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Published in:
Journal of Experimental Child Psychology

DOI:
10.1016/j.jecp.2014.03.007

Journal of Experimental Child Psychology 126 (2014) 91–102

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Preschoolers learn to switch with causally related feedback

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ARTICLE INFO

Article history:
Received 25 April 2013
Revised 14 March 2014

Keywords:
Causally related feedback
Switch behavior
Preschoolers
DCCS
Cognitive flexibility
Feedback connected to stimulus

ABSTRACT

Training cognitive flexibility in preschoolers is of great interest but is not easy to achieve. In three experiments, we studied the effects of feedback on preschoolers' switch behavior with a computerized version of the Dimensional Change Card Sorting (DCCS) task. The task was designed such that feedback was connected to the stimulus and causally related to children's behavior. Experiments 1 and 2 showed that children receiving feedback on their post-switch behavior performed better than children administered a standard (no feedback) DCCS task. This effect transferred to a subsequent standard DCCS task after 5 min and after 1 week. Experiment 3 showed that children switched to the new post-switch sorting rules and not to rules that oppose the pre-switch sorting rules. These results highlight preschoolers' sensitivity to the design of feedback in learning an abstract rule.

Introduction

Executive control is an umbrella term for a set of cognitive abilities that subserve flexible goal-directed behavior (Zelazo, Carlson, & Kesek, 2008). The development of executive control during early childhood is predictive of success later in life (as indexed by, e.g., academic achievement, health. and income; Blair & Razza, 2007; Moffit et al., 2011). Interventions intended to improve executive control, therefore, might serve an important goal. Successful examples of these interventions include specific preschool curricula (Diamond, Barnett, Thomas, & Munro, 2007), aerobics, martial arts, yoga or

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http://dx.doi.org/10.1016/j.jecp.2014.03.007
0022-0965/

mindfulness (Diamond & Lee, 2011), and training programs targeting the specific components that constitute executive control (e.g., Karbach & Kray, 2009; Kloo & Perner, 2003; Rueda, Checa, & Cómbita, 2012; Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2009). Providing feedback on their performance is an important and very often used way of training young children (Bohlman & Fenson, 2005; Chatham, Yerys, & Munakata, 2012; Diamond, Lee, & Hayden, 2003; Espinet, Anderson, & Zelazo, 2013).

One of the cognitive abilities that constitute executive control is cognitive flexibility (Diamond, 2013; Huizinga, Dolan, & van der Molen, 2006; Zelazo, Müller, Frye, & Marcovitch, 2003). This is the ability to change plans in response to relevant changes in the environment and, complementarily, to maintain activities when changes in the environment are irrelevant (Diamond, 2006b). The Dimensional Change Card Sorting (DCCS) task is a very frequently used paradigm to study cognitive flexibility in preschoolers (Zelazo, 2006). In this task, children are required to sort two bivalent test cards according to shape or color on two stacks marked by target cards. Each test card matches one target card on color and the other target card on shape. After sorting a series of test cards according to one dimension (e.g., color), children are asked to sort the same test cards according to the other dimension (e.g., shape). Nearly all 3- to 5-year-olds sort correctly in the pre-switch phase regardless of which dimension is presented first. Most 3-year-olds perseverate in the post-switch phase by sorting test cards according to the initial dimension, whereas most 4- and 5-year-olds switch immediately to the new dimension when asked to do so (Kirkham, Cruess, & Diamond, 2003; Perner & Lang, 2002; Zelazo, Frye, & Rapus, 1996).

A few studies have looked at the possibility to train cognitive flexibility. Espinet and colleagues (2013) isolated the role of reflection in a training study for preschoolers with a computerized version of the DCCS task. According to the revised cognitive complexity and control theory (CCC-r; Zelazo et al., 2003), children who perseverate on the DCCS task have difficulties in reflecting on their rule representations, that is, formulating and using a higher order rule for selecting which set of rules (color rules or shape rules) must be used. Children that perseverated on a standard pre-training version of the DCCS task were given reflection training with a different version of the task (with different stimuli) and after 1 day performed the standard pre-training DCCS task again. The brief training procedure consisted of corrective feedback on post-switch performance in combination with reflection on children's rule representations (based on Kloo & Perner, 2003). In the training version of the DCCS, children who received reflection training and children who received solely corrective feedback switched to the correct sorting rules. However, only the combination of corrective feedback and reflection training resulted in improved performance on the post-training DCCS task, whereas corrective feedback alone or mere practice with the DCCS task (without feedback) did not. The effect on the post-training DCCS in the reflection training condition showed near transfer to a three-box version of the DCCS task with different target and test cards.

Bohlman and Fenson (2005) studied the effects of feedback on the performance of preschoolers in a manual version of the DCCS task. Results showed that children who received corrective feedback on their post-switch performance switched to the correct sorting rules. However, successful performance on the DCCS task with feedback did not lead to improved performance on a subsequent standard DCCS task (without feedback) that was administered immediately after the first DCCS task. Bohlman and Fenson concluded that poor performance on the standard DCCS task can be interpreted as the inability to monitor one's own performance in the absence of clear guidance because in a DCCS task with feedback (i.e., clear guidance) 3-year-olds had no problem in switching to the correct sorting rules.

In the current project we also looked at the effects of feedback on preschoolers' switch behavior, but we took a different approach. The corrective feedback in Espinet and colleagues' (2013) study and in Bohlman and Fenson's (2005) study consisted of verbal feedback of the experimenter on children's post-switch performance in combination with a demonstration of the correct sorting of the test card when the trial was incorrect. In Espinet and colleagues' study, a computerized version of the DDCS task was used and the experimenter pointed to the correct button on the response pad while saying, "You are supposed to press this button." In Bohlman and Fenson's study, a manual version of the DCCS task was used and the experimenter turned the incorrectly sorted test card face-up and moved it to the correct sorting tray while saying, "Remember, in the shape game all the birds go here." The results of both studies show that corrective feedback is effective for switching in the task at hand but is not enough to learn to switch in a subsequent task; that is, there is no transfer or carryover effect.

Infant studies show that an important aspect of feedback is the connectedness of the feedback to the stimulus (Diamond, Churchland, Cruess, & Kirkham, 1999; Diamond et al., 2003). Diamond and colleagues (2003) tested 9- and 12-month-old infants on a non-matching to sample task. In this task, the child was presented an object. After a delay, the object was presented again together with a novel object. The child was rewarded for choosing the novel object. In the standard version of the task, the reward was in a well beneath the stimulus. Children younger than 21 months did not succeed on this version of the task. But when the reward was attached to the base of the stimulus (although a separate and separable object), most infants of 9 and 12 months age succeeded. The importance of physical causality above spatial and temporal proximity was also shown for newborns (Mascalzoni, Regolin, Vallortigara, & Simion, 2013). Diamond (2006a) argued that perceiving conceptual connections in the absence of physical connections is an elementary ability that is not even fully mature in toddlers. Learning to switch—that is, the transfer of DCCS training to a subsequent DCCS task—involves learning an abstract rule instead of stimulus response associations.

In the current study, we examined the immediate and long-term effects of feedback that is connected and causally related to the test card without intervention of the experimenter in a computerized version of the DCCS task. When a child sorts a test card correctly, it moves to the chosen sorting stack and turns around, after which the experimenter gives the child enthusiastic feedback. However, when a child sorts a test card incorrectly, the test card also moves to the chosen sorting stack but does not turn around (as if the computer stops working). The experimenter then gives verbal feedback and models the correct sorting of the test card.

Experiment 1 compared the performance of children administered a standard version of the DCCS task (without feedback) with that of children given feedback on the post-switch trials with a connection between stimulus and feedback on a touch-screen monitor. Whether children learned from the received feedback was assessed with the administration of two subsequent standard DCCS tasks with different stimuli: one after 5 min and one after 1 week. Experiment 2 replicated the findings of Experiment 1 with an extended version of the first DCCS task with six extra post-switch trials, such that children could not copy the complete procedure of the first task to the second and third tasks. Feedback was provided only on the last six post-switch trials of the first task in the feedback condition. Because the first six post-switch trials of the first task were exactly the same in the two conditions, we could test for possible preexisting differences between the two conditions in Experiment 2. Chatham and colleagues (2012) postulated the idea that children who receive feedback in the post-switch phase of the DCCS task might sort the post-switch test cards according to rules that oppose the pre-switch sorting rules and, hence, use the pre-switch concepts for their post-switch sorting rules. Because each test card matches one target card on color and the other target card on shape, one cannot be completely sure whether a child switched from using the color rules (e.g., red goes with red and blue goes with blue) to using the shape rules (e.g., frog goes with frog and snail goes with snail) or to using the opposite color rules (e.g., red goes with blue and blue goes with red). In Experiment 3, we introduced new test cards in an additional generalization phase that distinguished between the post-switch rules and the opposite pre-switch rules.

Experiment 1

Method

Participants

A total of 56 3-year-olds participated in this experiment (M = 41.5 months, SD = 3.9, range = 35–52, 29 girls and 27 boys). We tested another 23 children, but their data could not be used because they did not pass one or more of the pre-switch phases (n = 17) or did not complete testing (n = 6). This dropout rate seems high compared with earlier studies with the DCCS task, but in the current project no feedback was provided on children's sorting in the pre-switch phase. The dropout rate of studies that do not provide feedback in the pre-switch phase is comparable to ours (e.g., Diamond, Carlson, & Beck, 2005, dropout rate = 42%). In addition, we included only children who passed the first phase of all three tasks in Experiments 1 and 2. The percentage of children failing the first phase of the first task in these experiments is comparable to the percentage of children failing the pre-switch phase in earlier studies with only one DCCS task (±13%). Children needed to sort at least five of the six test cards correctly to pass the pre-switch phase. Children in this and the other two experiments reported in this article were recruited from day-care centers and preschools in The Netherlands. Informed consent was obtained from the parents of all children who participated.

Design

Children were randomly assigned to one of two conditions: the *feedback* condition ($n = 27$, $M = 42.0$ months, $SD = 4.1$, range = 36–52, 14 girls and 13 boys) or the *control* condition ($n = 29$, $M = 41.0$ months, $SD = 3.6$, range = 35–47, 15 girls and 14 boys). In both conditions, children performed three DCCS tasks. All three tasks consisted of six pre-switch trials and six post-switch trials. The first two tasks were administered on the same day with a 5-min break between them. The third task was administered 1 week after the administration of the first two tasks. Children in the feedback condition received feedback on their sorting in the post-switch phase of the first DCCS task only. During the other two tasks, no feedback was given. Children in the control condition did not receive feedback in any of the tasks. The order of the two sorting dimensions was counterbalanced within each condition but was the same in the three tasks.

Materials

The experiment was conducted using a laptop computer with a separate touch-screen monitor. Stimuli were presented against a dark gray background. Two light gray sorting stacks were present in the bottom left and right corners of the screen. The target cards were depicted above them. A test card appeared at the bottom center of the screen when the experimenter pressed a key on the computer. Children sorted the test cards by touching the appropriate target card or sorting stack. The test card then moved to the chosen sorting stack and turned around. See Fig. 1 for an example of the computer screen.

In each task, a different set of target and test cards was used. The card set used in the first DCCS task consisted of the following shapes and colors: frog, snail, red, and blue. The card set used in the second DCCS task consisted of the following shapes and colors: chicken, rabbit, yellow, and green. The card set used in the third DCCS task consisted of the following shapes and colors: pig, fish, orange, and purple. See Fig. 2 for the target and test cards used in the three DCCS tasks in both conditions in Experiment 1.

Procedure

Children were tested individually in a quiet room in their day-care center or preschool. Once a child was comfortable with the experimenter, the touch screen was introduced and the experimenter verified the child's knowledge of the shapes or colors that were relevant in the pre-switch phase of the first task.

The experimenter explained the sorting rules of the pre-switch phase and demonstrated the sorting of the two different test cards. The child was then asked to sort six test cards by himself or herself. The two different test cards were presented in pseudo-random order, so that no test card was presented

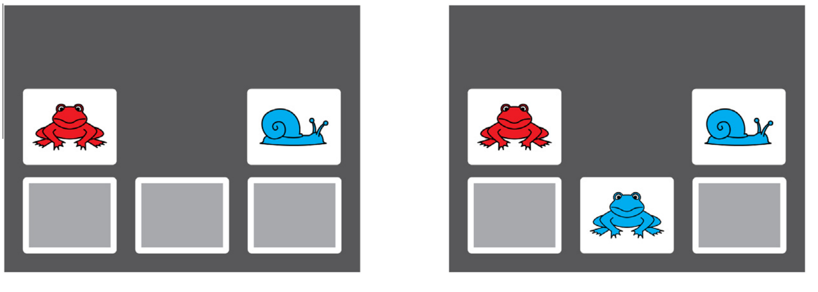

Fig. 1. Example of the computer screen.

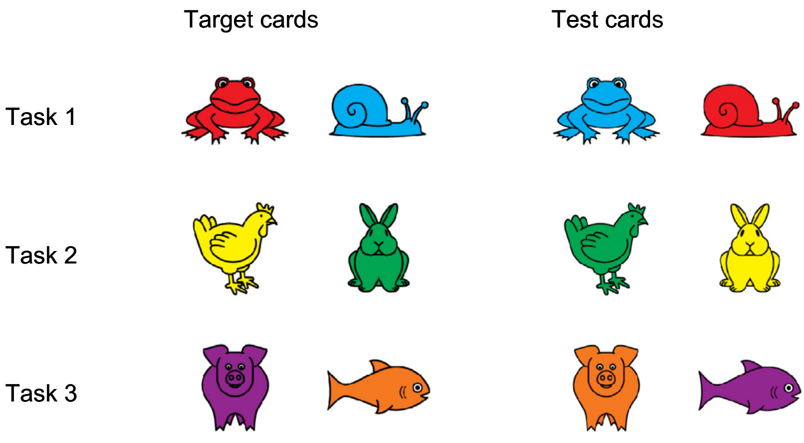

Fig. 2. Target and test cards used in the three DCCS tasks in both conditions of Experiments 1 and 2.

more than twice in a row. On every trial, the experimenter repeated the relevant sorting rules. Immediately after the repetition of the rules, a test card was presented. The experimenter labeled the test card with the relevant dimension only (e.g., "This is a red one"). Children were not given feedback on their sorting.

At the start of the post-switch phase, the experimenter verified the child's knowledge of the shapes or colors that were relevant in the post-switch phase of the first DCCS task. The experimenter explained the sorting rules of the post-switch phase but did not demonstrate the sorting of the two test cards. The child was then asked to sort six test cards by himself or herself. As in the pre-switch phase, the two different test cards were presented in pseudo-random order, the experimenter repeated the relevant sorting rules before every trial, and the experimenter labeled the test cards with the relevant dimension only. Children in the feedback condition received feedback on their sorting of the post-switch trials. If the test card was sorted correctly, the test card moved to the chosen sorting stack and turned around. The experimenter gave enthusiastic feedback ("Yes, well done. That is where the red ones go in the color game"). If the test card was sorted incorrectly, the test card also moved to the chosen sorting stack but did not turn around. The experimenter gave verbal feedback and modeled the correct sorting of the test card ("No, that is not correct. In the color game, the red ones go here"). The experimenter then touched the correct sorting stack, and the test card moved to the sorting stack and turned around. Children in the control condition were not given feedback on their sorting. All cards they sorted (correct and incorrect) moved to the chosen sorting stack and turned around. After the administration of the first DCCS task, there was a break of approximately 5 min during which the experimenter and the child read a book. The administration of the third task occurred 1 week after the administration of the first two tasks. The procedure for the administration of the second and third DCCS tasks was exactly the same as the procedure for the administration of the first DCCS task except that children in both conditions were not given feedback on their sorting.

Results

No significant effects were found for gender or order of the two sorting dimensions in this and the other two experiments reported in this article. Therefore, all results were collapsed across those variables in the three experiments. In the post-switch phases of the three DCCS tasks in Experiment 1, most of the children responded correctly on either zero or one (feedback condition: 16%; control condition: 54%) or five or six (feedback condition: 73%; control condition: 30%) of the six post-switch trials. Given the bimodal nature of the data, non-parametric analyses (chi-square tests) were used to analyze the data. Children who sorted at least five of the six post-switch trials correctly were considered to have passed the post-switch phase. The percentages of children passing the post-switch phase of the three tasks in the two conditions in Experiment 1 are shown in Fig. 3. More children passed the post-switch phase in the feedback condition compared with the control condition in the first DCCS task, $\chi^2(df = 1, N = 56) = 13.09$, $p < .01$, the second DCCS task, $\chi^2(df = 1, N = 56) = 4.58$, $p < .05$, and the third DCCS task, $\chi^2(df = 1, N = 56) = 12.09$, $p < .01$.

Children who sorted six of the six post-switch trials correctly did not receive any feedback, so they were treated equally in the feedback and control conditions. If we exclude these children from the analyses, again more children passed the post-switch phase in the feedback condition compared with the control condition in the first DCCS task, $\chi^2(df = 1, N = 45) = 12.02$, $p < .01$, the second DCCS task, $\chi^2(df = 1, N = 45) = 8.19$, $p < .05$, and the third DCCS task, $\chi^2(df = 1, N = 45) = 11.39$, $p < .01$.

Discussion

The results of Experiment 1 show that 3-year-olds can learn to switch when given feedback in the post-switch phase of the DCCS task. But do children really learn to switch between rules, or do they simply copy the procedure of sorting six cards according to one set of rules and then six cards according to another set of rules? To test this, we added six post-switch trials to the first DCCS task in Experiment 2. Feedback was provided only on the last six post-switch trials of the first task in the feedback condition. Because the first six post-switch trials of the first task were exactly the same in the two conditions, we could test for possible preexisting differences between the two conditions in Experiment 2 as well.

Experiment 2

Method

Participants

A total of 51 3-year-olds participated in this experiment ($M = 41.7$ months, $SD = 3.3$, range = 37–47, 24 girls and 27 boys). We tested another 37 children, but their data could not be used because they did not pass one or more of the pre-switch phases ($n = 29$) or did not complete testing ($n = 8$).

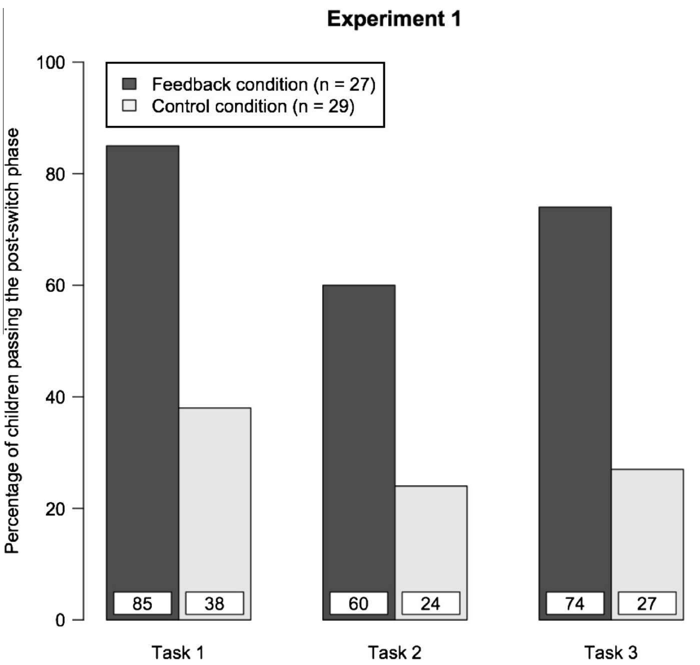

Fig. 3. Percentages of children passing the post-switch phase in the three tasks of the two conditions in Experiment 1.

Design

Children were randomly assigned to one of two conditions: the *feedback* condition ($n = 26$, $M = 41.6$ months, $SD = 3.6$, range = 36–47 months, 14 girls and 12 boys) or the *control* condition ($n = 25$, $M = 41.7$ months, $SD = 3.3$, range = 36–46, 10 girls and 15 boys). In both conditions, children performed three DCCS tasks, as in Experiment 1.

Materials and procedure

The materials and procedure of Experiment 2 were exactly the same as in Experiment 1 except for the number of post-switch trials in the first DCCS task. In the second experiment, children in both conditions were asked to sort 12 test cards in the post-switch phase of the first task. Children in the feedback condition received feedback on their sorting on the last six post-switch trials. Children in the control condition were not given feedback on their sorting. In the second and third DCCS tasks of Experiment 2, children in both conditions received six post-switch trials and were not given feedback on their sorting. See Fig. 2 for the target cards and test cards used in the three DCCS tasks in both conditions in Experiment 2.

Results

In the post-switch phases of the three DCCS tasks in Experiment 2, most of the children responded correctly on either zero or one (feedback condition: 18%; control condition: 65%) or five or six (feedback condition: 64%; control condition: 27%) of the six post-switch trials. The percentages of children passing the post-switch phase of the three tasks in the two conditions in Experiment 2 are shown in Fig. 4. More children passed the post-switch phase in the feedback condition compared with the control condition on the second half of the post-switch phase in the first DCCS task, $\chi^2(df = 1, N = 51) = 12.28$, $p < .01$, on the post-switch phase in the second DCCS task, $\chi^2(df = 1, N = 51) = 5.79$, $p < .05$, and on the post-switch phase in the third DCCS task, $\chi^2(df = 1, N = 51) = 12.24$, $p < .01$. There

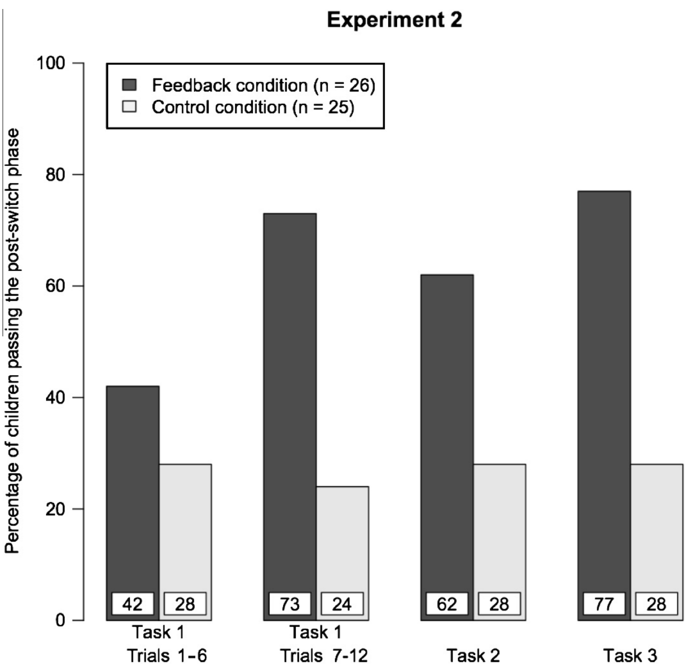

Fig. 4. Percentages of children passing the post-switch phase in the three tasks of the two conditions in Experiment 2.

was no difference in performance between the two conditions on the first half of the post-switch phase in the first DCCS task.

Children who sorted six of the six post-switch trials correctly did not receive any feedback, so they were treated equally in the feedback and control conditions. If we exclude these children from the analyses, again more children passed the post-switch phase in the feedback condition compared with the control condition in the first DCCS task, $\chi^2(df = 1, N = 34) = 9.27$, $p < .01$, the second DCCS task, $\chi^2(df = 1, N = 34) = 6.84$, $p < .05$, and the third DCCS task, $\chi^2(df = 1, N = 34) = 11.46$, $p < .01$.

Discussion

The results of Experiment 2 show that 3-year-olds really learn to switch in the post-switch phase of the DCCS task and do not simply copy the procedure of the first DCCS task when performing the two subsequent DCCS tasks. In addition, no preexisting differences between the feedback and control conditions were found. Although the results of Experiment 2 provide evidence that children really learn to switch in subsequent tasks, even when these consist of fewer trials than the number of trials in the first task, the experiment is not conclusive about what exactly children have learned. In particular, one alternative hypothesis stems from Chatham and colleagues (2012), who postulated the idea that children who receive feedback in the post-switch phase of the DCCS task might sort the test cards in the post-switch phase according to rules that oppose the pre-switch sorting rules (e.g., red goes with blue and blue goes with red instead of frog goes with frog and snail goes with snail) and, hence, use the pre-switch concepts for their post-switch sorting rules. Therefore, in Experiment 3 we introduced new (non-conflicting) test cards that distinguish between the post-switch rules and the opposite pre-switch rules. The non-conflicting test cards exactly match the target cards (a red frog and a blue snail; see Fig. 5). If children use opposite pre-switch rules, they are expected to sort these cards incorrectly (red frog with blue snail and blue snail with red frog). If children use the post-switch or pre-switch rules (when they perseverate in the post-switch phase), they are expected to sort these cards correctly (red frog with red frog and blue snail with blue snail).

Experiment 3

Method

Participants

A total of 52 3-year-olds participated in this experiment ($M = 41.4$ months, $SD = 3.0$, range = 35–47, 21 girls and 31 boys). We tested another 10 children, but their data could not be used because they did not pass the pre-switch phase ($n = 7$) or did not complete testing ($n = 3$).

Design

Children were randomly assigned to one of two conditions: the *feedback* condition ($n = 26$, $M = 40.6$ months, $SD = 2.8$, range = 36–45, 11 girls and 15 boys) or the *control* condition ($n = 26$,

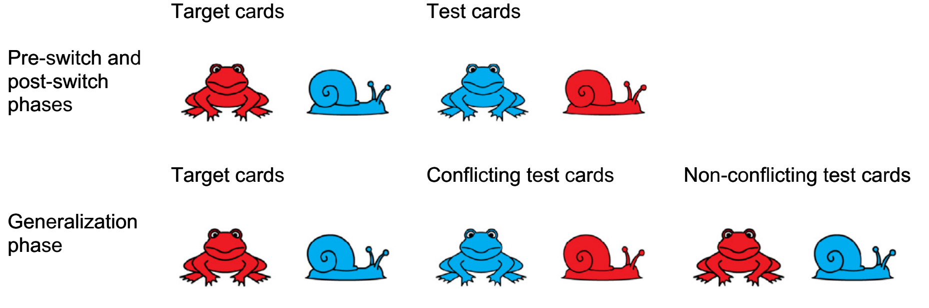

Fig. 5. Target and test cards used in the pre-switch, post-switch, and generalization phases of the two conditions in Experiment 3.

$M = 42.2$ months, $SD = 3.0$, range = 35–47, 10 girls and 16 boys). In both conditions, children performed one DCCS task directly followed by a generalization phase. The DCCS task consisted of six pre-switch trials and six post-switch trials. The generalization phase consisted of eight trials. Children in the feedback condition received feedback on their sorting in the post-switch phase of the DCCS task. Children in the control condition did not receive feedback. The order of the two sorting dimensions was counterbalanced within each condition.

Materials

The materials used in Experiment 3 were the same as in the first DCCS task of the first two experiments. The target cards in all phases of the task depicted a red frog and a blue snail. The test cards in the pre-switch and post-switch phases of the task depicted a blue frog and a red snail. Each test card matched one target card on color and the other target card on shape. In the generalization phase, four different test cards were used: two conflicting test cards depicting a blue frog and a red snail (as in the pre-switch and post-switch phases of the task) and two non-conflicting test cards depicting a red frog and a blue snail (exactly matching the target cards). See Fig. 5 for the target and test cards used in both conditions in Experiment 3.

Procedure

The procedure for the administration of the pre-switch and post-switch phases of the DCCS task in Experiment 3 were exactly the same as in the first DCCS task in Experiment 1. All children performed six pre-switch trials and six post-switch trials. Children in the feedback condition received feedback on their sorting in the post-switch phase, whereas children in the control condition were not given feedback on their sorting. Immediately after the post-switch phase, children were administered eight generalization trials: two trials with conflicting test cards, followed by two trials with non-conflicting test cards, two trials with conflicting test cards, and finally two trials with non-conflicting test cards. At the start of the generalization phase, children were encouraged to keep on playing the same game (‘‘You are doing great. Just continue what you are doing’’). The rules of the game were not repeated in the generalization phase. The experimenter did not label the test cards but simply asked, ‘‘Where does this one go?’’ Children were not given feedback on their sorting in the generalization phase.

Results

In the post-switch phase of the DCCS task, most of the children responded correctly on either zero or one (feedback condition: 8%; control condition: 48%) or five or six (feedback condition: 73%; control condition: 38%) of the six post-switch trials. The percentages of children passing the post-switch and generalization phases in the two conditions in Experiment 3 are shown in Fig. 6. More children passed the post-switch phase in the feedback condition compared with the control condition, $\chi^2(df = 1, N = 52) = 6.32$, $p < .05$. The criterion for passing the conflicting generalization phase and the non-conflicting generalization phase was sorting all four cards correctly. Performance on the conflicting generalization trials in the two conditions matched performance on the post-switch trials. More children passed the conflicting generalization phase in the feedback condition compared with the control condition, $\chi^2(df = 1, n = 52) = 13.18$, $p < .01$. Performance on the non-conflicting generalization trials did not differ between the two conditions. Nearly all children sorted all four non-conflicting generalization trials correctly. Only 3 children in the feedback condition and 2 children in the control condition made one mistake.

Discussion

The results of Experiment 3 show that 3-year-olds learn to switch to the post-switch sorting rules and not use the opposite pre-switch sorting rules in the post-switch phase of the task. Nearly all children sorted the non-conflicting test cards correctly in the generalization phase (red frog with red frog and blue snail with blue snail). If they had used the opposite pre-switch rules, they would have sorted the non-conflicting test cards conversely (red frog with blue snail and blue snail with red frog). The conflicting test cards in the generalization phase were sorted according to the sorting rules children

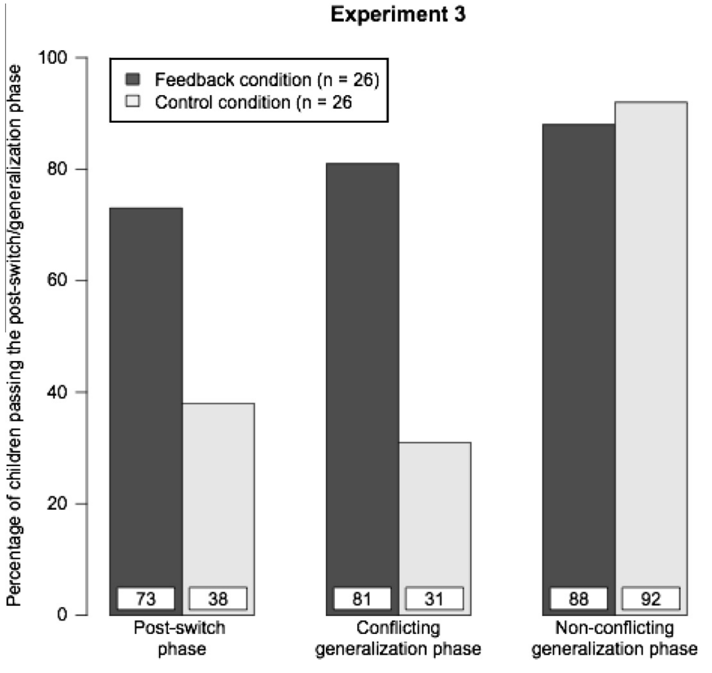

Fig. 6. Percentages of children passing the post-switch, conflicting generalization, and non-conflicting generalization phases of the two conditions in Experiment 3.

used in the post-switch phase of the task (the correct rules for switchers and the incorrect rules for perseverators).

General discussion

In three experiments, we studied the effects of feedback on preschoolers' perseverative behavior on the DCCS task. Results of the first experiment show that children who received feedback performed better compared with children who were administered a standard (no feedback) DCCS task. Children in the feedback condition also performed better compared with children in the control condition on a subsequent standard DCCS task after 5 min and after 1 week. In the second experiment, we replicated the findings of the first experiment with an extended version of the DCCS task, such that children could not copy the complete procedure of the first task to the second and third tasks. These results suggest that children learned to switch and that the effects of feedback were not transient. The results of the third experiment show that children did use post-switch sorting rules based on a new sorting dimension instead of reversing their pre-switch sorting rules. What the children learned was how to switch in a DCCS task and not only new sorting rules in the task at hand, as in former feedback-only conditions of the DCCS task (Bohlman & Fenson, 2005; Espinet et al., 2013).

Our intervention was a rather small adaptation and did not take much longer to administer than the standard DCCS task. Children received the following corrective feedback on their post-switch performance in a computerized version of the DCCS task. If the trial was correct, the test card moved to the chosen sorting stack and turned around while the experimenter gave positive verbal feedback. If the trial was incorrect, the test card also moved to the chosen sorting stack but did not turn around (as if the computer stopped working). The experimenter gave negative verbal feedback and demonstrated the correct sorting by touching the correct sorting stack. Thereafter, the test card moved to the correct sorting stack and turned around.

Why is this intervention successful? What aspect of our procedure is effective? In the current project, and in the studies of Espinet and colleagues (2013) and Bohlman and Fenson (2005), the experimenter gave verbal feedback whether children sorted the test card correctly or not. Moreover, in all three of these studies, the correct way of sorting the test cards in the post-switch phase was demonstrated to children after an incorrect trial. However, only in the current study did transfer occur of DCCS training to a subsequent standard DCCS task. Learning to switch—that is, the transfer of DCCS training to a subsequent DCCS task—involves learning abstract rules (if a color game, things of the same color go together; if a shape game, things of the same shape go together) (Zelazo et al., 2003). For learning abstract rules, perceiving the connectedness of stimulus and reward is essential for infants and preschoolers (Diamond, 2006a). Compared with earlier studies, the unique feature of the current study seems to be that there was a causal relation between the feedback children received and the stimulus without intervention of the experimenter. This task feature provides the impression that the computer is causally reacting to participants' action on the stimulus. Future research should directly compare a condition with only verbal feedback and a condition with only causally related feedback to draw stronger conclusions about the effective aspects of feedback.

Although the results of our study clearly show that children can learn to switch between conflicting sorting rules when given causally related feedback, it is very unlikely that this means we improved the cognitive flexibility or even executive control of preschoolers with our rather small adaptation. Additional inquiry is needed to examine the far transfer of the effects of causally related feedback on preschoolers' perseverative behavior found in the current study, for example, transfer to related but different executive control tasks. Because the development of executive control is predictive of success later in life (Blair & Razza, 2007; Moffit et al., 2011), interventions that improve executive control early in life are highly relevant. The current study shows preschoolers' sensitivity to the design of feedback in learning an abstract rule, which is a very small but promising first step in the direction of an intervention to improve executive control.

Acknowledgments

The research of Bianca van Bers and Maartje Raijmakers is sponsored by an NWO VIDI grant. We thank participating children, parents, day-care centers, and preschools. Thanks also go to Anna Groothuizen, Sophia Kaatee, Hannah van der Linde, Suzanne van Muiswinkel, Martine Ooteman, Sophie Schijf, Saskia Visser, Marije op de Weegh, Beau Welberg, and Hadewich van Zwam for assisting with data collection. We also thank the anonymous reviewers for their helpful comments.

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