Dynamics, models, and mechanisms of the cognitive flexibility of preschoolers

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The distinctive effects of exogenous factors on preschoolers' DCCS performance

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Abstract

Different factors that influence preschoolers' performance on cognitive tasks can be described as endogenous (top-down, under the voluntary control of the child) or exogenous (stimulus driven, bottom-up). In the current project we studied the distinctive effects of exogenous factors on the performance of 143 3-year-olds on the Dimensional Change Card Sorting (DCCS) task. The exogenous factors investigated in this experiment are either related to the sorting rules (changes in the values of the sorting dimensions) or *not* related to the sorting rules (position of the cards on the screen or outline shape of the cards). By fitting latent Markov models to the trial-by-trial accuracy data of the post-switch phase we could test for differences in the consistency of switching or perseverating, in addition to differences in the proportion of switchers and perseverators. Marginally fewer children switched sorting rules in the card shape change condition compared to the control condition. Children in the total change condition (values of both sorting dimensions change), and children in both conditions with changes that are not related to the sorting rules, perseverated less consistently compared to children in the control condition. The hypothesis of Yerys and Munakata (2006) that changes in a dimension would draw attention towards that dimension leading to more sorting according to that dimension could not be confirmed. Exogenous factors can distract attention away from the pre-switch relevant dimension, but not necessarily direct attention towards the post-switch relevant dimension.

4.1
Introduction

When habits and automatic behavior fail to provide guidance in a rapidly changing environment, cognitive flexibility is an essential trait. It is one of the abilities that together with inhibition and working memory consitute cognitive control (Diamond, 2013; Huizinga, Dolan, & van der Molen, 2006; Zelazo, Müller, Frye, & Marcovitch, 2003). It is the ability to change plans in response to relevant changes in the environment, and, complementary, to maintain activities when changes in the environment are irrelevant (Diamond, 2006a). Between the ages of 3 and 5 years there are marked improvements in cognitive flexibility (Carlson, 2005). A widely used paradigm to study cognitive flexibility in preschoolers is the Dimensional Change Card Sorting (DCCS) task (Zelazo, 2006). In this task, children are required to sort two bivalent test cards according to the dimensions color or shape 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 series of test cards according to the other dimension (e.g. shape). Nearly all children sort correctly in the first phase (the pre-switch phase), regardless of which dimension is relevant first. However, most 3-year-olds perseverate in the second phase (the post-switch phase) by sorting the test cards according to the initially relevant 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).

Different factors that influence preschoolers' selective sustained attention have been described as exogenous and endogenous (Fisher, Thiessen, Godwin, Kloos & Dickerson, 2013). Exogenous factors are the characteristics of the stimuli (e.g. contrast, brightness, motion). These factors are bottom-up and not under the voluntary control of the child. Endogenous factors, by contrast, are top-down and under the voluntary control of the child (e.g. goal-directed actions). The selective sustained attention of newborns and very young infants is typically described as stimulus-driven or automatic. Endogenous factors are thought to become more important over the course of development (Fisher et al., 2013; Snyder & Munakata, 2010; Smith & Yu, 2012). In the DCCS task not only selective sustained attention is important, but switching selective attention plays a significant role as well. In the pre-switch phase of the task children have to focus attention on the, at that time, relevant dimension of the stimuli (e.g. color). In the post-switch phase of the task children have to switch the focus of their attention to the other dimension of the stimuli (e.g. shape), and suppress attention to the earlier relevant dimension color. Two factors are at play in the post-switch phase of the standard DCCS task. The first factor is formed by the post-switch relevant sorting rules that the experimenter repeats verbally before each trial, which have to be kept in working memory. This factor is under voluntary control of the children, and we therefore call it the endogenous rule factor. The second factor is formed by the pre-switch relevant sorting rules, which are automatized by sorting according to these rules several times. This factor is not under voluntary control of the children, and we therefore call it the automatic rule factor.

Several studies looked at the influence of an additional third factor. This factor is a stimulus factor: changes in the values of the dimensions of the stimuli introduce stimulus novelty. Since this factor is stimulus-driven, it is exogenous (cf. Fisher et al., 2013). Zelazo, Müller, Frye, and Marcovitch (2003; experiment 7, 8, and 9) investigated the role of stimulus novelty in the DCCS task. Results in the versions of the task in which only the values of one dimension change are not very clear. There was a trend for better performance in the partial change version (values of the dimension that is relevant in the post-switch phase change) compared to the standard DCCS task. And there was a trend for worse performance in the negative priming version (values of the dimension that is relevant in the pre-switch phase change) compared to the standard DCCS task. In two of the three experiments children performed better in the total change version (values of both dimensions change) compared to the standard DCCS task. Zelazo et al. (2003) took the results of the total change version of the DCCS task as evidence that children perseverate DCCS sorting rules at the level of the specific values of the dimensions and not on the dimension itself.

However, a large proportion of children failed in the total change version (21, 37, and 31% respectively in experiments 7, 8, and 9). Moreover, children performed better on the total change version than on the negative priming version. These results cannot be explained by a representation of the sorting rules at the level of the values of dimensions or at the level of dimensions. Because in both versions the values of the dimension that was relevant in the pre-switch phase changed. Yerys and Munakata (2006) gave a completely different explanation for these results. In the total change version (and not in the negative priming version) the values of the dimension that is relevant in the post-switch phase, changed. These changing values would draw attention towards the correct sorting dimension in the post-switch phase, which would make switching easier. The trend for a significant difference between the partial change version and the standard task (Zelazo et al., 2003; Experiment 8) would support this idea. In the negative priming version the values of the dimension that is irrelevant in the post-switch phase changed. These changing values would draw attention to the irrelevant sorting dimension in the post-switch phase, which would make switching more difficult, and perseverating more likely. The trend for a significant difference between the negative priming version and the standard DCCS task would support this idea (Zelazo et al., 2003; Experiment 7). Following this line of reasoning one would expect that changes in the task that are not related to the sorting rules of the pre-switch phase or the post-switch phase would distract attention from the post-switch relevant dimension (which would make switching more difficult), but not necessarily in the direction of the pre-switch relevant dimension (which would make perseverating less likely).

Van Bers, Visser and Raijmakers (in press, Chapter 3) investigated the role of stimulus novelty in a generalization task that matched the DCCS task very closely. After sorting a series of test cards according to one dimension (as in the pre-switch phase of the DCCS task), children were asked to generalize their sorting rules to novel stimuli in one of three conditions. Very high performance on the generalization task of all children in the relevant change condition (only values of the relevant sorting dimension change) suggests an abstract rule representation at the level of dimensions (same colors go together) for all children. Performance on the generalization task in the irrelevant change condition (only values of the irrelevant sorting dimension change), and in the total change condition (values of both dimensions change) was related to DCCS task performance. Children with high cognitive flexibility (switchers on the DCCS task) more often switched their attention to the irrelevant dimension in the generalization task if only the values of the irrelevant sorting dimension changed. Children with lower cognitive flexibility were more often inconsistent in their sorting on the generalization task if values of both dimensions changed. Changes in the values of the irrelevant sorting dimension seemed to distract children from focusing on the relevant sorting dimension. These results match the explanation of Yerys and Munakata (2006) of the results of Zelazo et al. (2003).

In the current study we replicated the experiments of Zelazo et al. (2003) with three versions of the DCCS task because the results of the experiments of Zelazo et al. were inconclusive due to changing results in the standard version of the task. We compared performance in a standard version of the task to performance in the pre-switch relevant change condition (only values of the pre-switch relevant dimension change), performance in the post-switch relevant change condition (only values of the post-switch relevant dimension change), and the total change condition (values of both dimensions change). We expect better performance in the post-switch relevant change condition and the total change condition compared to the standard version of the task because the change in the post-switch relevant dimension in these two conditions draws attention towards this dimension, which makes switching easier (in agreement with Yerys and Munakta, 2006). We expect worse performance in the pre-switch relevant change condition compared to the standard version because the change in the pre-switch relevant dimension draws attention towards this dimension, which makes switching more difficult and perseverating more likely.

The stimulus factors studied in Zelazo et al., (2003) and van Bers et al., (in press, Chapter 3) are related to the sorting rules that are relevant in the pre-switch phase or in the post-switch phase of the DCCS task. There is evidence for impact in these cases. However, less is known about the influence of exogenous factors that are not related to the sorting rules. Following the line of reasoning of Yerys and Munakata (2006) we would expect that changes that are not related to the pre-switch or post-switch sorting rules would distract attention from the relevant dimension (which makes switching more difficult), but not necessarily in the direction of the irrelevant dimension (which makes perseverating less likely). Hence, we expect that unrelated changes result in less consistent switching or perseverating behavior. Coldren and Colombo (2009) made a first attempt to study the effect of unrelated stimulus factors by investigating the influence of changing the color of the background of the test cards in the DCCS task. Children made more errors if the color of the background of the test card was the same as the color of the figure on the test card when switching from color to shape. However, when the change in color of the background was completely unrelated to the sorting rules (changed to grey) no effect was found on children's performance on the DCCS task.

In the current project the influence of exogenous factors that are not related to the sorting rules is investigated with two conditions, in addition to the four conditions that replicate the study of Zelazo et al. (2003) concerning the influence of exogenous factors that are related to the sorting rules. In the card shape change condition the outline shape of the target- and test cards changes and in the card position condition the position of the target- and test cards on the screen changes in the post-switch phase. We expect that the changes that are not related to the sorting rules in the last two conditions distract the attention from the post-switch relevant dimension but not necessarily in the direction of the irrelevant dimension, which results in less consistent switching behavior. With the standard way of analyzing DCCS task data it is not possible tot test for differences in the consistency of switching and perseverating behavior between the conditions. Therefore, in order to test for the consistency of switching and perseverating behavior in addition to differences in the proportion of switchers and perseverators between conditions, we analyzed the trial-by-trial accuracy data of the post-switch phase of the task with latent Markov models (see the subsection statistical approach in the method section; Rabiner, 1989; Van de Pol, & Langeheine, 1990; Visser, 2011).

4.2
Method

Participants

A total of 143 3-year-old children participated in this study (*M* = 41.5 months, *SD* = 3.4, range = 35 - 47 months, 79 girls). We tested another 23 children but their data could not be used because they did not pass the pre-switch phase (*n* = 15), did not complete testing (*n* = 7), or due to experimenter error (*n* = 1). A child had to sort at least five of the six test cards correctly to pass the pre-switch phase. Children were recruited from day-care centers and preschools in the Netherlands. Informed consent was obtained from the parents of all children that participated.

Design

Children were randomly assigned to one of six conditions: the *control* condition (*n* = 25, *M* = 42.7 months, *SD* = 3.0, range = 35 - 47 months, 15 girls), the *pre-switch relevant change* condition (*n* = 25, *M* = 41.4 months, *SD* = 3.4, range = 35 - 46 months, 14 girls), the *post-switch relevant change* condition (*n* = 24, *M* = 42.0 months, *SD* = 3.7, range = 35 - 47 months, 16 girls), the *total change* condition (*n* = 24, *M* = 40.4 months, *SD* = 3.8, range = 36 - 47 months, 15 girls), the *card shape change* condition (*n* = 23, *M* = 41.9 months, *SD* = 2.7, range = 36 - 46 months, 10 girls), or the *card position change* condition (*n* = 22, *M* = 40.6 months, *SD* = 3.8, range = 36 - 47 months, 9 girls). In the control condition children performed the standard version of the DCCS task with the same target cards and test cards in the pre-switch phase and the post-switch phase. In the pre-switch relevant change condition the values of the sorting dimension that is relevant in the pre-switch phase change on the target cards and test cards in the post-switch phase. In the post-switch relevant change condition the values of the sorting dimension that is relevant in the post-switch phase change on the target cards and test cards in the post-switch phase. In the total change condition the values of both dimensions change on the target cards and the test cards in the post-switch phase. In the card shape change condition the outline of the target cards and test cards changes from rectangular in the pre-switch phase to circular in the post-switch phase. In the card position change condition the position of the cards on the computer screen changes. In the pre-switch phase the format of the screen is landscape and the target cards and stacks are on the left and right side of the screen with the test cards in the bottom center of the screen. In the post-switch phase the experimenter turns the laptop 90 degrees and the format of the screen becomes portrait. The target cards and stacks are now at the bottom and top of the screen with the test cards in between them on the left side in the center of the screen. See Figure 4.1 for an example of the computer screen with the target cards and test cards in the pre-switch phase and the post-switch phase in the six conditions. The order of the two sorting dimensions color and shape is counterbalanced within each condition.

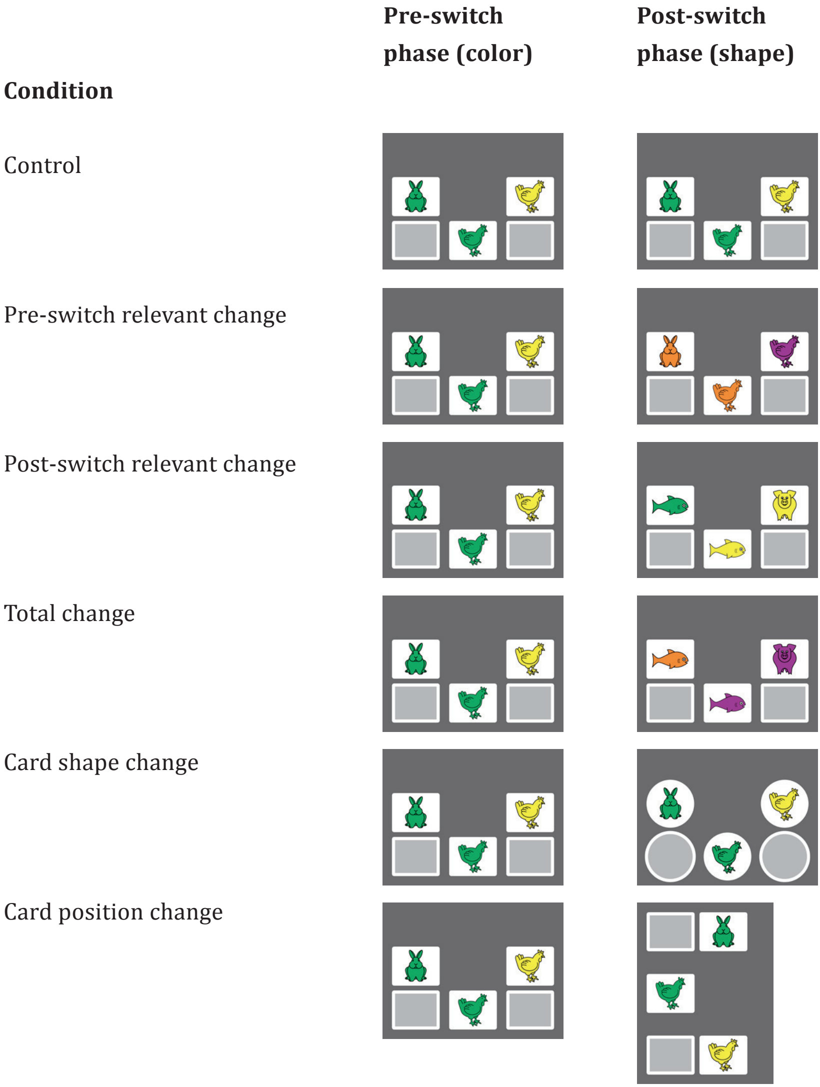

Figure 4.1 *Computer screen with target cards, sorting stacks and test card in the pre-switch phase and the post-switch phase of the task in the six conditions.*

Materials

The experiment was conducted using a laptop computer with an integrated touch-screen monitor. Stimuli were presented against a dark grey background. Two light grey sorting stacks were present in the bottom left and right corner of the screen. Above them the target cards were depicted. A test card appeared in the bottom center of the screen when the experimenter touched the stack of test cards. 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.

The target cards and test cards used during the pre-switch phase were the same in all six conditions. The target cards depicted a green rabbit and a yellow chicken, and the test cards depicted a yellow rabbit or a green chicken. The target cards and test cards used during the post-switch phase of the task were different in the six conditions. In the control condition the target cards and test cards in the post-switch phase were the same as the target cards and test cards used in the pre-switch phase. The target cards depicted a green rabbit and a yellow chicken, and the test cards depicted a yellow rabbit or a green chicken. In the pre-switch relevant change condition the values of the sorting dimension that is relevant in the pre-switch phase change on the target cards and test cards in the post-switch phase. If, for example, the pre-switch relevant sorting dimension was color, the target cards depicted a purple rabbit and an orange chicken, and the test cards depicted an orange rabbit or a purple chicken. In the post-switch relevant change condition the values of the sorting dimension that is relevant in the post-switch phase change on the target cards and test cards in the post-switch phase. If, for example, the post-switch relevant sorting dimension was shape, the target cards depicted a green fish and a yellow pig, and the test cards depicted a yellow fish or a green pig. In the total change condition the values of both dimensions change on the target cards and test cards in the post-switch phase. The target cards depicted an orange fish and a purple pig, and the test cards depicted a purple fish or an orange pig. In the card shape change condition the target cards and test cards used during the post-switch phase depicted the same shapes and colors as in the pre-switch phase. Nevertheless, the outline of the target cards and test cards changed from rectangular in the pre-switch phase to circular in the post-switch phase. In the card position change condition the target cards and test cards used during the post-switch phase depicted the same shapes and colors as in the pre-switch phase. Nevertheless, the orientation of the computer screen and the position of the target cards and test cards on the computer screen changed in the post-switch phase. See Figure 4.1 for an example of the computer screen with the target cards and test cards in the pre-switch phase and the post-switch phase in the six conditions.

In both the pre-switch phase and the post-switch phase of all six conditions each test card matched one target card on the dimension color and the other target card on the dimension shape. Therefore, the correct answer when sorting according to color was the wrong answer when sorting according to shape and vice versa.

Procedure

Children were tested individually in a quiet room in their day-care center or preschool. Once the 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 task.

The experimenter then 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 him- or herself. The two different test cards were presented in pseudo-random order, so that no test card was presented 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 task. The experimenter then explained the sorting rules of the post-switch phase, but did not demonstrate the sorting of the two different test cards. The child was then asked to sort six test cards him- or herself. As in the pre-switch phase, the two different test cards were presented in pseudo-random order, the relevant sorting rules were repeated before every trial, the experimenter labeled the test card with the relevant dimension only, and children were not given feedback on their sorting.

Statistical approach

Differences in the proportion of switchers between the conditions were analyzed by chi-square tests, as in most previous studies. In order to get a more detailed picture of DCCS performance we fitted latent Markov models (Rabiner, 1989; Van de Pol & Langeheine, 1990; Visser, 2011) to the trial-by-trial accuracy data of the post-switch phase of the DCCS task using the package Depmix (Visser, 2007) for the R statistical programming environment (R Development Core team, 2009). This approach allowed for the identification of the number of latent states underlying the sequences of responses in the post-switch phase of the task. Moreover, with these models we could also quantify possible transitions between latent states within individuals over the course of the six post-switch trials. The latent Markov models were defined by a number of parameters that allowed us to identify the nature of the latent states: response probabilities, initial probabilities, and transition probabilities. The response probability is the probability of a correct response, conditional on being in a certain latent state. The initial probability is the probability of being in a certain latent state at the first post-switch trial. The transition probability is the probability of moving to another latent state, conditional on being in a certain latent state. Differences in the initial probabilities of the latent states between the conditions denote a difference in the proportion of switchers and perseverators between the conditions. Differences in the response probabilities of the latent states, and differences in the transition probabilities between the conditions denote a difference in the consistency of switching behavior or perseverating behavior of individuals between the conditions.

Possible differences between the six conditions were investigated by the application of multi-group latent Markov models. We tested whether model parameters could be set equal between conditions. Models were fit to the data by calculating maximum likelihood estimates of the parameters. We used log-likelihood difference tests (e.g. Wickens, 1982) to compare the base model without constrains (equivalent to six separate models) to the multi-group models with equality constraints. If the difference in goodness-of-fit is significant, the null hypothesis of equal model fit is rejected, and the less parsimonious (unconstrained) base model is preferred, indicating differences between conditions. Otherwise the more parsimonious (constrained) model is preferred. If model parameters are not equal between conditions, there is a significant difference between conditions and we test with separate post-hoc tests for differences between the control condition and other conditions. We use a Bonferroni correction for the significance level to correct for multiple tests.

4.3
Results

Standard analyses

In the post-switch phase of the task most of the children either responded correctly on zero or one (40%), or five or six (41%) 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. No significant effects were found for gender or order of the two sorting dimensions color and shape within each of the six conditions when comparing the proportion of switchers. Therefore, all results are collapsed across those variables within each condition. The percentage of children passing the post-switch phase in the six conditions is shown in Figure 4.2. There was a significant difference in performance between the six conditions, $\chi^2(df = 5, N = 143) = 10.85, p = .05$. Planned comparisons revealed no significant difference between the control condition and any of the other conditions. The overall difference between the conditions was caused by a significant difference between the post-switch relevant change condition and the card shape change condition, $\chi^2(df = 1, n = 47) = 7.98, p < .01$, and a marginal significant difference between the post-switch relevant change condition and the card position change condition, $\chi^2(df = 1, n = 46) = 5.74, p < .05$. More children passed in the post-switch relevant change condition compared to the other two conditions.

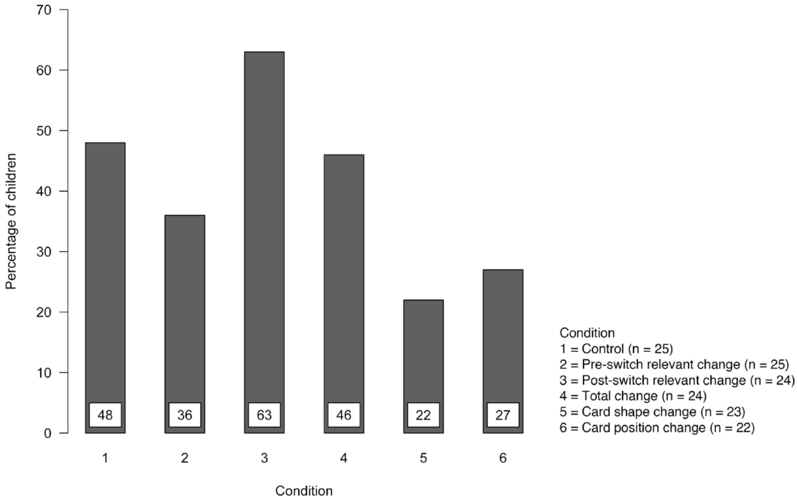

Figure 4.2 *The percentage of children passing the post-switch phase of the task in the six conditions.*

Model-based analyses

In order to test for differences between the six conditions in the proportion of switchers and perseverators, and in the consistency of switching and perseverating we fitted latent Markov models to the trial-by-trial accuracy data of the post-switch phase in the six conditions. Earlier results (Van Bers, Visser, van Schijndel, Mandell, & Raijmakers, 2011, Chapter 2; Van Bers et al., in press, Chapter 3) showed that a model with two latent states with reciprocal transitions between the two states describes the trial-by-trial data of the post-switch phase of the standard version of the DCCS task best. Therefore, the base multi-group latent Markov model has two latent states with reciprocal transitions between the two states for each condition. The different parameters that define the base multi-group latent Markov model are freely estimated for the six conditions separately. Consistent with a perseveration state and a switch state, the response probability of one latent state is much higher (> .75) than the response probability of the other latent state (< .25) in all six conditions.

In order to reveal if there were differences between the six conditions on the different parameters of the multi-group model we first tested which of the parameters of the base model could be set equal across the six conditions without significantly aggravating the fit of the model. An equality constraint could be imposed on the response probability of the switch state and on both transition probabilities, indicating that these parameters do not differ between the conditions. The response probability of the switch state is .956, the probability of a transition from the switch state to the perseveration state is .010, and the probability of a transition from the perseveration state to the switch state is .061 in all six conditions. However, a significant difference was found between the fit of the base model and the model with an equality constraint on the response probability of the perseveration state, $\chi^2(df = 5, N = 143) = 22.67$, $p < .01$, and the model with an equality constraint on the initial probability of the switch state, $\chi^2(df = 5, N = 143) = 12.45$, $p < .05$. This indicates that these parameters differ between conditions.

The second step was to test in which condition the response probability of the perseveration state differed from the response probability of the perseveration state in the control condition. A significant difference (alfa = .01, correcting for multiple comparisons) was found between the response probability of the perseveration state in the control condition and the total change condition, $\chi^2(df = 1, N = 143) = 16.63$, $p < .01$, the card shape change condition, $\chi^2(df = 1, N = 143) = 8.55$, $p < .01$, and the card position change condition, $\chi^2(df = 1, N = 143) = 7.05$, $p < .01$. However, the response probability of the perseveration state in the card shape change condition and the card position change condition did not differ significantly from each other. The response probability of the perseveration state in the total change condition is the highest of all six conditions ($Resp_{pers} = .212$). The response probability of the perseveration state in the card shape change condition ($Resp_{pers} = .107$) and the card position change condition (p = .093) is higher than in the control condition ($Resp_{pers} = .000$).

The third step was to test in which condition the initial probability of the switch state differed from the initial probability of the switch state in the control condition. A marginal significant difference was found between the initial probability of the switch state in the control condition and the card shape change condition, $\chi^2(df = 1, N = 143) = 4.652$, $p < .05$. However, the initial probability of the switch state in the card shape change condition and the card position change condition did not differ significantly from each other. The initial probability of the switch state in the card shape change condition ($Init_{switch} = .181$) is lower than the initial probability of the switch state in the control condition ($Init_{switch} = .491$). In accordance with the results of the standard analyses, the initial probability of the switch state in the post-switch relevant change condition differed significantly from the initial probability of the switch state in the card shape change condition, $\chi^2(df = 1, N = 143) = 7.65$, $p < .01$, and differed marginally significant from the initial probability of the switch state in the card position change condition, $\chi^2(df = 1, N = 143) = 5.17$, $p < .05$. Table 4.1 shows the parameter values of the constrained multi-group latent Markov model for the six conditions.

Table 4.1 *Parameter values of the constrained multi-group latent Markov model for the six conditions.*

Condition	Response probability perseveration state (Resp	Initial probability switch state (Init
Control	.000	.491
Pre-switch relevant change condition	.000	.400
Post-switch relevant change condition	.048	.627
Total change condition	.212*	.491
Card shape change condition	.107*	.181°
Card position change condition	.093*	.256

Note. * *denotes a significant difference with the control condition at the .01 level and ° denotes a marginal significant difference with the control condition at the .05 level. The response probability in the switch state is .956, the probability of a transition from the switch state to the perseveration state is .010, and the probability of a transition from the perseveration state to the switch state is .061 in all six conditions.*

4.4
Discussion

In this study we investigated the distinctive effects of exogenous factors on preschoolers' DCCS task performance. Exogenous factors are stimulus-driven, bottom-up, and not under the voluntary control of the child. The exogenous factors investigated in this study could be divided in exogenous factors that are related to the sorting rules (changes in the values of one or both sorting dimensions) and exogenous factors that are not related to the sorting rules (position of the cards on the screen or outline shape of the cards).

By fitting latent Markov models to the trial-by-trial accuracy data of the post-switch phase in the six conditions we could test for differences in the consistency of switching or perseverating between the conditions, in addition to differences in the proportion of switchers and perseverators between the conditions. A marginal difference in the proportion of switchers and perseverators was found between the control condition and the card shape change condition. Fewer children switched sorting rules in the card shape change condition compared to the control condition. Standard analyses did not show a difference in the proportion of switchers and perseverators between the control condition and any of the other conditions. However, with both types of analysis we did find a significant difference in the proportion of switchers and perseverators between the post-switch relevant change condition on the one hand, and the card shape change condition and the card position change condition on the other hand. More children switched sorting rules in the post-switch relevant change condition compared to the two conditions with a change that was not related to the sorting rules.

Based on the idea of Yerys and Munakata (2006) that changes in the values of a dimension direct the attention towards that dimension, we expected to find a difference in the proportion of switchers and perseverators between the control condition and the conditions with changes in one or both dimensions. Although we did not find a significant difference in the proportion of switchers and perseverators between the conditions, the percentage of children passing the post-switch phase and the initial probabilities of the switch state in the control condition (48%; $\text{Init}_{\text{switch}}$ = .491), the pre-switch relevant change condition (36%; $\text{Init}_{\text{switch}}$ = .400), and the post-switch relevant change condition (63%; $Init_{switch} = .627$) point in the right direction. The results in the total change condition of the experiments of Zelazo et al. (2003) concerning the role of stimulus novelty in the DCCS task could not be replicated. We did not find a difference in the proportion of switchers and perseverators between the total change condition and the control condition.

A difference in the consistency of perseverating was found between the control condition on the one hand, and the total change condition, the card shape change condition and the card position change condition on the other hand. Children in the total change condition, the card shape change condition, and the card position change condition perseverated less consistently than children in the control condition. Perseverators in these three conditions seem to be distracted from the pre-switch relevant sorting dimension, without sorting consistently according to the post-switch relevant sorting dimension. This is exactly what we expected for the two conditions with changes that were not related to the sorting rules. In contrast, for the total change condition we expected more children to switch because changes in the post-switch relevant dimension in this condition would draw attention towards the correct sorting dimension in the post-switch phase, which would make switching easier.

The results in the total change condition of the current study match the results in the total change condition of the study of van Bers et al. (in press, Chapter 3) concerning the role of stimulus novelty in a generalization task. Performance of perseverators in the total change condition of that study (values of both dimensions changed) was less consistent compared to performance of perseverators in the irrelevant change condition (only values of the irrelevant dimension changed). The probability of sorting an item according to the relevant dimension for perseverators in the total change condition of that study was .31 compared to .06 in the irrelevant change condition. A possible explanation for the unexpected results in the total change conditions of both studies is that not only changes in the post-switch relevant dimension take place in these conditions (which would direct attention towards the post-switch relevant dimension). Changes in the pre-switch relevant dimension take place as well (which would direct attention towards the pre-switch relevant dimension). A Change in both dimensions directs the attention of children in two directions at the same time, which could be confusing and result in less consistent behavior.

An alternative explanation, that should be explored in future research, is that all exogenous factors (both related to the sorting rules and unrelated to the sorting rules) distract children from the pre-switch relevant dimension, but not necessarily direct their attention towards the post-switch relevant dimension.

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