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Implicit and explicit motor learning in children with and without Down's syndrome

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This paper reports a study investigating the degree of dissociation between performance shown by children with or without Down's syndrome (DS), matched on non-verbal MA-level, following an implicit or explicit learning procedure. Task-specific factors were tightly controlled using the same task for both modes of learning. The implicit learning task was based on the manipulation of a graphic production principle. Our procedure trained participants to reverse the principle. In the explicit task, participants had to learn the two rules that account for this reversed principle. Whether they were trained implicitly or explicitly, participants then performed the same test in which the impact of their training was assessed.

Children with DS performed as well as controls in the implicit learning condition. They benefited less from the explicit learning condition than controls. They appeared to be impaired in the ability to recollect explicit information about the implicit training situation in comparison with controls. These results are discussed in the light of the current literature on the implicit and explicit modes of learning, and hypotheses are formulated about specific information processes that may be impaired in individuals with DS.

A growing body of research has appeared in the last years on the relationships between implicit and explicit learning (e.g. Shanks, Rowland, & Ranger, 2005; Wallach & Lebiere, 2003). Implicit learning covers all forms of unintentional learning in which, as a consequence of repeated experience, an individual's behaviour becomes adapted to the structural regularities of a situation without, at any time, being told to learn anything about this situation (e.g. Perruchet & Vinter, 1998; Reber, 1993). Explicit learning, by contrast, is best illustrated by situations in which rules (either grammatical, logical, or other) are explicitly taught, participants being required to devote conscious effort to recall them. These two modes of learning are obviously used naturally by humans throughout their life. Their relevance for our adaptation to daily life justifies the study of their comparative efficiency in children, particularly in children with intellectual impairment. Indeed, the difficulties these individuals encounter in any task requiring

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effortful or intentional information processing are well documented in the literature (e.g. Bebko & Luhoarg, 1998; Bray, 1979; Brown, 1974). However, the discovery that some cognitive capacities, based on automatic, non-intentional, or implicit information processing, are relatively preserved in these individuals has renewed interest in this domain of research (Jones, Vaughan, & Roberts, 2002; Parkin & Russo, 1990; Takegata & Furutuka, 1993; Wyatt & Conners, 1998). The present experiment aimed to compare both the implicit and explicit modes of information processing in typically developing children and children with Down's syndrome (DS) possessing IQs between 30 and 70. We investigated whether the degree of dissociation between the two learning modes differed across groups.

Three arguments are put forward in the literature to claim a dissociation between the two forms of learning. The first argument relates to the postulate of age independency advanced by Reber (1992): implicit learning should be age-independent while explicit learning should evolve with age. That implicit learning did not vary as a function of age was concluded in several studies, whether they involved typically developing children (Karatekin, Marcus, & White, 2007; Meulemans, Van der Linden, & Perruchet, 1998; Reber, 1993; Thomas & Nelson, 2001; Vinter & Perruchet, 2000), elderly participants (Howard & Howard, 1989, 1992; Myers & Conner, 1992), or children with intellectual disability (Vinter & Detable, 2003). However, in a few studies a correlation between both modes of learning and age was found (Fletcher, Maybery, & Bennett, 2000; Maybery, Taylor, & O'Brien-Malone, 1995), as it was also reported in a few implicit–explicit memory studies (Murphy, McKone, & Slee, 2003; Wyatt & Conners, 1998).

A second argument deals with the IQ independency postulate sustained by Reber (1992): implicit learning should be IQ-independent, while explicit learning performance should correlate with IQ. Several studies have provided support for this claim (Atwell, Conners, & Merrill, 2003; Don, Schellenberg, Reber, DiGirolamo, & Wand, 2003; Feldman, Kerr, & Streissguth, 1985; McGeorge, Crawford, & Kelly, 1997; Maybery *et al.*, 1995; Reber, Walkenfeld, & Hernstadt, 1991), though contradictory results were also found (Fletcher *et al.*, 2000; Salthouse, McGuthry, & Hambrick, 1999). However, all of these studies, except Atwell *et al.*, have used different tasks for the investigation of explicit versus implicit learning. When assessing implicit and explicit performance on exactly the same task but under different instructions, a clear dissociation between the two types of learning with regard to IQ was obtained in an impressive study, conducted on a large sample of participants and analysing varied measures of learning and intelligence (Gebauer & Mackintosh, 2007).

The third argument often brought to bear when the implicit and explicit modes of learning are compared, suggests that implicit learning leads to better performance than explicit learning, and above all when complex material is presented to the participants. Reber (1976) showed that, in an artificial grammar learning task, participants who engaged in an explicit process of rule discovery performed worse than participants who learned incidentally. However, contradictory results have again been published in the literature (e.g. Dienes, Broadbent, & Berry, 1991; Dulany, Carlson, & Dewey, 1984). The Gebauer and Mackintosh (2007) study revealed that the type of task played a crucial role in this comparison. To our knowledge, only the Atwell *et al.* (2003) study has compared directly the impact of both modes of learning in individuals with intellectual disability, using an artificial grammar learning paradigm. Their conclusion agreed with Reber (1976), demonstrating a superiority effect of implicit over explicit learning in participants. However, their study involved young adults with IQs varying only from 50 to 75, and with intellectual impairment caused by mixed aetiologies. It therefore remains an open empirical question whether implicit learning leads to better performance than explicit learning in children with IQs varying across a wider range, from 30 to 70, and when studying a single specific aetiology. In keeping with the view that intellectual disabilities should be explored by identifying aetiologies and not merging them (e.g. Burack, 1990; Dykens & Hodapp, 2001; Hodapp & Dykens, 2001), we included only individuals with DS. We also decided to use a non-verbal MA-level match for the contrast group (see the Methods section).

A greater impact of implicit over explicit learning can be expected in children with DS because two characteristics of their cognitive functioning, their overly compliant approach to tasks, and their strong tendency to rely on imitation (Rast & Meltzoff, 1995; Wright, Lewis, & Collis, 2006) would tend to shape their behaviour in accordance with the structure of the encountered situations. The predominance of such 'empirical' functioning may make them particularly sensitive to the incidental conditions of learning and to the action of automatic associative processes that are thought to capture structural regularities present in the learning situation (Perruchet, Vinter, Pacteau, & Gallego, 2002). By contrast, their difficulties when effortful or intentional processing is required are regularly reported (e.g. Cuskelly, Jobling, & Buckley, 2002). Indeed, implicit learning can be seen as a form of learning driven by bottom-up processes, during which the individual's behaviour is progressively shaped in accordance with the particular features of environment. By contrast, explicit learning requires effortful, conscious, purposeful control from individuals, and can be seen as driven by top-down influences. Interestingly, writing more than four decades ago, Inhelder (1963) described in some detail the predominance of accommodation (bottom-up processes) over assimilation (top-down processes) in children with intellectual impairments, under a Piagetian framework.

The current literature on implicit memory also gives some support to the prediction of better implicit than explicit performance in individuals with DS (Krinsky-McHale, Kittler, Brown, Jenkins, & Devenny, 2005; Vicari, Bellucci, & Carlesimo, 2000), but these studies tested adults and used different tasks to assess the two types of memory. Note, however, that the Vicari *et al.* study included also a measure of implicit learning, using the serial reaction time paradigm, which gives stronger support to our expectations concerning the relationships between implicit and explicit learning in individuals with DS.

The cognitive profile of individuals with DS is characterized by a clear deficit in language ability, especially in morphosyntax (e.g. Fowler, 1995), while visuospatial short-term memory appears relatively preserved (e.g. Hick, Botting, & Conti-Ramsden, 2005). The linguistic deficit seems more pronounced in production than in comprehension (Vicari, 2006). We therefore designed an explicit task that relied more on comprehension than production, and in which visuospatial cues were added in order to facilitate task understanding. Following Gebauer and Mackintosh's (2007) methodology, we selected the same task to explore both forms of learning, but modified the instructions so that learning was incidental in one case, and intentional towards the rules themselves in the other case.

The implicit learning task we used was based on the manipulation of a natural covariation present in drawing closed geometrical figures, called the start-rotation principle (Van Sommers, 1984). This principle states that when drawing a circle, for instance, if the right-handed drawers select a starting-point located at the top, they will predominantly use an anticlockwise rotation, while a starting-point located at the bottom will be mainly associated with a clockwise rotation (Figure 1). This principle develops rapidly in children between 4 and 7 years (Meulenbroek, Vinter, & Mounoud, 1993). In our task, we trained participants, by implicit means, to associate anticlockwise rotations with bottom starting-points (instead of top starting-points), and clockwise rotations with top starting-points (instead of bottom starting-points), when they traced over geometrical figures like circles, which went against their spontaneous drawing behaviour (Vinter & Perruchet, 1999, 2000, 2002). With respect to Seger's (1998) classification of the types of implicit learning tasks, this task involved a motor type of implicit learning, like the pursuit motor task or the serial reaction time task. These tasks

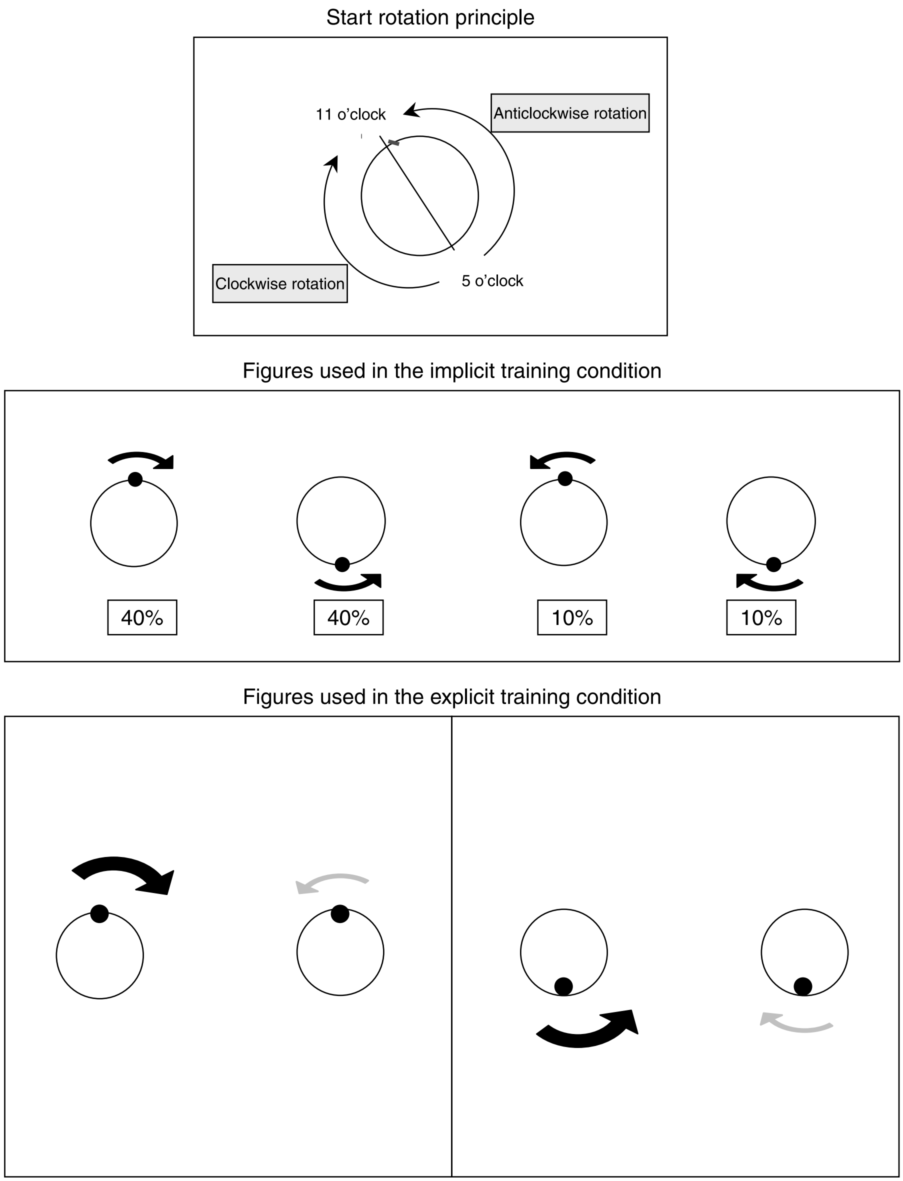

Figure 1. Illustrations of the start-rotation principle and the figures used in the training phases.

have in common that learning is assessed via motor response facilitation. However, our graphic task appears much easier than the serial reaction time task and, consequently, is particularly suitable for individuals with relatively severe intellectual disability. It has already been shown to be successful in revealing their sensitivity to the implicit learning processes (Detable & Vinter, 2004; Vinter & Detable, 2003). However, would children with DS learn as well following an explicit training? To develop a version of the task adapted to an explicit learning procedure, we 'translated' the drawing behaviour elicited under the implicit instructions into two explicit rules. Following Atwell *et al.* (2003), we expected, in children with DS, a greater impact of learning in the implicit than explicit condition. However, the superiority of implicit learning would be absent in typically developing children, because they would easily understand and memorize the simple rules taught in the explicit condition. Finally, following the testing phase, participants in the implicit learning condition were questioned about any explicit knowledge gained during the procedure. Similarly, participants in the explicit condition were questioned about their explicit memory of the rules they learned previously. Whatever the learning condition, we expected the level of explicit recollection of information or explicit memory for participants with DS to be inferior to that of controls.

Method

Participants

The final sample consisted of 28 right-handed children (13 females) with DS and 28 right-handed control children (14 females). The children with DS 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 IQs between 30 and 70. A larger number of children were actually recruited than were included in the analysis (DS children, N at outset = 32; controls, N at outset = 39). The selection was based on two criteria. First, we retained only participants who spontaneously applied the start-rotation principle in a minimum of 7 out of 12 cases in the tracing task they received before training. Four children with DS and five controls were not included in the study for this reason. Second, typically developing children were matched on mental age (MA) to children with DS. This criterion also resulted in some control children being left out, as detailed below. An assessment of MAs was made using a non-verbal test, the Kohs Block Design Test (Kohs, 1920; French adaptation, 1972). The choice for the matching strategy was based on an assessment of non-verbal performance, as both the implicit training task and the test consisted of mainly non-verbal components. The DS participants were aged between 7;9 and 13;7, with a mean age of 11;4. The controls were aged between 4;8 and 7;5 (mean age = 5; 11). None of the participants had a known secondary physical or sensory impairment. Parental consent was obtained for each child.

Both groups of children were divided into two learning groups, 14 children receiving implicit instructions and 14 explicit, in such a way that mean chronological age and mean MA were similar in both groups between the implicit and explicit learners. Furthermore, from the 39 control children initially tested, 28 were retained so that comparable mean MAs were obtained in the four subgroups of children (with or without

DS in the implicit or explicit learning condition). The main characteristics of the four subgroups are detailed in Table 1.

Table 1. Main participant characteristics by group (CA, chronological age (in years and months); MA, mental age (in years and months))

Group	*N*	IQ range mean (*SD*)	CA range mean (*SD*)	MA range mean (*SD*)	Gender (male) *N*
Children with DS					
Implicit learning	14	32–67 54.3 (9.1)	7;9–13;7 11.56 (2.6)	4;4–7;4 5.7 (1.9)	7
Explicit learning	14	36–66 53.9 (8.7)	8;1–13;6 11.16 (2.01)	4;9–7;3 5.6 (1.3)	8
Children without DS					
Implicit learning	14		4;10–7;5 6.0 (1.1)	5–7;7 6.0 (0.9)	7
Explicit learning	14		4;8–7;4 5.10 (1.2)	5–7;6 5.11 (0.88)	7

Materials

All of the measures were taken from the paper-and-pencil experimental tasks. To obtain an assessment of the spontaneous degree of the use of the start-rotation principle (baseline phase), we used a tracing task in which the participants were required to trace twice over six pre-printed circles of 1.6 cm diameter displayed inside a frame of 23 × 5 cm. A black point of 0.2 cm diameter indicating where to start tracing was located either at the top (12 o'clock) in half of the circles or at the bottom (6 o'clock) in the other half. In the training phase of the implicit task, the participants were asked to trace over a series of 20 pre-printed circles (diameter 1.6 cm) displayed inside four frames of 21 × 5 cm (five circles in each frame), with two frames per sheet of paper. Again, a black point indicated where to start (the same locations as in the baseline phase) together with an arrow of 1 cm in length, showing the direction of tracing (anticlockwise or clockwise). The arrow was displayed either 0.5 cm above the top starting-point or below the bottom starting-point.

In the training phase of the explicit task, the participants were explained the rules, using four pre-printed circles (1.6 cm diameter) displayed inside two frames of 12 × 9.5 cm (two circles in each frame). In one frame, the circles had a top located starting-point with either a 'big' arrow in black ink located 0.5 cm above the point, and showing the clockwise direction (a bold arrow of 1.6 cm in length, 0.2 cm in width), or a 'small' arrow in light grey ink (same location, anticlockwise direction), of 0.8 cm in length and 0.1 cm in width. In the other frame, the two circles were similar, but the starting-points were located at the bottom; the 'big' arrow indicated an anticlockwise direction, while the small arrow a clockwise direction. The differences of size and the intensity of colour of the arrows were intended to visually symbolize the 'most' and 'few' concepts used in the verbal instructions. These arrows and points provided important visuospatial cues to facilitate the understanding of the task instructions. The start-rotation principle (Figure 1, top) and the different figures used in the training phases are depicted in Figure 1. Finally, whatever the training phase, the material used in the test was similar to the one described for the baseline pre-test phase, except that the participants were required to trace once over 12 circles instead of twice over 6 circles.

Procedure

The entire experimental session comprises four phases: baseline (pre-test), training, test, and explicit questioning. A few days (between 6 and 9) separated the baseline phase from the training phase, while only 2–4 minutes separated the other phases from one another.

A tracing task over pre-printed circles was presented twice to the participants in the baseline phase, with a 1-day interval, to avoid the systematic repetition of similar types of movements as pointed out by Van Sommers (1984). The participants were told that the experimenter was interested in how accurate and fast they could be when they had to trace over circles in one single movement, starting at prescribed positions. In a preliminary warm-up task, they were invited to draw spontaneously circles of different sizes, starting from the top or the bottom. Then, they were required to trace twice, as accurately and as fast as possible, over six circles, three with a top and three with a bottom starting-point. They did not receive any instructions concerning the movement rotation except if they explicitly asked in which direction they should draw, in which case they were told that they could draw in the direction of their choice. The experimenter ensured that the participants started at the indicated position, and noted for each traced circle which movement direction they used. An assessment of the spontaneous adherence to the start-rotation principle was made after the second repetition of the tracing task. Only the children who applied the principle for at least 7 out of 12 circles were retained for the training phase. The Kohs Block Design Test was given to the participants during one of these two baseline periods.

In the implicit learning phase, children were required to trace over a series of 20 circles as accurately and as quickly as possible, starting at the indicated point and using the indicated movement direction. There were equal numbers of top/bottom starting-points and clockwise/anticlockwise directions, but these parameters were combined so that only 20% of the circles of the series were traced in conformity with the start-rotation principle, i.e. eight figures with a top start and clockwise rotation, eight with a bottom start and anticlockwise rotation, two with a top start and anticlockwise rotation, and two with a bottom start and clockwise rotation. The sequence of the various combinations of starting-point and rotation direction was random across the series.

In the explicit learning phase, children were told that the experimenter wanted to teach them 'how to draw nice circles', starting either at the top or at the bottom of the circle. They were presented with the four circles displaying a starting-point and big or small arrows to illustrate the rules (Figure 1). The two circles with the top start were shown first. The experimenter told participants that there was a rule for drawing the circle starting at the top such that a movement 'going like that' (clockwise – pointing to the circle with the big arrow) should be used most often, in most of the cases, and that the movement 'going like that' (anticlockwise – pointing to the circle with the small arrow) should be used less often, in few cases. Children had to repeat the rule, showing the corresponding illustration each time after the experimenter expressed it, indicating with the appropriate movement the rotation direction associated with, respectively, 'most often – most cases' or 'less often – few cases'. This scenario was repeated five times, and the participants had to demonstrate the rule on their own in the sixth trial. The experimenter then introduced the cases in which a circle started at the bottom, where the rule was ‘to go more often in that direction’ (anticlockwise – pointing to the circle with the big arrow) than ‘in that direction’ (clockwise – pointing to the circle with the small arrow). The scenario was identical to that used for top start circles.

The vocabulary used to express the meanings of ‘more often’ or ‘less often’ was varied (e.g. most cases, many times, a lot of times, much). To facilitate the children’s understanding of these terms, each learning session started with a short ‘game’ during which the experimenter tested whether the participants understood what ‘most’ or ‘few’ meant. Ten small plastic toys representing fruits were put on the table, and the experimenter told the children that she had decided to give them ‘most of the toys’ (she put eight toys in front of them) while she took ‘a few of them’ (two toys). She repeated this scenario twice, and then asked children to take ‘most of the toys’ and to give her ‘a few of them’. All children, regardless of intellectual disability, gave two toys to the experimenter and took the remaining ones. At the end of the training phase, the experimenter asked the children to recall the rules, with the help of illustrations showing a circle with a top start and a circle with a bottom start: ‘When you start at the top/bottom here, what should you do? Show me in what direction you trace most often/less often’. All children recalled the rules correctly.

A few minutes after the training phase, either implicit or explicit, the test phase was introduced to the participants. They were asked to trace over a series of 12 circles: 6 with a top start and 6 with a bottom start. The instructions on test were identical for both learning groups. They were told ‘to draw nice circles on their own, tracing as quickly and accurately as possible over pre-drawn circles, starting at the indicated starting-point’. Regardless of the learning condition, if the participants asked which movement direction to use, they were told that they should ‘do as they think for tracing nice circles as quickly and accurately as possible’. The direction of tracing selected by the participant for each circle was coded by the experimenter. Thus, their percentage of adherence to the principle after training could be assessed.

Finally, an explicit questioning phase followed, to assess whether any explicit knowledge had been gained from the implicit training or to assess explicit memory for rules. The implicit learners were given a forced-choice test in which they were asked to remember when they had traced over circles starting at the top (or the bottom) during the training phase. With regard to each location, they had to decide whether they had used mainly an anticlockwise or clockwise movement direction (these directions were illustrated by a hand movement). The explicit learners were also asked to remember the training phase, and to recall the rules they learned at this moment. We coded the number of correct responses between 0 and 2.

Results

We expected that both the implicit and explicit learning conditions would have an impact on the drawing behaviour of participants in this study, but with a differential effect on children with DS. We assessed compliance with the start-rotation principle at baseline and at test, and considered a change in performance to be an index of learning. However, the amount of change that was possible varied with initial compliance levels – the higher the level, the greater the possible amount of change. Consequently, because baseline performances covaried with the ability to exhibit learning in the task, we decided to treat the pre-learning score as a covariate and to run a Group (2) by Learning Condition (2) ANCOVA, with post-learning score as the dependent variable.

Learning Condition yielded a significant main effect. The degree of compliance with the principle at test remained higher after explicit (44.05%) than implicit learning (26.5%) ($F(1, 51) = 13.8$, $p < .01$). Regardless of learning condition, the adherence to the principle at test did not differentiate children with DS (36.9%) from typically developing children (33.6%) ($F < 1$). However, as shown in Figure 2, the Group × Learning Condition interaction was significant ($F(1, 51) = 5.2$, $p < .05$). The impact of training was similar in both groups after the implicit learning procedure, while the typically developing children learned more efficiently than children with DS following the explicit training condition. In children with DS, the effect of training was clearly larger after an implicit procedure than after an explicit one ($F(1, 25) = 21$, $p < .01$), though these children did show some learning after the explicit procedure, as demonstrated by the drop in the degree of compliance with the start-rotation principle between baseline and test. No difference between the training groups appeared in control children ($F(1, 25) < 1$, $p > .50$).

We looked for the correlations (Spearman rank correlations) between the impact of learning (the difference between the compliance with the principle in pre-test and the one in post-test for each participant) and mental age. None of the correlations computed in the implicit condition were significant (DS participants: $r = .08$, $t(12) < 1$, $p > .30$; non-DS participants: $r = .06$, $t(12) < 1$, $p > .30$). The impact of implicit learning did not vary as a function of mental age irrespective of the group. In contrast, explicit learning correlated significantly with mental age ($r = .56$, $t(26) = 3.5$, $p < .01$), and this correlation remained significant when computed only for the participants with DS ($r = .60$, $t(12) = 2.6$, $p < .05$). It was marginally significant for the typically developing children ($r = .49$, $t(12) = 1.95$, $p = .07$).

Explicit recollection of information and explicit memory

Regardless of the type of learning, participants received the same forced-choice explicit test at the end of the experimental session. In the case of implicit learning, the test investigated the explicit recollection of information the participants reported with

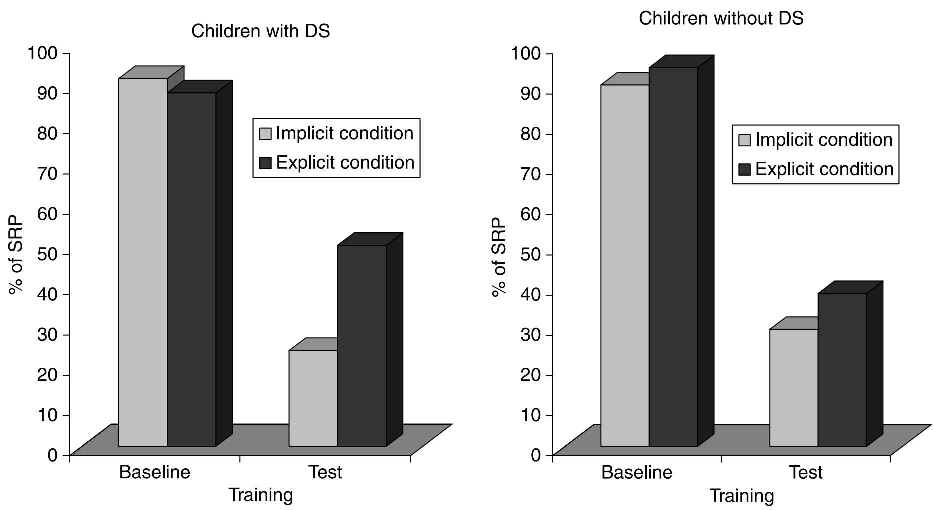

Figure 2. Percentage adherence to the start-rotation principle in the implicit and explicit learning conditions before (baseline) and after (test) training.

respect to the specific associations between the starting location and the rotation direction they experienced during training. In the case of explicit learning, the test assessed the degree of explicit memory of the rules participants displayed at the end of the experimental session.

An ANOVA was run with Group (2) and Learning Condition (2) as between-subjects factors on the memory score as the dependent variable. The results are shown in Figure 3.

The Group factor just reached significance. Children with DS achieved a lower level of explicit recollection of information (60.7%) than controls (73.2%) ($F(1, 52) = 3.7$, $p = .05$). Moreover, explicit knowledge resulting from a recording of the studied rules (75%) was higher than explicit knowledge issued from the implicit procedure (58.9%) ($F(1, 52) = 6.1$, $p < .05$). The Group × Learning Condition interaction was not significant ($F(1, 52) < 1$).

Finally, we checked whether these percentages of explicit remembering significantly departed from chance (50%). For the participants with DS, the scores in the implicit learning condition (53.6%) did not depart from chance ($t(13) = 0.56$, $p > .50$), but those in the explicit learning condition (67.8%) did reach significance ($t(13) = 2.7$, $p < .05$). For the typically developing children, the scores in the implicit learning condition (64.3%) differed significantly from chance ($t(13) = 2.3$, $p < .05$), as did those obtained in the explicit learning condition (82.1%) ($t(13) = 4.8$, $p < .01$).

Discussion

The present experiment compared the effects of implicit and explicit learning in children with and without DS. We selected the same task for both learning conditions, but modified the instructions given to the participants. We investigated, in a

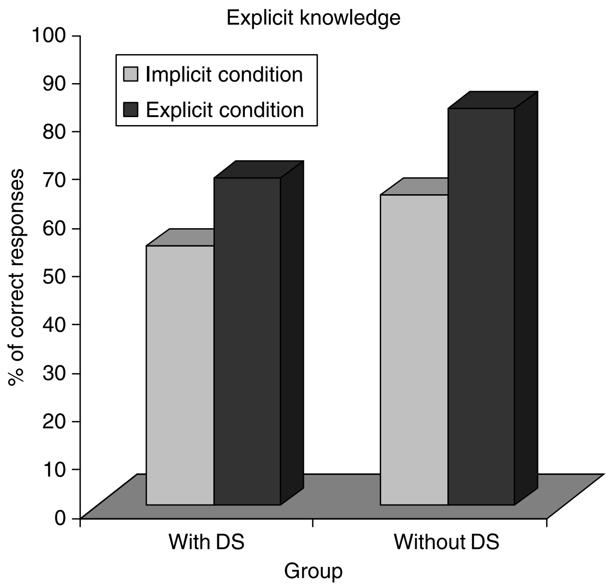

Figure 3. Percentage of correct explicit responses in the explicit test as a function of learning conditions.

post-experimental phase, the explicit knowledge gained or remembered by the participants about the training phase. We paid particular attention to checking children's understanding of the tasks, and to adding visuospatial cues (arrows, hand movements) each time verbal instructions were delivered. Finally, we focused on children with DS only, and did not merge different aetiologies of intellectual impairment. These features make our study original in regard to the literature.

Our results demonstrate that the implicit performance of children with DS did not differ from that of their controls, but that they learned less in an explicit learning context. These results are in line with those reported in the learning literature (Atwell *et al.*, 2003; Maybery *et al.*, 1995; McGeorge *et al.*, 1997; Myers & Conner, 1992; Reber *et al.*, 1991; Vinter & Detable, 2003), as well as in the memory literature (e.g. Burack & Zigler, 1990; Krinsky-McHale *et al.*, 2005; Perrig & Perrig, 1995; Vicari, 2001; Wyatt & Conners, 1998; Yeates & Enrile, 2005). Moreover, our results showed a greater impact of implicit learning than explicit learning in children with DS. Note, however, that Klinger and Dawson (2001) reported results that were at odds with these, showing that individuals with DS performed better in an explicit than implicit rule formation condition, while controls succeeded in both conditions. The reason for this divergence remains obscure to us. Superiority of an implicit over an explicit learning context in individuals with intellectual impairment, when an identical task was used, has been revealed in only one study to date, but with adults (Atwell *et al.*, 2003). Reber (1976) claimed that such a superiority would occur especially when the material structured by complex rules has to be processed. Surely, the explicit rules constituted more complex material for DS children than for controls. This is probably the reason why no superiority effect appeared in typically developing children. However, this claim has been challenged (e.g. Dienes *et al.*, 1991), and Gebauer and Mackintosh (2007) have shown that the relationships between the two types of learning are a function of the task. They are also a function of the subject's mental level, because complexity is a relative notion. The particular sensitivity of children with DS to the implicit learning procedure could be due to a global cognitive functioning in which an 'empirical' approach to tasks dominates (Wright *et al.*, 2006). It could also be argued that the quantity of motor practice involved in the implicit task was specifically favourable to a strong impact of the implicit learning procedure in these children.

To what extent these results could be generalized to children with learning difficulties, in general, requires further empirical investigation, as demonstration of differences in several cognitive domains between individuals with DS and individuals with Williams syndrome, for instance, urges to caution. Vicari (2001) has shown that young adults with DS performed as well as MA-matched controls in two implicit learning tasks (among which one was a serial reaction time task), but not in an explicit memory task. A reverse pattern of results was obtained when adolescents with Williams syndrome were compared with MA-matched controls. However, this is in contrast to the results of a more recent study, which revealed similar age- and IQ-related dissociations between implicit and explicit memory in middle-aged adults with Williams syndrome or with DS, while no age-related dissociation was observed in adults with unspecified intellectual impairment (Krinsky-McHale *et al.*, 2005). All these contradictions call for caution when accounting for results in this domain. Studies on implicit–explicit memory should not be confused with studies on implicit–explicit learning (Buchner & Wippich, 1998). When the implicit and explicit processes are compared, similar tasks should be used (Gebauer & Makintosh, 2007). When individuals with intellectual impairment are compared with controls, different aetiologies should be studied separately. Finally, as pointed out by Krinsky-McHale *et al.* (2005), age should also be taken into consideration. To date, the dissociation between implicit and explicit learning observed in our study in children with DS is echoed by the Atwell *et al.* study with adults with unspecified intellectual disability, and in the Gebauer and Mackintosh study with a large sample of typically developing children and adults.

However, concluding that individuals with DS have a specific impairment in explicit learning and not in implicit learning needs to be made with further caution, considering our results. The level of compliance with the start-rotation principle demonstrated by the children with DS after explicit training (49.9%) makes it difficult to completely rule out an alternative hypothesis, arguing that these children behaved at chance in the test, maybe because of a more global deficit in verbal abilities and despite the precautions we took in order to ensure children understood the task. We checked that these children did not systematically select the same movement direction across the 12 trials in the test, or did not systematically alternate between a clockwise and an anticlockwise movement, two behaviours that could reflect difficulties in understanding the task's instructions. A large number of children (19 out of 28) made explicit reference, on test, to what they had previously learned, acknowledging that they now knew 'how to draw nice circles on their own'. However, it could be suggested that the remaining nine children failed to recall the instructions delivered in the learning phase and, consequently, also failed to recall the associated procedure. They would maintain a high level of adherence to the principle at test, in contrast to those children retrieving explicitly the learning phase. To check for this potential bias, we compared the mean level of adherence to the principle at test achieved by the 19 children who explicitly referred to the learning phase (48%) to the mean percentage achieved by the 9 remaining children (52%). The difference was not significant ($t(26) = 0.76$, $p > .40$) demonstrating that the children's explicit retrieval of these instructions did not affect performance on the test. Moreover, a previous study using instructions that explicitly asked children to draw the circles, as they had previously learned, revealed similar results (Detable, 2003).[1] These arguments make the alternative hypothesis of a bias due to a specific verbal deficit rather unlikely.

Children with DS performed worse overall than the controls in the final explicit questioning phase that was devoted to the investigation of collected or remembered explicit knowledge about the associations between the starting-point locations and the rotation directions. Owing to their often mentioned difficulties in explicit information processing (e.g. Bebko & Luhaorg, 1998; Ellis, 1970), this result was expected. More interestingly, they were nevertheless better at remembering the associations learned in the explicit learning condition than at making explicit information about these

[1] *In a previous similar experiment, explicit instructions were used during testing, after the explicit training (Detable, 2003). The participants were told to use the rules that they had been taught during training. Note that in this experimental condition, participants with and without intellectual impairment demonstrated a decrease in the degree of compliance with the principle (they applied the principle in, respectively, 48% and 31% of the cases). However, it could be argued that assessing differences in what the explicit and implicit groups learned during training becomes difficult in this case, because it is hard to know whether they were due to what occurred during training or to what they were told during testing. Using explicit instructions after the implicit training was not convenient, because it would make it impossible to disentangle conscious influences exerted by the test instructions from unconscious influences issued from the implicit training (Vinter & Perruchet, 1999). In contrast, using implicit instructions after an explicit training was suited to our drawing task because, as the participants did not practice any drawings between the baseline phase and the test phase, if the systematic modifications of their behaviour appeared in the test, they would necessarily result from the training phase. The implicit instructions* per se *could not induce any change from the baseline condition. The instructions were most similar in baseline and test.*

associations as experienced in their tracing behaviour in the implicit learning condition. Only the former performance was above chance. By contrast, typically developing children performed above chance in both conditions. These results call for further discussion.

Children with DS succeeded in the recall test of the explicit learning condition, showing that differences between the explicit and implicit conditions cannot be attributed to flaws in the establishment of explicit learning. Although their performance was globally inferior to that of controls, they maintained in memory the results of their previous explicit learning, at least until the moment of the recall test (on average, 15 minutes after the end of the explicit training). The short duration that elapsed between learning and recall, together with the relative simplicity of the rules, can account for the good performance of the children with DS.

Accounting for the explicit judgments following the implicit learning procedure requires greater caution. Shanks and St. John (1994) have cogently argued that implicit learners may gain explicit knowledge from the training phase. This is in line with the theory developed by Perruchet and Vinter (2002) that implicit learning shapes an individual's phenomenal awareness, i.e. how the learning situation is perceived, such that associations between implicit performance and explicit awareness about the situation may emerge. As a matter of fact, in our study, controls performed at an above chance level of correct judgments about the recognition of the predominant associations between starting-point and movement rotation experienced during the implicit training period. However, children with DS failed to succeed on this test. How can we account for this result?

Our forced-choice explicit test relied on recognition, i.e. on deciding whether or not a given case has been encountered often during the training phase. As shown by Kinder, Shanks, Cock, and Tunney (2003), participants may use different strategies in this test. By default, they would use an analytic strategy based on the recollection of the episodic information contained in the previously experienced training phase, comparing each case presented at the moment of the test with prior experience. Such a strategy would require them to reflect upon whether a specific association between starting-point and movement rotation had already been encountered. As a consequence, participants' explicit judgments may be accurate or confused, complete or partial, depending on contextual factors. The first account of our results would suggest that this analytic strategy is impaired in children with DS, as supported by the literature describing the individuals with intellectual disability as processing information in a mainly non-analytic way (e.g. Belmont & Mitchell, 1987; Turnure, 1987). Kinder *et al.* (2003) showed that participants may switch to a non-analytic strategy, when using an analytic strategy turns out to be inefficient, and may process the 'familiarity' of the case presented at test. Such a strategy would require participants to reflect upon how 'familiar' to them is a specific association between the starting-point and the movement rotation. This process is very likely to be a basis for the establishment of the implicit learning (e.g. Johnstone & Shanks, 2001; Perruchet & Vinter, 2002; Servan-Schreiber & Anderson, 1990): as training progresses, the more frequently encountered case becomes more familiar than the others, and the participants develop a preference towards them. Thus, processing familiarity at the moment of the explicit test should also lead to accurate explicit judgments. A complementary account of our data would thus suggest that children with DS are impaired at switching strategies, when one is inefficient. This difficulty may come from impairments in executive functions (Pennington & Bennetto, 1998) or in metacognitive processing (Bebko & Luhoarg, 1998). Further research is needed to obtain better insights into these issues.

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