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Cognitive flexibility and strategy training allow young children to overcome transfer-Utilization Deficiencies

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Transfer of learning is critical for development, because it allows children to generalize their skills and use their knowledge more flexibly (Brown, 1989). Transfer occurs when knowledge or a cognitive skill, previously acquired in a main task, is re-used on a different, but somewhat similar, transfer task. In this article we examine the transfer of memory strategies, with a focus on factors influencing the effectiveness (for recall) of a successfully transferred strategy.

First, several definitions and issues in transfer need to be discussed. Near transfer and far transfer must be distinguished, based on both the content and the context of transfer. Regarding content, reflecting the long-lasting distinction between structure and surface elements of tasks (Chi & Van Lehn, 2012; Gentner, 1989; Ross, 1989), many authors converge in defining near transfer as occurring between tasks sharing the same deep structure, with only surface elements being slightly different (Carr, Alexander, & Schwanenflugel, 1996; Chang, Rosenberg-Lee, Qin, & Menon, 2019; Resch, Keuler, Martens, van Heugten, & Hurtz, 2018).

As to the context, according to Barnett and Ceci (2002)'s taxonomy, in near transfer two tasks share many contextual elements such as physical, temporal, functional and social contexts, and also use the same task modality (i.e., testing features as visual vs auditory, written vs verbal, book learning vs oral exam, etc.). Furthermore, similarity of contents and contexts implies that near transfer involves the same cognitive processes in the main and transfer tasks (Aladé, Lauricella, Beaudoin-Ryan, & Wartella, 2016; Bürki, Ludwig, Chicherio, & de Ribaupierre, 2014). Conversely, far transfer occurs when main and transfer tasks share only a few of these content and context elements.

In an example of near transfer, Schleepen and Jonkman (2014) presented children with a sort-recall task (main task) using twelve drawings from three categories (e.g., fruits, animals, clothes). These cards were laid on the table in such a way that the categories were not highlighted, but they could be moved into category groupings (semantic grouping strategy). Both strategic and recall scores were noted. A second, transfer, sort-recall task was then presented, which was the same as the main task except it used drawings from three new categories (e.g., tools, vegetables, vehicles). The authors considered it near transfer because the tasks are structurally similar (a sort-recall task with a semantic grouping category) and vary only on the specific categories covered. Also, the context is the same. Following Barnett and Ceci (2002)' s taxonomy, far transfer would have occurred in this study if several contextual elements had changed between the main and the transfer task, such as the place where the study was conducted (school vs home), the people gathering the data (experimenter vs teacher), or the functional context (academic vs play). In brief, the fewer shared elements, the farther the transfer (Robins, 1996).

Despite many attempts to show that far transfer occurs, it remains difficult for children (Sala & Gobet, 2016). On the contrary, near transfer occurs frequently, in such different tasks as mathematics problem-solving (Chang et al., 2019), organizational strategy in geometry (Resch et al., 2018), or memory strategies (Schleepen & Jonkman, 2014). Near transfer may be easier than far transfer, because similar task content and context make the connection between the two tasks more obvious (Robins, 1996). The ability to detect similarities develops very early in life (Paik & Mix, 2006), and this may allow even young children to transfer what they previously learned to a new, similar, task. Studying how young children begin to master near transfer, as in the current study, may provide insights into the processes involved in far transfer.

Another important issue in the transfer literature is how best to assess transfer. Evidence for transfer varies, depending on how transfer is assessed (Barnett & Ceci, 2002; Nokes, 2009). Focusing both on what knowledge is transferred and how it is transferred, several studies have assessed the transfer of cognitive strategies in children (Cook, Dufy, & Fenn, 2013; Schleepen & Jonkman, 2014; Schwenck, Bjorklund, & Schneider, 2009). Still, given the large literature on children’s strategy use, little attention has been given to the specific processes underlying strategy transfer. In one of the most influential strategy development models, Siegler (1995) outlined the importance of studying the cognitive developmental processes underlying strategy selection but did not directly address strategy transfer. Yet, the processes underlying strategy transfer are important in such models, because a child facing a new task permitting several strategies must learn to select the most appropriate one. Moreover, the child must adapt it to the task in such a way that the strategy will be as effective as possible. Even in near transfer, there are variations in the level of similarities and alignments between the tasks, which children would need to recognize and take into account.

This issue of assessment is particularly important for studying processes of strategy transfer in children. Although it typically is assumed that good strategies benefit performance (e.g., recall), this remains an empirical question. Thus, it is essential to assess any benefit, independently of the transfer of the strategy, to show both transfer and benefit.

The present research examines children’s transfer of memory strategies, using a near transfer paradigm. Like the transfer of cognitive strategies more generally, memory strategies are general procedures that potentially can benefit children’s learning over a wide range of tasks. Memory strategies are of particular interest because early childhood activities often require a child to memorize information. Children often can maintain memory strategies from the initial to transfer task (Lange & Pierce, 1992; Schwenck, Bjorklund, & Schneider, 2007, 2009). In doing this, they must note differences between the tasks and adapt the strategy accordingly, as adaptation is a very general process required in transfer (Schwartz, Chase, & Bransford, 2012). The present two studies focus on three prevalent memory strategies in the developmental literature thought to benefit recall—verbal rehearsal and two organizational strategies—grouping similar items together during encoding and clustering similar items during retrieval.

Surprisingly, previous studies rarely have examined whether, and how much, the transferred memory strategy helps recall. Does the strategy successfully transferred from the main task to the new task always benefit memory recall? Using a near-transfer paradigm, a recent study showed that children may transfer a strategy but not its benefit (Clerc & Miller, 2013). This phenomenon was called a transfer-Utilization Deficiency. The implication is that effective near transfer may not always be as easy as researchers have typically proposed.

Utilization Deficiencies and Transfer-Utilization Deficiencies

Transfer-utilization deficiencies are a subcategory of the earlier-studied utilization deficiencies. Although strategies often are beneficial, in some circumstances they are not, or they provide less benefit than expected. This low strategy effectiveness, called a utilization deficiency (UD, Miller, 1990), has been observed in a variety of memory strategies, such as selective attention (e.g., Miller, Woody-Ramsey, & Aloise, 1991), rehearsal (e.g., Schlagmüller & Schneider, 2002; Schneider, Kron-Sperl, & Hünnerkopf., 2009), and sorting and/or clustering (e.g., Bjorklund, Coyle, & Gaultney, 1992; Stone, Blumberg, Blair, & Cancelli, 2016). Research on UDs expanded theorizing about strategy development by identifying a phase when a strategy is first acquired but still is highly demanding of cognitive resources. During this fragile time, producing a strategy leaves few resources to devote to memorizing per se**,** and thus the strategy does not benefit recall, and a UD occurs. Several factors, including capacity and metamemory (knowing why particular strategies work), moderate the effectiveness of strategies (e.g., DeMarie, Miller, Ferron, & Cunningham, 2004). Only after the strategy is well practiced and becomes more automatic can it leave enough resources for memorizing, thus eliminating the UD. A UD also is reduced (presumably by reducing cognitive load) when the task materials are embedded in a familiar context (Miller, Seier, Barron, & Probert, 1994). UDs occur not only when children spontaneously produce a strategy but also when the experimenter prompts children to use a strategy (Bjorklund, Miller, Coyle, & Slawinski, 1997).

More recent research showed that UDs occur not only when a strategy is produced on an initial task, but also during strategy transfer, and thus are called a transfer-Utilization Deficiency (t-UD). Using three isomorphic selective memory tasks (one initial and two transfer), Clerc and Miller (2013) observed a t-UD when children aged 4 to 5 transferred a selective attention strategy, but their recall decreased in both transfer tasks. Specifically, on the transfer tasks children showed high strategy production (at least equal to that in the initial task) but lower recall than in the initial task. Similarly, t-UDs also occurred among 4-year-olds making same-different judgments after using a matching strategy (Clerc, Rémy, & Leclercq, 2017). In this study, participants had to apply a matching strategy, in order to decide whether two series of seven elements were the same (judgment task). They maintained their strategic score between two slightly different versions of the task using either toys or wooden cubes, but their judgement scores decreased from the main to the transfer task, which is a pattern of t-UD. To date, t-UDs have been shown only in these two studies. It is important to know whether t-UDs are a frequent phenomenon, which would inform our theoretical understanding of the development of memory, strategies, and transfer. Thus, this paper examines the robustness of t-UDs across different strategies, materials, conditions, and age groups.

One plausible cause of t-UDs is that, during transfer, cognitive resources must be redirected from cognitive function, such as memorizing, to the process of deciding whether to transfer or reject the strategy for the new context. Specifically, in memory tasks, a strategy that enhanced recall on the initial task might provide little or no help on a transfer task because of the increased demands on the child's limited cognitive resources during transfer (Clerc, Miller, & Cosnefroy, 2014). Executive function is a cognitive function especially likely to demand resources during transfer, as a child compares the similarities and differences between the two tasks, decides whether the strategy is relevant for the transfer task, and adapts the strategy to the specifics of the transfer task.

Executive Function

Executive function (EF) includes cognitive skills involved in adaptive, goal directed behaviors, especially in novel situations. A transfer task is a novel situation, which makes EF likely to be involved in transfer. Low EF skills may increase the effortfulness of cognitive actions during a new, transfer task and thus decrease the available cognitive resources. Two studies (Stone & Blumberg, 2013; Stone et al., 2016) found that preschoolers with a strategy UD on a spatial memory task had lower EF than preschoolers showing strategy effectiveness for recall. Such lower EF may be associated with strategy transfer as well, that is, with a UD occurring when a strategy is transferred to a new task.

EF is thought to involve three related but somewhat separable components: working memory, inhibition of prepotent or automatic responses, and cognitive flexibility (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Among EF, researchers often consider cognitive flexibility to be implied in transfer in young children (Barr, 2010; Brown, 1989; Elsner & Schellhas, 2012; Pauen & Bechtel-Kuehne, 2016). Because flexibility entails set shifting, it could help children decenter from the transfer task and switch attention back and forth between that task and the initial one (main task). After comparing tasks, the child may conclude that though the surface elements (e.g., physical appearance of task, number of items, specific instructions) differ, that does not change the basic logic (structure) of the task, such as remembering only relevant items and ignoring irrelevant ones.

Cognitive flexibility is known to play a role in transfer of tool use (Pauen & Bechtel-Kuehne, 2016), and in analogical transfer (Brown, Kane, & Echols, 1986; Stad, Vogelaar, Veerbeek, & Resing, 2017), but no study has focused on strategy transfer. Moreover, to the best of our knowledge, only two studies have focused jointly on measures of transfer and of flexibility in young children. These two studies confirmed that the more flexible a child, the more successful the transfer (Pauen & Bechtel-Kuehne, 2016; Stad et al., 2017). To date, no study has attempted to show a link between individual levels of cognitive flexibility and transfer of memory strategies. We examined this link, in two experiments.

Experiment 1

In our first experiment, we predicted that young children who use a rehearsal strategy in the initial recall task would reproduce the same strategy in a second, isomorphic task, but that transferring the strategy would result in a t-UD, evidenced by lower recall on the transfer task than on the initial task. Producing a rehearsal strategy sometimes, but not always, results in a UD (Bjorklund et al., 1997). Further, we expected cognitive flexibility to play a role in t-UDs, with greater flexibility related to higher recall on the transfer task. Thus, we included two tests of cognitive flexibility. To test for near transfer, we used two isomorphic tasks (main and transfer) which differed only in the items used (surface elements); all contextual elements were the same in the two tasks.

In addition, in order to reduce the cognitive resources needed to produce a memory strategy, we explicitly trained one group to use the memory strategy (experimental group). We compared it to a second group with no strategy training (control group). Practice should make the strategy less effortful and thus should decrease the cost of adapting the strategy to the transfer task, and thus reduce t-UDs. In numerous studies, children have successfully been trained to use memory strategies, including verbal rehearsal, the strategy trained in the current study (e.g., Ornstein, Medlin, Stone, & Naus, 1985). Although memory training studies sometimes examine whether the trained strategy generalizes to a slightly different task, the focus is on the strategy rather than the effectiveness of successfully transferred strategies, the focus of the current study.

Method

Participants

Sixty-eight children (*M* = 5;6 months, *SD* = 4.5, range 4;8 to 6;9, 30 girls) participated. Children came from various socio-cultural backgrounds and attended two rural preschools and one urban preschool, in the North of France. All had French as a native language.

Tasks

Serial Recall

We used two test lists (A and B) and two familiarization lists (C and D) of 6 black and white line drawings each. Lists A (test list 1) and C (familiarization list 1) included animals, fruits, and cooking utensils; drawings in lists B (test list 2) and D (familiarization list 2) were of plants, vegetables, and gardening tools (see online supplemental materials for details, Tables S1 to S4). The drawings came from Alario and Ferrand (1999) and frequency of use of the items' names was controlled through the MANULEX lexical database (Lété, Sprenger-Charolles, & Colé, 2004).

The task was presented as a game of memorizing the drawn objects. Following Hitch, Woodin, and Baker (1989), drawings were lined up on the table, face down. The experimenter turned over the leftmost card for two seconds, then turned it face down again. He then turned over the card immediately to the right for two seconds before turning it face down, and so on for all the cards. This was the encoding stage. Then the experimenter pointed to the leftmost card (face down) and asked the child to name the item shown on its other side. The experimenter then did the same for the rest of the cards. This was the recall stage. Children scored one point each time they correctly recalled the name of the item on the card being pointed to (right name at the right position). Strategy scores were rehearsal set sizes, specifically, the longest series of item names repeated aloud in the order the items were presented, during a single trial.

Cognitive Flexibility

We assessed cognitive flexibility through two different switching tasks. We used the Dimensional Change Card Sort (DCCS) because it is widely used for assessing flexibility in preschoolers (Zelazo, 2006). We also used the Color Trails for Children (CTC, Williams et al., 1995) because it assesses cognitive processes more relevant to our memory task. More specifically, DCCS is based on a child mastering a complex system of hierarchically-embedded "if-then" rules, which defines a high level of cognitive complexity (Zelazo, Muller, Frye, & Marcovitch, 2003). In particular, reflection is one of the core processes that underline success on the DCCS, since children must reflect on an abstract system of two levels of sorting-rules, in order to sort two series of drawings. In numerous studies, DCCS has allowed researchers to provide a fine-grained description of the development of cognitive flexibility in young children

(Doebel & Zelazo, 2015). Yet, the hierarchical structure of rules the DCCS is based on, was not present in the recall tasks used in the present study. Thus, the inclusion of another switching task without this requirement seemed appropriate and necessary. CTC is such a task, in which switching is required between two series of visual items, based on perceptual cues. In the CTC, no abstract system of embedded rules is present, but instead the child must switch attention between digits belonging to two perceptually different series. This task taps into children's ability to switch their attention back and forth, and for this reason it may be associated more highly with a transfer paradigm than would the DCCS task. Indeed, transfer of a cognitive strategy requires that a child keeps in mind the main and the transfer task, and switches between tasks in order to efficiently adapt the strategy to the transfer task. In short, although they are both switching tasks, the two tests measure different processes underlying cognitive flexibility, with the DCCS focusing on conceptual processes (reflection on hierarchically-embedded rules for sorting items) and the CTC focusing on perceptual processes (switching from a first colored background to a second colored background). As this is the first study which tests for a link between cognitive flexibility and strategy transfer, we reasoned that using a more conceptual flexibility test along with a more perceptual flexibility test would provide a more detailed account of cognitive flexibility processes in strategy transfer. Another reason for using two different switching task is that they assess different aspects of responses. The DCCS measures accuracy and CTC measures reaction time. Using both should provide more information on the association between cognitive flexibility and t-UDs.

DCCS. This task consisted of a set of test cards, with each card showing one of two objects in one of two colors (e.g., a red rabbit or a blue boat). In Phase 1 the child was told to sort the cards according to one of the two dimensions (shape or color), placing each card in one of two boxes, each of which shows a picture of a target card (e.g., blue rabbit or red boat). For example, if color was the chosen dimension, the child was told: “In the color game, blues go here [blue rabbit] and reds go here [red boat].” After two demonstration trials came six trials without assistance. No feedback was given, but the rules were repeated before each trial. In Phase 2, the child had to sort the cards according to the other dimension. As in Phase 1, the child was not given any feedback and the rules were repeated before each trial, but there were no demonstration trials. Of more interest in this study, the phase 3 involved introducing a new set of cards on which the picture (rabbit or boat) had a black border. Pictures with a black border had to be sorted according to the color of the object; cards with no black border had to be sorted according to the shape of the object. Again, the child was not given any feedback and the rules were repeated before each trial. Phase 3 comprised 12 trials. In order to avoid ceiling effects, and because phase 3 requires that a child takes into account two embedded rules in order to be flexible, the only DCCS scores that we used in the analyses were the number correct over these 12 trials in phase 3.

CTC. The CTC is a version of Reitan’s (1971) Trail Making Test adapted for children. The CTC requires children to draw a line between numbers 1 to 15, in ascending order. First, in the control trial, each number appears only once; odd numbers are within pink circles, even numbers within yellow circles. Thus, children could simply focus on the numbers. Then, in the switching trial, the number 1 appears only once. There are two of each of the other numbers—one on a pink background and one on a yellow background. Children have to link the numbers, alternating between those written on a pink background and those on a yellow background: the pink “1” has to be linked to the yellow “2”, which has to be linked to the pink “3”, etc. Scores were the time taken to complete the alternating-colors trial minus the time taken to complete the control trial. Mistakes were corrected immediately by showing the child the next correct number.

Procedure

The study included seven phases, five memorization phases followed by two flexibility assessments (see Table 1). Participants were randomly assigned to either an experimental group who received explicit training in using a rehearsal strategy (N=34) or an untrained group receiving no explicit strategy training (N=34) during the memorization phases.

Memorization (phases 1 to 5)

Two familiarization trials were followed by five memorization phases, each with two trials. In each of these ten trials, items were presented in a random order. The familiarization trials followed the same procedure as in the pretest (see below) but used items from list C or D.

The pretest (phase 1) consisted of encoding and recall on each trial, as described above. The child had to do a counting task for 30 seconds between the two trials (buffer clearing task). In the trained group, the first strategy training phase followed (phase 2), during which the experimenter explained the rehearsal strategy before the first trial and encouraged the child to use this strategy during both trials: “When I want to memorize drawings, I repeat the names of the pictures several times, out loud, like this”. The experimenter then demonstrated the rehearsal strategy by saying the first word out loud several times, then saying the first two words, then the first three words, etc., up until the sixth word in the series. The child then had to rehearse the names of the six items in the same way. The child then did the first training trial, followed immediately by the second trial. In the second strategy training phase (phase 3), the experimenter again asked the child to use the rehearsal strategy and try to recall the items. If the child could not remember the strategy, the experimenter demonstrated it again by repeating the names of the first three drawings. The posttest (phase 4) was identical to the pretest, that is, no strategy prompt was given and there was a counting task between the two trials. Transfer trials (phase 5) also had no strategy prompt and had a counting task, but used a new list of items for recall (A or B, whichever was not used in phases 1-4). The untrained group followed the same procedure for familiarization and then the five phases, except they had no strategy training (but otherwise did the tasks the same) in phases 2 and 3. We noted recall scores (0-6 words recalled correctly) and strategy scores (0-6 words repeated) for every child on each trial. The entire memorization session lasted about 30 min for each child.

Cognitive Flexibility (phases 6 and 7)

Participants carried out the DCCS and CTC tasks on a separate day, in two sessions. Half started with the CTC; the other half started with the DCCS. For the CTC test, positive differences (time for switching trial minus time for control trial) showed that completing the alternating-colors sequence was more difficult. DCCS scores were based only on the third – Border- stage, which is most challenging (maximum score 12). Total duration was about 20 mn.

The whole cycle may last from 8 to 9 days due to days off – Wednesdays, Saturdays and Sundays are usually days off for children in France. The typical schedule was: Monday (familiarization trials and pretest), Tuesday (first strategy training or control trials), Thursday (second strategy training or control trials), Friday (posttest), Monday (transfer) and Tuesday (cognitive flexibility).

Table 1

Typical Timeframe of Experiments 1 and 2

MEMORY TASKS									FLEXIBILITY TASKS	
Phases	1 PRE-TEST	2 TRAINING OR CONTROL	3 TRAINING OR CONTROL	4 POST-TEST	5 TRANSFER				6 DCCS	7 CTC
DAY	MONDAY	TUESDAY	THURSDAY	FRIDAY	MONDAY				TUESDAY (AM)	TUESDAY (PM)
Score	Recall		Strategic		Recall		Strategic		Phase 3 Border stage	Time difference
Trial	1	2	1	2	1	2	1	2	/12	Trial 2 – Trial 1
Total	/6	/6	/6	/6	/6	/6	/6	/6		

Results

Preliminary data analysis showed no effects from gender or list of words, thus these factors were not included in the following analyses. Descriptive statistics for rehearsal strategy and serial recall are provided in Table 2.

Rehearsal Strategy

The first step in assessing t-UDs is to examine whether children maintained the rehearsal strategy from the main task (phases 1-4) to the transfer task (phase 5). In order to maximize statistical power and avoid type 2 error, rehearsal set size was subjected to a 3 X 2 Repeated Measures Analysis of Covariance (rmAncova) with the within-subject factor of *task* (Pretest, Posttest, Transfer), and the between-subject factor of *group* (trained vs untrained). Ancovas were conducted in order to increase the statistical power (Tabachnick & Fidell, 2013). Flexibility scores at DCCS and CTC, as well as age, were covariates. The main effect of group was significant, $F(1, 63) = 23.48$, $p < .001$, $\eta^2_p = .27$, with the trained group outscoring the untrained group. The Task X Group interaction was significant, $F(2, 126) = 9.85$, $p < .001$, $\eta^2_p = .14$, and no significant difference appeared between groups at pretest. No other effect was significant. In order to further understand the Task X Group interaction (see Figure 1a), we performed two ANOVAs with repeated measures on the task factor, one for each group. In the untrained group, the effect of task was significant, $F(2, 66) = 3.95$, $p = .024$, $\eta^2_p = .11$. Follow-up post-hoc analysis (Bonferroni) indicated a significant increase from pretest ($M = .09$; $SE = .06$) to transfer ($M = .49$; $SE = .17$), $p < .020$. No other significant differences were observed. Most relevant was a nonsignificant difference between posttest and transfer, indicating that children transferred the rehearsal strategy from the main task to the transfer task without no decline in the quality of the strategy. In the trained group, the effect of task was significant, $F(2, 66) = 18.04$, $p < .001$, $\eta^2_p = .35$. As predicted, post-hoc analysis (Bonferroni) showed significant differences between pre- ($M = .29$; $SE = .13$) and posttest ($M = 1.93$; $SE = .35$), $p < .001$, and between pretest and transfer ($M = 2.06$; $SE = .33$), $p < .001$. Posttest and transfer strategy scores did not differ significantly. In sum, as expected, the mean strategy scores did not change from posttest to transfer in both groups (Fig. 1a), which is the first condition for a t-UD.

Table 2

Mean (SEs) Scores for Rehearsal Strategy and Recall Scores, Experiment 1

	Untrained		*Trained*	
	Rehearsal Strategy	*Serial Recall*	*Rehearsal Strategy*	*Serial Recall*
Pretest	*.09 (.06)*	*2.08 (.21)*	*.29 (.13)*	*2.24 (.21)*
Posttest	*.32 (.10)*	*2.94 (.22)*	*1.93 (.35)*	*2.79 (.24)*
Transfer	*.49 (.17)*	*1.93 (.21)*	*2.06 (.33)*	*2.75 (.21)*

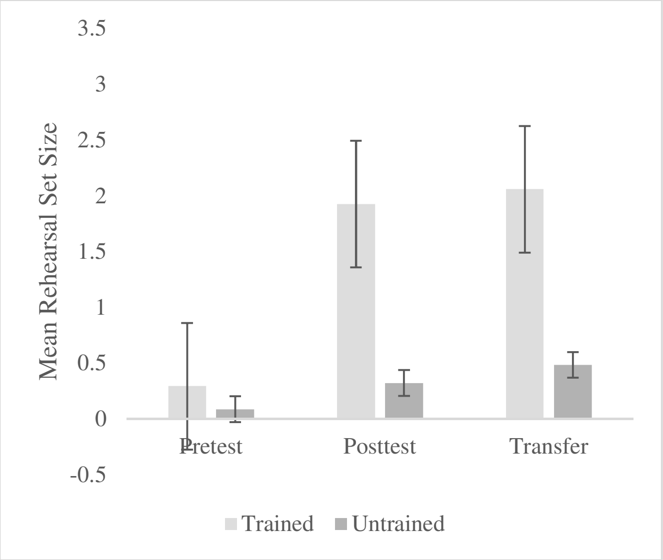

Figure 1a. Mean rehearsal set size at pretest, posttest and transfer, in trained and untrained children in experiment 1. Vertical bars indicate standard errors.

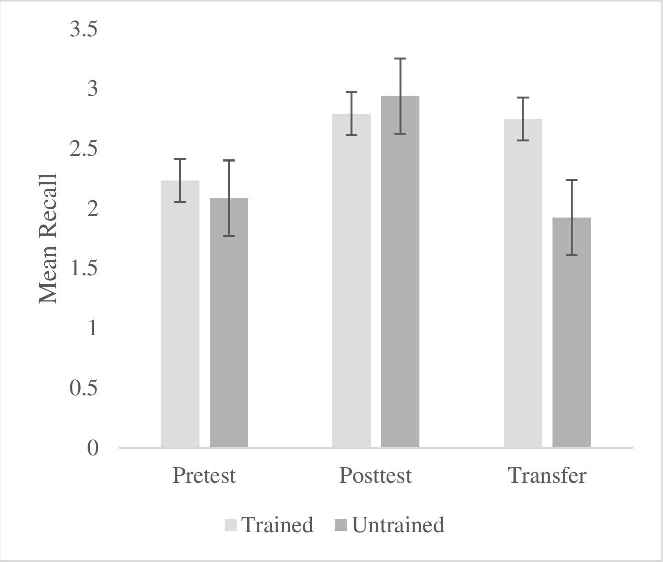

Figure 1b. Mean recall scores at pretest, posttest and transfer, in trained and untrained children in experiment 1. Vertical bars indicate standard errors.

Serial Recall

Now that the strategy has been examined, the second step is to determine whether the transferred strategy was accompanied by a decrease in recall, which would indicate a t-UD. The mean recall scores were subjected to a 3 X 2 rmAncova with the within-subject factor of *task* (Pretest, Posttest, Transfer), and the between-subject factor of *group* (trained vs untrained). Again, flexibility scores (DCCS and CTC) and age were covariates The effect of group approached significance, $F(1, 63) = 3.37$, $p = .071$, $\eta^2_p = .05$. The Group X Task interaction was significant, $F(2, 126) = 4.02$, $p = .020$, $\eta^2_p = .06$, and no significant difference appeared between groups at pretest. In order to understand the Group X Task interaction (see Figure 1b), we performed two ANOVAs with repeated measures on the task factor, one for each group. In the untrained group, the effect of task was significant, $F(2, 66) = 8.39$, $p < .001$, $\eta^2_p = .20$. Recall improved significantly ($p = .006$) from pretest to posttest, but most relevant is that it decreased significantly ($p < .001$) from posttest to transfer, indicative of a t-UD (Table 2). In the trained group, the effect of task was significant, $F(2, 66) = 3.8$, $p = .027$, $\eta^2_p = .10$. Recall improved significantly (Bonferroni test, $p = .047$) from pretest to posttest, but most relevant is that, in contrast to the untrained group and as predicted, no significant difference appeared between posttest and transfer, indicating no t-UD (Fig. 1b).

The overall effect of age was significant, $F(1,63) = 4.94$, $p = .029$, $\eta^2_p = .07$, but this was true at pretest only ($p = .034$). Importantly, the CTC score had a significant effect on recall, $F(1,63) = 8.07$, $p = .006$, $\eta^2_p = .12$, which was true only at posttest ($p = .009$) and transfer ($p = .006$). There was no significant effect of the DCCS score (descriptive statistics for both tests of cognitive flexibility are provided in Table 3). Finally, as we conjectured that DCCS and CTC are two switching tasks that measure different processes in cognitive flexibility, we computed the correlation between DCCS and CTC scores. This was non-significant, $r = .05$, $p =.717$, further supporting the notion that these tests may be assessing somewhat different skills.

Table 3

Descriptive Values for EF Tasks

Variable		*M*	*SD*
	Experiment 1 (n=68)		
Age		5y7m (4y9m to 6y10m)	5m
DCCS		7.81	2.5
CTC (sec)		78.78	84.8
	Experiment 2 (n=72)		
Age		6y7m (5y9m to 7y6m)	6m
DCCS		8.64	1.86
CTC (sec)		73.06	53.09

Note. DCCS = Dimensional Change Card Sort, CTC = Color Trails for Children.

Discussion

Results extend the findings of previous studies, by showing t-UDs in a recall task with a rehearsal strategy in children aged 4 to 6. Moreover, as a start towards identifying processes underlying t-UDs, as predicted we detected t-UDs in the group with no rehearsal strategy training, but not in the group that received the strategy training. In the untrained group, strategy scores were stable from posttest to transfer, showing that the change in task did not adversely affect the children's ability to generate the strategy. However, recall decreased significantly from the last posttest to the first transfer trial, indicating t-UDs. As we know that adaptability is core in transfer (Schwartz et al., 2012), adapting the strategy to the transfer task may have taxed children's cognitive resources, leaving little for encoding for recall. In contrast, trained children increased their rehearsal strategy scores from pretest to posttest, showing the effectiveness of the training, and strategy scores remained stable from posttest to transfer, indicating the robustness of the training effect. Importantly, in these trained participants recall remained stable between posttest and transfer, thus showing no t-UD. This suggests that strategy training decreased the effortfulness of strategy production, thus protecting them from a t-UD—decreased recall from the posttest to the transfer task. It is worth noting that untrained children also increased their strategy production from the pretest to the transfer, suggesting that experience with the task helped them spontaneously acquire the strategy and transfer it to some extent. However, the strategy, less practiced than in the trained children, did not let them maintain their level of recall during transfer (t-UD). This finding is consistent with studies showing the superiority of explicit over implicit strategy training (Chen & Klahr, 1999).

Thus, this study provides the first direct evidence for t-UDs when transferring a rehearsal strategy across word-recall tasks. In fact, t-UDs previously had been explicitly detected only by two studies examining the transfer of selective attention (Clerc & Miller, 2013) or matching (Clerc et al., 2017) strategies (some older studies showed patterns of results that since have been interpreted as t-UDs [Bjorklund, Schneider, Cassel, & Ashley, 1994; DeMarie-Dreblow & Miller, 1988; De Corte, Verschaffel, & Van de Ven, 2001; Schwenck et al., 2009]). Also, in addition to showing the generality of t-UDs, our study provides additional evidence that demand on cognitive resources may be a mechanism underlying t-UDs, by comparing trained and untrained children. Training is thought to reduce the cognitive resources required for the strategy. These findings offer a new perspective on the difficulties of teaching children skills that not only will transfer to new problems or settings but also are effective there.

The current study also supports evidence that the cognitive flexibility component of EF affects the occurrence of t-UDs. In this study, recall during transfer was predicted by CTC scores but not by DCCS scores. Interestingly, CTC and DCCS were not correlated, suggesting that these two switching tasks measure different processes of cognitive flexibility. There are several differences between the two tasks that could account for the significance of CTC but not DCCS, for example, use of the speed measure for CTC versus accuracy for DCCS. One difference that may be especially important is that the CTC involves only one if-then rule, whereas the DCCS involves a hierarchy of two embedded if-then rules. In the CTC, children determine which number to choose, then apply the if-then color-change rule; successive numbers are linked only if they have different color backgrounds. Thus, CTC seems to tap into a more perceptual part of cognitive flexibility, sometimes referred to as attentional switching (Konstantopoulos, Vogazianos, Thodi, & Nikopoulou-Smyrni, 2015). In contrast, in the more complex DCCS, children have to first apply the if-then rule governing the choice of sorting criterion (shape or color) based on whether or not the drawing is surrounded by a black border, and then apply the if-then sorting rule according to that criterion. Although the DCCS is supposed to assess switching of attention between rules (Doebel & Zelazo, 2015), it is a complex cognitive task which may also tap into a more conceptual part of flexibility, usually referred to either as representational flexibility (Eichanbaum, 1997) or “thinking outside the box” (Diamond, 2013). Transferring a rehearsal strategy from one list of words to another does not require understanding a complex system of hierarchical rules, such as those involved in the DCCS. Instead, it may require a strong ability to switch one’s attention back and forth between the two lists, comparing their features. Such attentional switching is assessed more directly in the CTC, which could explain why CTC scores were significantly associated with recall at transfer whereas DCCS scores were not.

Experiment 2 tests the robustness and generality of t-UDs further, by examining the transfer of two organizational strategies—sorting at encoding and clustering at recall—in a free recall task. Past research shows that introducing new words and categories in a free recall task from one stage to another in the same session or from one session to another can lead to a t-UD pattern. That is, children transfer their organizational strategy (grouping same-category items) but recall less (Bjorklund et al., 1994; Schwenck et al., 2007). Again, we examined the roles of strategy training and cognitive flexibility, and tested children slightly older than in study 1.

Experiment 2

This experiment had the same design as Experiment 1: five memorization phases and two phases to test cognitive flexibility (Table 1). Among children not receiving strategy training, t-UD should emerge in a free-recall task with a sorting strategy and a clustering strategy, and cognitive flexibility should impact recall at transfer. Strategy training should eliminate t-UDs.

Method

Participants

Participants were 72 children from two rural preschools and an urban preschool in the North of France (*M* = 6.6 months; *SD* = 5.55, age range 5;7 to 7;5, 36 girls). Children came from low to middle SES level and all had French as a native language.

Tasks

Free Recall

The material consisted of words typically taught to young French school students being introduced to science. We constructed two new test lists (E and F), each containing 20 drawings covering four categories (5 drawings per category), and reused lists C and D from Experiment 2 as familiarization lists. The drawings in list E were of animals, fruits, cooking utensils, and clothes; those in list F were of plants, vegetables, gardening tools, and furniture. Again, we carefully took into account the items' characteristics, to equate the difficulty of the lists (see online supplemental materials for details, Tables S5 and S6). The task was presented as a game in which children had to memorize the items shown in the drawings. The experimenter randomly placed the 20 drawings face up on the table, ensuring that no two cards from the same category were side-by-side. After being exposed for two minutes, the drawings were hidden and the child had to verbally recall as many of the items as possible. Recall scores were the number of items recalled correctly, regardless of the order in which they were remembered.

We used two measures of strategy: a sorting score at encoding and a clustering score at recall (see Bjorklund et al., 2009); both were measured using Adjusted Ratio of Clustering scores (ARC, see Roenker, Thompson, & Brown, 1971), which can range from 0 (no sorting/clustering) to 1 (perfect sorting/clustering). Sorting is a purer measure of strategy than clustering, because clustering is partly the result of non-strategic associative processes (Hasselhorn, 1992). On the other hand, sorting is more difficult to measure if, as often happens, children do not handle the cards but still mentally put items into categories. Combining both strategy measures partly compensates for each measure's drawbacks. We scored sorting as follows. Any movement of the cards produced an ARC score based on whether or not cards were placed together. A card placed next to (less than 2 cm distance) a card from the same category was counted as a true repetition (the "R" value in the ARC formula). Two judges independently rating a sample of the scores achieved 92% agreement. Discrepancies were solved by discussion. The resulting ARC scores were between 0 and 1 (rare negative values were treated as 0, see Roenker et al., 1971). If a child touched none of the cards, we excluded that child when computing the mean ARC score, leading to some missing values. In clustering, the order in which the items were recalled was taken into account in ARC scores: ARC scores increased if items from the same category were recalled one after the other and decreased if the items were recalled independently of their category.

The task began with two familiarization trials using the items from list C (list D for half of the participants). Each child was shown four drawings in the first trial and six drawings in the second trial. The child then completed five memory phases, each with two trials using the 40 items from lists E and F (list E was used in the first four phases for half of the participants).

Cognitive Flexibility

As in Experiment 1, cognitive flexibility was assessed using DCCS and CTC during the second session. Despite the fact that scores on DCCS did not predict recall in Experiment 1, we included the DCCS task in Experiment 2 because it is the most commonly used task to measure cognitive flexibility in developmental EF research, and because it may provide additional information for understanding transfer of sorting and clustering strategies.

Procedure

Thirty-six children were randomly assigned to the experimental group and 36 to the control group. The experimental group was given explicit training in the sorting strategy during the memorization phases. Children were not given any training in clustering, but research has shown that sorting training alone increases both sorting and clustering scores (Schwenck et al., 2007). Children in the control group did not receive any strategy training.

Memorization (Phases 1 to 5)

The typical schedule was the same as in Experiment 1. After familiarization trials came a free recall task in five phases, one per day, and then both tests of cognitive flexibility were given during the last two phases. The whole cycle may thus last from 8 to 9 days due to several constraints (days off). During the pretest, posttest, and transfer phases, the children were asked to do a counting task between trials. The first strategy training phase (phase 2) began with the experimenter explaining the sorting strategy to each child in the experimental group, saying: “When I want to remember the drawings, I put together all the pictures that belong to the same family, like this.” The experimenter then placed the items in groups of five according to their category and put each group of five items at one of the four corners of an imaginary square. The drawings in each category were placed in a line of three drawings above and a line of two drawings just below. Next, the experimenter explained the links between the items in each category, going through all four categories (e.g., “see, a fish is an animal and so is a cow, so we can put them together, they belong to the same family”). The experimenter grouped the items into the four categories, named each category, pointed to each and said: “Now, I look at them carefully in each family so I remember them”. He then jumbled up the drawings, making sure no two items from the same category were side by side, and gave the child 2 minutes to group them into the four categories in order to memorize them. He then photographed the child’s array, hid the items, and tested for recall. The second trial followed the same procedure. During the second strategy training phase (phase 3), the experimenter asked the child to sort the items, but did not demonstrate the procedure. If in the first trial the child could not remember the strategy, the experimenter grouped three items from one category and then asked the child to complete that category and group together the remaining drawings into the other three categories. Each child completed two further trials during both the posttest (phase 4) and transfer (phase 5), but no mention was made of any strategy. The untrained group carried out these phases, except with no strategy training. Presentation order of the two lists was counterbalanced: 40 children (21 from the trained group) received list E in the main task and F in transfer, and 32 children (15 from the trained group) had F then E. The entire memorization session lasted about 25 min.

Cognitive Flexibility

Then, on a different day (phases 6 and 7), children received the two flexibility tests. Half of the children started with the CTC and half started with the DCCS.

Results

Preliminary Analyses

We wanted to rule out any effects of gender and, especially, difficulty of word lists. Although the counterbalancing of list order eliminated any confounding, ideally the word lists would be of equal difficulty so that a t-UD would occur when moving between lists of equal difficulty. A 2 (gender) × 2 (list E *vs* list F) × 2 (time of test: pre- vs posttest) MANOVA with repeated measures on the last factor was performed on mean sorting, clustering and recall scores. Due to missing data on the sorting score at posttest in 21 participants (trained: 8 girls, 5 boys, mean age 84 months; untrained: 5 girls, 3 boys, mean age 83 months), the analysis included only 51 participants. Time of test was significant, Wilk's Lambda = .40, $F(3,46) = 22.59$, $p < .001$, $\eta^2_p = .60$; but gender and list were not. A 2 (gender) × 2 (list E *vs* list F) MANOVA was performed on mean sorting, clustering and recall scores at transfer, with data of 48 children (missing data in 24 participants: 8 girls and 5 boys receiving training, mean age 84 months; 6 girls and 5 boys without training, mean age 83 months). The effect of gender was nonsignificant. The effect of list just failed to reach significance, Wilk's Lambda = .84, $F(3,43) = 2.78$, $p = .052$, $\eta^2_p = .16$, with scores for the list E being higher than those for the list F. Thus, contrary to our expectations, the levels of difficulty may have differed. List thus was a factor in the following analyses concerning transfer.

Sorting

Due to missing data combined across posttest and transfer, sorting was analyzed based on the results from 45 children (see Table 4 for details). Because the two item lists may differ in difficulty, we could not include transfer in the same analysis with pre- and posttest, since the list changed between posttest and transfer. A 2 (group: trained *vs* untrained) × 2 (time of test: pre- *vs* posttest) rmAncova with repeated measures on the latter factor was performed on the mean sorting scores, with flexibility scores at CTC, at DCCS, and age as covariates, in order to test for an effect of strategy training in the main task. The main effect of group was significant, $F(1,33) = 48.61$, $p < .001$, $\eta^2_p = .60$, as was the Group X Time of test interaction, $F(1,33) = 41.72$, $p < .001$, $\eta^2_p = .56$. Bonferroni tests localized the significant differences. The two groups did not differ significantly at pretest. The trained group improved significantly from pretest ($M = .04$; $SE = .02$) to posttest ($M = .70$; $SE = .05$), $p < .001$. In contrast, the untrained group did not change significantly from pretest ($M = .00$; $SE = .02$) to posttest ($M = .00$; $SE = .05$); in fact, untrained children rarely sorted at any point. No other significant effect was found. Thus, our training manipulation succeeded in inducing strategies.

Second, to see if children transferred their strategies, Wilcoxon or *t*-tests compared sorting from posttest to transfer for each group and each list. Table 4 indicates that, in the untrained group, sorting was stable from posttest to transfer, regardless whether the participants received the list E first then list F ($M = .00$; $SE = .01$, and $M = .02$; $SE = .05$, respectively) or the F-E list order ($M = .00$; $SE = 0$, and $M = .07$; $SE = .26$, respectively). In trained participants, the same pattern was observed with the F-E list order ($M = .78$; $SE = .38$, and $M = .80$; $SE = .24$, respectively); a decrease in sorting was approaching significance in the E-F list order ($M = .68$; $SE = .38$, and $M = .50$; $SE = .29$, respectively), $p = .052$. Thus, only the training group developed a significant amount of sorting, which was maintained somewhat during transfer.

Table 4

Mean Sorting, Clustering and Recall Scores (SD) at Posttest and Transfer in Each Group X Word List Condition, Experiment 2.

	Posttest			Transfer			*t*	*p*	*D*
	Sorting	Clust	Recall	Sorting	Clust	Recall			
	List E			List F					
Trained	.68 (.38)[a]			.50 (.29)[a]			2.15	.052	
(n=21)		.61 (.29)			.50 (.33)		1.25	.22	.35
			13.76 (3.47)			7 (2.79)	11.07	**.001**	2.20
	List F			List E					
Trained	.78 (.38)[b]			.80 (.24)[b]			7*	.89	
(n=15)		.72 (.26)			.87 (.17)		2.68	**.017**	.74
			12.73 (4.15)			11.2 (4.68)	1.61	.12	.36
	List E			List F					
Untrained	.00 (.01)[c]			.02 (.05)[c]			.71	.49	
(n=19)		.49 (.29)			.48 (.29)		.04	.97	.01
			11.55 (2.47)			8 (2.77)	5.91	**.001**	1.39
	List F			List E					
Untrained	.00 (0)[d]			.07 (.26)[d]			1.04	.32	
(n=17)		.34 (.20)			.43 (.29)		1.32	.20	.41
			10.32 (2.05)			8.3 (2.52)	3.07	**.001**	.90

Note. Clust = Clustering. Exact *p*s and Cohen's *d* are reported. Sample sizes for sorting: a = 13, b = 7, c =11, d = 14. *Wilcoxon T test was used instead of student *t*, due to the small *n*.

Clustering

As for sorting above, a 2 (group: trained vs untrained) × 2 (time of test: pre- vs posttest) rmAncova with repeated measures on the latter factor examined clustering scores, with age, DCCS scores and CTC scores as covariates. The main effect of group was significant, $F(1,66) = 9.51$, $p = .003$, $\eta^2_p = .13$, as was the Group X Time of test interaction, $F(1,66) = 5.60$, $p = .021$, $\eta^2_p = .08$. Bonferroni tests showed no significant differences between groups at pretest. The trained group improved significantly between pre- ($M = .36$; $SE = .04$) and posttest ($M = .64$; $SE = .05$), $p < .001$, showing the effects of strategy training; but the untrained group did not (pretest:

M = .33; *SE* = .04 ; posttest: *M* = .42; *SE* = .05). The CTC X Time of test interaction was significant, *F*(1,66) = 6.54, *p* = .013, η^2_p = .09, the CTC being significantly associated to clustering at pretest (*p* = .026) but not at posttest. No other effect was significant.

To examine transfer of clustering, the clustering scores at posttest and transfer were compared by *t*-tests, in each group and for each list. Clustering remained at the same level from posttest to transfer in the untrained group regardless whether they were given the E-F list order (*M* = .49; *SE* = .29, and *M* = .48; *SE* = .29, respectively) or the F-E list order (*M* = .34; *SE* = .20, and *M* = .43; *SE* = .29, respectively). In the trained group receiving the E-F list order, the same pattern was observed between posttest (*M* = .61; *SE* = .29) and transfer (*M* = .50; *SE* = .33). The trained group receiving the F-E list order significantly increased their clustering from posttest (*M* = .72; *SE* = .26) to transfer (*M* = 87; *SE* = .17), *p* = .017, see Table 4. Thus, the training successfully induced clustering, which was maintained during transfer.

Recall

When searching for t-UDs, a second step is to compare recall from posttest to transfer, in order to detect whether recall decreased. A series of t-tests showed that, as predicted, in the untrained group, recall decreased significantly both with the E-F list order (*M* = 11.55; *SE* = 2.47, and *M* = 8; *SE* = 2.77, respectively) and with the F-E list order (*M* = 10.32; *SE* = 2.05, and *M* = 8.3; *SE* = 2.52, respectively, see Table 4). In the training group, the predicted stable recall was found only with the F-E list order, indicating no t-UD (*M* = 12.73; *SE* = 4.15, and *M* = 11.2; *SE* = 4.68, respectively); the recall of the E-F group declined significantly, indicating a t-UD (*M* = 13.76; *SE* = 3.47, and *M* = 7; *SE* = 2.79, respectively, *p* < .001).

In contrast, recall from pretest to posttest showed the typical improved recall expected in memory studies before transfer. A 2 (group: trained *vs* untrained) × 2 (time of test: pre- vs posttest) rmAncova with repeated measures on the last factor was performed on the mean recall scores, with age, CTC scores and DCCS scores as covariates. The main effect of group was significant, $F(1,66) = 6.07$, $p = .016$, $\eta^2_p = .08$. The Group X Time of test interaction was significant, $F(1,66) = 8.23$, $p = .006$, $\eta^2_p = .11$. Groups did not differ significantly at pretest (Bonferroni tests). The trained group increased significantly from pre- ($M = 8.74$; $SE = .40$) to posttest ($M = 13.24$; $SE = .52$), $p < .001$. The untrained group also improved significantly from pre- ($M = 8.72$; $SE = .40$) to posttest ($M = 11.07$; $SE = .52$), $p < .001$. The trained group outperformed the untrained group at posttest, $p = .001$. No other effect was significant.

In sum, as predicted, the untrained group showed t-UDs, with recall decreasing during transfer even as sorting and clustering remained stable. The trained group maintained their level of recall with one word list (i.e., no t-UD) but not the other (thus a t-UD).

To examine further the link between flexibility and transfer, we examined CTC scores, DCCS scores and age as predictors of recall in a multiple regression analysis at transfer. CTC predicted recall, $F(1,67) = 12.87$, $p < .001$, R2 = .20. Neither age nor DCCS predicted recall. Finally, CTC and DCCS scores were not significantly correlated, $r = -.19$, $p = .110$, suggesting that they were tapping different processes.

Discussion

Experiment 2 extended evidence for t-UDs to clustering and sorting strategies, and in children older than in the previous experiment. Specifically, in untrained children, clustering and sorting remained stable from posttest to transfer, but recall decreased significantly. The predicted protection from a t-UD in trained children (i.e., no decline in recall during transfer) was found again, but with one of the word lists only. This unexpected outcome for one list order (E then F) might be due to the fact that sorting nearly declined significantly ($p = .052$). If sorting actually did decline rather than remain stable, then a decline in recall is not surprising. Finally, the pattern of results for sorting is difficult to interpret because untrained children rarely sorted, and not until the posttest if they did.

As in Experiment 1, training successfully induced strategies, but, unlike in Experiment 1 in which untrained children developed some strategic competence on their own over trials, in Experiment 2 their clustering and sorting scores did not increase from pretest to posttest. With no explicit permission to move the cards, the untrained group may not have thought of moving the cards or may have felt that they should not.

As to cognitive flexibility, CTC scores significantly predicted recall scores on the transfer task but DCCS scores did not. Thus, contrary to our expectations, DCCS did not provide any additional information for understanding transfer of sorting and clustering strategies. Once again, these results confirm the results of Experiment 1, suggesting that the kind of cognitive flexibility important for transfer of strategies on these tasks involves switching attention back and forth between the two (main and transfer) tasks rather than manipulating a complex system of rules.

General Discussion

Two experiments show the prevalence of t-UDs over a wide age range (4 to 7), for two types of memory tasks, and for three types of memory strategies. This is important because t-UDs have been noted only recently, and their frequency across memory tasks was unknown. Although children can successfully transfer their strategies to new tasks with superficial differences, it comes at a cost, because recall declines. A strategy that normally would help recall no longer does. Providing strategy training protects against t-UDs. Low flexibility EF scores predict t-UDs, though this depends somewhat on the match between the type of flexibility test and the type of cognitive activities required by the task. Our results regarding t-UDs have important implications for theorizing regarding the development of transfer and of strategies.

Implications for Understanding Transfer

Our findings regarding t-UDs can shed light on the processes underlying the transfer of learning and thus contribute to our theoretical understanding of transfer. Past literature on strategy transfer has focused on how to facilitate children's transfer of a strategy (Lange & Pierce, 1992; Schleepen & Jonkman, 2014). However, the t-UD phenomenon shows that successful transfer of a strategy does not always mean that transfer is successful as a whole, for the successfully transferred strategy may not yet yield expected levels of recall on the transfer task. That is, incomplete transfer can occur. This finding is particularly important for theorizing about transfer, because many authors believe that near transfer is easy (Chang et al., 2019; Robins, 1996; Schleepen & Jonkman, 2014) and strategy transfer is often investigated through near transfer paradigms, leading to the idea that strategy transfer would be most often a success. This belief may be somewhat inaccurate because it is based on only strategy transfer; strategy effectiveness is generally not assessed, and when it is assessed and a pattern resembling a t-UD is observed, authors do not make a direct link with transfer processes (Bjorklund et al., 1994; see also Schwenck et al. (2009) and the so-called "production deficiency cluster"). The results of the two studies show that even near transfer can be partially failed. Namely, a memory strategy can be transferred successfully but its benefit on recall is not. This was shown here using two different recall tasks and three different memory strategies, in children aged 4 to 7, attesting to the robustness of the phenomenon. In light of these results, theories of transfer and especially of near transfer should be revisited in order to integrate t-UDs.

The existence of t-UDs suggests that previous theories of transfer of learning in children are incomplete because they do not consider strategy effectiveness on the transfer task. Moreover, the observed role of flexibility argues for future research and theorizing about the specific underlying cognitive processes required for adapting knowledge to a new, transfer, task. Although the question of adaptability in transfer has been underlined by researchers (Schwartz et al., 2012), no precise mechanisms have been proposed. Which cognitive processes allow a child to adapt to novelty? Cognitive flexibility seems a good candidate.

Our finding that the cognitive flexibility component of EF is associated with greater performance (recall) during transfer is consistent with previous research (Brown et al., 1986; Pauen & Bechtel-Kuehne, 2016; Stad et al., 2017) and suggests that a satisfactory theory of transfer must include this skill. High levels of cognitive flexibility that permit comparing similarities and differences between the main and transfer tasks may reduce the cognitive resources needed for transferring the strategy, which frees resources for encoding items to be remembered. Stad et al. (2017) recently showed that cognitive flexibility plays a role in transferring newly acquired series completion skills, but, to the best of our knowledge, our study provides the first evidence for cognitive flexibility’s importance in transferring memory strategies. Given that some studies report success in training EF in young children, including flexibility (Scionti, Cavallero, Zogmaister, & Marzocchi, 2020), one practical application would be to add such training to the school curriculum, to increase the impact of strategy transfer on children’s recall on new tasks. Demonstrating this impact in future research would further support the hypothesis that EF is an underlying process in the transfer of strategy effectiveness.

Furthermore, our results suggest that a type of attentional switching (Konstantopoulos et al., 2015), like the one assessed in the CTC, may be important when transferring memory strategies. Such a perceptual flexibility was associated with better recall in the two studies. The faster children linked the digits in the CTC, the better their recall at transfer (no speed-accuracy trade-off). Surprisingly, a type of more conceptual or representational flexibility (Eichenbaum, 1997), which may operate in the DCCS, did not contribute to the transfer of sorting and clustering strategies, even though both the DCCS and the sorting and clustering strategies are based on the use of conceptual categories (e.g., animal, fruits, etc.). This outcome thus was more surprising in this experiment than it was in Experiment 1 with the rehearsal strategy, which does not involve conceptual categories. In short, the DCCS type of flexibility appears not to be involved in transfer of either a simpler, earlier-acquired strategy (Bjorklund, Dukes, & Douglas-Brown, 2009) or a more complex, later one that can be acquired only after a child masters the categories of items to be recalled. Furthermore, DCCS and CTC scores were not correlated, in spite of their common use in evaluating the same broad "cognitive flexibility" construct in children. The theoretical contribution of these findings is that switching attention back and forth between the main and the transfer task, which is likely to be measured through the CTC, is an important cognitive skill in strategy transfer. On the contrary, the ability to master a complex system of hierarchically-embedded "if-then" rules, necessary to succeed in the DCCS, does not seem to contribute to strategy transfer. These findings can provide hypotheses for future research to identify precise links between cognitive flexibility and transfer (Clerc & Josseron, in press).

Implications for Understanding Strategy Development

Miller (1990) has argued that UDs (of which t-UDs are a subcategory) are one phase in typical strategy development, when children have acquired a strategy but it does not yet provide the expected help to recall. Our demonstrations of t-UDs with several tasks suggest that UDs may persist during transfer even after children progress further in their strategy development and overcome UDs (i.e., benefit from the strategy) on an initial task. In other words, strategy development may look like a longer developmental process when transfer is considered.

One debate among strategy researchers concerns the prevalence of utilization deficiencies. Some researchers have argued that UDs are relatively rare and only affect certain children (Schlagmüller & Schneider, 2002; Schneider, Kron, Hünnerkopf, & Krajewski, 2004). Our experiments provide a new perspective on this debate. They suggest that UDs would seem more prevalent if researchers looked in the right place, specifically, at attempted transfer of strategies. The regular occurrence of t-UDs in two studies across two tasks, three strategies, and several ages suggests that they are not a rare phenomenon. Importantly, finding t-UDs across several strategies also suggests that t-UDs occur during several types of cognitive processes. Rehearsal is based on repetitively processing information to be memorized, whereas sorting and clustering involve categorizing items in order to group them together and therefore remember them more easily.

Past strategy research has shown frequent intra-individual variability in strategy use, with children still using old strategies even as new ones are acquired (Siegler, 2007). What has been less studied is whether intra-individual variability occurs in strategy transfer. Regarding t-UDs, it may be that some children show this pattern of results with one memory strategy but not with another, or with the same strategy in some trials only (see Bjorklund et al., 1992, and Schwenck et al., 2007, for results consistent with this possibility). Future research should look at these sorts of intra-individual variability. Moreover, exploring the occurrence of t-UDs when a child uses several different strategies could extend our knowledge of multiple strategy use. Most interesting would be whether the particular combination of strategies transferred affects recall during transfer (i.e., whether a t-UD occurs).

Our results also suggest an underlying process in strategy effectiveness: Strengthening the strategy, especially through explicit training, may be necessary for completely successful transfer, such that the level of recall on the main task is maintained into the transfer task. A strategy produced with less effort may require fewer cognitive resources and thus permit children to focus on encoding. In the two experiments, the effects of training are robust, lasting through transfer a day or more. Furthermore, the role of teaching in the acquisition of memory strategies has been outlined by several researchers (Coffman, Ornstein, McCall, & Curran, 2008; Schneider & Ornstein, 2019). Coffman et al. (2008) showed that the more the teachers talk about memory and encourage children to use several memory processes, the higher the strategic level in their pupils, as soon as the first grade. A practical application of our findings is that when children are taught a new memory strategy in school, they may need to "overlearn" it. That is, they need to practice the strategy well beyond the point at which they appear to have acquired the strategy. Otherwise, the strategy may not benefit recall.

Limitations

Although the two studies enrich our understanding of the complexities of strategy transfer, they have several limitations that should be addressed in future research. In both studies, the transfer phase included only two trials, which limits our understanding of the time-related evolution of transfer performance. In a recent study of transfer of tool use in toddlers, Pauen and Bechtel-Kuehne (2016) showed that 22 to 24-month-olds were better at transfer when they demonstrated a higher level of cognitive flexibility. This was limited to the first two transfer trials. Consistent with this, the results reported here in 4 to 7-year-olds show that more flexible children obtain better recall scores in two transfer trials. Borrowing these authors' explanation, we may hypothesize that the role of flexibility in transfer is more likely to occur at the very beginning of the transfer task, when the effort required for adapting the strategy is the highest. In our studies, we cannot be sure that this is true, since we only included two transfer trials. Future studies should test this possibility by including more transfer trials. Finally, our sample was limited in that all children came from a same cultural European background. Several studies have shown variation in measures of cognitive flexibility with East Asian children often outperforming Western children (Sabbagh, Carlson, Moses & Lee, 2006; Lan, Legare, Ponitz, Li & Morrison, 2011; Imada, Carlson & Itakura, 2013). This suggests that cognitive flexibility is highly malleable and is impacted by culture-specific practices and experiences. In light of these cross-cultural studies and the present findings, the degree to which t-UDs are experienced during transfer may also vary across cultures. To date, no studies have explored this idea.

Conclusions

The present studies have identified some of the subtleties of acquiring strategies and applying them effectively to other tasks, a cornerstone of learning. The surprising prevalence of t-UDs across tasks, strategies, and ages, and evidence for the impact of strategy strength and cognitive flexibility open up new avenues of research on strategies, transfer of learning, and the role of EF during cognitive development.

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