in these persons (e.g., Bebko & Luhaorg, 1998). We expect that a task that involves only perceptual and motor components, avoids verbal responses, and minimizes contamination by explicit processes should show that implicit-learning processes are efficient in these individuals. We developed and tested such a task with children and adults who were developing typically (Vinter & Perruchet, 1999, 2000, 2002).

The task we developed, the neutral parameter procedure, was specifically designed to assess unconscious influences on behavior, something that is a far from easy task (Shanks & St. John, 1994). This procedure is based on two criteria. The *task demands* criterion requires that instructions lead participants to focus on behavioral components other than those on which the unconscious influences are assessed, and the *neutral effect* criterion stipulates that unconscious effects must be assessed on the basis of a behavioral parameter that is neutral with regard to task achievement. These criteria are intended to ensure that any possible explicit influences should, a priori, have no consequence on the crucial behavioral parameter used for assessing the unconscious influences.

It also appears crucial for individuals with mental retardation that the task they are required to complete involves no conceptual component and avoids the reporting of any verbal response. The neutral parameter procedure exploits a natural covariation present in drawing, which Van Sommers (1984) called the *start-rotation principle.* This principle states that the direction of movement in the drawing of closed geometrical figures is dependent on the starting position. For example, consider a circle. If the starting point is set above a virtual axis going from 11 o'clock to 5 o'clock, we predominantly rotate counterclockwise, whereas we draw clockwise for the lower half of the circle. The experimental manipulation consisted, through appropriate practice in a tracing task, in inversing this principle without the participants knowing it. The results revealed that adults and children (Vinter & Perruchet, 1999, 2000) presented a much lower level use of the principle after principle incongruent training than after congruent or free training.

This tracing task appeared particularly suitable for individuals with mental retardation because of its simplicity, though the procedure required a number of adaptations. First, the current literature does not provide any information about whether persons with mental retardation use the start-rotation principle in drawing. Consequently, a within-subjects design was adopted, in which a preliminary phase was devoted to the assessment of the baseline level of adherence to the start-rotation principle for each participant, the impact of training being measured using a before-training/after-training comparison. Second, only circles were included in the present task because drawing other geometrical figures might be beyond the capabilities of certain individuals. Finally, we chose a paper-and-pencil task, whereas a computer-assisted task was used previously, which we believed might involve too many stress-inducing experimental conditions for our participants. Because of this set of simplifications, we expected to observe a clear effect of principle-incongruent training on the subsequent degree of adherence to the start-rotation principle irrespective of IQ by participants affected by mild or moderate mental retardation. They should, thus, reveal a significant decrease in adherence to the principle in the test phase when compared to their baseline level, and no interaction between mental retardation and training should appear.

The literature shows contradictory results with respect to the relationship between age and implicit learning, irrespective of whether mental retardation is involved. In one group of studies, the researchers concluded that implicit learning does not vary as a function of age (Howard & Howard, 1989, 1992; Myers & Conner, 1992; Meulemans, Van der Linden, & Perruchet, 1998; Roter, cited in Reber, 1993; Thomas & Nelson, 2001; Vinter & Perruchet, 2000). However, this conclusion is contradicted by another group of studies (Fletcher et al., 2000; Maybery et al., 1995), in which no obvious factor accounted for this contradiction. We considered it unlikely that an age effect would emerge in our study because of our choice of a simple sensorimotor task and the neutral parameter procedure, given that age-sensitivity is more likely when conceptual components are involved in the implicit task or when the learning process is susceptible to contamination by explicit influences. Children ages 7 to 8 years and adolescents ages 13 to14 years were included in the present study. Irrespective of age, a principle-incongruent training effect should appear, whereas the interaction between age and training should not.

A developmental approach to mental retardation was adopted in accordance with Zigler's hypotheses (1967, 1969). We included four groups of typically developing children matched on MA with the four groups of participants with mental retardation. This led us to test children with CAs ranging approximately between 4 and 7 to 8 years. If MA mediates implicit-learning performances, as claimed by Fletcher et al. (2000), and if persons with mental retardation do not present particular deficits when matched on MA with children of average intelligence (Zigler, 1967, 1969), the same type of effect of implicit training should be observed in each matched pair of groups of children. Moreover, a comparison between the groups with and without mental retardation that are similar in CA (around 7 to 8 years) was added. If, as claimed by Reber (1993), implicit learning is not related to IQ, these groups should present similar implicit performances.

Finally, we also included individuals with organic mental retardation and with familial mental retardation. Zigler (1969) has pointed out the importance of etiology, considering that persons with organic mental retardation may form a separate group where specific deficits can be expected (see also Burack, Hodapp, & Zigler, 1988, 1990). However, a more moderate hypothesis suggests that the divergence between the two groups is not systematic and that it is worth exploring mental retardation in the light of organic etiology in the same way as familial mental retardation has been investigated (Cichetti & Pogge-Hesse, 1982). In the present study, we first grouped all participants irrespective of etiology and then checked whether differences appeared when we subgrouped by etiology for analytic purposes. Our main expectation was that both groups would exhibit significant implicit learning.

In synthesis, the claim that implicit learning is IQ- and age-independent should find support through three expectations. An effect of implicit training should appear equally well in children with mild and moderate mental retardation, in MA-matched children, and in CA-matched children. This impact of training should not vary as a function of age in children with or without mental retardation, and it should not vary as a function of etiology of mental retardation.

Method

Participants

We tested 58 right-handed children and adolescents with mental retardation. They complied with the criteria for the diagnosis of mental retardation according to the *Diagnostic and Statistical Manual of Mental Disorders*–DSM-IV (American Psychiatric Association, 1994) and had an IQ under 70 and over 29. They were subgrouped to form samples with moderate (IQ < 50, n = 28) or mild (49 < IQ < 70, n = 30) mental retardation. Participants were divided into four groups according to their level of mental retardation (mild or moderate) and their mean CA (7 to 8 years or 13 to 14 years). Different measures of IQ and MA were available for these children, including the Peabody Picture Vocabulary Test IQ (revised form, French adaptation, Dunn, Thériault-Whalen, & Dunn, 1993). They all attended specialized institutions for children with mental retardation and were observed inside their institution. The main characteristics of the four groups are detailed in Table 1.

This sample included 28 children exhibiting organic mental retardation (17 Down syndrome and 11 other neurological causes: fragile X, Turner, West, Williams, and Cornelia de Lange syndromes). The neurological diagnosis was found in the medical file of the participant. The remaining participants had a nonspecific developmental retardation (n = 30). The distribution of participants with organic mental retardation and with nonspecific mental retardation across the four groups revealed fewer children presenting a nonspecific deficit in the moderate retardation group (n = 10) than in the mild retardation group (n = 20). None of these children had a secondary physical or sensory impairment. Only 5 of them were receiving medication because of epilepsy.

Four groups were matched on MA with the experimental group in such a way that their respective mean MA corresponded one-to-one to the mean MA of the participants in the groups with mental retardation, as indicated in Table 1. Mental ages were assessed using the Peabody Picture Vocabulary Test-Revised Form (Dunn et al., 1993). A total of 53 right-handed children between 3 and 8 years of age were thus examined. These children, who were described as typically developing by their teachers, were observed individually at school. To simplify the remainder of this article, we have designated these groups as the 4-year-olds (matched with the children with moderate mental retardation), the 5-year-olds (matched with the children with mild retardation), the 5- to 6-year-olds (matched with the adolescents with moderate retardation), and the 7- to 8-year-olds (matched with the adolescents with mild retardation). The children of this last group were also matched to their age peers who had mental retardation.

Whatever the group, a larger number of participants were actually observed than were includ-

Table 1. Main Participant Characteristics by Group

	Experimental group[a]								Matched controls[c]			
		CA							CA			
Group[b]	IQ	Mean	*SD*	Mean MA	Gender	*n* with DS	*n* with OND	*n* with NMR	Mean	*SD*	*n*	Mean MA
1 (11)	50–69	7.67	.95	4.58	8 girls	4	2	5	4.83	.15	12	4.75
2 (19)	50–69	13.25	.90	7.42	10 girls	0	4	15	7.42	.83	16	7.50
3 (10)	30–49	8.17	.73	3.67	7 girls	4	1	5	4.08	.64	12	4.08
4 (18)	30–49	14.50	.92	5.50	12 girls	9	4	5	5.50	.88	13	5.58

[a]DS = Down syndrome, OND = other neurological disease, NMR = nonspecific mental retardation. [b]1 = children with mild retardation, 7 to 8 years old; 2 = adolescents with mild mental retardation, 13 to 14 years old; 3 = children with moderate mental retardation, 7 to 8 years old; and 4 = adolescents with moderate mental retardation, 13 to 15 years old. *N*s in parentheses. [c]CA of Group 1, 4 to 5 years; Group 2, 7 to 8 years; Group 3, 4 years; and Group 4, 5 to 6 years.

ed in the analysis (N at outset = 136). However, the selection was based on the participants' mean spontaneous degree of use of the start-rotation principle: Only children presenting a mean percentage above or equal to 60% were included. Thus, 15 participants with mental retardation were not included in the study, as were 10 typically developing children.

Materials

All the measures were taken from paper-and-pencil experimental situations. To obtain an assessment of the spontaneous degree of use of the start-rotation principle (baseline phase), we used three different tasks, in which participants were asked to draw 5 circles on a 21 × 5 cm sheet of paper twice with a regular pen, to copy 5 circles of 1.6 cm diameter drawn in black ink on a line below the models twice within a 21 × 5 cm preprint rectangle, and to trace over 5 preprinted circles of 1.6 cm twice on a 21 × 5 cm sheet of paper. In the training phase, the participants were required to trace over a series of 20 preprinted circles (diameter 1.6 cm) displayed inside 4 frames of 21 × 5 cm (5 circles in each rectangle), with 2 frames per sheet of paper. A black point of 0.2-cm diameter that indicated where to start tracing was located at either the top (12 o'clock) or the bottom (6 o'clock) of these circles. At the same time, an arrow of 1 cm in length, indicating the direction of tracing (counterclockwise or clockwise) was displayed either 0.5 cm above (when the starting point was at the top) or below the starting point (when it was at the bottom). Finally, in the test phase, the participants had to trace over a series of 12 circles, 6 showing a top starting point and 6, a bottom starting point. No indication was given as to direction of tracing. The circles were displayed in 2 frames of 23 × 5 cm, with 6 circles per frame.

Procedure

The entire experimental session was comprised of four phases: baseline, training, test, and questionnaire. Around 2 to 3 weeks separated the baseline phase from the training phase, which was followed 4 or 5 minutes later by the test phase.

Three different tasks were used in the baseline phase, with each task being repeated twice. (Although only the tracing task was of interest for our main objective, three different tasks were selected in the baseline phase to determine understanding of the start-rotation principle by individuals with mental retardation.) The tasks were presented in a random order, with one repetition a day (the data were collected over 6 successive days). In the free task, the participants were twice required to draw 5 circles "as they usually do" (i.e., in the absence of any constraint). In the copy task, they were twice required to copy 5 circles presented as models, "as best as they can." In the tracing task, they had to trace over 5 circles twice "as accurately and as fast as possible." Whatever the task, they did not receive any instructions concerning the starting point or the movement rotation. We observed that they spontaneously introduced changes in these parameters across the diverse repetitions of the baseline tasks. They were instructed to draw the circles in one single movement. In each case, the experimenter noted the location of the starting point and the direction of the drawing movement, thus permitting an assessment of the spontaneous degree of use of the start-rotation principle. A total of 30 circles were drawn by participants in this phase. Only those who performed in conformity to the start-rotation principle at a level above or equal to 60% (18/30 drawings or more) were included in the training phase. (However, a few children who did not reach the 60% criterion in the tracing task were not excluded from the study: 5 [out of 58] in the groups with mental retardation and 8 [out of 53] in the groups without mental retardation. These children were retained because they showed a decrease of their baseline performance after training. Furthermore, when the main ANOVAs were run without these children, the results did not change. The demonstration of the effect of implicit learning was only larger.)

The training phase occurred around 2 to 3 weeks later. The participants were asked to trace "as accurately and as fast as possible" over the series of 20 circles, using the instructions for starting point and movement direction. These parameters were combined in such a way that only 20% of the figures were traced in conformity with the start-rotation principle. More precisely, 8 figures presented a top start with a clockwise rotation; 8, a bottom-start with a counterclockwise rotation; 2, a top start with a counterclockwise rotation; and 2, a bottom start with a clockwise rotation. The distribution of the various combinations of starting point and rotation direction was random across the series. We note, however, that over the whole session, there were as many top as bottom starts and as many clockwise as counterclockwise rotations. A familiarization phase was necessary for most children with mental retardation and for the youngest control participants to become familiar with the instructions.

After the training phase was completed, there was a pause of 4 to 5 minutes, followed by the test phase, in which the participants were required to trace fast and accurately over a series of 12 circles while adhering to the indicated starting point. They were free to trace in either direction. Half of the figures presented a top starting location and half, a bottom starting location. Learning was not assessed on the basis of speed and accuracy, stressed in the task instructions, but on a parameter that was irrelevant for task completion: the direction of tracing selected by the participant, of which association with the starting location may or may not reflect the training conditions.

In the questionnaire phase, the participants were told to report anything that they might have noticed during training. They were then given a forced-choice test and asked to remember when they had to trace a figure from the top. They had to decide (a) whether they were simultaneously required to trace mainly clockwise or counterclockwise (these directions were illustrated by a hand movement) and (b) whether the same procedure applied for figures started at the bottom. We coded the number of correct responses, which could vary between 0 and 2. Not all the children with mental retardation were able to complete this explicit test. However, enough of them completed the test to allow us to perform an analysis of the data.

Results

We first analyzed the baseline data collected in the groups with and without mental retardation separately and checked that no differences occurred between each matched pair of groups (baseline performance analysis). Then, we compared the mean percentage of adherence to the start-rotation principle obtained in the baseline task with that obtained in the posttraining test phase (implicit-learning performance analysis). The effect of implicit training was analyzed in the groups with mental retardation to verify whether age or mental retardation effects were revealed. A comparison of this effect between each matched pair of groups was carried out, together with an independent analysis of the performances of the children who were developing typically. We checked whether a difference appeared between the organic mental retardation group and the nonspecific mental retardation group and also tested the Down syndrome children separately. Finally, we analyzed the explicit responses provided by the participants in the questionnaire (explicit performance).

Baseline performance. The baseline tasks provided 30 measures (3 tasks $\times$10 trials) of spontaneous respect for the start-rotation principle by participant. Because trials was never significant as a main effect or in interaction with the other factors, data were collapsed over the trials in each task. An ANOVA was performed with mental retardation (2: mild or moderate) and age (2: 7 to 8 or 13 to 14 years) as between-subjects factors and task (3: free, copy, tracing) as a within-subjects factor.

The participants with mental retardation presented a high percentage of drawings that conformed to the start-rotation principle (90% on average) in the baseline tasks (remember, however, that we selected those achieving a percentage above 59%). Task had a significant effect on this behavior, $F(2, 108) = 6.34$, $p < .01$, with fewer employing the start-rotation principle in the tracing task (84.31%) than in the copy (95.51%) or free (95.68%) tasks. Age reached significance, $F(1,54) = 3.95$, $p = .052$, with the adolescents showing a greater level of use of the start-rotation principle (93.82%) than did the children (88.12%). There were no other significant effects, in particular, none for degree of mental retardation. A high degree of use of the principle was observed in the nonspecific group (94.33%), in the organic group (89.16%), as well as in the Down syndrome group (85.88%). The difference between the nonspecific group and the Down syndrome group was significant, $F(1, 45) = 6.83$, $p < .05$. The task effect was present in each subgroup, $ps < .05$; the lowest percentage of use of the start-rotation principle was recorded in the tracing task in each case.

A separate ANOVA was carried out for the typically developing children, with age (4: 4, 5, 5 to 6, and 7 to 8 years) as a between-subjects factor and task (3) as a within-subjects factor. Task was significant, $F(2, 98) = 17.11$, $p < .001$, with the tracing task again leading to a lower level of use of the principle (75.47%) than the free (91.13%) or copying (95.28%) tasks. Moreover, spontaneous use of the start-rotation principle tended to increase with age, $F(3, 49) = 2.73$, $p = .053$. The youngest children (around 4 years old) employed the principle in 81.94% of the cases, whereas the oldest (7 to 8 years) showed a greater use (93.54%). Thus, the profiles of results for the baseline performances were similar between the groups with and without mental retardation. To lend further support to this finding, we ran four separate ANOVAs on each matched pair of groups, with group (2: mentally retarded or typically developing) as a between-subjects factor and task (3) as a within-subjects factor. Group was never significant and neither were the Group × Task interactions. The same result was obtained when the comparison involved the groups of similar CAs. Thus, no differences appeared between children or adolescents with mental retardation and their MA- or CA-matched controls. The covariation between starting location and rotation direction captured by the start-rotation principle was present to a very high degree in the drawing behavior of both samples of participants.

Implicit-learning performance. The impact of anti-start-rotation principle training was assessed by comparing the mean percentages of use of the start-rotation principle obtained in the test phase with those obtained in the tracing task, where the lowest level of spontaneous use of the start-rotation principle was recorded. Figure 1 presents the results for the children with mental retardation, and Figure 2, those of the children who were developing typically.

An ANOVA was run with age (2) and level of mental retardation (2) as between-subjects factors, and training (2: baseline or test) as a within-subject factor. As shown by Figure 1, training had a clear and significant impact on use of the start-rotation principle, $F(1, 54) = 120.49$, $p < .001$, which fell from 84.30% to 32.18% after appropriate training. (The baseline tasks were administered in a random order over 6 days. We checked that the repetition of this start-rotation principle measure was not subject to a mean regression effect, which would be most prejudicial because the assessment of the effect of training relies on a predicted decrease of this measure. An ANOVA was conducted on the entire sample of participants [$N = 111$], with group as a between-subjects factor [8: the 4 groups with mental retardation and the 4 groups without mental retardation] and days [6] as a within-subjects factor. Days failed to yield significance [mean percentages of use of the start-rotation principle at Day 1, 80.37%; Day 2, 86.87%; Day 3, 86.50%; Day 4, 90.48%; Day 5, 88.22%; and Day 6, 90.86%]. The Days × Group interaction also did not reach significance.) Degree of mental retardation yielded a marginally significant main effect, $F(1, 54) = 3.48$, $p = .06$, whereas the Training × Level of Mental Retardation interaction did not. There were no other significant effects. The main effect obtained for mental retardation means that considering the percentages of use of the start-rotation principle both before and after learning, children and adolescents with mild mental retardation tended to exhibit a higher level of usage of the start-rotation principle (62.44%) than did those with a more severe level of mental retardation (54.03%). However, in terms of impact of training, the decrease in the percentage of use of the start-rotation principle was similar in participants with moderate mental retardation (on average, 54% decrease) and those with mild mental retardation (on average, 50.4%), as indicated by the nonsignificant Level of Mental Retardation × Training interaction. However, children with organic mental retardation might react differently to children with nonspecific mental retardation because the former have a homogeneous and globally more severe level of mental retardation. We, therefore, performed an ANOVA with age (2) and etiology (2) as between-subjects factors and training (2) as a within-subjects factor. Etiology was not significant, and neither was the Etiology × Training interaction. Participants from the organic group displayed a 48.51% decrease in use of the start-rotation principle compared to 54.84% for the chil-

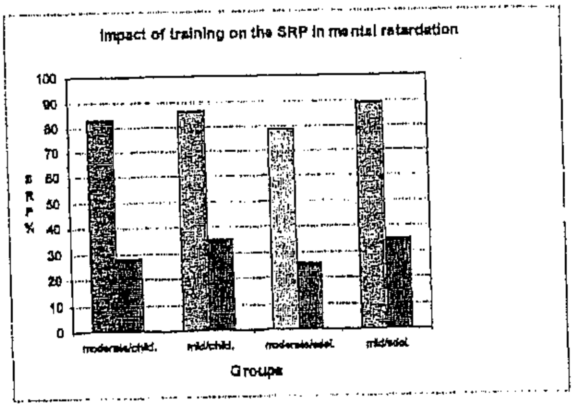

Figure 1. Impact of training on respect for the start-rotation principle in individuals with mental retardation. Light bars = before training, dark bars= after training. SRP = start-rotation principle.

dren whose mental retardation was not specified. A significant training effect was also found when only the Down syndrome children were analyzed, with the percentage of use of the principle decreasing from 71.66% to 30.03%, $F(1, 15) = 39.02$, $p < .001$.

Though no effect of level of mental retardation was observed in implicit learning when the groups of children with mental retardation were compared, we believed that a difference might emerge if they were compared to typically developing children. Before carrying out this comparison, we first checked that a training effect was present in this latter group. An ANOVA with age (4) as a between-subjects factor and training (2) as a within-subjects factor was performed. The results are presented in Figure 2, where it can be seen that training had a large and significant effect on the percentage of use of the start-rotation principle, $F(1, 49) = 71.46$, $p < .001$. Age also yielded significant results, $F(3, 49) = 2.82$, $p < .05$, with the youngest children exhibiting, on average, a lower level of use of the start-rotation principle (44.30%) than did the oldest children (64.06%) when baseline and test phases were combined. However, the Age × Training interaction did not reach significance. Each matched pair of groups was then examined. Four ANOVAs were run with group (2) as a between-subjects factor and training (2) as a within-subjects factor. Globally, the analyses failed to reveal any significant group effect or Group × Training effect. A nearly significant group main effect was identified in only one case, namely, when the 7-year-old children with mild mental retardation were compared to their MA-matched group, $F(1, 21) = 5.10$, $p < .05$. All groups of children with mental retardation exhibited a globally higher mean percentage of use of the start-rotation principle, baseline and test phases combined, than did their controls. However, the Group × Training interaction was not significant. The impact of training was globally the same in the children with mental retardation (decrease of 47% between the tracing task and the test) and in their matched groups (decrease of 42%). Finally, the comparison between the CA-matched groups definitively confirmed that the influence of training in our tracing task was independent of mental retardation. Group (children with moderate mental retardation versus the 7- to 8-year-old matched group) was not significant, nor was the Group × Training interaction.

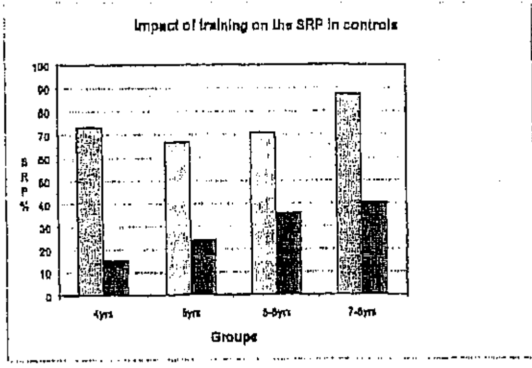

Figure 2. Impact of training on use of the start-rotation principle (SRP) in the typically developing children. Light bars = before training, dark bars= after training.

Fletcher et al. (2000) suggested that MA mediates differences in implicit learning. We computed correlations between the participants' MA and their learning effect ratings (baseline performance on tracing minus test performance). A correlation was found for the participants with mental retardation, $r(56) = .11$, $p = .41$, and for the control groups, $r(51) = -.08$, $p = .56$, indicating that we failed to find any significant correlations between MA and training effect in a group of children who differed substantially in terms of MA. The correlation was slightly higher but still not significant, $r(15) = .25$, when the Down syndrome children were considered separately. Finally, this correlation was still not significant when computed on the performances of the children with a nonspecific cause of mental retardation, $r(28) = .03$, or on the performances of all the children with an organic type of mental retardation, including Down syndrome, $r(26) = .09$.

Explicit performance. Irrespectively of their intelligence, the participants with mental retardation did not spontaneously report anything regarding the training phase that might have been related to the experimental manipulation. Only the responses provided to the two-choice forced test were of interest. However, 8 children and 2 adolescents with mental retardation did not respond appropriately to this test, which reduced the set of analyzable responses to 48 (13 children and 35 adolescents). The three possible explicit scores were 0, 1, or 2 (number of correct responses), and their chance probabilities were .25, .50, and .25, respectively. We ran a series of chi-square tests (with 2 degrees of freedom) comparing the observed frequencies for the explicit scores with the frequencies expected under the .25, .50, and .25 model. Table 2 displays the results.

As shown in Table 2, the distribution of explicit scores did not depart from chance in the group of children with mental retardation, whether the entire group was tested or each group was tested separately. By contrast, significant results were obtained for the typically developing children when the entire sample was tested as well as at 5 years and at 7 to 8 years. This means that when their attention was specifically focused on a precise component of the learning situation, a significant number of typically developing children were able to correctly remember the predominant association between the starting location and movement rotation they followed during this learning period.

Finally, to test whether the impact of training could be due to those participants who correctly named the training conditions, all participants who scored 2 were removed from the analysis, and two ANOVAs were run on the remaining participants: six 7- to 8-year-olds with mild mental retardation, 4 with moderate mental retardation, 13 adolescents with mild mental retardation, and 12 with moderate retardation; for the controls, eight 4-year-olds, seven 5-year-olds, seven 5- to 6-year-olds and eight 7- to 8-year-olds. Training was still significant, with a decrease in use of the principle of 53.2% by the children with mental retardation, $F(1, 31) = 87.08$, $p < .01$, and 42.1% by the typically developing children, $F(1, 26) = 34.48$, $p < .01$. These results show that there is no relationship between implicit performance and the explicit memory of the previously experienced training situation.

In summary, the results show that persons with mental retardation modified their drawing behavior after an appropriate implicit training in the same manner as did MA- or CA-matched participants. This effect of training appeared independent of the level of mental retardation, etiology, and age. Moreover, it was maintained when participants demonstrating clear post-hoc explicit knowledge about the training situation were removed from the analysis. In this respect, typically developing children exhibited globally more explicit knowledge than did those with mental retardation. Finally, the results also incidentally showed that the spontaneous drawing behavior of children with mental retardation was organized in a way similar to that found in typically developing children, with a significant increase with age in the use of the start-rotation principle.

Discussion

The present study was intended to show that implicit-learning processes assessed in a simple sensorimotor task are efficient in persons with mental retardation and that they do not vary as a function of age or level of mental retardation. Furthermore, in terms of the efficiency of these pro-

Table 2. Frequency of Explicit Scores (Correct Responses) to Explicit Remembering Test by Group

	Explicit scores			
Group	0	1	2	χ^2
Mentally retarded				
7–8 yrs/mild retardation (n = 7)	0	6	1	3.85
7–8 yrs/moderate retardation (n = 6)	1	4	1	0.66
13–14 yrs/mild retardation (n = 18)	2	9	7	2.77
13–14 yrs/moderate retardation (n = 17)	3	10	4	0.65
Entire group (n = 58)	6	29	13	4.12
MA-matched control				
5 yrs (n = 12)	0	6	6	6*
4 yrs (n = 12)	2	7	3	0.5
7–8 yrs (n = 16)	1	7	8	6.37*
5–6 yrs (n = 13)	1	6	6	3.92
Entire group (n = 53)	4	26	23	13.64**

*$p < .05$. **$p < .01$.

cesses, we did not expect any significant effect of etiology (organic vs. nonspecific) or any difference due to the presence of mental retardation. This did not exclude a possible significant difference in terms of quantity of impact of implicit learning. Our results are discussed in three ways. First, although it was not a central concern here, results relating to the performance of persons with mental retardation in the baseline tasks are discussed briefly. Second, we examine the extent to which our results lend support to Reber's (1993) two postulates stipulating the independence of implicit-learning processes with regard to age and intelligence. Finally, the relation between mental retardation and explicit remembering of the incidental training conditions is discussed.

Mental Retardation and a Drawing (Start-Rotation) Principle

Children with mental retardation usually exhibit a deficit in drawing ability. However, our results show that the start-rotation principle described by Van Sommers (1986) holds for these children. The ratio of individuals with mental retardation who did not spontaneously use this principle at a significant level was 15 out of 58 (26%). This ratio is about one third larger than that found in typically developing children (19%), but the difference was not significant. Moreover, respect for the principle increased with age in both samples, probably as a result of increasing practice at drawing during development, which conforms to the developmental trend reported in the literature (Meulenbroek, Vinter, & Mounoud, 1993; Vinter & Meulenbroek, 1993). Furthermore, the tracing task resulted in a lower level of use of the principle than did the other tasks in both samples. This represents a good illustration of the functionality of the start-rotation principle, which ensures the optimal visual monitoring of the movement of the pen and of the trace left on the paper, particularly at the moment when the circle is closed, thus guaranteeing accuracy. Of course, in the case of a tracing task, the question of the production of the figure's shape is resolved in advance, and the task, therefore, resembles a pursuit task in which it is necessary to keep track of a stationary trajectory.

Implicit Learning, Age, and IQ

Reber (1993) has claimed that implicit-learning processes should be both age and IQ-independent. Our results support such a view. The impact of implicit learning was 50% in the children with mental retardation (ages around 7 to 8), and 53% in the adolescents (around 13 to 14 years). It reached 58% in the youngest typically developing children, and 47% in the oldest ones. Invariance with age of implicit-learning processes has also been reported in typically developing children in several studies (e.g., Meulemans et al., 1998; Vinter & Perruchet, 2000). The stability of the impact of implicit learning was also observed when participants with mild mental retardation (50%) were compared to individuals with a more severe level of retardation (54%), a result that provides support for the claim of the IQ invariance of implicit-learning processes. Similarly, the impact of training did not vary as a function of etiology of mental retardation, either when we compared individuals with organic mental retardation to those with nonspecific mental retardation, or when Down syndrome children as a specific group were compared to children with nonspecific mental retardation.

Thus, our results are very different from those recently obtained by Fletcher et al. (2000), who reported both significant age and IQ effects and suggested that MA could mediate implicit learning. There are two possible reasons for this empirical disagreement. Because the pattern of results reported by Fletcher et al. looks very similar to those generally obtained in explicit-learning studies, one possibility is that the covariation task they used was contaminated by explicit influences. Indeed, in the traditional implicit-learning paradigms, we can never be sure that learning performance is not due, at least in part, to explicit influences (see Shanks & St. John, 1994). This is why we adopted the neutral parameter procedure in the present study (Vinter & Perruchet, 1999). This procedure prevents this type of explicit influence on performance. Fletcher et al. suggested the second possibility, that participants might have used a common conceptual structure for representing spatial information to complete both their explicit- and implicit-learning tasks. This common spatial framework may involve a conceptually based understanding of body axes. If this is the case, it would not be surprising if implicit-learning performance varies as a function of age and IQ. The reason that in our own study implicit-learning performance was not affected by age or by IQ could be that our implicit-learning task was largely nonconceptual, with a strong, if not exclusive, perceptuomotor component. The nature of the implicit task certainly influences the relations among implicit learning, age, and intelligence. We suggest that the greater the conceptual burden of the task, the less age- and intelligence-invariant implicit learning can be. Following the same line of reasoning, Komatsu, Naito, and Fuke (1996) have shown that persons with mental retardation performed similarly to control participants in an implicit-memory task that primarily involved perceptual processing but worse than control participants when a conceptual processing of information was required. Of course, clearly differentiating a perceptual from a conceptual task is no easy matter. From our point of view, the complexity of the structure embedded in the implicit task (e.g., complexity of the rules, or of the covariations, or of the hidden repeated sequence) is not a crucial parameter with this usage. By contrast, a conceptual processing of the task is likely to be elicited as soon as the transactions between the participant and the task are no longer direct and immediate but involve verbal encoding or choices of response based on highly explicit decisional processes. Investigating the role of the type of task in implicit-learning settings is a worthwhile topic for further research.

In our view (see Perruchet & Vinter, 1998), implicit learning relies on basic associative mechanisms that are automatically elicited when certain elements repeatedly enter into the subject's attentional focus. In the case of our tracing task, this means that a new association between two movement parameters, namely, starting location and drawing direction, is formed and consolidated through exercise. It is worth noting that this type of association constitutes one of the basic components of handwriting movements. Results of the present study show that this executive component of handwriting could be established through implicit-learning procedures. However, before speculating on the relevance of our results in the context of the teaching of handwriting, for instance, we must examine two important points, namely, whether this implicit learning persists over time and whether it can be transferred. Indeed, if we were to find that it vanishes after a few minutes or is limited to the specific geometrical figure on which training was performed, its value for practical applications would be greatly reduced. Thus, further empirical investigation is needed before clear applications in the field of remedial or educational programs can be suggested.

Another interesting point for discussion is the relationship between implicit learning and attentional processes, which has been the subject of a large body of research (e.g., Jimenez & Mendez, 1999; Stadler, 1995). This relation may appear counterintuitive because implicit-learning processes are often described as automatic and not requiring effort. However, if these processes are nonintentional, the relevant information underlying the to-be-learned behavior must be attended to and encoded before associative processes can be elicited. The active role of attention has been pointed out in other conditions where automatic information processing occurs, such as conditioning (e.g., Mackintosh, 1975) or implicit memory (e.g., Crabb & Dark, 1999). The fact that persons with mental retardation do implicitly modify their behavior in a way similar to that of MA-matched children indicates that attentional processes that are crucial for implicit learning (at least in psychomotor tasks) are preserved in these individuals. The attention in implicit learning is probably some kind of selective attention that supports parsing and encoding. Iarocci and Burack (1998) reviewed a series of studies in which the researchers, indeed, showed that attentional processes are not systematically impaired in persons with mental retardation.

Explicit Remembering of the Training Conditions and Mental Retardation

Participants with mental retardation did not explicitly remember the relevant conditions of training, whereas a significant number of typically developing children did pass this test. The pattern of results concerning explicit remembering was globally asymmetrical when we compared the groups with mental retardation to their controls: The former failed to explicitly remember the training conditions, whereas the latter succeeded overall, with the clear exception of the youngest participants. Because the groups were matched on MA, the between-groups difference was not due to this variable. Moreover, it was not due simply to CA either because the group that failed the test was the *older* group (i.e., the group with mental retardation), and the group that succeeded on the test was the *younger* group (i.e., the group without mental retardation). However, the role of these two variables cannot be ruled out because the youngest typically developing children also failed the explicit test, a result that is consistent with a large body of research supporting a significant effect of CA on explicit memory. Our present results are similar to those of Vicari et al. (2000), who observed that the performance of persons with mental retardation in explicit-memory tests was in all cases below that of typically developing children matched on MA, whereas the two groups obtained comparable performances in implicit-memory tasks. Other studies have documented similar impaired performance in explicit memory in individuals with mental retardation when compared to controls matched on CA (e.g., Ellis, 1970). Several components of explicit memory seem to be affected in persons with mental retardation, especially the encoding process (see, e.g., Carlesimo, Marotta, & Vicari, 1997; Katz & Ellis, 1991). Our explicit-remembering test was not constrained enough to permit elaborating on the type of memory process that could be impaired in our participants with mental retardation.

In conclusion, although further studies are needed to ensure the stability of the behavioral changes that can be induced implicitly in persons with mental retardation, the present study lends support to a newly emerging area of research in mental retardation suggesting that implicit-training techniques may provide a promising source of educational or remedial methods.

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