Disentangling dimensions in the dimensional change card-sorting task
Daniela Kloo and Josef Perner

Department of Psychology, University of Salzburg, Salzburg, Austria

Abstract

The dimensional change card-sorting task (DCCS task) is frequently used to assess young children's executive abilities. However, the source of children's difficulty with this task is still under debate. In the standard DCCS task, children have to sort, for example, test cards with a red cherry or a blue banana into two boxes marked with target cards showing a blue cherry and a red banana. Typically, 3-year-olds have severe problems switching from sorting by one dimension (e.g. color) to sorting by the other dimension (e.g. shape). Three experiments with 3- to 4-year-olds showed that separating the two dimensions as properties of a single object, and having them characterize two different objects (e.g. by displaying an outline of a cherry next to a red filled circle on the card) improves performance considerably. Results are discussed in relation to a number of alternative explanations for 3-year-olds' difficulty with the DCCS task.

The dimensional change card-sorting task (DCCS task; Frye, Zelazo & Palfai, 1995; Zelazo, Frye & Rapus, 1996) is often used to assess the self-control abilities of preschool children. In the standard version, children are required to sort test cards (e.g. blue banana, red cherry) first according to one dimension (e.g. color) and then according to another dimension (e.g. shape) into two boxes, each marked with a target card (red banana, blue cherry). Each test card matches one target card on one dimension and the other target card on the other dimension. In the pre-switch phase, children are told a pair of rules, for example, the color rules: they are asked to sort all the blue ones into the box portraying something blue and to sort all the red ones into the box displaying something red. Typically, 3-year-olds have no problems when sorting the cards according to the first dimension. However, they usually have severe difficulties in the post-switch phase when the sorting rules change from, for example, color to shape. By about 4 years of age, most children switch correctly to the new dimension.

Several explanations have been proposed in the literature to explain 3-year-olds' difficulty. The traditional explanation (e.g. Zelazo & Frye, 1997) is referred to as the cognitive complexity and control theory (CCC theory). Complexity corresponds to the number of levels of embedding inherent in complex rule systems (systems of condition–action statements). Zelazo and Frye analyzed the card-sorting task in terms of conditional relations from different antecedents (a) to consequences (c) that change according to setting conditions (s) of the form 'if s, then if a, then c'. According to CCC theory, the rule pairs that children are given ('If it is something blue, then it goes here; if it is something red, then it goes there') have to be embedded within the higher-order conditional antecedent of which game is being played ('If we are playing the color game'). Younger children are thought unable to represent 'a higher-order rule that integrates two incompatible pairs of rules' (Zelazo & Frye, 1997, p. 120).

However, several findings refute this account. Three-year-old children easily master a card-sorting task if no target cards are used, although the rule structure remains the same (Kloo & Perner, 2003, exp. 1; Lang, 2001, exp. 4; Perner & Lang, 2002; Towe, Redond, Houston-Price & Cook, 2000). They are able to switch their responses to an incompatible pair of rules in a reversal shift task, in which rules reverse the use of a single dimension (Brooks, Hanauer, Padowska & Rosman, 2003, exp. 1; Kloo & Perner, 2003, exp. 1; Lang, 2001, exp. 4; Perner & Lang, 2002). Furthermore, children's performance in the standard task improves when they are induced to actively re-describe the test cards according to the...
post-switch dimension, although the ‘if-if-then’ structure of embedded conflicting rules is still present (Kirkham, Cruess & Diamond, 2003; Tows et al., 2000). In response to these findings, Zelazo, Müller, Frye and Marcovitch (2003) proposed a revision of the CCC theory (CCC-r) to account for these results while retaining the key claims of CCC theory.

These findings also refute another classical account by Carlson and Moses (2001) and by Perner, Stummer and Lang (1999). These authors explained 3-year-olds’ problems on the DCCS task as being due to a failure to exert executive inhibition of an interfering response tendency at the level of action schemas. They argued that correct sorting in the post-switch phase requires inhibition of the interfering pre-switch action schema. Tasks without target cards or tasks with reversal shifts would also require such inhibition but, as noted above, these tasks are easy for children. Zelazo et al. (1996) also discussed inhibition problems at the level of action schemas because children were able to answer knowledge questions about the sorting rules correctly while sorting the cards incorrectly. But Munakata and Yerys (2001) demonstrated that these dissociations between knowledge and action disappear when knowledge questions and sorting measures are more closely matched for amount of conflict. Further evidence against a response inhibition account comes from a study by Jacques, Zelazo, Kirkham and Smees (1999). They found that 3-year-olds also have problems in the DCCS task when they do not respond by sorting themselves but by judging whether a puppet is sorting the cards correctly: in the post-switch phase, children judged the puppet to be correct when the puppet sorted correctly. This suggests that children may have difficulty disengaging their attention from the pre-switch rules correctly. This inhibition of the values of the irrelevant dimension has to be stopped in the post-switch phase when this very dimension becomes the relevant dimension. Difficulty in exerting the required disinhibition prevents children from drawing their attention to the values of the currently relevant dimension resulting in a negative priming effect. To test this, Müller and Zelazo (2001) altered the values of the previously relevant dimension but retained the values of the previously irrelevant dimension at the beginning of the post-switch phase (negative priming version). For example, children had to sort red rabbits and blue boats according to color in the pre-switch phase, and then they had to sort yellow boats and green rabbits according to shape in the post-switch phase. If negative priming plays a role, children should still have difficulties in this condition. The negative priming version (27% passing) was almost as difficult as the standard version (23% passing) indicating that negative priming does play an important role.

A third explanation in terms of problems at an attentional level was proposed by Kirkham et al. (2003; see also Diamond & Kirkham, 2001; Kirkham & Diamond, 1999). They suggested that 3-year-old children have difficulty overcoming ‘attentional inertia’. Kirkham et al. showed that if children label each test card by the relevant dimension before actually sorting it (in contrast to the standard DCCS where the experimenter labels the card) their difficulties are eased (see also Tows et al., 2000). The 3-year-olds performed significantly better in
this label condition (78% correctly switched dimensions) than in the standard task (42% correct). Kirkham et al. (2003) argued that labeling helped children to overcome attentional inertia. More specifically, they claimed that 3-year-olds’ difficulty in the DCCS task lies in disengaging from a mindset:

We hypothesize that when asked to sort by the second criteria, children of 3 years have difficulty inhibiting their focus on the first aspect of a stimulus that was relevant for their behavior (e.g. its ‘blueness’), and hence do not switch the focus of their attention to the currently relevant aspect (e.g. its ‘truckness’) . . . We posit that 3-year-old children’s difficulty lies in disengaging from a mindset (a way of thinking about the stimuli) that is no longer relevant. (Kirkham et al., 2003, p. 451)

A further explanation by Perner and Lang (2002) and by Kloo and Perner (2003) is that children find it difficult to re-describe the objects on the test card from say ‘a banana’ to ‘a blue thing’. The claim is that re-description becomes necessary in the DCCS because of the use of target cards, which trigger a general rule, for example: ‘Put each card with the target that has the same thing on it’. A recent pilot study (Kloo, 2003, exp. 7) confirms the use of a general rule, as opposed to individual rules for each individual value of a dimension. In a card-sorting task using three test cards (yellow apples, blue bananas and green pears), children had practically no problems extending the rules learned with only two items (put bananas with the banana and apples with the apple) to the third item by putting the green pear with the blue pear target. This immediate generalization would not be possible if children had encoded individual rules for each value of a dimension, for example, rule 1: put the blue bananas with the yellow banana; rule 2: put the yellow apples with the green apple, as the analysis by Zelazo and Frye (1997) suggests.\(^1\)

Using a general rule of the suggested form, ‘Put each card with the target that has the same thing on it’, it is also essential that children describe the objects on the test cards under a particular perspective, that is, according to their shape (or what it is), or color, but not both — or else they would not know which was the ‘corresponding target’. Looking at the standard DCCS task instructions for the post-switch phase, one can see that they provide children with verbal descriptions of similar rules as used before. From the child’s perspective it just seems that these old rules are demonstrated with the other dimension. For example, ‘Now the blue things go into the box with a blue thing on it’ (as opposed to bananas going into the box with a banana on it). We adults immediately get the message that this means to treat objects as entities under this new description but, strictly speaking, children are not explicitly told that from now on the blue banana (so far treated as a banana) has to be re-described as a blue thing. We suggest that the problem children have with the standard version is that they do not explicitly understand that re-description of objects as being of a different kind is possible and, consequently, they do not realize what the experimenter really means with his or her instructions for the post-switch phase.

One critical finding for children’s use of a general rule and their difficulty with re-description is that children’s difficulty on the DCCS task hinges on the use of the target cards (Kloo & Perner, 2003; Lang, 2001, exp. 4; Perner & Lang, 2002; Towse et al., 2000). For example, in Perner and Lang’s target characters condition, the target cards were replaced by target pictures displaying familiar characters, such as Donald Duck, as owners of each box. The switch from the pre-switch dimension to the post-switch dimension was described as a change of the character’s preference. In the pre-switch phase, Donald wanted all red things and was to be given red cars, whereas in the post-switch phase, he wanted all the suns and consequently was to be given yellow suns. In this task, 3-year-old children had no serious problems. For only when target cards are used can the general strategy, ‘Put each card with the target that has the same thing on it’, be used, and only this strategy creates the need for re-describing the objects on the test cards when the switch in rules occurs.

Another finding is the fact that if the switch in dimension (and consequently the need to re-describe the cards) was avoided by using a reversal shift instead of an extra-dimensional shift, children had no serious problems (Brooks et al., 2003, exp. 1; Kloo & Perner, 2003; Lang, 2001, exp. 4; Perner & Lang, 2002). For example, Perner and Lang showed that 3-year-olds can switch to an incompatible pair of rules, so that in the ‘normal’ shape game, the cars go to the car target and the suns go to the sun target, but in the ‘reversed’ or ‘silly’ shape game, the cars go to the sun target and the suns go to the car target. Furthermore, as noted above, children’s difficulties are eased when they are induced to actively re-describe the cards according to the new dimension (Kirkham et al., 2003; Towse et al., 2000).

This re-description theory is similar to the attentional inertia approach (Kirkham et al., 2003) because both accounts share the hypothesis that children have difficulty because they need to think about or describe one

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\(^1\) This task analysis is also reflected in Zelazo and Frye’s (1997) formal structure of embedded rules, in which under setting 1 (shape game) the antecedent \(a_1\) links to consequent \(c_1\) and \(a_2\) links to \(c_2\). The variables \(a_1\) and \(a_2\) need to be instantiated with blue banana and yellow apple, and the variables \(c_1\) and \(c_2\) with ‘put to yellow banana’ and ‘put to green apple’, respectively.
and the same thing (e.g. a blue banana) differently (e.g. as a banana versus a blue thing). To test this hypothesis, we replaced the usual cards that show objects of a certain color, where the color is an integral aspect of the object (e.g. a blue banana), with cards on which the relevant object (banana) and the relevant color (blue) were realized as separate entities: an outline of a banana next to a blue filled circle. According to both the attentional inertia account and the re-description theory, children's difficulty should vanish with the new stimulus material. Although children can still use the general rule ‘Put each card with the target that has the same thing on it’, they can do so by switching their attention from the object on the card with the relevant shape (banana versus cherry) to the objects that differ only in color (blue versus red circle).

In contrast, for the four alternative theories, the new stimulus material should make little difference. (1) CCC-r theory: the complexity of rules remains the same. In fact, Zelazo et al. (2003) explicitly stated that CCC-r theory would predict that children perform poorly on a DCCS version involving spatially separated dimensions ‘because it requires them to cross major branches of a tree-like [rule] structure’ (p. 57). (2) Executive inhibition deficit: as before, a switch to a new action schema is required, presumably requiring inhibition of the pre-switch schema. (3) Attention disengagement deficit: children still need to be able to switch their attention, for example, from the colorless shape on the card that was relevant in the pre-switch phase to the colored circle that is relevant in the post-switch phase. (4) Negative priming: the previously irrelevant entity (e.g. the colored circle) becomes the relevant one after the switch.

A second aim of Experiment 1 was to investigate whether children focus their attention primarily on test cards or on target cards. To this end, four different card-sorting versions were used: the standard DCCS, a task with dimensions separated only on test cards, a task with dimensions separated only on target cards, and a version with dimensions separated on test and target cards. It was assumed that separating dimensions on test cards would have the more prominent effect because under the hypothesis that children use a general rule (‘Put each card with the target that has the same thing on it’), it is especially important that children describe the objects on the test cards according to the currently relevant dimension.

The test cards are more critical than the target cards because, in order to put the test card in the box with the same thing on it, the child has to first decide what kind of thing is on the test card. And here there is a choice: is the thing on it a banana or a blue thing? The younger children, who cannot understand that it can be both things at the same time, will use the description they have used before in the pre-switch phase, for example, ‘a banana’ because the post-switch instructions do not force upon them the different description of ‘a blue thing’. But once the child is able to see the test card object as a blue thing the child will look for a blue thing on the target cards. When looking for a blue thing, even the youngest can see a blue cherry as a blue thing even though they used to treat it as a cherry in the pre-switch phase.

**Experiment 1**

**Method**

**Participants**

A total of 49 children were recruited from three nursery schools in Upper Austria and two nursery schools near the city of Salzburg. One child was excluded from the final sample because of information from the head of the nursery school that the child was developmentally delayed. The final sample comprised 48 children (27 girls and 21 boys). Most participants were Caucasian and came from a middle-class background, although data about race and socioeconomic status were not systematically collected. Their ages ranged from 3.0 to 4.7 years (mean age = 3.9 years, SD = 4.39 months).

**Design**

Children were tested individually. Each child was given one of four different versions of the card-sorting task: 12 children received the standard version, 12 were given a version with dimensions separated on test and target cards (fully separated version), 12 received a version with dimensions separated only on test cards (separated test cards version), and 12 received a version with dimensions separated only on target cards (separated target cards version). These four groups of children did not differ in age, $F(3, 44) = .12, p > .90$. The direction of shift (from color to shape or from shape to color) was counterbalanced.

**Materials**

We used four sets of cards (10.5 cm × 7.5 cm). Each set consisted of two target cards and 12 test cards. In the standard version, the target cards displayed a yellow dog and a blue rabbit. The test cards showed blue dogs and yellow rabbits. In the fully separated version, target cards displayed a red filled circle next to an outline of a banana and a blue filled circle next to an outline of a banana.
cherry. Test cards showed either a blue filled circle next to an outline of a banana or a red filled circle next to an outline of a cherry. In the separated test cards version, target cards displayed a green cat and a red mouse. Test cards showed either a red filled circle next to an outline of a cat or a green filled circle next to an outline of a mouse. In the separated target cards version, target cards consisted of a yellow filled circle next to an outline of an apple and a green filled circle next to an outline of a pear. Test cards showed green apples and yellow pears. In all versions, the two target cards were each affixed to a (28.5 cm × 18.5 cm × 10.0 cm) box. The test cards had to be posted into one of these boxes through a slit on top.

Procedure

Each task involved a pre-switch phase and a post-switch phase. The procedure was the same in all versions and followed the standard DCCS task (Zelazo et al., 1996). For example, in the standard version, the experimenter pointed at the two target cards and explained the two dimensions (shape and color). Then she said, ‘Now we are going to play a game, the animal game. In this game, all the dogs go here (point), but all the rabbits go there (point).’ The experimenter sorted one test card of each kind (one dog and one rabbit) into each box to demonstrate what the child was required to do. Then, the children were asked to sort five cards on their own. On each trial, the experimenter randomly selected a test card, labeled the card by the relevant dimension only (e.g. ‘Here is a dog.’), and asked the children to post the card appropriately with the supporting question, ‘Where does this card go in the animal game?’ On each trial, children were told whether they had sorted the card correctly.

When the children had completed five pre-switch trials, the post-switch phase began. Children were told, ‘Now we are going to play a new game, the color game. The color game is different: all the yellow ones go here (point), but all the blue ones go there (point).’ Again, the children had to sort five cards according to the new rules. Children were given no direct feedback. However, every time a card had been sorted incorrectly, the experimenter repeated the post-switch rules.

Results and discussion

During the pre-switch phase, children were almost perfect. Only three children sorted one card incorrectly (one in the standard version, one in the separated target cards version, and one in the fully separated version).

Post-switch performance in all four card-sorting versions is displayed in Figure 1. Most children sorted either mostly correctly (four or five correct) or mostly incorrectly (none or one correct). In the standard version, five children had none correct, one child had two correct, and six children had four or five correct. In the separated target cards version, five children sorted four or five times incorrectly, and seven children sorted five times correctly. In the separated test cards version, one child had none correct, two children had two or three correct, and nine children had five correct. In the fully separated version, two children sorted three cards correctly, and 10 children sorted four or five cards correctly.

Performance was analyzed with a two-way ANOVA with item display (dimensions separated versus integrated) on test cards and item display on target cards as between-participants factors and number of cards correctly sorted as dependent measure. It revealed a significant main effect of item display on test cards, $F(1, 44) = 7.99, p < .01$, partial $\eta^2 = .154$. If color was detached from shape on test cards children performed significantly better than if color and shape were integrated on test cards (see Figure 1). There was no significant main effect of item display on target cards, $F(1, 44) = .55, p > .40$, partial $\eta^2 = .012$. Therefore, separating the two dimensions on target cards had no significant influence. The two-way interaction (item display on test cards × item display on target cards) was also not significant, $F(1, 44) = .02, p > .80$, partial $\eta^2 = .001$.

Children’s performance was also evaluated categorically. Children were classified as passing the post-switch phase if they sorted four out of the five cards correctly. A logistic regression on numbers of passers revealed an almost significant effect of item display on test cards (Wald statistic = 3.27, $p = .071$), and no significant effect of item display on target cards (Wald statistic = .40, $p > .50$).
This study demonstrates that if color is detached from shape on test cards, children's performance increases dramatically in a DCCS task (90% correct in the fully separated version; 83.3% correct in the separated test cards version). Separating the two dimensions on target cards has no independent significant effect. Thus, as hypothesized, children seem to focus their attention on test cards (which have to be sorted), and disentangling the two dimensions on test cards significantly enhances children's ability to switch to another sorting criterion. That is, eliminating the need to describe one and the same entity differently (e.g. 'banana' versus 'blue thing') improves performance considerably.

This result contrasts with the finding by Zelazo et al. (2003) that separating dimensions on the test cards did not improve performance. However, the card-sorting task Zelazo et al. used is difficult to interpret. We can only speculate here what might have led to their results. Their task is rather unusual since children only ever got to sort one kind of test card. In Zelazo et al.'s bidimensional separated version, the target cards were integrated, and the test cards were separated but in a different way to Experiment 1. For example, target cards depicted one red rabbit and one blue boat. And all test cards were half blue and half white with an outline of a rabbit on the white half. Children were told, for example, two color rules ('If it's red it goes here, but if it's blue it goes there') in the pre-switch phase and two shape rules in the post-switch phase. Test cards were labeled simply as 'one' (e.g. 'Where does this one go?').

There are two reasons why this kind of separated task might be difficult. First, in the pre-switch phase, children are told, for example, 'If it is a rabbit, it goes there, etc.' The pronoun 'it' clearly refers to 'the thing shown on the card'. However, in the post-switch instructions, 'If it is blue . . .', the 'it' seems to refer to the card (or part of the card) itself. This change in interpretation is exactly the kind of metalinguistic flexibility children below 4 years of age seem to lack. Retaining the original meaning of 'it', the younger children find that the object shown on the card is neither blue nor red, just a rabbit that they are familiar with and have put with the red rabbit previously. Second, when children are told, for example, the color rules on each trial ('If it's red it goes here, but if it's blue it goes there'), their attention is directed at the target cards, because there is nothing red on the test cards. But the target cards are integrated, and so the re-description problem raises its head again.

One weak point of Experiment 1 is that the material differed in each of the four card-sorting versions. However, the typical developmental pattern of children's performance in the card-sorting task has been demonstrated in a host of studies using a number of different stimulus materials (e.g. Carlson & Moses, 2001; Kirkham et al., 2003; Perner & Lang, 2002; Towse et al., 2000; Zelazo et al., 1996). Furthermore, Experiment 2 (see below), in which the separated and integrated versions employed the same color/shape combinations, replicated the finding that separating sorting dimensions considerably improves performance. Therefore, the use of different colors and different objects in the present experiment should not account for children's good performance with the new item display.

### Experiment 2

Experiment 1 demonstrated that visually separating dimensions on test cards enhances children's performance. However, although children did not have to describe the objects on the test cards differently in the separated version, they still had to describe the test cards themselves (the stimuli) differently; for example, they had to describe the card as something with a banana versus something with a blue circle. However, we suggest that children have particular difficulty describing objects as being of a different kind; we do not suggest that children have problems describing experimental stimuli in different ways. In contrast, CCC-r theory puts its focus on the stimulus. Zelazo et al. (2003) state that the key conditions for children's difficulty on the DCCS task are 'that (a) there is conflict among at least two rules such that children are required to respond in two different ways to the same stimulus [italics added] and (b) the conflicting rules are nested under different major branches in the hierarchical tree structure' (p. 101).

To apply a more radical test of the re-description account, we separated the two sorting dimensions by attaching them to different physical objects. Two object-sorting tasks were created: in the integrated dimensions object sorting task, children had to sort colored paper cut-outs, for example, red apples, just as in the standard DCCS. In the separated dimensions object sorting task, instead of the red apple, a pair of paper cut-outs consisting of a red rectangle and a plain paper shape of an apple was used. The paper cut-outs were presented on a white paper plate, that is, the experimental stimulus was a white paper plate with either the one (integrated version) or the two (separated version) paper cut-outs on it.

According to the object re-description theory, children should perform well on the separated version because it does not require them to describe one and the same object differently. Children still would have to respond to one and the same experimental stimulus differently, that is, to either pick up the red rectangle or the apple from the plate. Consequently, according to CCC-r
theory, children should perform poorly on this separated version of the DCCS.

Method

Participants

Sixteen children (nine girls and seven boys) from one nursery school near Salzburg participated in the study. The majority of children were Caucasian and middle class, although data about race and socioeconomic status were not systematically collected. Children’s ages ranged from 3.0 to 3.10 years (mean age = 3.6 years, SD = 2.50 months).

Design

Children were tested individually in one session lasting about 15 minutes. Each child was given two object-sorting tasks. There were two experimental groups: one group of children received two integrated dimensions object-sorting tasks. The other group was given two separated dimensions object-sorting tasks. These two groups of children did not differ significantly in age, t(14) = .79, p > .40. The direction of shift (from color to shape, or from shape to color) was counterbalanced.

Materials

We used four sets of paper cut-outs. Each set consisted of two target objects (integrated dimensions) or two pairs of target objects (separated dimensions) and 12 test objects (integrated dimensions) or 12 pairs of test objects (separated dimensions). In the integrated dimensions object-sorting tasks, Set A consisted of one yellow car and one green house as well as six yellow houses and six green cars. Set B comprised one red bird and one blue fish as well as six blue birds and six red fish. The two separated dimensions object-sorting tasks employed the same color/shape combinations as the two integrated dimensions object sorting tasks. However, instead of, for example, a yellow house, a pair of objects – a yellow rectangle (8 cm × 6 cm) and an uncolored (white) paper cut-out of a house – was used (Set A). In all versions, the two target objects or pairs of target objects were each affixed to one of two (28.5 cm × 18.5 cm × 10.0 cm) boxes. The test objects had to be placed into one of these boxes through a slit. Set A was always given first.

Procedure

Each task involved a pre-switch phase and a post-switch phase. The procedure was the same in all task versions and followed the standard procedure employed in Experiment 1; only the stimuli to be sorted differed. First, the experimenter pointed to the two target objects or pairs of target objects and explained the two dimensions (shape and color). Then, the only deviation from the standard procedure was the use of a white paper plate for presenting the test objects or pairs of test objects. For example, in the pre-switch phase of the separated dimensions object-sorting task, the experimenter first stated the pre-switch rules, for example, ‘Now we are going to play a game, the shape game. In this game, all the houses go into the box with a house on it (point), but all the cars go into the box with a car on it (point)’. Then she presented a paper plate with a yellow rectangle and an uncolored (white) house on it, took the house, and sorted it into the box with an uncolored house and a green rectangle on it. Then, she presented a green rectangle and an uncolored car and demonstrated the correct sorting response. Subsequently, the children were required to sort on their own. On each trial, the experimenter randomly selected a pair of test objects, presented both objects on the paper plate, and said, for example ‘Here is a house’. Then, the children were asked to sort one object into one of the boxes (‘Where does this go in the shape game?’).

Results and discussion

During the pre-switch phase, children were almost perfect. Only two children sorted one object incorrectly (one in an integrated dimensions object-sorting task and one in a separated dimensions object-sorting task).

Children’s post-switch performance in the two object-sorting versions is displayed in Figure 2. In all four

![Figure 2](image-url)
tasks, the majority of children (seven out of eight) sorted either five times correctly or five times incorrectly. Postswitch performance was analyzed with a $2 \times 2$ mixed design ANOVA with experimental group (integrated dimensions versus separated dimensions) as between-participants factor, and time (first task versus second task) as within-participants factor. This revealed a main effect of experimental group: children in the separated dimensions object-sorting group performed significantly better ($M = 90.0\%$ correct, $SD = 17.7$) than the children in the integrated dimensions object-sorting group ($M = 37.5\%$ correct, $SD = 41.3$), $F(1, 14) = 10.91$, $p < .01$, partial $\eta^2 = .44$ (see Figure 2). No other effects or interactions reached statistical significance.

Children’s performance was also evaluated using nonparametric categorical analyses. Children were classified as passing the object-sorting tasks if they sorted correctly on eight out of the ten post-switch trials. A logistic regression on numbers of passers confirmed that children performed better on the separated dimensions object-sorting tasks than on the integrated dimensions object-sorting tasks (Wald statistic = 5.12, $p < .05$).

This demonstrates that 3-year-old children can easily sort first according to one dimension and then according to another dimension if the two sorting dimensions are separated by using separate objects. In contrast, if dimensions are integrated within the same object, most 3-year-olds have great difficulty.

**Experiment 3**

The first two experiments showed that separating sorting dimensions reduces children’s difficulty with the DCCS to practically nil. Although children in both experiments reached 90% correct on the completely separated condition, the sample of children tested in Experiment 1 reached 50% correct on the standard DCCS task, whereas the sample of Experiment 2 reached only 40% correct. This raises the possibility that when using the same sample we might find separation of dimensions to be more effective for sorting objects than for sorting cards displaying two objects. This was tested in Experiment 3. A second aim of Experiment 3 was to confirm the results of Experiments 1 and 2 by using a within-participants manipulation.

**Method**

**Participants**

A total of 32 children were recruited from three nursery schools near Salzburg. The majority of children were Caucasian and middle class, although data about race and socioeconomic status were not systematically collected. Five of the children were dropped from the final sample for the following reasons: four children failed the pre-switch phase (sorting more than one out of five items incorrectly), and one boy refused to co-operate in the second integrated card-sorting task. The final sample comprised 27 children (18 girls and nine boys). Children’s ages ranged from 3.2 to 4.2 years (mean age = 3.8 years, $SD = 3.54$ months). To display age trends, we divided the children in three equal-sized age groups: Nine children ranging in age from 3.2 to 3.6 (mean age = 3.4 years, $SD = 1.64$ months), nine children ranging in age from 3.7 to 3.8 (mean age = 3.7 years, $SD = .44$ months), and nine children ranging in age from 3.9 to 4.2 (mean age = 4.0 years, $SD = 1.45$ months).

**Design**

Children were tested individually in one session lasting about 15 minutes. Each child was given two sorting tasks: an integrated dimensions task and a separated dimensions task in counterbalanced order. Two different sets of material were used: half of the children received two card-sorting tasks. The other half received two object-sorting tasks. These two groups of children did not differ in age, $t(25) = .008$, $p = .99$. The direction of shift (from color to shape or from shape to color) was counterbalanced.

**Materials and procedure**

We used two sets of cards (integrated and separated cards) and two sets of objects (integrated and separated objects). In the integrated dimensions card-sorting task, the target cards displayed a red bird and a blue fish. The test cards consisted of six red fish and six blue birds. In the separated dimensions card-sorting task, target cards displayed a green filled circle next to an outline of a house and a yellow filled circle next to an outline of a car. Test cards consisted of six cards showing a yellow filled circle next to an outline of a house and six cards showing a green filled circle next to an outline of a car. The two object-sorting tasks employed the same color/shape combinations as the two card-sorting tasks. In the integrated dimensions object-sorting task, a paper cut-out of a red bird and a paper cut-out of a blue fish were used as target objects. The test objects consisted of six paper cut-outs of red fish and six paper cut-outs of blue birds. In the separated dimensions object-sorting task, pairs of paper cut-outs were used. The target objects consisted of a yellow rectangle ($8\,\text{cm} \times 6\,\text{cm}$) paired with an uncolored (white) car and a green rectangle ($8\,\text{cm} \times 6\,\text{cm}$. © Blackwell Publishing Ltd. 2005
6 cm) paired with an uncolored house. As test objects, six pairs of yellow rectangles (8 cm × 6 cm) and uncolored houses as well as six pairs of green rectangles (8 cm × 6 cm) and uncolored cars were used. The test cards or test objects had to be posted into one of two boxes (28.5 cm × 18.5 cm × 10 cm) through a slit. For the card-sorting tasks, the procedure was the same as in Experiment 1. For the object-sorting tasks, the procedure was the same as in Experiment 2.

Results and discussion

During the pre-switch phase, only one child made one error in the integrated dimensions card-sorting task. The variable of interest was the number of correct responses in the post-switch phase. In both object sorting tasks and in the integrated dimensions card-sorting task, the majority of children sorted either five times correctly or five times incorrectly: All 13 children in the integrated dimensions object-sorting task, 11 out of 13 children in the separated dimensions object-sorting task, and 12 out of 14 children in the integrated dimensions card-sorting task did so. However, in the separated dimensions card-sorting task, the sorting patterns were somewhat less consistent: only six out of 14 children sorted either all cards correctly (n = 5) or all cards incorrectly. Four children sorted correctly on three post-switch trials, and four children sorted correctly on four post-switch trials.

Figure 3 shows the developmental trend on the integrated and separated dimensions tasks. Post-switch performance was analyzed with a 2 × 2 × 2 mixed design ANOVA (two task versions: separated versus integrated dimensions within participants; two sets of stimulus material: cards versus objects and two orders of tasks between participants) with age as covariate. This revealed a significant main effect of task version; children performed significantly better on the separated dimensions tasks (M = 83.7% correct, SD = 26.0) than on the integrated dimensions tasks (M = 37.8% correct, SD = 47.8), F(1, 22) = 7.95, p = .01, partial η² = .27. The interaction between age and task version was also significant, F(1, 22) = 6.03, p < .05, partial η² = .21. This reflects the fact that even the youngest children performed as well as the oldest on the separated dimensions versions. In contrast, on the integrated dimensions versions, there was a developmental improvement (see Figure 3). No other effects or interactions reached statistical significance.

Children’s performance was also evaluated categorically. Children were classified as passing or failing the post-switch phase if they sorted four out of the five items correctly. Logistic regression analyses on numbers of passes confirmed that the stimulus material (cards versus objects) did not influence performance (Wald statistic = 0.42, p > .05, for the integrated dimensions versions; Wald statistic = 2.58, p > .05, for the separated dimensions versions), and that children’s performance improved over age on the integrated dimensions versions (Wald statistic = 3.98, p < .05) but not on the separated dimensions versions (Wald statistic = 0.6, p > .05). A McNemar’s χ² test confirmed that children performed better on the separated dimensions versions than on the integrated dimensions versions, χ² (1, n = 27) = 6.66, p < .01.

In sum, Experiment 3 substantiates the results of Experiments 1 and 2: separating sorting dimensions markedly improves 3-year-olds’ performance on dimensional change sorting tasks, irrespective of whether the sorting material consists of cards or objects.

General discussion

This set of experiments demonstrates that separating sorting dimensions enables most 3-year-old children to switch sorting criteria. Instead of one experiment with a large sample, three small sample experiments using different designs (between-participants manipulation versus within-participants manipulation) and different materials (cards versus objects) were conducted to demonstrate the stability of the effect. Results from all three experiments invariably show that eliminating the need to describe one and the same thing differently enhances performance. Therefore, these results are largely consistent with the object re-description hypothesis as well as the attentional inertia account (Kirkham et al., 2003).

We argue that in the standard DCCS task, children follow a general rule (‘Put each card with the target that has the same thing on it’) and consequently must understand that one and the same thing can be described in

![Figure 3](image-url)
two different ways. If dimensions are separated, children need not understand that one object can be described in two different ways; they just have to switch between objects, for example, switch from sorting the line drawings in the pre-switch phase to sorting the colored circles in the post-switch phase. More specifically, we suggest that children have particular difficulty re-describing objects as being of a different kind but not that they have problems responding to experimental stimuli in different ways (Zelazo et al., 2003, p. 101). In fact, in both separated sorting tasks, children still have to describe the stimulus itself (card or paper plate with their objects on it) differently but they perform close to ceiling.

The separated dimensions versions differ from the integrated dimensions (standard) sorting tasks only in the use of different stimuli. Traditional accounts of children’s difficulty with the DCCS task find it therefore difficult to explain these data. (1) According to the proponents of a cognitive complexity account (Zelazo et al., 2003), separating the two dimensions does not alter the embedded rule structure. Therefore, it is difficult for CCC-r theory to explain the performance difference. Moreover, (2) separating dimensions does not remove the need for switching to a new action schema. Therefore, the present results provide further evidence against an executive inhibition deficit account. Furthermore, despite separation of dimensions, children still have to disengage their attention from the previously relevant dimension and shift it to the previously irrelevant dimension. Therefore, children’s difficulties can be explained neither by (3) an attention disengagement deficit nor by (4) an attention re-engagement deficit (negative priming).

However, research on negative priming in adults has shown that the spatial separation of targets and distractors reduces negative priming; though even well-separated distractors produce significant negative priming (for a review, see Fox, 1995). Therefore, the present results cannot rule out the negative priming explanation because separating dimensions may reduce the magnitude of negative priming. Similarly, separating dimensions may reduce the amount of executive control to be exerted to successfully disengage attention from the previously relevant dimension.

Thus, the two explanations (3 and 4) in terms of a lack of attentional flexibility can account for our results, provided they adopt with the re-description hypothesis the following assumption: switching attention between dimensions that pertain to a single object requires more executive control than switching attention between dimensions across objects.

With this move, these two ‘attentional inflexibility’ accounts become very similar to the re-description deficit hypothesis. Now, both the attentional inflexibility accounts and the object re-description deficit hypothesis postulate a specific kind of cognitive flexibility – the ability to think about one object in different ways – as crucial for mastering the DCCS task. Yet, they still remain distinct. The difference is that the re-description hypothesis sees the observed developmental progress in solving the DCCS as a conceptual change in understanding that objects can be re-described as being of a different kind without assuming any changes in executive control. In contrast, the lack of attentional flexibility accounts see developmental improvement in executive control without assuming any conceptual changes about objects. They explain the developmental gap in mastering the separated dimensions versions before the standard DCCS by the assumption that sufficient executive control for mastering the former is attained earlier than the amount of executive control required for the latter.

This also distinguishes the attentional inertia account (Kirkham et al., 2003) from the re-description hypothesis. Kirkham et al. argue that sufficient inhibitory control is needed to inhibit a way of thinking about the stimuli that is no longer relevant. In contrast, according to the object re-description hypothesis, children’s difficulties do not arise from a lack of inhibitory control but from a failure to understand that objects can be described in different ways. The present results do not allow a clear refutation of any one of these theoretical positions in terms of attentional or re-description inflexibility. They do, however, forcefully make clear that re-description of objects plays an important role in children’s mastery of the DCCS task.

Shepp and colleagues (e.g. Shepp & Barrett, 1991; Shepp, Barrett & Kolbet, 1987) have suggested that younger children (about 5 years of age) perceive multi-dimensional objects as undifferentiated wholes, whereas older children perceive these objects as conjunctions of separable features or dimensions. Due to this, younger children may find it difficult to attend selectively to a single feature or a single dimension in the DCCS when integrated stimuli are used. And, consequently, separating the two dimensions improves performance.

However, previous research on the DCCS task indicates that even 3-year-old children can attend selectively to the color or shape of an integrated, bi-dimensional object when no target cards are used (Kloo & Perner, 2003; Perner & Lang, 2002; Towse et al., 2000). For example, Perner and Lang demonstrated that 3-year-old children can switch to another sorting criterion if the target cards are replaced by target pictures displaying familiar characters like Donald Duck. Furthermore, Ridderinkhof, van der Molen, Band and Bashore (1997), using a selective attention task in a sample of 5- to 12-year-old children, showed that stimulus configuration
are partialled out (e.g. Carlson & Moses, 2001; Frye the false belief task, even when age and verbal intelligence repeatedly been shown to be specifically correlated with not seem to be coincidental because the DCCS task has parallel developmental progress does not develop earlier in bilingual children, and therefore they are better able to switch attention between dimensions in the DCCS task (Bialystok, 1999).

At about the same age that children master the DCCS task, they also pass the false belief task (Wimmer & Perner, 1983). This parallel developmental progress does not seem to be coincidental because the DCCS task has repeatedly been shown to be specifically correlated with the false belief task, even when age and verbal intelligence are partialed out (e.g. Carlson & Moses, 2001; Frye et al., 1995; Perner, Lang & Kloo, 2002). Further support for a developmental link between these two tasks comes from a recent training study (Kloo & Perner, 2003) showing transfer of training: a false belief training improved DCCS performance, and a DCCS training significantly increased children's performance on the false belief task.

One explanation for this developmental link is that children's inability to understand re-description is the common denominator underlying children's difficulty with the standard DCCS task and their failure to understand false belief. Both tasks require an understanding that one entity (e.g. the identity of an object or a certain situation) can be described differently from different perspectives. To understand false belief, one has to understand that someone else can have a description of the real world that differs from one's own description. And understanding of re-description of objects may underlie the DCCS task. Other authors (e.g. Carlson & Moses, 2001; Diamond, 2002) explained the developmental link between the false belief task and the DCCS task by referring to similar executive control requirements. They argued that both theory of mind tasks and particular executive tasks require working memory plus inhibition.

There is independent evidence that young children before the age of about 4 years have difficulty understanding that objects can be re-described. Although children fairly early acquire different names for things (Clark, 1997), they are reluctant to use both terms at the same time, as reflected in the well-known mutual exclusivity bias (Carey & Bartlett, 1978; Markman & Wachtel, 1988). Doherty and Perner (1998) asked children to explicitly acknowledge that something can be two things at the same time, for example, that something can be a rabbit and a bunny, or a rabbit and an animal (Perner, Stummer, Sprung & Doherty, 2002). Children's ability to do so emerges with their ability to understand false belief (Doherty & Perner, 1998; Perner et al., 2002) and also with their ability to master the post-switch phase of the DCCS task (Stummer, 2001).

In sum, this set of studies makes clear that a specific kind of cognitive flexibility – the ability to think about one and the same object in different ways – is crucial for mastering the DCCS task. However, future studies will have to clarify whether this kind of flexibility is brought about by improvements in executive control or by a conceptual change in understanding that objects can be re-described as being of a different kind.

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