Cognitive flexibility in preschoolers: the role of representation activation and maintenance

Nicolas Chevalier and Agnès Blaye

Laboratoire de Psychologie Cognitive, University of Provence, France

Abstract

Preschoolers’ lack of cognitive flexibility has often been attributed to perseverative processing. This study investigates alternative potential sources of difficulty such as deficits in activating previously ignored information and in maintaining currently relevant information. In Experiment 1, a new task tapping attentional switching was designed to isolate the difficulty of overriding an initial representation, that is, perseverative processing (’Perseveration’ version), and the difficulty of activating a previously ignored representation, that is, activation deficit (’Activation-deficit’ version). Three-year-olds’ performance suggested that inflexibility may primarily stem from an activation deficit. Control experiments confirmed that the difficulty of the ‘Activation-deficit’ version could not be attributed to the effect of attraction to novelty. In Experiment 2, ‘distraction’ errors, alleged to reflect a failure to maintain a relevant representation, and ‘perseverative’ errors were distinguished. The results highlighted the important role of representation maintenance in flexibility. The present study indicates that preschoolers’ lack of cognitive flexibility is multi-determined and prompts us to reconsider the role of perseveration.

Introduction

As they develop, children are prone to face situations in which they must respond flexibly, voluntarily adapting their behaviours to changes occurring in the environment. Such behaviours are possible because of the development of cognitive flexibility (sometimes referred to as attentional or mental flexibility), which can be defined as the ability to switch mental sets in response to changing relevant cues in the environment, and complementarily, to maintain a mental set when changes are irrelevant (e.g. Sternberg & Powell, 1983). Cognitive flexibility has been shown to relate to many cognitive abilities such as theory of mind (e.g. Carlson & Moses, 2001; Müller, Zelazo & Imrisek, 2005), language (e.g. Deák, 2003; Jacques & Zelazo, 2005), or arithmetical skills (e.g. Bull & Scerif, 2001). It is now well documented that it develops dramatically in the preschool years, as evidenced by young children’s increasing performance on a wide array of tasks (e.g. Deák, 2000; Espy, 1997; Jacques & Zelazo, 2001; Smidts, Jacobs & Anderson, 2004; Zelazo, Frye & Rapus, 1996; many of them are reviewed in Carlson, 2005). For instance, 4- and 5-year-old children encounter little difficulty in switching between sorting cards by shape and colour in the Dimensional Change Card Sort (DCCS; Frye, Zelazo & Palfai, 1995; Zelazo, Müller, Frye & Marcovitch, 2003) whereas most 3-year-olds fail to do so, continuing to sort by the initial criterion after being explicitly instructed that it is no longer relevant. Such perseverative errors may reflect two alternative processes: failed inhibition of previously relevant information and/or failed activation of previously ignored information (see Jacques, Zelazo, Kirkham & Semcesen, 1999; Zelazo et al., 2003). The present study sets out to investigate the respective roles of these processes in perseverative errors, and to investigate another error type in preschoolers, distraction errors.

Several theoretical accounts have been proposed to explain how flexible behaviours develop (for a review, see Chevalier & Blaye, 2006). Zelazo and colleagues (Frye et al., 1995; Zelazo & Frye, 1998; Zelazo et al., 1996) proposed the Cognitive Control and Complexity (CCC) theory, according to which flexible use of different sorting rules for the same objects is made possible by the ability to organize such rules into a hierarchical structure that clearly indicates when to use each of them. Such a hierarchical structure is allowed by children’s increasing reflection on (i.e. awareness of) the sorting rules they know (Zelazo, 2004). As they are unable to build this hierarchical structure, young children may adopt a default strategy consisting in always selecting the initial rule because it is the most strongly associated with the task at hand. Alternatively, Munakata (2001) posited that flexible behaviours evolve as a function of memory resources that support increasingly strong representations. Flexibility is observed whenever the relevant representation is strong enough to override its initially relevant but now irrelevant competitors.

These proposals attribute a secondary role to inhibitory control because inhibition of the initial representation is
thought to result from other variables than inhibition (hierarchical-structure building, memory resources). However, other researchers advocate a primary role for inhibitory control. According to the 'attentional-inertia' position (Diamond, Carlson & Beck, 2005; Diamond & Kirkham, 2005; Kirkham, Cruess & Diamond, 2003), children's flexibility depends on the ability to inhibit attention to a particular feature of an object (e.g. the redness of a red boat leads children to consider it as a 'red thing') and refocus it onto another feature of that object (thinking of the red boat as a 'boat'). The 'redescription hypothesis' (Kloo & Perner, 2003, 2005) also emphasizes the re-representation of a multidimensional object, but it accounts for attentional inertia not in terms of an immature inhibitory control, but instead by a conceptual limitation preventing children from understanding that a single object can be considered from different viewpoints.

**Perseveration versus activation deficit**

As this brief summary points out, the processes responsible for the development of cognitive flexibility during the preschool period remain highly controversial. Nonetheless, all of these approaches agree with the claim that children behaving inflexibly do so because they perseverate on the initially relevant representation. Indeed, such an idea is so widespread in the psychological literature (not only in developmental psychology) that it has almost become a commonplace. Yet, following Deák (2000; Deák & Narasimham, 2003), it may be argued that perseverative performance is not all-alike and may result from processes other than failed inhibition of initially relevant representations. A recent study (Zelazo et al., 2003; see also Müller, Dick, Gela, Overton & Zelazo, 2006) suggests that a failure to activate a previously ignored representation could also be responsible for inflexibility, hence offering a negative-priming hypothesis.1 Zelazo et al. used the DCCS, in which children must sort bidimensional objects according to a first pair of rules related to one dimension (e.g. red objects go to the red target, and blue objects go to the blue target) and then switch to a pair of rules linked with the other dimension (here, boats go to the boat target, rabbits go to the rabbit target), and designed two modified versions. In an 'Activation-deficit' version2 (that the authors labelled 'Negative Priming'), the values of the relevant dimension in the preswitch phase no longer appeared in the postswitch phase (e.g. if shape was the first sorting criterion, 'red boats' and 'blue rabbits' were replaced with 'red cars' and 'blue flowers'). Consequently, perseveration on the initially relevant representation was impossible (i.e. sorting boats with boats and rabbits with rabbits in the postswitch could not be implemented), but an alternative source of difficulty remained: children could still err because they failed to activate the values of the dimension that had to be ignored in the preswitch phase. In a 'Perseveration' version (that the authors labelled 'Partial Change'), the values of the relevant dimension in the preswitch remained present in the following phase so that perseveration could still occur. However, the values of the initially to-be-ignored dimension were changed in the second phase. As a result, children could not err because of a failure to activate previously ignored information. These modified versions were compared to the standard version which made possible both sources of difficulty. Consistent with all the theoretical accounts presented above, the modified version in which perseveration was still possible turned out to be as difficult as the standard task. However, surprisingly, performance was not any higher in the version in which errors could stem only from an activation deficit. These results highlighted that the development of cognitive flexibility not only depends on overriding the tendency to persevere on an initial representation, but relies on successful activation of previously ignored representations as well.

This conclusion is strengthened by recent findings with adults. Dreisbach and Goschke (2004) used a task in which participants saw for instance pairs of differently coloured letters (e.g. a blue 'I' and a red 'A') on each trial and had to say whether the letter of a given colour (e.g. blue) was a vowel or a consonant. After a series of trials, the relevant colour was changed. In the 'perseveration' version, participants had now to attend to a novel colour (e.g. yellow) while ignoring the formerly relevant one (blue), and could only err because of perseveration on the blue colour. In the 'activation-deficit' version, they had to switch to the previously irrelevant colour (red) while ignoring a novel colour (e.g. yellow), and could thus err only because of failure to now attend to the red colour. Participants took longer to respond after a switch in both versions. These findings, consistent with Zelazo et al.'s (2003), further evidence involvement of the difficulty of activating previously ignored representations in switching situations.

A recent study with adults by Maes, Damen and Eling (2004; see also Maes, Vich & Eling, 2006), using a card-sorting task in which stimuli could be sorted according to three dimensions (size, colour, and shape), casts doubts on the very role of overcoming previous representations. The results revealed that participants encountered much more switching difficulties when the task required that the previously ignored dimension be switched to than when it only needed to override the initially relevant dimension (see also Gauntlett-Gilbert, Roberts & Brown, 1999). The authors concluded that perseverative behaviour, that is, the repetition of previously relevant responses,

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1 Throughout this article, we will refer to this hypothesis as the 'activation-deficit' hypothesis. Indeed, the phrase 'negative priming' focuses on what initially happens when the irrelevant representation is being ignored, whereas the phrase 'activation deficit' emphasizes the later difficulty in reactivating this representation because of its being previously ignored. Of course the two aspects are not distinguishable. However, 'negative priming' is often understood as arising from efficient controlled inhibition whereas 'activation deficit' is more neutral in this respect. See the General Discussion for further consideration.

2 Each task version is referred to by the difficulty that remains to be overcome (either perseveration or activation deficit).
may primarily reflect a difficulty in activating a previously to-be-ignored representation. Such a conclusion is at odds with the main theoretical proposals accounting for the development of cognitive flexibility because these accounts equate perseverative responses with perseverative processing of previously relevant representations. The first purpose of the present study was to further investigate the respective contributions of perseveration on an initial representation and failure to activate a previously ignored representation on children's inflexible behaviour.

Perseverative and distraction errors

The exclusive reliance on perseverative errors to account for preschoolers' inflexible behaviour has completely left aside another potential source of inflexibility: failure to maintain a representation. The absence of interest in this variable may at least partly relate to how tasks tapping cognitive flexibility are designed. Most of them only offer two response options: responding correctly, or repeating previously correct responses which are then interpreted as ‘perseverative errors’. No other error types are possible.

Failure of representation maintenance has been highlighted on the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948), in which participants have to switch between two of three response options (traditionally based on shape, number and colour), using failure-to-maintain-set and distraction errors (e.g. Barceló & Knight, 2002; Stuss, Levine, Alexander, Hong, Palombo, Hamer, Murphy & Izukawa, 2000). For instance, Barceló and Knight (2002) showed that healthy adults almost exclusively committed distraction errors (when participants err by selecting the incorrect response that was also incorrect before the switch) on the WCST, whereas perseverative errors (selecting responses that were formerly correct) were very rare. Similarly, Crone, Riderinkhof, Worm, Somsen and van der Molen (2004) used a task in which participants had to switch between three types of rules, and revealed that from 8 years to early adulthood distraction errors were more frequent than perseverative errors. Moreover, both error types did not show strictly identical developments: Perseverative errors greatly decreased for the younger groups and reached adult levels at around 11–12 years of age whereas distraction errors did not reach adult levels before 13–15 years of age. It therefore appears that the ability to maintain a representation contributes to cognitive flexibility from middle childhood through early adulthood. However, we ignore its potential role in the development of flexibility in preschoolers. Therefore, the second purpose of the present study was to explore the role of maintenance of a currently relevant representation in preschool-aged children.

In Experiment 1A, we sought to establish, using a new task, whether perseverative performance results from perseverative processing of initially relevant representation or instead from an activation failure. Experiment 2A then explored whether there may be other displays of inflexibility than perseverative performance by investigating an alternative error type, distraction errors.

**Experiment 1A**

As mentioned earlier, recent studies with children and adults have cast doubt on the claim that perseverative errors reflect only perseveration on an initial representation, and they highlighted the role of failing to activate the previously ignored representation. This issue has been addressed in preschoolers, with direct manipulations of task features, using the DCCS (Müller et al., 2006; Zelazo et al., 2003), though indirect evidence can be gleaned from other tasks (see for instance Deák, 2000). Experiment 1 aimed to expand these results to a new flexibility task that was designed to test the respective contribution of perseveration on the initial representation and failure to activate the newly relevant representation to the development of cognitive flexibility. The letter-judgment task used by Dreisbach and Goschke (2004) was adapted for preschool-aged participants into the Preschool Attentional Switching Task (PAST). Children were presented with two bidimensional objects (e.g. a blue cat and a yellow flower). They had to focus on, say, the blue object and perform a shape-matching task. After a first series of trials (preswitch phase), the relevant colour was changed (postsswitch phase, yellow becomes relevant) and they had to perform the same processing on the yellow object of the current stimulus.

One advantage of the PAST is that it isolates attentional switching from processing switching between the two phases. During the postswitch phase of the DCCS, children have to implement both an attentional switch (e.g. from the information about object shape in the preswitch to the information about the object colour in the postswitch) and at the same time a switch between two types of processing (e.g. from sorting by shape to sorting by colour). In the PAST, children only have to switch attention between the two phases (e.g. from blue to yellow) and keep implementing the same processing modes (sorting by shape) throughout the task. Therefore, performance on the PAST was expected to inform on the difficulty of attentional switching per se and whether activation failures observed on the DCCS (Müller et al., 2006; Zelazo et al., 2003) can be generalized across task formats.

In the standard version, the same two colours were used on both phases. Consequently, errors in the postswitch phase may reflect perseveration in processing the object of the initially relevant colour. For instance, children could keep attending to blue objects, whereas the postswitch phase required playing the yellow game, because blue objects still appeared on postswitch trials. Errors may also reflect a difficulty of now processing the object of the previously ignored colour. For instance, children could fail to attend to yellow objects because
they ignored them in the preswitch. In the ‘Perseveration’ version, the relevant colour in the preswitch phase (e.g. blue) became irrelevant in the postswitch phase, leaving perseveration on this colour possible. However, the irrelevant colour in the preswitch was replaced by a novel colour, thus eliminating the possibility of erring because of an activation deficit. In contrast, in the postswitch phase of the ‘Activation-deficit’ version, the initially irrelevant colour (e.g. yellow) became relevant while a novel colour (e.g. red) was irrelevant (see Figure 1). Here, errors may reflect only failure to activate the previously ignored colour (perseveration on the previously relevant colour – here, blue – was impossible as this colour was not present in the postswitch).

The respective difficulty of these versions was investigated in 3- to 4-year-old children because this age range appears to be a turning point in the development of cognitive flexibility as evidenced by the transition from a majority of 3-year-olds failing on the DCCS to a majority of 4-year-olds succeeding (Zelazo et al., 1996). Relying on the main theoretical accounts of this development (Zelazo et al., 1996; Kirkham et al., 2003; Kloo & Perner, 2003; Munakata, 2001), one would predict that the ‘Activation-deficit’ version would lead to better performance than the other two versions as it suppressed the supposedly main obstacle to flexibility, perseveration on the initial representation. In contrast, in the light of recent findings highlighting an activation difficulty (Dreisbach & Goschke, 2004; Maes et al., 2004; Zelazo et al., 2003), one would predict no difference in difficulty between the standard and ‘Activation-deficit’ version. A question of particular interest was whether the ‘Perseveration’ version would turn out to be easier than the other versions.

Method

Participants

Participants were 69 children (37 girls) recruited in French preschools. Written informed consent for participation was obtained from parents. Children ranged in age from 3;0 to 3;11 (mean age = 42.6 months, SD = 2.9 months). Five additional children’s data were eliminated because children could not discriminate the colours and shapes used in the PAST. Participants were tested individually in a quiet room of their preschools.
now, we are going to play a new game. We no longer play
proceeded to the postswitch phase. Only children who successfully passed the preswitch phase
if the criterion was not satisfied after a total of 16 trials. The preswitch phase was failed
first eight trials, the test cards were displayed anew until
consecutive trials. If this criterion was not satisfied after the
Participants completed at least eight test trials. To pass
+ rules or
'Perseveration'; 43.3 months in 'Activation-deficit') and
Mean age (42.6 months in standard; 42 months in
Results
Mean age (42.6 months in standard; 42 months in
'Perseveration'; 43.3 months in 'Activation-deficit') and
sex ratio did not significantly differ across versions. The
preswitch phase of the PAST was identical in all versions. Not surprisingly, performance in the preswitch phase did not differ across versions, $\chi^2(2, N = 130) = 1.47, p > .48$, with 60% of the participants succeeding on the preswitch phase in the standard version, 58% in the 'Perseveration' version and 65% in the 'Activation-deficit' version. It appears that even before the relevant colour was switched, many children encountered some difficulty in processing the relevant colour in the face of the interference created by the alternative colour.
Children who succeeded in the preswitch phase then completed the postswitch phase. It consisted of six conflicting trials (i.e. trials in which each colour led to a different response) and two non-conflicting trials (i.e. trials in which the colours led to the same response). Performance on the non-conflicting trials (in which the two colours led to the same response) were close to ceiling (mean percent correct = 93, $SD = 19$), suggesting that children were not responding randomly.
After the preswitch phase, there remained 13 participants in the standard version (mean age = 42.6 months,
The six conflicting trials) showed a significant main effect in the postswitch phase (number of correct responses on the screen) of results. The ANOVA computed on the scores showed that the 'Activation-deficit' version of the PAST than in the 'Perseveration' version (79%) was significantly more difficult than the 'Perseveration' version (36% children passing) was significantly different across versions. The percentages of children in the 'Perseveration' version ($M = 42.0$, age range $= 3;4–3;11$) and 14 children in the 'Activation-deficit' version ($M = 36.6$, age range $= 3;1–3;11$). Mean age and sex ratio did not significantly differ across versions. The percentages of children who passed the preswitch phase of each PAST version are shown in Figure 2. Approximately half of the children succeeded in the standard version of the PAST. The chi-square analyses revealed that the 'Activation-deficit' version (with 36% children passing) was significantly more difficult than the 'Perseveration' version ($\chi^2(1, N = 28) = 5.25, p < .05$, but did not differ from the standard version (46%), $p > .45$. Success rates tended to be higher in 'Perseveration' than in the standard version, $\chi^2(1, N = 27) = 3.04, p = .08$. These results show that children experienced more difficulty in the 'Activation-deficit' version of the PAST than in the 'Perseveration' version.

Parametric statistical analyses suggest a convergent pattern of results. The ANOVA computed on the scores in the postswitch phase (number of correct responses on the six conflicting trials) showed a significant main effect of version, $F(2, 37) = 4.67, MSE = 1.86, p < .05$. Tukey post-hoc tests revealed that performance was higher in the 'Perseveration' version ($M = 5.29, SD = .83$) than in the 'Activation-deficit' version ($M = 3.71, SD = 1.90, p < .05$), whereas the standard version ($M = 4.61, SD = 1.12$) did not differ from any of them ($ps > .21$).

**Discussion**

Experiment 1A aimed at investigating the role of the difficulty of activating previously ignored information in young preschoolers’ lack of flexibility. Toward this end, we designed a new switching task, the PAST, that required attentional switching between a pre- and a postswitch phase. The specific features of the PAST led about one-third of 3-year-olds to encounter difficulty in the pre-switch phase, which contrasts with similar phases on other tasks such as the DCCS that were revealed to be unsatisfactory. How can this preswitch difficulty be accounted for? A first hypothesis may stipulate that it relates to stimulus complexity because, in the PAST, two bidimensional objects appeared simultaneously on the screen instead of one in the DCCS (cf. Brooks, Hanauer, Padowska & Rosman, 2003). However, as will be shown in Experiment 2A, the proportion of children passing the preswitch phase of the PAST is not reduced when stimuli are even more complex with three objects instead of two (see also Déak, 2000).

Alternatively, the preswitch difficulty may result from a switching requirement already present in this original phase. Indeed, in this phase (and in the following one as well) of the PAST, an attentional switch is needed within each trial since the children must switch from the colour dimension (that indicates which object is relevant) to the shape dimension (that signals which key to press). This within-trial attentional switch may lead children to change their representations of the object (e.g. from a ‘blue thing’ to a ‘flower’). Such bidimensional object re-representations have been hypothesized to contribute to children’s switching difficulties (Kirkham et al., 2003; Kloo & Perner, 2005). Therefore, some children may have failed in the preswitch phase because of the object re-representation demand. It should nonetheless be noted that object re-representation may be challenging either because it requires that the first (colour) representation be inhibited or because of the difficulty of activating the second (shape) representation. There is hence no a priori reason to believe that children who passed this phase were more efficient at overcoming a perseverative process than an activation deficit. The reverse seems even more plausible. To determine which object is relevant, children had to ignore the shape (otherwise they would be in a deadlock situation, the two object shapes leading to divergent responses) in order to focus on the colour. It seems highly probable that some children then encountered difficulty in reactivating the shape representation. In contrast, once the relevant object was selected, the shape representation had to be reactivated but the colour one did not need to be suppressed since it did not lead to a conflicting response in the PAST. As a consequence, failure due to perseverative processing of colour seems improbable here.

Investigating the difficulty of activating previously ignored representation was the main purpose of Experiment 1A and was manipulated between the two phases. As the difficulty of object re-representation is identical in the pre- and postswitch phases and as the second phase was only administered to children succeeding in the first one, postswitch performance is assumed to reflect the additional requirement to switch attention to a newly relevant colour. This difficulty could have been even increased by feedback withdrawal in the postswitch phase that may have hampered children’s performance monitoring (see Bohlman & Fenson, 2005). The results showed that the ‘Activation-deficit’ version was significantly more difficult than the ‘Perseveration’ version.
but did not significantly differ from the standard one, hence bringing new evidence confirming the role of an activation deficit in preschoolers. The finding that the ‘Activation-deficit’ PAST was as difficult as the standard one (respectively, 36% and 46% children succeeding) is consistent with the difference observed by Zelazo et al. (2003) between the ‘Negative-Priming’ DCCS (analogous to ‘Activation-deficit’ PAST) and standard version with 29% and 19%, respectively, in their Experiment 8; 25% and 56% in their Experiment 9. The present results complement previous findings by showing that this deficit, revealed on the DCCS (Müller et al., 2006; Zelazo et al., 2003), is not limited to that particular task format, but is also involved in other switching measures. The role of activation deficit appears all the more compelling as it was observed here on a subgroup of children who were ‘selected’ on the basis of the switching demands already present in the preswitch phase and can thus be supposed to have more efficient executive control than in the general population. Moreover, the finding that switching difficulties assessed on the PAST are higher in situations requiring activation of a previously ignored representation than those requiring inhibition of an initial representation is consistent with the results of Maes et al.’s (2004) study with adults. Müller et al. (2006) investigated the features of the activation difficulty and showed that it is elicited even with one single preswitch trial, that it is more frequent when the frequency of conflicting trials in the preswitch is high and can still be observed even after a 10-minute delay between the pre- and postswitch phases. They also concluded that the activation difficulty only occurs when the preswitch test and target cards conflict on the DCCS. The results on the PAST, on which there is no conflict between the stimuli and the target drawings but instead between the different objects of each stimulus, showed that the critical feature is the presence of conflict per se in the preswitch.

The present results do not favour the claim that a major difficulty on the PAST is to avoid perseverating on an initial representation since performance was better in the ‘Perseveration’ than in the ‘Activation-deficit’ PAST. This contrasts with Zelazo et al.’s (2003, Experiment 8) findings that the ‘Partial-Change’ DCCS (analogous to the ‘Perseveration’ PAST) yielded performance that did not significantly differ from the ‘Negative-Priming’ (activation-deficit) DCCS (respectively, 50% and 29% children passing). With so few studies investigating perseveration versus activation deficits in preschoolers, every attempt to explain this discrepancy in results may only be speculative and more research is clearly needed. Although the differences observed on the PAST and the DCCS go in the same direction, the partially divergent conclusions may be related to the difference between attentional- and processing-switching. In the PAST, children have to keep implementing a shape-matching processing while switching attention between blue and yellow information, whereas in the DCCS, they have to switch between two processing modes (sorting by colour and sorting by shape) and switch attention between colour and shape information. Further research is needed to assess to what extent the kind of switching (attentional versus processing) and the kind of processing difficulty (activation deficit vs. perseveration) are linked.

Overall, the results suggest that young preschoolers’ inflexible responses on the PAST reflect to a greater extent a failure to activate previously to-be-ignored information than perseverative processing as evidenced by worse performance in the ‘Activation-deficit’ version than in the ‘Perseveration’ version. Thus activating previously irrelevant information appears as a main obstacle to flexible behaviour. Nonetheless, one should be cautious about such a conclusion because a potentially confounded variable could also account for the difference in scores between the ‘Perseveration’ and ‘Activation-deficit’ versions, attraction to novelty. That is, in the ‘Perseveration’ version, the novel colour in the postswitch phase was relevant whereas it was irrelevant in the ‘Activation-deficit’ version. If novelty captures attention, it may be particularly challenging to ignore a novel colour, hence explaining the poor performance in the ‘Activation-deficit’ version. In contrast, it may be especially easy to switch to a novel colour as in the ‘Perseveration’ version. The possible role of attraction to novelty was acknowledged by Zelazo et al. (2003) on their DCCS variants, though not empirically tested. To clarify this issue on the PAST, the role of attraction to novelty was tested in a control experiment.

**Experiment 1B: First control experiment**

A control task was designed to study the role of attraction to novelty per se. In this ‘Novelty’ task, the relevant colour remained unchanged throughout the task, hence imposing no attentional switch between the two phases. A novel colour was introduced in the postswitch phase, but as it had to be ignored, attraction to novelty was the only possible source of difficulty in the postswitch phase of the ‘Novelty’ task. Therefore, if attraction to novelty accounts for the difficulty of the ‘Activation-deficit’ version, then there should be no difference in performance between the ‘Activation-deficit’ and ‘Novelty’ versions. By contrast, if the ‘Activation-deficit’ version was particularly difficult because it required that the previously ignored colour be activated, then the ‘Novelty’ version should be easier than the ‘Activation-deficit’ version because no attentional switch to a previously ignored colour was required in the former.

**Method**

**Participants**

Twenty-two 3-year-old children (11 girls) recruited from a French preschool participated in this experiment. Written informed consent for participation was obtained.
from parents. Participants ranged in age from 2;10 to 3;9 (mean age = 42.5 months, SD = 3.1 months). Two additional children's data were eliminated because children could not discriminate the colours and shapes used in the task. Participants were tested individually in a quiet room of their preschools.

Materials and procedure

The materials and procedure used in this control experiment were similar to those in Experiment 1A, except that the relevant colour was the same in both phases whereas the irrelevant colour was changed in the second phase. Moreover, participants were told in the postswitch phase that they would have to go on playing the same game though they would see new pictures. Then the rules for the relevant colour were repeated. The scoring procedure was identical to the one used in Experiment 1A.

Results

Performance on the ‘Novelty’ version was compared to performance on the ‘Activation-deficit’ version from Experiment 1A. Mean age and sex ratio did not significantly differ across the two versions. The chi-square analysis for the preswitch phase revealed no significant difference in success rates between these versions (64% in ‘Novelty’ and 66% in ‘Activation-deficit’), \( \chi^2(1, N = 28) = 5.25, p > .05 \). The postswitch phase was administered to the 14 children who succeeded in the preswitch (mean age = 42.5 months, age range = 3;1–3;11). They did not significantly differ in age or sex ratio from the children in ‘Activation-deficit’. The analysis of the postswitch phase showed that the children obtained significantly higher performance in the ‘Novelty’ than in ‘Activation-deficit’ version, with respectively 79% and 36% of children succeeding on this phase, \( \chi^2(1, N = 28) = 5.25, p < .05 \). A t-test computed on the mean number of correct responses for conflicting trials confirmed that the two versions significantly differed (\( M = 5.14, SD = 1.17 \) in ‘Novelty’, \( M = 3.71, SD = 1.90 \) in ‘Activation-deficit’; \( t(26) = 2.40, p < .05 \)).

Discussion

Experiment 1B was set to determine whether the particular difficulty of the ‘Activation-deficit’ version in Experiment 1A resulted from an attraction-to-novelty effect. Higher performance in the ‘Novelty’ task than in the ‘Activation-deficit’ version does not lend support to the hypothesis that poor performance in ‘Activation-deficit’ was entirely due to an attraction to the novel but irrelevant colour in the postswitch phase. However, performance in the ‘Novelty’ task was not at ceiling, since 21% of children erred though no switch was required. It therefore remains possible that attraction to novelty modulated performance in Experiment 1A without fully accounting for it. Maes et al. (2004) suggested that a marginal attraction-to-novelty effect could account for the poorer (yet nonsignificant) performance on the ‘Activation-deficit’ version of their task than in the standard one (that also required that ignored information be activated). Such a marginal role of attraction-to-novelty could also explain similar patterns of results observed on the PAST as well as on the DCCS (Zelazo et al., 2003, Experiment 9). The control experiment also indirectly strengthened Zelazo et al.’s (2003) conclusion that children encountered some difficulty activating ignored information on the DCCS, though Zelazo and his colleagues did not test for the potential role of attraction to novelty. Further discussion of a potential attraction-to-novelty effect is postponed until Experiment 2B.

Just as it seems that variables other than perseveration on an initial representation may underlie ‘perseverative errors’, different error types may reflect immature flexibility. Experiment 2A was devoted to the investigation of one such alternative error type: ‘distraction errors’.

Experiment 2A

Behaving flexibly not only requires switching between representations in response to relevant changes occurring in the environment, but also maintaining a given representation when changes are irrelevant to the current goal (Blaye, 2001; Sternberg & Powell, 1983). Recent studies have shown in middle childhood and adulthood the existence of errors linked with the unsuccessful maintenance of the relevant representation on WCST-like tasks (Barceló & Knight, 2002; Crone et al., 2004). Errors of maintenance, or ‘distraction errors’, differ from ‘perseverative errors’ in that participants fail to respond flexibly by not selecting the incorrect response that was previously relevant, but instead by selecting an incorrect response that had not just previously been relevant. As a consequence, this type of error can only be revealed on tasks with more than two response options. Yet, most studies investigating the development of cognitive flexibility in preschoolers have used tasks with only two response options, thus not allowing us to distinguish between the two error types. In Experiment 2A, a task with three response options was used in order to evaluate, using the potential existence of distraction errors, the contribution of representation maintenance to preschoolers’ flexibility.

Method

Participants

Ninety-nine children (50 girls) participated in this experiment. They were recruited from two French preschools.

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3 Here, the word ‘perseverative’ refers to the performance outcome, that is, the repetition of a previously correct but now incorrect response. However, it should be kept in mind that the phrase ‘perseverative errors’ does not induce a specific process: it can result from either perseverative processing of the initially relevant representation or failed activation of the previously ignored one.
Written informed consent was obtained from the parents. They ranged in age from 3:0 to 5:11 and were split into three age groups: 34 3-year-olds (mean age = 40.8 months, standard deviation = 2.5 months, age range = 3:0–3:9), 29 4-year-olds (M = 52.8, SD = 3.5, age range = 4:0–4:11), and 36 5-year-olds (M = 66.1, SD = 3.3, age range = 5:0–5:11). Four additional children's data were eliminated because children could not discriminate the colours and shapes used in the PAST-3. Participants were tested individually in a quiet room of their preschools.

Materials and procedure

The materials and procedure used for the Preschool Attentional Switching Task with three response options (PAST-3) were similar to those used for the PAST in Experiments 1A and 1B, with the following exceptions. First, three differently shaped and coloured objects (e.g. a blue car, a green cat, and a yellow flower) were presented on each trial and were to be matched to three non-coloured target cards depicting a flower, a car and a cat. Second, the entire rule for the three shapes (e.g. ‘In the Blue Game, when the blue picture is a cat, press here [on the “cat” key], when the blue picture is a flower, press there [on the “flower” key], and when the blue picture is a car, press there [on the “car” key]’) was repeated on the first two trials of each phase. On the subsequent trials, children were only reminded of a short rule (e.g. ‘We are playing the Blue Game’). Third, in addition to the scoring method used in Experiment 1 and the control experiment, errors were classified as ‘perseverative’ or ‘distraction’ following Barceló and Knight’s (2002) procedure. That is, as one colour was relevant in the preswitch phase (e.g. blue) and another in the postswitch phase (e.g. yellow), the third colour (green) was never relevant throughout the task. In the postswitch phase, errors that consisted in responding on the basis of the previously relevant colour (in the example, blue) were labelled ‘perseverative’, and errors that consisted in selecting the colour that was never relevant (in our example, green) were termed ‘distraction errors’ (see Figure 3).

Results

Analysis of success rates in the PAST-3

Five-year-old children almost reached ceiling in the PAST-3 with only one of 36 children failing the preswitch phase and one of 35 failing the postswitch phase. Similarly, errors were very rare for this age group (only four children committed errors in the postswitch phase). Consequently, 5-year-olds’ data were excluded from the subsequent analyses.

A chi-square analysis showed that fewer 3-year-olds passed the preswitch phase than 4-year-olds (68% and 90%, respectively), χ²(1, N = 63) = 4.39, p < .05. The success rate for 3-year-olds is comparable with that observed for the two-response-options version in Experiment 1A. For the postswitch, there remained 23 3-year-olds (mean age = 40.8 months, age range = 3:0–3:9) and 26 4-year-olds (M = 52.8, age range = 4:0–4:11). The percentage of children passing the postswitch phase at age 4 was significantly higher than at age 3 (77% and 39%, respectively), χ²(1, N = 49) = 7.22, p < .01. A t-test computed on the number of correct responses for incompatible trials confirmed that 4-year-olds (M = 52.3, SD = 1.24) outperformed 3-year-olds (M = 4.22, SD = 1.35) in the postswitch phase (t(47) = 2.74, p < .01). Thus, the results showed that both phases of the PAST-3 are developmentally sensitive in the preschool years.

Analyses of error types on the postswitch phase

As errors were not normally distributed, they were first analysed categorically. Preliminary analyses showed that more children committed errors (whatever the type) at age 3 than at age 4, with 74% and 38%, respectively, erring at least once, χ²(1, N = 49) = 6.20, p < .05. We then analysed the frequency of participants committing each error type (see Table 1). Fifty-seven percent of 3-year-old participants committed perseverative errors and 61% committed distraction errors. At age 4, 35% committed perseverative errors and only 8% committed distraction errors. The frequency of participants committing distraction errors significantly dropped between 3 and 4, χ²(1, N = 49) = 15.69, p < .001, whereas the difference in perseverative errors was not significant, p > .12. Analyses run on the number of errors committed provided convergent results with a significant drop between 3 and 4 only for distraction errors (Mann-Whitney's U(1, N = 49) = 143.50, p < .01 for distraction errors, p > .19, for perseverative errors; see Figure 4).

A 2 (Age) × 2 (Error Type) repeated measure ANOVA was computed on the number of errors that children committed. There was a significant effect of age (F(1, 47)
Table 1  Frequency (percentage) of 3- and 4-year-old children committing errors in Experiments 2A and 2B

<table>
<thead>
<tr>
<th>Experiment</th>
<th>No error</th>
<th>Perseverative errors only</th>
<th>Distraction errors only</th>
<th>Both types of error</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-year-olds</td>
<td>2A</td>
<td>6 (26)</td>
<td>3 (13)</td>
<td>4 (17)</td>
</tr>
<tr>
<td>4-year-olds</td>
<td>2A</td>
<td>16 (61)</td>
<td>8 (31)</td>
<td>1 (4)</td>
</tr>
<tr>
<td>3-year-olds</td>
<td>2B</td>
<td>4 (27)</td>
<td>2 (13)</td>
<td>4 (27)</td>
</tr>
</tbody>
</table>

Figure 4  Percentage of 3- and 4-year-old children by number of perseverative and distraction errors committed in the postswitch phase of the PAST-3 (Experiment 2A).

Discussion

Using a task with three response options, Experiment 2A explored the role of representation maintenance in preschoolers’ cognitive flexibility. The results revealed the existence of distraction errors in preschool-aged children, and showed that they occurred as frequently as perseverative errors at age 3. Experiment 2A thus suggests that the cognitive inflexibility observed at this age is partly attributable to a difficulty in maintaining a currently relevant representation. This source of difficulty had been underestimated in previous studies that used two-response-option tasks.

A similar age trend was observed on the Flexible Induction of Meaning (FIM) task (Deák, 2000) in which more than two response options are available. On this task, children had to perform successive selections of objects on the basis of predicate cues. Selections had to be made for sets of multiple objects that allowed them to differentiate between perseverative patterns (children failing because of repeated selection of the formerly correct responses) and other, non-perseverative error patterns that Deák calls ‘indiscriminate errors’ (children failing by selecting other responses than the formerly correct ones). On both the FIM task and the PAST, non-perseverative errors decreased more than perseverative patterns between ages 3 and 4. However, Deák (2000) did not attribute indiscriminate patterns to a maintenance failure, but instead to lack of understanding that object selections on the FIM task must be driven by predicate cues. Having understood that they are expected to make a novel selection but they are unable to rely on predicate cues, some children may adopt a random-responding strategy. On the PAST-3, instructions referred to colours familiar to 3-year-olds and they were explicit regarding which colour to attend to in the postswitch phase. Therefore, it seems reasonable to assume that, on this task, distraction errors mostly reflected a maintenance failure (see also Crone et al., 2004).

On the PAST-3, as well as the FIM task, distraction errors disappeared before perseverative errors did. Such a discrepancy has also been observed in a situation requiring children to associate pictures according to categorical (thematic/taxonomic) relations. Children succeeded at maintaining one relation in the face of the other interfering relation before they could successfully switch between them (Maintenant & Blaye, 2005). In that experiment and in the present one, representation maintenance was achieved before perseverative errors stopped occurring. Although Crone et al. (2004) also observed a discrepancy between the two error types, in their study with older children, distraction errors reached adult levels after perseverative errors did. The occurrence of both error types is probably closely tied to the differences between the tasks used in each study. For instance, the rules were repeated before each trial in the PAST-3 and were explicitly stated in Maintenant and Blaye’s study, thus imposing lighter demands on working memory than the task used by Crone et al. in which relevant rules had to be inferred from cues or feedbacks. As working memory demands are likely to influence representation maintenance, it would be interesting to assess it in a version of the PAST that imposed a heavier load on working memory (for instance, by requiring that the rules be inferred from feedback) that would therefore be more challenging for older preschoolers.
Experiment 2B: Second control experiment

The PAST-3 used in Experiment 2A offers the opportunity to further address the role that attraction to novelty might have played in Experiment 1A. It was important to rule out the possibility that poorer performance in the ‘Activation-deficit’ version than in ‘Perseveration’ (Experiment 1A) was the mere reflection of an attraction-to-novelty effect. Experiment 1B showed that attraction-to-novelty could not entirely account for this performance difference. Nonetheless, it may be argued that the Experiment 1B design was not perfectly suited to rule out the role of attraction-to-novelty since no attentional switch was required between the phases, though Deák, Ray and Pick (2004) found, in another flexibility task, that performance on a version in which children were re-instructed on the same rule did not differ from a version in which they had to switch rules (see also Merriman, Marazita, Jarvis, Evey-Burkey & Biggins, 1995, for a comparable approach to attraction-to-novelty in a word-learning task). Indeed, the effect of attraction to novelty and activation difficulty may not be additive but instead interact. Yet, such interactive effects could not be caught with the design used in the Experiment 1B.

The hypothesis that the attraction-to-novelty effect only occurs in settings with switching demands (such as the ‘Activation-deficit’ version) was tested using a version of the PAST-3 (‘Novelty’ PAST-3) in which the never-relevant colour was changed in the postswitch phase (e.g. from green to red) so that the postswitch involved both the need to switch attention (e.g. from blue to yellow) and the need to resist attending to a novel colour (here, red).4 If attraction to novelty is crucially involved when there is a switching demand, then one would expect more distraction errors in this control version than in the standard PAST-3 used in Experiment 2A (attention will be caught by the novel, irrelevant colour). In contrast, if attraction to novelty only plays a marginal role, there should be no difference in distraction errors between the ‘Novelty’ PAST-3 and the standard version (Experiment 2A).

Method

Participants

Twenty-three children (13 girls) (mean age = 40.5 months, SD = 4.29 months, age range = 2;11–4;1) participated. They were recruited from a French preschool. Written informed consent was obtained from the parents. Six additional children’s data were eliminated because children could not discriminate the colours and shapes used in the PAST-3. Participants were tested individually in a quiet room of their preschools.

Materials and procedure

The materials and procedure are strictly the same as those used in Experiment 2A, except that the colour that was relevant in none of the phases changed between the preswitch and the postswitch phase.

Results and discussion

The whole group of participants, and the subset that succeeded in the preswitch, did not differ in age or sex ratio from the 3-year-old group in Experiment 2A, hence allowing performance comparisons. Sixty-five percent of the children (15 children) passed the preswitch phase of the ‘Novelty’ PAST-3 (mean age = 41.3 months, age range = 2;11–4;1). Among the remaining children, 47% succeeded in the postswitch phase. These success rates are roughly equivalent to those in Experiment 2A (68% in the preswitch, 39% in the postswitch) to whom the ‘Novelty’ PAST-3 was then compared to explore for an effect of attraction to novelty.

In the ‘Novelty’ PAST-3 there was no significant difference in the frequency of perseverative and distraction errors (47% and 60% of the children, respectively, McNemar χ² < 1; see also Table 1). The frequency of participants committing distraction errors did not significantly differ from the Experiment 2A version (respectively, 60% and 61%; χ²(1, N = 38) = .002, p > .95). Similarly, the comparison of the numbers of distraction errors committed in each version turned out to be non-significant (Mann-Whitney’s U(1, N = 38) = 156, p > .62). There were no version effects for perseverative errors as well (47% in the ‘Novelty’ PAST-3 and 57% in the standard version; all ps > .55).

Finally, the 2 (Condition) × 2 (Error Type) ANOVA run on the numbers of errors that children committed (in the ‘Novelty’ version: M = 1, SD = 1.60 for perseverative errors; M = 1.13, SD = 1.12 for distraction errors; in the standard version: M = .87, SD = .91 for perseverative errors; M = .91, SD = .90 for distraction errors) revealed no main or interaction effects (all Fs < 1). Therefore, the results for 3-year-olds in Experiment 2A were replicated with the ‘Novelty’ PAST-3 which was no more difficult than the standard version used in Experiment 2A. These results plead against the hypothesis that attraction to novelty and switching demands interacted. It remains possible, however, that, as previously mentioned, attraction to novelty had a marginal additive effect in the ‘Activation-deficit’ version in Experiment 1A.

General discussion

The main objective of the present study was to evaluate the role of perseveration on initial representations in preschoolers’ developing flexibility and contrast it with alternative sources of difficulty. Toward this end, a new switching task (PAST), which isolates attentional switching,
was designed for use with preschoolers. In Experiments 1A, 1B, and 2B, different versions of the PAST that dissociated the processes potentially responsible for perseverative behaviours were compared and showed that ‘perseverative errors’ on the PAST reflect to a greater extent a difficulty of activating a representation that had been previously ignored than a perseverative tendency, contrary to what may have been expected. Similarly, Experiment 2A highlighted the existence of another error type, ‘distraction errors’, in preschool-aged children, suggesting that representation maintenance is also a fundamental component of cognitive flexibility. As a whole, these results bring new support to the claim that perseverative behaviours are not all alike but instead that the lack of flexibility may result from multiple processes (Deák, 2000; Deák & Narasimham, 2003).

**Activation deficit: an automatic-inhibition phenomenon?**

The present research brings new evidence showing that the difficulty in activating previously ignored representations is a major variable underlying poor cognitive flexibility in young preschoolers. Such an activation deficit may be interpreted as a consequence of a negative priming phenomenon (Müller et al., 2006; Zelazo et al., 2003). However, developmental studies have traditionally considered that the absence of negative-priming phenomena in children suggest inefficient inhibitory control (e.g. Perret, Paour & Blaye, 2003; Pritchard & Neumann, 2004) because a representation is alleged to be hard to activate if it has been voluntarily and efficiently inhibited when it was a direct threat for successful performance on the previous task. How could children fail in some situations because of too much inhibition whereas too little inhibition is found to characterize their behaviours in other situations (e.g. Gerstadt, Hong & Diamond, 1994)?

Such a paradox holds only if negative priming is considered to result from voluntary inhibition. However, it is not necessary to hypothesize a controlled-inhibition mediation to account for negative priming. Recent research has introduced at least two alternative explanations (see May, Kane & Hasher, 1995; Tipper, 2001, for further discussion). First, although less influential than the inhibitory position, the episodic retrieval account (Neill, 1997) assumes that when a stimulus is first encountered in a situation in which it is irrelevant, an episodic memory trace is formed, marking the stimulus with a ‘do-not-respond’ tag. Later, when the stimulus is encountered again, this episodic memory is automatically retrieved and conflicts with the current demands to now respond to the stimulus, thus engendering the negative-priming phenomenon. Here, negative priming, and consequently the activation difficulty, are accounted for by episodic memory phenomena without postulating any inhibitory mediation. Such an account is therefore consistent with findings of negative priming in preschoolers. Second, Müller et al. (2006) suggested that negative priming may involve a type of inhibition that is less effortful than voluntary inhibition. Indeed, the automatic inhibitory account of negative priming remains plausible. Automatic and controlled forms of inhibition have often been distinguished (Nigg, 2000; Perner, Stummer & Lang, 1999), and Kipp Harnishfeger (1995) states that automatic inhibition is involved in negative-priming situations (see also Maes et al., 2004). If negative priming is engendered by automatic inhibition, then there is no paradox in observing negative priming in some situations and at the same time a deficit in inhibitory control in others. Such accounts are supported by recent findings showing evidence for spatial negative priming in infants (Amso & Johnson, 2005) whose inhibitory control is far from mature. Consequently, flexible behaviours may require the ability to both voluntarily inhibit one’s irrelevant representations and overcome the effects of automatic inhibition when it is no longer adaptive to the current situation.

**Maintenance failure and working memory capacity**

Just as performance on the modified versions of the PAST highlights the role of an activation deficit, performance on the PAST-3 shows that disrupted maintenance of representations is an important contributor to young preschoolers’ poor cognitive flexibility. This result is in line with previous findings (Barceló & Knight, 2002; Crone et al., 2004; Deák, 2000), and is also consistent with Narasimham and Deák’s (2001, in Deák, 2003) findings using a version of the DCCS with objects differing in three dimensions (shape, colour, and size) and two postswitch phases. These authors found that performance was more variable than the traditional dichotomy, observed on the standard DCCS, between children who respond flexibly on all postswitch trials and those who always perseverate on the preswitch rules. More specifically, some 3-year-old children perseverated in one postswitch phase but not in the other, and some made perseverative errors whereas others committed errors that were not perseverative. These results thus indirectly suggest that the maintenance difficulty may occur across task formats. This difficulty has also been stressed on the Stroop task in which children may fail not because they cannot inhibit reading a word stimulus but instead because of a difficulty in maintaining the task set of naming its colour (Bub, Masson & Lalonde, 2006).

The difficulty of representation maintenance probably depends on the degree of interference present in a situation, and consequently, may be closely related to the ability to resist interference. Resistance to interference lies at the core of some models of working memory such as that proposed by Engle and Kane (e.g. Engle, 2002; Engle, Kane & Tuholski, 1999) who argue that ‘working memory capacity reflects the ability to apply activation to memory representations, to either bring them into focus or maintain them in focus, particularly in the face of interference or distraction’ (Engle et al., 1999, p. 104). It therefore seems reasonable to assume that cognitive
flexibility and working memory might be closely tied, though Zelazo et al. (2003) showed that flexibility cannot be accounted for by short-term memory alone on the DCCS.

The role of memory in interfering situations has been previously stressed. Diamond (2000; Diamond, Kirkham & Amso, 2002; Gerstadt et al., 1994) claimed that preschoolers find particularly challenging situations in which they have to hold information in mind and exert inhibition. Working memory is also a key element in Morton and Munakata’s (2002; Munakata, 2001; Munakata & Yerys, 2001; Stedron, Sahni & Munakata, 2005) account of flexibility development. They hypothesized that flexibility increases as a function of the ability to maintain sufficient activation in memory to information that conflicts with latent biases created by previous behaviours. Both Diamond and Munakata’s theories are in line with the claim, derived from Experiment 2A, that working memory is involved in flexibility. However, these theories agree with the idea that, because of limitations in working memory in interfering situations, children keep on processing previously relevant information. Our results went one step further by showing that maintenance failures can bring about specific patterns of errors that do not reflect perseverative processing.

The occurrence of such distraction errors on the PAST-3 is all the more striking as children were reminded of the relevant rules on every trial. Our claim is not that children fully forgot the relevant colour but instead failed at times to maintain it sufficiently active to base actions on it. Such maintenance failures are evidence of a goal-neglect phenomenon, that is, disregard of task requirement despite knowing and understanding it (Duncan, Emslie, Williams, Johnson & Freer, 1996; Kane & Engle, 2003). Dissociations between knowledge and action are commonly observed on the DCCS (Zelazo et al., 1996). Furthermore, recent research has brought evidence for goal neglect on the DCCS, showing that scores on this task correlated with scores on a goal-neglect task (Towse, Lewis & Knowles, 2007) and performance declined on a version favouring goal neglect (Marcovitch, Borsevski & Knapp, 2007). These studies converged with the present one to the conclusion that part of preschoolers’ inflexibility relates to a difficulty in maintaining relevant representations in memory.

Reconsidering the role of perseveration

By identifying two major contributors to preschoolers’ emerging flexibility, the present study prompts us to reconsider the conception of the role of perseveration on initial representations (see also Stahl & Pry, 2005). The main theoretical accounts of the development of cognitive flexibility in preschool-aged children (Bialystok & Martin, 2004; Kirkham et al., 2003; Kloo & Perner, 2003; Munakata, 2001; Zelazo et al., 1996) emphasize how children eventually manage to overcome perseverative processes. Focusing on perseveration, these accounts have contributed to overestimating its importance, meanwhile drawing only a fragmented picture of cognitive flexibility and its development.

One of these accounts is the CCC theory (Zelazo et al., 1996) that particularly focuses on rule complexity and perseveration: children are thought to perseverate on initial rules when rules are otherwise too complex. Asymmetrical performance between the ‘Perseveration’ and ‘Activation-deficit’ PAST (Experiment 1A) disconfirmed this account in two respects since it showed (1) that activation deficit contributes to cognitive inflexibility to a greater extent than perseveration; and (2) that tasks with rules of similar complexity did not challenge children to the same degree (see also, e.g. Perner & Lang, 2002). By contrast, this finding is consistent with the revised version of the CCC theory (CCC-r; Zelazo et al., 2003), which assumes that rule complexity must be considered in conjunction with an activation difficulty. More specifically, it hypothesizes that children experience switching difficulties because they are unable to both unselect the previously relevant rules and redirect their attention to the rules that they previously ignored, in other words because both perseverative processing and an activation deficit. When the degree of self-reflection on rules is sufficiently developed, that is when children realize that they know different rules for a single object, they can organize them into a unified, complex hierarchical rule structure. This hierarchical structure helps determine when to use each, and thus overcome children’s perseverative tendency and activation deficit. This proposal undoubtedly marks an advance in the understanding of the development of cognitive flexibility, but is still not comprehensive as it focuses exclusively on ‘perseverative errors’. It therefore needs to integrate a representation-maintenance component. Finally, such an account should also consider how specific features of each situation requiring flexible behaviour are likely to modulate inhibitory, activation, and maintenance-of-activation processes. Some of these variables have been identified by Deák (2000, 2003; Deák & Narasimham, 2003; Deák et al., 2004), who suggested that flexibility is influenced by discourse-level and social cues (for recent empirical evidence on the DCCS, see Moriguchi, Lee & Itakura, 2007).

As a consequence, further conceptualizations of the processes underlying cognitive flexibility and its development should take into account multiple sources of difficulty such as activation and maintenance deficits besides a more adequately evaluated perseverative process. Such accounts may greatly benefit from efforts to identify different types of flexible behaviours such as attentional and processing switching, and study how each of them relates to the above-mentioned variables.

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