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SAGE Publications
and The National
Autistic Society
Vol 4(3) 299–320; 012607
1362-3613(200009)4:3

# Executive functioning and memory strategy use in children with autism

## The influence of task constraints on spontaneous rehearsal

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ABSTRACT An executive functioning deficit in autism should be reflected in a low level of active strategy use on memory tasks. This study was a direct examination of memory strategy use in two problem-solving situations by children with autism. Two groups with autism were tested, one high-functioning group and one with moderate cognitive impairments. All participants took part in two memory experiments to examine the effect of changing the nature of the learning situation on strategy use: one experiment used a serial recall task, and the other a recall readiness task. In contrast to previous studies, significant spontaneous strategy use was found on both memory tasks, particularly among the high-functioning group. Similarly, changing task structure was found to have an important impact on increasing strategy use, particularly for the moderate-functioning group. However, the overall rate of strategy use for the children with autism was still lower than would be expected for non-handicapped groups. The results support an executive functioning deficit interpretation, but a deficit that is less extensive among high-functioning individuals. Practical implications of the study in terms of cognitive training are also discussed.

KEYWORDS *autism; executive; high functioning; memory; strategy*

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Executive functioning impairments have been hypothesized as a fundamental deficit in the information processing skills of individuals with autism. A number of studies have supported this hypothesis, spanning a considerable age range from childhood to the adult years (e.g. Bennetto et al., 1996; Ozonoff and McEvoy, 1994; Prior and Hoffman, 1990; Rumsey and Hamburger, 1988). Such difficulties in executive functioning are often

neurologically associated with frontal lobe dysfunction, a view that has been supported by Bennetto et al. (1996).

Executive functioning refers to goal-directed behaviors that include activities such as selection of a cognitive strategy appropriate to a task, then monitoring, altering and evaluating the strategy's effectiveness during the task (e.g. Borkowski et al., 1984; Lawson, 1985). The use of memory strategies is one such goal-directed behavior, and it is critical for the cumulative development of an individual's knowledge base. That is, strategies ranging from simple to complex are essential for information in working memory to be processed further, such as for organizing information, or for the association of new information with previously learned information. Indeed, memory skills are one of the more frequently studied aspects of cognitive functioning involving executive skills, and memory strategy use should be generally impaired if there is an executive functioning deficit in autism.

A variety of memory skills have been studied in populations with autism. However, most studies have tended to focus on output measures (e.g. recall, recognition) in an effort to describe memory performance abilities and limitations (e.g. Boucher, 1981a; 1981b; Boucher and Warrington, 1976; Prior and Chen, 1976). Few have looked at the development of strategies in these children, or have examined the processes or mechanisms involved in the emergence of these strategies.

While overall memory performance may be generally lower in individuals with autism than for non-handicapped peers, less impaired areas have also been identified intermittently over the years. Areas of lesser impairment have included rote memory skills, memory for immediate or short-term recall, acoustic memory, echoic memory, and performance on tasks that benefit from cues generated by others. Results are mixed on tasks that require the utilization of meaningful, contextual variables to improve performance.

By comparison, some of the more significant difficulties individuals with autism display on memory tasks have included: low free recall on supraspan tasks, difficulty with memory for recent events and poor recall of temporal order information on verbal tasks (see Bennetto et al., 1996 and others for reviews of these literatures).

Interestingly, memory skills in these areas of greater difficulty may be enhanced by the use of active acquisition strategies to help the child process the relevant information prior to recall. The self-generation of such strategies is one aspect of executive functioning, and non-handicapped children frequently generate them. In contrast, since some of the earliest memory research in autism (e.g. Hermelin and O'Connor, 1970), as well as in more recent work (Bennetto et al., 1996), it has been suggested that children

with autism are not active strategy users. However, strategy use has typically not been directly investigated in these studies; instead it has been indirectly inferred from children's recall or recognition performance. In the present study, we directly examine processing strategies used by participants during the initial acquisition of information in two learning situations. Of particular interest was the strategy of rehearsal.

Rehearsal is one of the most extensively investigated of the basic memory strategies. It has been found to be used spontaneously and effectively by a majority of young non-handicapped children as early as 6 years of age (e.g. Bebko, 1984; Kail, 1990). Rehearsal involves the repetition of stimuli during and after presentation, several times in order until recall. For example, if pictures of a ball, a cup and a sock are shown one at time, a rehearsing child repeats until recall: 'ball, cup sock; ball, cup, sock; ball, cup, sock'. Rehearsal develops early and is useful in a variety of contexts, particularly when information is recent and must be remembered in order, two areas noted above where memory deficits have been identified in autism. It is a language-based strategy, typically involving verbal repetition (or manuals signs: Bebko, 1984; Bebko and McKinnon, 1990). Thus, improvements in rehearsal strategy use have been found to be more likely as the child's language proficiency develops (Bebko et al., 1998).

A number of researchers have consistently replicated the developmental trend in rehearsal use, with younger children being more passive, and older children (i.e. 6 years and older) being more active in initiating the strategy, and tailoring their strategy use to the demands of the particular task. Rehearsal use has also been investigated in children with a variety of developmental challenges, including cognitive impairment (e.g. Bebko and Luhaorg, 1998), learning disabilities (Torgesen, 1977) and deafness (Bebko et al., 1998). While rehearsal use has been found with these populations, the strategy may be slower to emerge spontaneously or be used less systematically, commonly resulting in overall performance deficits. In addition, executive functioning impairments have been directly or indirectly linked with the rehearsal strategy difficulties of these groups. However, rehearsal use has yet to be systematically investigated in autism. (For more extensive reviews of the development of memory strategies, including rehearsal, see Bebko and Luhaorg, 1998; Bjorklund, 1990.)

In summary, the present experiments were designed to examine directly rehearsal strategy use in children with autism. Specifically, we were interested in whether or not memory strategies would be generated spontaneously, the effects of strategy use on performance, and the role of task conditions in eliciting greater strategy use. The serial recall task used in experiment 1 requires the ordered recall of new information, which has been identified as a task on which children with autism have difficulty, and

one that could benefit from the use of a goal-directed rehearsal or other strategy. Therefore, if an executive functioning deficit is a central characteristic of autism, then no or ineffective rehearsal strategy use would be expected. To the extent that executive functioning skills are intact, greater strategy use is expected to be observed on this task.

A recall readiness task was used in experiment 2 to examine the effect of manipulating task variables that are assumed to impact positively on executive functioning. Therefore, increased strategy use was expected to be seen on the recall readiness task. On both tasks, rehearsal strategy users were anticipated to have higher recall scores than children who did not rehearse.

## Experiment 1

### Method

**Participants** Two samples of children and adolescents with autism were tested, as well as a normally developing comparison group. One of the autism samples consisted of a group of high-functioning children. The second sample was of children with autism plus mild to moderate intellectual impairments, who were tested to improve precision of the findings, since functional intellectual impairments have been identified as co-occurring in a majority of children with autism (Rutter, 1983). Composition of the two groups was based on the nature of the child's school program, and on the results of diagnoses and standardized testing conducted previously in the participants' schools or clinics.

The high-functioning group was 11 boys, with verbal IQ (VIQ) >70, a mean verbal mental age (VMA) of 9 years 6 months (range 5:11 to 14:11) and a mean CA of 9 years 7 months (range 6:3 to 12:9). Three met the DSM-IV criteria for Asperger syndrome. The others had been diagnosed with autism (five) or 'a PDD' (three).

The moderate-functioning group was 11 boys, with VIQ 40–70 ($\pm$ 2 to allow for the standard error of measurement of the tests) and VMA >4 years. The mean VMA for this group was 6 years 7 months (range 4:2 to 9:5) and the mean CA was 11 years 8 months (range 7:10 to 16:7). All met the DSM-IV diagnostic criteria for autism or PDD-NOS with associated intellectual impairment.

Since a key expectation was the possibility of little strategy use by the groups with autism, particularly the moderate group, a group of non-clinical children was included to ensure that the adapted procedures were comparable with previous studies, and did not inadvertently inhibit rehearsal. This group was selected to be in an age range at which an approximately equal number of spontaneous rehearsers and non-rehearsers were expected, and

to be approximately comparable with, or to somewhat underestimate, the verbal mental age of the moderate-functioning autism group, assuming a normal distribution of intelligence and language skills among the normally developing children. Any underestimation may, if anything, reasonably be assumed to work to the advantage of the moderate autism group in terms of their verbal skills. Therefore, this typically developing group was 11 boys from regular public schools, with no identified behavioral or medical problems, and with a mean age of 6 years 0 months (range 4:5 to 7:4).

English was the first language of participants in all groups. (See Table 1 for a summary of characteristics of the samples.)

**Materials and procedure** A portable camcorder with a tripod was used to record the participants' behavior during testing, and a stopwatch was used to ensure that the delays between stimulus displays and responses were consistent. Given that language is one of the central difficulties in children with autism (Olley, 1992), the serial recall task was modified, and instructions were given both verbally and non-verbally by gesture and demonstration. The task was practiced to a criterion of success to demonstrate understanding of the procedures before test trials were given.

The stimuli were 6 × 8 cm pictures of common objects (e.g. apple, coat, spoon) mounted on 6 × 10 cm white cards. There was one picture per card, and a total of 12 stimulus cards. For every stimulus card there was an identical response card, yielding a total of 24 cards (two of each picture). The child received two blocks of three trials, each block consisting of one trial each of sequence lengths three, four and five pictures. Sequences were random selections of pictures, with the exception that no picture occurred more than once in any given sequence, and no sequence occurred more than once across trials. Varying sequence lengths were used to maintain interest and limit potential ceiling effects in performance.

The general procedure for this task was adapted from Bebko (1984). First, participants were asked to label all of the stimulus cards to verify that they were familiar objects. The response cards were then placed in front of the child and covered with a large piece of blank Bristol board. The experimenter explained and demonstrated that the child would be shown some pictures and then asked to remember them in the same order that they had been presented. These stimulus cards were shown to the child, one at a time, for 3 seconds each, and then placed face down from the child's left to right. Following the last stimulus card there was a 15 second delay and then the response cards were uncovered for recall. The child was asked to match response cards to the corresponding face-down stimulus cards. Following each trial, the response cards were returned to the array and covered. Children were given positive verbal feedback for completing the task.

***Table 1*** **Summary of characteristics of the participants in the two experiments[a]**

| *Group* | *N* | *Males, females* | *Chronological age (CA) (years:months)* | | *Verbal mental age (VMA) (years:months)* | |
|---|---|---|---|---|---|---|
| | | | *Mean* | *Range* | *Mean* | *Range* |
| *Autism groups* | | | | | | |
| High autism | 11 | 11, 0 | 9:7 | 6:3–12:9 | 9:6 | 5:11–14:11 |
| Moderate autism | 11 | 11, 0 | 11:8 | 7:10–16:7 | 6:7 | 4:2–9:5 |
| *Normally developing groups* | | | | | | |
| Experiment 1 | 11 | 11, 0 | 6:0 | 4:5–7:4 | 6:0 | 4:5–7:4 |
| Experiment 2 | 11 | 10, 1 | 5:7 | 4:5–6:7 | 5:7 | 4:5–6:7 |

[a] Estimates derived from the assumption of a normal distribution of intellectual and language skills (see text).

Participants were given up to eight familiarization trials using different stimuli (colors) prior to the data trials. Once a child demonstrated understanding of the task by meeting a practice criterion of two trials with at least two correct responses, the data trials began, as described above. None of the children in the samples failed to meet the criterion.

During the presentation of the stimuli and the 15 second delay periods, the child's behavior was carefully observed and any indication of overt cumulative rehearsal was recorded. During the course of the six trials, each child was asked whether any 'memory tricks' had been used to help remember the information (see classification criteria below).

**Scoring** Using the videotapes and detailed response sheets, the following dependent variables were obtained for each subject.

The first was *serial recall score*, i.e. the overall number of items recalled in their correct serial positions, representing an index of the child's memory performance (maximum across trials = 24). Scores were translated into proportions for analyses.

The second was *rehearser classification*. Each child was identified as a spontaneous rehearser or non-rehearser based on observations of overt rehearsal or from a verbal report of rehearsal. Overt signs of cumulative rehearsal included verbal rehearsal (e.g. saying 'apple, ball, shoes; apple, ball shoes . . .'), or recognizable lip or rhythmic body movements directed towards the stimuli (pointing a finger at the stimuli in sequence, rhythmic head or eye movements). If any of these behaviors were observed on a minimum of two trials, then the child was classified as a rehearser. As in previous studies (e.g. Bebko, 1979; 1984; Bebko et al., 1998; Flavell, 1970), two trials was used as a cutoff to ensure that classification was based on a consistent use of rehearsal and not a transitory use on a single trial. In cases where identification of rehearsal was based on observation of rhythmic body movements, corroboration of rehearsal was sought from evidence of a primacy effect in the serial position curves for the child. A primacy effect was indicated by elevated recall performance on the first items relative to the middle items in a sequence.

In addition to exhibiting overt rehearsal behaviors, many children in previous studies with the serial recall paradigm have been found to be covert rehearsers: that is, they manifested few outward signs of rehearsal, but reported having used rehearsal internally when asked (e.g. Bebko, 1984; Oyen and Bebko, 1996). Therefore, in addition to overt rehearsal behaviors on the serial recall task, participants who indicated clear 'memory tricks' (strategies) in response to our question were also identified as rehearsers. Non-ambiguous answers such as, 'I said the pictures over and over in my head', were considered evidence of cumulative rehearsal. Ambiguous

answers were followed with up to two neutral prompts for additional information (e.g. 'What if I showed three pictures, say: chair, hands and spoon?'). Such verbal reports were not required for classification as a rehearser. The assumption was that if the child could report having used the strategy, that report is as significant as the behavioral observations. Therefore, verbal reports were used not as a necessary criterion, but rather as a sufficient inclusionary criterion. In summary, a child was classed as a non-rehearser on the serial recall task unless one of two conditions were satisfied: behavioral observations of strategic behavior on at least two trials, supplemented by evidence of a primacy effect when needed; or verbal reports of rehearsal strategy use.

**Reliability** Two raters independently classified each of the children as a rehearser (strategy user) or non-rehearser (non-strategy user) to evaluate reliability of classification. Inter-rater agreement was 96 percent. The few discrepancies were solved by discussion, until a mutual agreement on classification was obtained.

## Results

To evaluate the comparability of the adapted task to other studies using similar paradigms, the results for the non-handicapped groups are briefly examined first. As is apparent in the bottom of Table 2, a wide range of potentially strategic behaviors were observed (these will be discussed further when the results for the autism groups are presented), and two children reported having used rehearsal. As described in detail earlier, if rehearsal-related behavior was observed on at least two trials (or if rehearsal was reported) the participant was classified as a rehearser. More than half the children in the normally developing group (73 percent) were classified as spontaneous rehearsers, which is similar to previous studies. As expected, children who were rehearsing recalled significantly more information than non-rehearsers (Table 3), $F(1, 9) = 18.36$, $p = 0.002$. Having established that the minor modifications of procedures for the serial recall task used in this experiment were not more inhibitory with regard to strategy use than procedures used in previous studies, we next examined the results for the groups with autism.

The procedures, themselves, appeared to be equally engaging for the children with autism. No participant was unable to meet the practice criterion, little difficulty was noted on either task, and most participants appeared to enjoy the tasks. The variety of potentially strategic behaviors observed during stimulus presentation and the delay period are summarized in Table 2. The pre-rehearsal strategy of labeling was the most frequent strategy observed among the autism groups, followed by cumulative

*Table 2* **Frequency of verbal reports and range of behaviors observed on more than one trial across the two experiments**[a]

**Experiment 1: serial recall task**

| | *Pre-rehearsal behaviors* | | *Rehearsal behaviors* | | | |
|---|---|---|---|---|---|---|
| | *Labeling* | *Repetitive labeling* | *Rhythmic body movements* | *Lip movements* | *Cumulative rehearsal* | *Verbal report* |
| *Autism groups* | | | | | | |
| Moderate autism | 9/11 | 1/11 | 0/11 | 0/11 | 1/11 | 0/11 |
| High autism | 11/11 | 0/11 | 4/11 | 0/11 | 4/11 | 2/11 |
| *Normally developing groups* | | | | | | |
| Experiment 1 | 11/11 | 1/11 | 3/11 | 4/11 | 3/11 | 2/11 |
| Experiment 2 | 9/11 | 1/11 | 0/11 | 0/11 | 1/11 | 0/11 |

**Experiment 2: recall readiness task**

| | *Self-testing* | *Pre-rehearsal behaviors* | | *Rehearsal behaviors* | | | |
|---|---|---|---|---|---|---|---|
| | | *Labeling* | *Repetitive labeling* | *Rhythmic body movements* | *Lip movements* | *Cumulative rehearsal* | *Sequential door openings* |
| *Autism groups* | | | | | | | |
| Moderate autism | 0/11 | 8/11 | 1/11 | 0/11 | 0/11 | 0/11 | 5/11 |
| High autism | 1/11 | 7/11 | 0/11 | 3/11 | 0/11 | 3/11 | 4/11 |
| *Normally developing groups* | | | | | | | |
| Experiment 1 | 1/11 | 6/11 | 0/11 | 2/11 | 1/11 | 2/11 | 3/11 |
| Experiment 2 | 0/11 | 7/11 | 0/11 | 0/11 | 1/11 | 2/11 | 5/11 |

[a] The normally developing group from experiment 1 was not a part of experiment 2; data are presented for completeness only.

***Table 3*** **Mean proportion of items recalled in correct serial position by group and rehearser classification[a]**

| *Group* | | | *Experiment 1: serial recall* | *Experiment 2: recall readiness* |
|---|---|---|---|---|
| *Autism groups* | | | | |
| High autism | Rehearsers | mean (SD) | 0.82 (0.18) | 0.64 (0.13) |
| | | *n* (%) | 7 (63) | 9 (82) |
| | Non-rehearsers | mean (SD) | 0.45 (0.21) | 0.40 (0.21) |
| | | *n* (%) | 4 (37) | 2 (18) |
| Moderate autism | Rehearsers | mean (SD) | 0.67 (0) | 0.46 (0.14) |
| | | *n* (%) | 1 (9) | 7 (64) |
| | Non-rehearsers | mean (SD) | 0.32 (0.21) | 0.16 (0.13) |
| | | *n* (%) | 10 (91) | 4 (36) |
| *Normally developing groups* | | | | |
| Experiment 1 | Rehearsers | mean (SD) | 0.78 (0.09) | 0.60 (0.20) |
| | | *n* (%) | 8 (73) | 7 (64) |
| | Non-rehearsers | mean (SD) | 0.47 (0.15) | 0.30 (0.11) |
| | | *n* (%) | 3 (27) | 4 (36) |
| Experiment 2 | Rehearsers | mean (SD) | 0.67 (0) | 0.53 (0.23) |
| | | *n* (%) | 1 (9) | 8 (73) |
| | Non-rehearsers | mean (SD) | 0.56 (0.16) | 0.40 (0.17) |
| | | *n* (%) | 10 (91) | 3 (27) |

[a] The normally developing group from experiment 1 was not a part of experiment 2; data are presented for completeness only.

rehearsal and rhythmic body movements. Only two participants (out of 22) showed no evidence of potentially strategic behaviors, and both were in the moderate-functioning autism group.

More than half of the children in the high autism group (64 percent) were identified as spontaneous rehearsers, which represents a highly significant finding in comparison with previous research (Table 3). Evidence for rehearsal came from a considerable variety of behaviors, as well as verbal reports by two participants. While the majority in this sample were rehearsers, and the mean age of the sample (both CA and VMA over 9 years) is beyond the age at which normally developing children are typically all rehearsing (usually by 6 years of age), there were still a number of children not spontaneously rehearsing. These non-rehearsers tended to be among the younger children in this group, although all but one had a CA of 7 years or older, and their mean VMA was 8.37 years. While the sample size is limited, these findings represent an apparent delay of one to several years in the emergence of spontaneous rehearsal use compared with findings with children without autism (e.g. Bebko, 1979; Flavell et al., 1966).

By comparison, in the present study a similar rate of rehearsal classification was seen in the non-handicapped group, although their mean age was a considerably younger 6.0 years.

In contrast to the high-functioning group, in the moderate-functioning autism group there was only one consistent rehearser on the serial recall task (VMA = 5.92 years). This difference in the rate of rehearsal use between the two samples with autism is significant, as indicated by a significant non-parametric test of independence, $\chi^2(1) = 7.07$, $p = 0.0078$.

In order to evaluate the efficacy of the rehearsal strategies being used on this task, the recall performance of the rehearsers and non-rehearsers (see Table 3) was compared. A 2 × 2 (rehearser/non-rehearser × high/moderate functioning) ANOVA revealed that rehearsers recalled significantly more than non-rehearsers, as hypothesized, $F(1, 21) = 8.64$, $p = 0.009$. An absence of a significant group main effect or an interaction (both $F < 1.4$; $p > 0.25$) indicates that the same relation holds for the high- and moderate-functioning groups, although the data for the moderate-functioning sample rehearsers must be interpreted with caution, as they are based on only one child. However, his level of recall is well within the range of the distribution of the recall scores for the high-functioning group (i.e. it is within one SD of their mean), and it is double the level of the non-rehearsers in the moderate sample.

## Discussion

The primary focus of this study was an examination of the use of a common memory strategy, cumulative rehearsal, by individuals with autism as a means of studying executive functioning. Since a hypothesized executive functioning deficit in autism should affect all strategies involving executive components, we expected to find reduced or no strategy use among the samples with autism, but considerable rehearsal use among the non-handicapped group on our task involving the ordered recall of information. These hypotheses were essentially supported, though not unequivocally for both groups.

The key question of interest was concerned with the rate of strategic rehearsal use among the samples with autism, when strategy use is assessed during presentation of the information – that is, prior to and independent of recall. The secondary question was the subsequent effect of rehearsal in recall. The finding of considerable spontaneous strategy use on these tasks, particularly among the high-functioning group, is important, as it is among the first direct evidence of active and effective strategic behavior on memory tasks in children with autism. In contrast to tasks on which participants have been assisted by strategies provided by others (e.g. retrieval strategies in cued recall: Bennetto et al., 1996; Boucher and Warrington,

1976; Tager-Flusberg, 1991), these individuals were spontaneously producing a simple, but appropriate, strategy to aid their own recall.

The finding of significant strategy use among the majority of the high-functioning group tends not to support the notion of a universal executive functioning deficit among this group. However, there are indications of at least weak executive skills among this group. For example, while the extent of rehearsal found for this group overall may be notable, the absolute level of rehearsal use was less than would be expected among normally developing peers of the same chronological age range (or verbal mental age range). A number of studies have shown that by the age of 6–7 years, well below the mean age of our autism samples, virtually all normally developing children are using rehearsal spontaneously (e.g. Bebko, 1979; 1984; Flavell et al., 1966). Among our high-functioning sample, while the youngest child was a non-rehearser, other non-rehearsers ranged up to 9 years of age (both chronological age and VMA), indicating that for some of these children, at least, strategy use is not a fluent process.

Overall, then, this combination of results for the higher-functioning group provides only weak support for executive functioning difficulties on cognitive activities that benefit from a basic memory strategy. The results appear to support more strongly a delay in the development of these executive skills, and a corresponding delay in strategy use, at least for the high-functioning group.

The findings for the moderate-functioning group represent much stronger support for a potential executive functioning deficit. This is reflected in the very low rate of rehearsal strategy use in the serial recall condition. The common pre-strategic behavior (i.e. a behavior not associated with improved recall) of labeling the individual stimuli on presentation was observed at a high rate in this group. Thus, the stimulus labels were available to the participants for rehearsal. However, this did not appear to lead to subsequent systematic strategic activity.

To examine further the contribution of a potential executive functioning deficit to performance in this type of task, a second study was conducted. In experiment 2, task variables were manipulated in ways that should externally support executive skills, which should, in turn, lead to more strategy use among our samples of children.

## Experiment 2

Rehearsal use in children who are not yet strategy users, or in others who are inefficient strategy users, has been shown to be increased when the conditions for strategy use are particularly supportive. These conditions include few constraints on study behavior, a careful explanation of the task

requirements, extensive practice, and slow presentation with relatively few items (e.g. Flavell et al., 1970; Turner and Bray, 1985). While our serial recall task in experiment 1 included the latter three conditions, there were constraints on the study behavior of participants implicit in the timed presentation of the stimuli and a fixed delay period prior to recall.

Flavell et al. (1970) and Turner and Bray (1985) demonstrated the effectiveness of relaxing constraints during presentation in a 'recall readiness task'. The unique feature of this task is that participants have greater control of the learning situation and are allowed to re-present single items to themselves in any order and as many times as they wish. For both very young children (Flavell et al.) and older adolescents with cognitive impairments (Turner and Bray), many individuals who are usually non-strategic on serial recall tasks show spontaneous strategy use when the task conditions are thus optimized. One advantage of these modified conditions is that they enable participants to externalize many of the component executive skills that are ordinarily required to be done internally to maintain effective strategy use. As a result, there is an assumed reduction in the internal cognitive demand of executing the strategy while the stimuli must simultaneously be retained in memory. Participants in both studies were observed to be more deliberate in studying the stimuli, to review information that might be forgotten, and to self-test their readiness to recall. These types of study behaviors have all been identified as component executive skills (Borkowski et al., 1984; Lawson, 1985). A recall readiness task was therefore used in experiment 2, with the expectation that increased strategy use would be observed in all groups.

## Method

**Participants** The two autism samples tested here were the same children as those tested in experiment 1. However, a new sample of normally developing children was tested. Because of the high incidence of rehearsal use among the normally developing children in experiment 1, potentially significant increases in rehearsal frequency would not have been observable in these children on the recall readiness task. (Note that the data are provided for this group in Table 2 for completeness, and demonstrate this 'ceiling effect'.)

Therefore, a new sample of normally developing children was constructed to validate the adapted recall readiness procedures. A pool of potential participants for the new group was first tested on the serial recall task of experiment 1. Then the sample was selected to match the rehearsal performance of the moderate-functioning autism sample on the serial recall task, while retaining comparability or underestimation in mean verbal

mental age. Therefore, the second normally developing group was constructed of 11 children with a mean age (and assumed verbal mental age) of 5 years 7 months (range 4:5 to 6:7). All met the same criteria as the first comparison group, with the exception that there were 10 boys and one girl in this sample, as there were not a sufficient number of boys in the pool of subjects in the appropriate age range who were non-rehearsers. In addition, previous studies have shown no significant gender differences on this task (e.g. Bebko, 1979; 1984).

**Materials and procedure** A 48 × 16 cm display board, specially constructed for this study, was used to present the stimulus pictures. The display board had six rectangular windows (6 × 8 cm, corresponding to the size of the stimulus pictures) in a single horizontal row, with each window 2 cm apart. Each window was covered by a door, hinged at the top, with a small handle. At the back of the box, there was a slot to hold a strip of Bristol board on which six stimuli were mounted.

Copies of the pictures used in experiment 1 were randomly chosen to construct four sequences of six stimuli, which remained constant for each participant. No picture occurred more than once on any given trial, and no combinations on two successive trials were the same. Duplicate individual picture cards were used as response cards.

After a stimulus card was inserted into the display board, the experimenter demonstrated the task and told the child that there were pictures behind the doors of the display board and that they could be looked at, in any order, as often and for as long as desired. The goal was to remember all of the pictures in their correct sequence. The task began with up to eight familiarization trials, using different stimuli from the test trials. The criterion for proceeding to the test trials was correctly matching a total of four stimuli across two trials. The child was instructed to inform the experimenter when ready to match the response cards to the stimulus cards. The response cards were immediately uncovered and the child was asked to place the correct response cards in front of the corresponding doors of the display box. Once all of the cards had been placed, the doors of the apparatus were lifted to show the child how many correct matches had been made. The child's responses and any evidence of strategic behavior were recorded.

**Scoring** Using videotapes and detailed response sheets, serial recall scores and rehearsal classification were the dependent variables obtained for each participant, as in experiment 1, with two differences. Verbal reports were not used for the recall readiness task because, during pretesting, the children consistently referred in their reports to their observable behaviors (e.g.

'I'm pointing' or 'I'm opening the doors in order'). However, an additional behavioral indicator was recorded: the child's pattern of door openings. The sequential opening of the doors at least twice in the same order was considered evidence of cumulative rehearsal. Observation of any of the indicators outlined for the task in experiment 1, then, or a sequential pattern of door openings, on two or more trials were used to classify a child as a rehearser on the recall readiness task.

**Reliability** Inter-rater reliability was calculated by having two raters independently classify each of the children as a rehearser (strategy user) or non-rehearser (non-strategy user). Agreement was 91 percent (30 of 33 participants). The few discrepancies were resolved by discussion, until a mutual agreement on classification was obtained.

## Results

The data from the normally developing sample were examined first to establish the comparability of the procedures used here to previous research. As expected, significantly more potential rehearsal behaviors were seen on the recall readiness task in comparison to their low rate of activity on the serial recall task (see the last row in the two panels of Table 2). Whereas labeling had been the main activity observed on the first task, this was supplemented by patterns of sequential door openings, as well as other behaviors.

The 700 percent increase (from one to eight) in the number of children identified as rehearsers was significant ($p < 0.05$), based on a paired McNemar non-parametric analysis for repeated measures (see 'experiment 2' rows of Table 3). Rehearsers recalled more than non-rehearsers (0.53 v. 0.40), although the difference was not statistically significant, $F(1, 9) = 1.304$, $p = 0.283$. These results indicate that, as expected, the recall readiness task is effective at eliciting greater rehearsal strategy use among young normally developing children who may not otherwise be spontaneous strategy users.

Results for the groups with autism were generally quite similar. Changing the nature of the task to the recall readiness procedures resulted in an increase in rehearsal use among the children with autism (see the rightmost column of Table 3). On this task, 82 percent of the children (9/11) in the high-functioning autism group were identified as rehearsers. While an important finding, this increase is not significant statistically since most of the children in the group were already rehearsing on the serial recall task. However, the increase (from one to seven) in the moderate autism group is significant, $p < 0.031$. A comparison of the number of high versus moderate children now classed as rehearsers indicated a non-significant

difference for experiment 2, $\chi^2(1) = 917$, $p = 0.338$. These findings provide support for the hypothesis that changing task constraints can have an important impact on strategy use in children with autism as well as normally developing children.

Finally, when recall performance in this task was examined in a 2 × 2 (rehearser/non-rehearser × high/moderate functioning) ANOVA, rehearsers were found to have recalled significantly more than non-rehearsers, as expected, $F(1, 21) = 15.74$, $p = 0.001$. However, there was also a significant main effect for group, with the moderate group of rehearsers recalling less than the high-functioning group, $F(1, 21) = 8.97$, $p = 0.008$. The interaction was non-significant.

## Discussion

The purpose of experiment 2 was to evaluate whether changing the nature of the memory recall task, i.e. creating a more supportive environment, would affect rehearsal behavior in children with autism. In the recall readiness paradigm, task variables were made less constrained, by giving control of learning, such as speed of presentation and number of viewings of items, to the participants. For both the normally developing group and the moderate-functioning autism group, both of whom were generally non-strategic in the serial recall task, the recall readiness paradigm appeared to be sufficient to elicit greater strategy use.

Many of the supported activities in this task are component executive skills involved in the maintenance of effective strategy use: monitoring the use of the strategy, evaluating its effectiveness, and determining when it has been used long enough. The provision of a supportive environment for these activities may have its impact by effectively reducing the demand on the child's internal processing resources. That is, the sum of the combined mental effort of the executive activities involved in implementing the strategies entirely internally, plus the mental effort required to retain in memory the actual information to be recalled, becomes lower by externally supporting some of the executive activities. Reducing the mental effort of the task frees up some of those resources that presumably are then available for the concurrent storage of the information to be remembered. Similar arguments on reduction in mental effort have been advanced previously for other populations with respect to the emergence of rehearsal, such as in Guttentag (1984), Bebko (1998), Bebko and Metcalfe-Haggert (1997) and Bebko and Luhaorg (1998).

## General discussion

Strategy use in children with autism was examined in these two experiments as a means to further understand the executive skills and difficulties of this group. Overall, we found that children with autism do use rehearsal strategies on tasks involving the ordered recall of information, although at a lower rate than their normally developing peers, and that this is more likely to be the case when task conditions are supportive. Furthermore, while the emergence of rehearsal may be at least delayed, once rehearsal is used, the strategy appeared to be effective in supporting accurate recall, in particular among the high autism group.

Evidence for the effectiveness of these strategies is that rehearsers recalled significantly more information than non-rehearsers in both groups of children with autism, and in both experiments. The recall levels for the high-functioning rehearsers on the serial recall task (experiment 1) compare favorably with the recall of rehearsing children in other studies (Bebko, 1984; Bebko et al., 1998). As well, they are comparable with the recall for the comparison groups in the study, who, while they were several years younger, were rehearsing at a similar rate. These data indicate that the rehearsers in the high-functioning autism sample are at a relatively mature stage in the use of this most fundamental of strategies. However, the presence of a number of non-rehearsers in this sample, and the mean VMA greater than 8 years of age, also provide evidence for at least a delay or a qualitative difference in the development of executive functioning skills. This is consistent with other research with high-functioning groups that has reported differences in executive skills, but not necessarily a complete deficit.

The recall performance results for the children in the moderate-functioning group are more complex. Their results in experiment 1 are typical of a general 'production deficiency' (Flavell et al., 1966). That is, there is little evidence of a strategy being produced, and there are correspondingly low levels of recall. In experiment 2, the recall readiness task was successful in eliciting greater strategy use, and rehearsers recalled more than non-rehearsers did.

Going beyond these initial findings, comparing the results of the two experiments presents an interesting pattern. Recall on the serial recall and recall readiness tasks cannot be compared directly since they were based on two different paradigms and different numbers of stimuli per trial. However, if an executive functioning difficulty characterizes at least some children with autism, it should be seen most clearly in the recall of the children in the moderate-functioning group, who, with one exception, are rehearsers only when the task variables are made more supportive. That is,

their executive skills appear to require the additional external supports provided by the recall readiness task to support a rehearsal strategy. If this is the case, then the resulting rehearsal on the recall readiness task may not mediate recall as effectively as the rehearsal of children who are more mature strategy users. This would be reflected in a degree of 'utilization deficiency' (Miller, 1990) among the moderate-functioning group. That is, while a strategy is produced and used, it should not necessarily result in the expected improvements in recall performance.

Support for this interpretation is provided by the significantly lower performance on the recall readiness task by the rehearsers in the moderate-functioning group (0.46) compared with the rehearsers in the high-functioning group (0.64). While rehearsers in both groups did recall more than non-rehearsers, the recall benefits for the rehearsal of the moderate-functioning group are less than for the high-functioning group in terms of overall recall level – the hallmark of a utilization deficiency. These data, then, are consistent with interpretations of executive functioning difficulties among children in the moderate group.

The finding of a greater executive difficulty among the moderate-functioning autism group, and only a delay among the higher-functioning children, is open to several interpretations. One is the possibility that the executive difficulties among the moderate-functioning group are associated with their co-occurring general cognitive developmental disability, and not their autism *per se*. Executive functioning difficulties and associated delays in strategy use have been identified in individuals with a range of developmental challenges, e.g. attention deficit hyperactivity disorder (e.g. Pennington and Ozonoff, 1996; Tannock and Schachar, 1996) and cognitive impairment (Bebko and Luhaorg, 1998). Thus, it is possible that executive functioning difficulties are associated more with delays in cognitive maturity, or developmental delay, than with autism uniquely.

An alternative interpretation of the findings centers on the nature of the specific strategy investigated. Rehearsal is a basic and fundamental strategy that emerges relatively early in children's cognitive development. Other, more complex strategies, many of which incorporate aspects of rehearsal, require more extensive executive control. These may be more severely affected, as was found to be the case in Bennetto et al.'s (1996) battery of memory measures.

Flowing from these argument are two sub-hypotheses. First, if rehearsal's emergence is associated with advancing cognitive maturity (e.g. VMA) for all children, with autism or without, then the higher-functioning group may simply already be past the level at which executive difficulties are common in children with autism for this basic strategy. Second, alternatively, the executive difficulties may not be a universal characteristic of all

related cognitive strategies in all children with autism. For example, executive difficulties may not apply to more basic cognitive strategies among high-functioning children with autism.

In evaluating these sub-hypotheses, it is clear that the high-functioning group has a higher level of cognitive maturity compared with the moderate group, as seen in the respective VMAs for the groups. However, the comparison group in experiment 1 also had a lower mean VMA than the high-functioning autism group (assuming their intellectual levels to be approximately in the average range, so that VMA is approximately equivalent to CA). Yet the rate of rehearsal among the comparison group was at least at a level comparable with the high-functioning autism group's. In our view, the evidence for at least a delay in strategy use for the high-functioning group implies the possibility that the findings for this group represent a residual executive difficulty on this basic strategy, one which is apparently overcome with increasing cognitive maturity. In contrast, the moderate autism group's executive difficulties remain clearly in evidence, despite even their verbal mental skills being slightly higher than that of the normally developing groups.

Overall, the findings of this study tend to support the view of an executive functioning difficulty in autism that hampers effective information processing in domains that benefit from the generation of strategies to manipulate ordered information. However, there appears to be a lesser deficit for higher-functioning children. The executive difficulty identified in both groups is manifested in a disinclination or delay associated with the generation of basic memory strategies, such as rehearsal. At the same time, however, the direct observation of significant strategy use among a subgroup of children with autism represents one of the first such findings in the literature. These findings indicate that the disinclination is not as pervasive as might have been suggested by earlier hypotheses of autism as a general amnesic syndrome (e.g. Boucher and Warrington, 1976), or by some of the previous research in the field (e.g. Boucher 1981a; 1981b; Hermelin and O'Connor, 1970). In these studies, direct observations at input were not made, and an absence of strategy use was inferred from eventual memory performance.

The results of these studies have clear educational implications for children with autism. The first implication is that, when the context permits it, learning tasks that involve significant memory components should be modified to be as supportive as possible for the limited executive skills of the children. These modifications should include providing maximum control of the learning environment to the child so that information can be studied at a pace appropriate for each child versus presentation at a preordained rate. In addition, a variety of external supports should be provided

to optimize attention and learning (i.e. visual aids, reminders and cues). However, such support alone may not be sufficient to improve performance to the child's greatest potential. The samples with autism in our second experiment were still rehearsing at levels comparable with the much younger comparison group, although other work with developmentally impaired populations on a similar task (e.g. Turner and Bray, 1985) had shown almost universal rehearsal on the recall readiness task.

Therefore, a second implication of the present findings is that there is a need to teach specific cognitive strategies directly to children with autism, and not simply to emphasize the content to be remembered, often in the assumption that the child will develop whatever method is needed to learn it. In other words, the *hows* of learning must be taught with an emphasis at least equal to, if not greater than, the *whats*. As our results indicate, this is the case even for high-functioning children, who are at least delayed in their ability to generate strategies spontaneously.

There has been a good deal of effort to teach strategy use to a variety of other populations with developmental challenges, and these have met with a degree of success (e.g. Bebko, 1984; Belmont et al., 1978; Blackman and Lin, 1984; Borkowski and Buchel, 1983). The successful extension of the use of standard memory paradigms to children with autism, as exemplified in the present study, indicates that some of these training efforts might also be extended successfully to this population. However, these teaching efforts clearly will need to be tailored to allow for the language and attentional difficulties endemic to autism.

## Acknowledgements

This project was partially supported by funding from the Social Science and Humanities Research Council small grants program and a Faculty of Arts, York University, research grant. The authors would like to thank Adrienne Perry of Thistletown Regional Centre, Rick Ludkin and Irene O'Connor from Woodview Manor, Jan Stewart and Paul Stewart, principals of the North York School Board involved, and all of the participants in the study. For help with the research, we would like to thank Nancy Freeman, Bonnie Grzesch, Tamara Klein, Simona Krivyan, Anne Lees and Alisa Metcalfe-Haggert.

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