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Two Types of Perseveration in the Dimension Change Card Sort Task

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Abstract

Three-year-old children in the Dimension Change Card Sort (DCCS) task can sort cards well by one dimension, but have difficulty switching to sort the same cards by another dimension when asked, i.e., they perseverate on the first relevant information. What is the information that children perseverate on? Using a new version of the DCCS, the experiments in this article reveal that there are two types of perseverators-- those who perseverate at the level of dimensions, and those who perseverate at the level of values (stimulus features). This novel finding has implications for theories of perseveration.

One of the important developing skills in executive functions is the ability to flexibly shift attention from one source of information to another as task demands change. Young children show marked improvement in this ability during the preschool years as measured by such tasks as the Dimension Change Card Sort (DCCS; Frye, Zelazo, & Palfai, 1995). In the DCCS, children are asked to sort a set of simple picture cards into boxes with target cards on them, as illustrated in Figure 1. The sorting cards (e.g., red rabbits and blue boats) match each target card (e.g., a blue rabbit and a red boat) on exactly one dimension--in this example, the red rabbit matches the blue rabbit on shape, and it matches the red boat on color; similarly for the blue boat. On the first phase of the task--the preswitch phase--children are asked to sort the cards by one dimension (e.g. by color) and then, on a second phase --the postswitch phase--they are asked to switch and sort the cards by the other dimension (e.g., by shape), therefore requiring that the cards be sorted into opposite boxes on the two phases. While almost all 3- and 4-year-olds sort the cards correctly by the first dimension, no matter which dimension is first, 3-year-old children tend to be unsuccessful on the postswitch phase, continuing to sort cards by the first relevant dimension even though they are asked to switch and sort by the other dimension instead--i.e., they perseverate. Four-year-old children, on the other hand, are much more likely to sort the cards correctly postswitch, demonstrating an ability to follow the new instructions and to flexibly switch their responses appropriately (e.g., Kirkham, Cruess, & Diamond, 2003; Perner & Lang, 2002; Towse, Redbond, Houston-Price, & Cook, 2000; Zelazo, Frye, & Rapus, 1996; for a review see Garon, Bryson, & Smith, 2008, and Hanania & Smith, 2009).

Attention-based theories of perseveration (e.g., Kirkham et al., 2003; see also Garon et al., 2008) explain sorting success in terms of children's ability to selectively attend to the relevant information--i.e., the ability to focus attention on just what is relevant, ignoring the

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misleading irrelevant information. Three and four year old children sort equally well by the first dimension, thus they all appear to be able to selectively attend to the preswitch relevant information. To be successful on the second sorting phase, children must shift attention to the other dimension and selectively attend to the postswitch relevant information. Since perseverators sort incorrectly postswitch, sorting instead as they did on the first phase, they appear to be stuck selectively attending to the preswitch relevant information, unable to switch away from it (e.g., Kirkham et al., 2003) or towards information that was irrelevant during the first phase (e.g., Müller, Dick, Gela, Overton, & Zelazo, 2006; Zelazo, Müller, Frye, & Marcovitch, 2003). What is the relevant information that these perseverating children attend to and get stuck on? Do children perseverate on the first-attended dimension (e.g., color) irrespective of the values on that dimension, or do they perseverate on the particular values (e.g., the stimulus features red and blue), such that perseveration is dependent on the presence of those same values on postswitch trials? Although some studies have attempted to answer this question (notably, Zelazo et al., 2003), there remains some uncertainty about the source of perseveration. The experiments in this article re-examine this issue using a novel version of the DCCS. The results reveal new insights about perseveration, and help resolve ambiguous previous findings by showing that there are two types of perseverators.

Dimensions versus values

In the standard DCCS task, the sorting cards on pre- and postswitch phases are exactly the same (e.g., red rabbits and blue boats), making it unclear whether children perseverate because they continue attending to the first relevant values (e.g., the stimulus features red and blue) or whether they perseverate because they continue attending to the first relevant dimension (e.g. color) regardless of the values on that dimension. Zelazo and colleagues (Zelazo et al., 2003) addressed this issue by designing a “Total Change” version of the DCCS in which the cards on the postswitch trials had different colors and shapes than the cards on the preswitch trials. In the Total Change version of the task, 3-year-old children were much more likely to sort the new cards correctly on postswitch trials (79% passed in Experiment 7, and 63% in Experiment 8) than were 3-year-olds in the standard DCCS where the postswitch cards were the same as the preswitch cards (42% passed in Experiment 7, and 19% in Experiment 8). The finding that changing stimulus features between and pre- and postswitch trials improved sorting performance on the second phase lends support to the theory that perseveration is at the level of values rather than at the level of dimensions since the stimulus dimensions remained unchanged on the two phases and cannot, therefore, account for the improvement. This result is also consistent with several current accounts of trends in the DCCS which predict stimulus-specific perseveration; for example, strong latent memories for specific stimuli (Morton & Munakata, 2002; Kharitonova, Chien, Colunga & Munakata, 2009), attentional inertia which could be at the level of values (Kirkham et al., 2003), and inhibition of action for the specific stimuli (e.g., Carlson & Moses, 2001). Furthermore, evidence for stimulus features affecting the ability to shift attention is also evident with adults in the task-switching literature (e.g., Gade and Koch, 2007; Waszak, Hommel & Allport, 2005; Wylie & Allport, 2000).

On the other hand, some researchers suggest the possibility that children may perseverate at the level of dimensions, even with a change of dimension values. For example, Yerys & Munakata (2006) point to two results which could indicate perseveration to dimensions. The first result comes from Zelazo et al.’s (2003) Total Change version of the DCCS. Although a significantly larger number of children passed the postswitch phase in the Total Change condition compared to the standard condition, a fairly large number of children still did not pass the postswitch phase of the task, despite a total change of stimulus features (21% in Experiment 7, 37% in Experiment 8, and 31% in Experiment 9). The second result comes

from Zelazo et al.'s (2003) "Negative Priming" version of the DCCS in which cards sorted during the postswitch phase had new values on the preswitch relevant dimension, but the same values on the preswitch irrelevant dimension. For example, if children sorted red and blue rabbits and boats by color on preswitch trials, they were asked to sort green and yellow rabbits and boats by shape on postswitch trials. In this version of the DCCS, 3-year-old children continued to sort by the first relevant dimension although the values on that dimension had changed. Both these results are consistent with perseveration at the level of dimensions, and they raise the possibility that children--at least some children--do perseverate on the first relevant dimension, regardless of dimension values.

Performance in other selective attention tasks is also relevant to this question of whether perseveration in the DCCS is dimension-based or value-based. The literature indicates that children (and adults) who selectively attend are likely to persist in selective attention to a dimension that was previously relevant. For example, in discrimination learning tasks (see Hanania & Smith, 2009, for an overview), children who learn to discriminate items by attending to values on the relevant dimension (e.g., learn that color is relevant; red wins and blue loses regardless of shape) perform better on transfer tasks which require continued attention to the same dimension (e.g., yellow wins and green loses) compared to transfer tasks which require learning about another dimension (e.g., circle wins and square loses; Kendler, Kendler & Ward, 1972; see also Kendler, Kendler & Wells, 1960; Tighe, 1973). Similarly, adults and non-human primates persist in attending to a previously relevant dimension in transfer of learning tasks (e.g., Kersten, Goldstone, Schaffert, 1998; Kruschke, 1996; Roberts, Robbins & Everitt, 1988). These findings suggest that if children in the DCCS are selectively attending, they might perseverate on the first relevant dimension, irrespective of values.

Thus, it is unclear whether perseveration in the DCCS is dimension-based or value-based. To examine this issue, Experiment 1 used a novel manipulation of the DCCS task which is similar to Zelazo and colleagues' (2003) Total Change manipulation, but in a within-subjects design.

Experiment 1: Three-phase DCCS

In the standard DCCS task, children are asked to sort the same picture cards (e.g. red rabbits and blue boats) first by the preswitch dimension on the first phase, and then to switch and sort by the postswitch dimension on the second phase. The new DCCS task, illustrated in Figure 2, is exactly like the standard DCCS on the first two phases, but there is an added third phase in which new cards (e.g., green flowers and yellow cars with corresponding target cards) are to be sorted by the same dimension as on the second phase. For example, a child might be asked to sort cards first by color, then by shape, and then to sort new cards by shape.

The question is whether children who perseverate on the second phase of the DCCS, unsuccessful at switching sorting to the postswitch dimension, will switch successfully on the third phase when the cards change. If children who perseverate in the DCCS are stuck selectively attending to the values that were relevant preswitch (e.g., the stimulus features red and blue), they should be able to switch and sort successfully by the postswitch dimension on the third phase when they are given new cards with new values since the information they perseverated on will have been removed. This is the value-based outcome suggested by the results of Zelazo et al.'s (2003) Total Change version of the DCCS. If, on the other hand, children who perseverate do so because they are stuck selectively attending to the dimension (not the values) that was relevant on preswitch trials (e.g., color), they should continue to sort incorrectly by the preswitch dimension even when given new cards

on the third phase of the task since the information they are stuck on (color) is still available. This is the result suggested by accounts of selective attention to dimensions, and would be unexpected based on the behavior of the majority of children in Zelazo et al's Total Change version of the task. In contrast to perseverators, children who sort correctly on the first and second phases, demonstrating an ability to flexibly switch attention across sorting dimensions with the same cards, should continue to sort well on the third phase since flexibility should not be impaired by change in values. To capture a full range of behavior and individual differences in sorting success and failure, the subjects for this experiment include both 3- and 4-year-olds.

Method

Participants—One hundred and forty-two 3- and 4-year-old children (M = 46.6 months, SD = 6.6; range = 35.5 to 59.3 months; 58 males) were recruited from a Midwestern college town and tested in their day cares or in the laboratory.

Stimuli and Procedure—The stimuli for the DCCS task were colored drawings on 10.25 × 11.25 cm^2 cards, and two sorting trays (as illustrated in Figure 2). Two sets of target and sorting cards were used: red and blue rabbits and boats, and green and yellow flowers and cars. For each set, two target cards were placed on the trays at the beginning of each phase: a blue rabbit and red boat for the rabbit/boat card set, and a yellow flower and green car for the flower/car set. The corresponding sorting cards were red rabbits and blue boats or green flowers and yellow cars. There were three phases with 6 sorting cards in each phase: Phase 1--a preswitch phase during which children sorted cards from one card set (e.g., 3 rabbits and 3 boats) by one dimension (e.g., color); Phase 2-- a postswitch phase during which children were asked to switch and sort cards from the same card set (3 rabbits and 3 boats) by the formerly irrelevant dimension (e.g., shape); and Phase 3-- in which new cards with new shapes and new colors (e.g., 3 flowers and 3 cars) were introduced, to be sorted by the same postswitch dimension that was relevant on the second phase (e.g., shape). The appropriate target cards were displayed on the trays at the start of each phase. The starting card set (rabbit/boat or car/flower) was randomized across children, as was the first sorting rule (color or shape).

As in standard version of the DCCS, the instructions on preswitch trials followed this form: "In this game, we're going to sort these cards by color. So in this game, all the red ones go in this box with this red one, and all the blue ones go in this box with this blue one". On the postswitch phase, the need to shift attention was made explicit following this form: "Now we're going to change the game; we're not going to sort by color any more. Now we're going to sort the cards by shape. So in this game, all the rabbits go in this box with this rabbit and all the boats go in this box with this boat." On the third phase, children were asked to continue sorting by the same dimension but with new cards: "Let's keep playing the shape game. So we're going to sort these cards by shape. Now the flowers go here with this flower, and the cars go here with this car". At the start of each phase, new target cards were placed on the tray back without removing previous target cards, even though they were identical between the first and second phase; this was to ensure that there was no difference in transition for the second and third phases. Every trial throughout the task began with an explicit statement of the sorting rule (e.g., "All the red ones go in here with this red one and all the blue ones go in here with this blue one"), and when a sorting card was presented to the child, both dimensions were labeled (e.g., "Here's a red rabbit. Where does it go?"). The cards were placed face down in the tray as they were sorted. The order of sorting cards was randomized with the constraint that the same card (e.g., red rabbit) did not appear more than twice in succession. Corrective feedback was given during the first phase, but not on subsequent phases.

Results and Discussion

Performance was measured by the number of correctly sorted cards on each phase of the DCCS. Consistent with the literature (e.g., Kirkham et al., 2003; Yerys & Munakata, 2006; Zelazo et al., 1996), on a majority of the sorting phases children either sorted all 6 cards correctly, or they sorted none of the cards correctly, sorting instead by the irrelevant dimension (across all children on the 3 phases, 86.4% of phase scores were 0 or 6; 95.5% of phase scores were ≥ 5 or ≤ 1). Since scores were bimodally distributed, children were categorized as passing or failing each phase, as is common in this literature. A child "passed" a phase if at least 5 of the 6 cards were sorted correctly; otherwise, the child "failed" that sorting phase.

Also consistent with the literature on 3- and 4-year-olds' performance in the DCCS task, almost all children (98.6%; 140 of 142 children) passed the first phase of the task, and they did so no matter which sorting dimension was first, color or shape. The 2 children who failed the preswitch phase were excluded from the following description and analysis. For the 140 children who passed Phase 1, sorting success on Phases 2 and 3 did not vary significantly with Gender or with the randomized variables (order of card sets, and first sorting dimension).

As shown in Figure 3, a majority of children (67.1%; 94 of the 140 children who passed Phase 1) failed to switch correctly to the new sorting dimension on Phase 2. That is, the majority of children perseverated, continuing to sort by the first dimension (e.g. color) even when asked to switch and sort the cards by the other dimension (e.g. shape). Perseveration is typical for younger preschool children in the standard version of the DCCS (see Hanania & Smith, 2009, for a review), and the perseverators in Experiment 1 were significantly younger than the children who sorted correctly by the postswitch dimension on Phase 2 (44.6 months vs. 50.6, $t(138)=5.595$, $p<.001$). Performance on phases 1 and 2 of this 3-phase version of the DCCS was, therefore, equivalent to that in the standard task.

Phase 3 provides the critical manipulation. On this phase, children were asked to sort by the same dimension as Phase 2 (e.g. shape), but with new cards. The main question is whether children who perseverated, failing to switch to the postswitch dimension on Phase 2, would sort correctly by that dimension when given new cards on Phase 3. The first important result is that children's sorting performance on Phase 3 of this task was decisive. As on Phases 1 and 2, the vast majority of children sorted unequivocally by one dimension or the other, either switching successfully and sorting all Phase 3 cards correctly by the postswitch dimension, or continuing to perseverate and sorting all cards incorrectly by the preswitch dimension (84.6% of scores on Phase 3 were 6 or 0; 90.7% of scores were ≥ 5 or ≤ 1).

The second important result (as shown in Figure 3) is that children who perseverated on Phase 2 were distinguished into two large groups by performance on the third phase: 34 children (36.2%) who failed to sort by the postswitch dimension on Phase 2, went on to sort cards correctly by that dimension on Phase 3 when the cards changed, suggesting value-based perseveration; the other 60 children (63.8%) who failed to sort by the postswitch dimension on Phase 2, also failed to sort correctly by that dimension on Phase 3 (continuing to sort the new cards by the preswitch dimension), suggesting dimension-based perseveration. The two groups of perseverators, those who passed Phase 3 and those who failed, did not differ in mean age (44.8 vs. 44.2 months, $t(92)=.468$, $p=0.64$, effect size $d=0.10$). Unlike perseverators, children who sorted cards correctly by the postswitch dimension on Phase 2 were almost unanimous in continuing to sort correctly by the postswitch dimension on Phase 3 (43 of 46 children; 93.5%).

These results suggest that children who perseverate are not all perseverating on the same preswitch information. Around one-third of perseverators switched successfully to the postswitch dimension when given new sorting cards on Phase 3, suggesting that they selectively attend and stick to information at the level of the values since they perseverated only in the presence of the same stimulus features. The other two-thirds of perseverating children continued to sort cards by the preswitch dimension even when given new cards on Phase 3, suggesting that they selectively attend and stick to information at the level of dimensions since they continued to perseverate even when the stimulus features changed. It is important to emphasize that children did not sort haphazardly on this new phase. Almost all children sorted the cards on Phase 3 strictly by one dimension or strictly by the other, and, thus, there is a stark difference in sorting patterns between the two types of perseverators. The finding that children may perseverate for different reasons is new and suggests differences in the selective attention processing of young preschool children, an issue that needs further, separate investigation.

The existence of two types of perseveration in the DCCS may help explain the mixed results in Zelazo et al.'s (2003) Total Change study where some children appeared to switch with new postswitch stimuli and others did not. However, in the current Experiment 1, the majority of children (63.8%) appeared to perseverate on the first relevant dimension while in Zelazo et al's Total Change experiment the majority of children (between 60% and 80%) switched successfully with new cards, suggesting that most children perseverate on values. One relevant difference between the experiments that may explain the divergence in findings is that the 3-phase version of the DCCS in Experiment 1 is a within-subjects design with the advantage of determining who perseverates on the standard DCCS (Phases 1 and 2) before testing the source of perseveration (Phase 3). In the between-subjects design of Zelazo's Total Change experiment, some of the children who sorted correctly when the cards changed on Phase 2 may have been flexible attention switchers who would not have perseverated in the standard DCCS.

Another factor that may account for differences between Experiment 1 (above) and Zelazo's Total Change experiment is the number of cards sorted by one dimension. Children who perseverated on Phase 2 in Experiment 1 sorted cards from the same card set (e.g. red rabbits and blue boats) by one dimension (the preswitch dimension) for two phases before the cards changed on Phase 3; they, therefore, sorted up to 12 cards by one dimension. In Zelazo et al's study, children sorted only 6 cards before new cards were introduced. It has been argued that the number of preswtich trials is not related to perseveration since children perseverate even after only 1 or 2 preswitch trials (e.g., Zelazo et al., 1996). Results of Experiment 1 may be an indication that the number of cards sorted by one dimension does affect the tendency to perseverate on that dimension. Future studies can test this possibility by varying the number of trials on Phases 1 and 2 to see whether this affects the proportion of value-based versus dimension-based perseveration.

Although Experiment 1 strongly implies two types of perseveration in the DCCS-- value-based vs. dimension-based--it could be that children's behavior on Phase 3 reflects influences unrelated to the source of perseveration. For example, perhaps the smaller group, those who switched successfully when given new cards on Phase 3, was composed of children who can flexibly switch sorting dimensions but who happened not to pay attention to instructions on Phase 2, only starting to pay attention when new cards were introduced on the third phase. Or perhaps this group of children was particularly attracted by the values on the preswitch dimension of the first card set (e.g., found red and blue particularly attractive), which caused perseveration on those stimulus features until new cards with new values were introduced. In either of these cases, perseveration on Phase 2 for these children would be temporary, simply a bump in the road for children who would otherwise switch sorting

dimensions successfully as instructed. Similarly, perhaps those who continued to perseverate on Phase 3, sorting by the preswtich dimension even with new cards, were not listening to instructions and sorted by whichever dimension they happened to choose. These children might choose to sort the new cards differently on another phase. Experiment 2 was designed to test these possibilities.

Experiment 2: Four-phase DCCS

As a further test of whether children perseverate at the level of dimensions (selectively attending and sticking with the first relevant dimension) or at the level of values (selectively attending and sticking with the first relevant stimulus features), children in Experiment 2 were presented with a 4-phase version of the DCCS. This version is the same as the 3-phase version of Experiment 1, with the addition of a fourth phase in which children are asked to sort the same cards as on Phase 3 by the original, preswitch, dimension. The structure of the task (illustrated on the left side of Figure 4) is such that Phases 3 and 4 are analogous to Phases 1 and 2 but with a different card set (i.e., new values), and the reverse order of sorting dimensions (i.e., the sorting dimension on Phase 4 is the same as the preswitch sorting dimension on Phase 1).

If there are two types of perseverators, as suggested by Experiment 1, the differences in perseveration should continue into Phase 4--those who perseverate on values should perseverate on values again with the second card set, while those who perseverate on the first dimension should continue to perseverate on that same dimension with the second card set. More specifically, value-based perseverators who fail Phase 2--sorting the first card-set by the preswitch dimension on both phases--and pass Phase 3--sorting the new cards correctly by the postswitch dimension--should continue to sort this second card-set by the postswitch dimension rather than shifting to the preswitch dimension as instructed. Therefore, value-based perseverators (those who pass Phase 3) should fail Phase 4. In contrast, dimension-based perseverators who fail Phase 2 and Phase 3, apparently stuck sorting cards by the preswitch dimension even when the cards change, should continue to sort the second card-set by the preswitch dimension, as instructed on Phase 4. Therefore, dimension-based perseverators (those who fail Phase 3) should pass Phase 4.

If, on the other hand, the patterns of responses in Experiment 1 do not reflect differences in perseveration to values versus dimensions, children may not sort according to this predicted pattern, and, furthermore, performance on Phase 4 may not align cleanly with performance on Phase 3. For example, if children who appear to perseverate on values instead fail Phase 2 and pass Phase 3 for another reason, such as temporary inattention on Phase 2 or attraction to specific features of the first card set, they may sort cards correctly on Phase 4 having gone past those temporary obstacles. Likewise, if children who appear to perseverate at the level of dimensions instead fail Phases 2 and 3 because they do not follow instructions, they may sort incorrectly by the postswitch dimension on Phase 4, or they may sort randomly.

It is expected that children who sort correctly on Phases 2 and 3 would continue to sort correctly on Phase 4 since they appear to switch attention flexibly between dimensions, independent of stimulus features. As in Experiment 1, the subjects for this experiment include both 3- and 4-year-old children in order to capture a full range of behavior and individual differences in sorting success and failure on the 4 phases.

Method

Participants—Sixty-two children (M = 45.5 months, SD = 8.0; range = 35.5 to 59.6 months; 31 male) were recruited from a Midwestern college town and tested in their day cares or in the laboratory.

Stimuli and Procedure—The stimuli for the 4-phase DCCS task were the same as for the 3-phase version in Experiment 1 (see Figure 2): red and blue rabbits and boats, and green and yellow flowers and cars. For each set, two target cards were placed on the trays at the beginning of each phase: a blue rabbit and a red boat for one card set, and a yellow flower and green car for the other set. The corresponding sorting cards were red rabbits and blue boats or green flowers and yellow cars. There were four phases with 6 sorting cards in each, and the first three phases were exactly as in the 3-phase version of Experiment 1 (see Figure 4): On Phase 1, children were asked to sort cards from one card set (e.g., 3 rabbits and 3 boats) by the preswitch dimension (e.g., shape); on Phase 2, children were asked to switch and sort cards from the same card set (e.g., 3 rabbits and 3 boats) by the postswitch dimension (e.g., color); on Phase 3, new target and sorting cards were introduced (e.g., yellow and green flowers and cars), to be sorted by the same postswitch dimension as on Phase 2 (e.g., color); and, lastly, a fourth phase was added during which children were asked to switch and sort the same card set as Phase 3 (e.g. 3 flowers and 3 cars) by the preswitch dimension that was relevant on Phase 1 (e.g., shape). The appropriate target cards were displayed on the trays at the start of each phase, and both the starting card set (rabbit/boat or car/flower) and the first sorting rule (color or shape) were randomized across children.

Instructions were the same as on the 3-phase version of the task, with the addition of a switch on Phase 4. As before, children were told that the rule was changing “Now we’re going to change the game; we’re not going to sort by color any more. Now we’re going to sort the cards by shape. So in this game, all flowers go in this box with this flower, and all cars go in this box with this car”. Every trial began with an explicit statement of the sorting rule (e.g., “All the flowers go in here with this flower and all the cars go in here with this car”), and when a sorting card was presented to the child, both dimensions were labeled (e.g., “Here’s a green flower. Where does it go?”). The cards were placed face down in the tray as they were sorted. The order of sorting cards was randomized with the constraint that the same card did not appear more than twice in succession.

Results and Discussion

Performance was measured by the number of correctly sorted cards on each phase of the DCCS. As in the standard DCCS and in the 3-phase version in Experiment 1, children tended to sort either all cards correctly or all cards incorrectly on any given phase (85.8% of all the phase scores were 6 or 0; 92.9% of all the phase scores were ≥ 5 or ≤ 1). This indicates again that almost all children on almost all phases sorted all cards either by one dimension or all cards by the other dimension; very few children mixed sorting dimensions within a phase. Since scores were bimodally distributed, children were categorized as passing or failing each phase. A child “passed” a phase if at least 5 of the 6 cards were sorted correctly; otherwise, the child “failed” that sorting phase. Results are summarized in Figure 4.

As in previous studies (cited above) and in Experiment 1, almost all children (96.8%; 60 of 62 children) passed the first sorting phase of the task whether they were sorting by color or by shape. The 2 children who failed were excluded from the following analysis. For the 60 children who passed Phase 1, sorting success on the other phases did not vary significantly with Gender or with the randomized variables (order of card sets, and first sorting dimension). Also as expected for this age-range, the majority of the children who passed Phase 1 failed Phase 2 (73.3%; 44 of 60 children), continuing to sort the first set of cards by the previously relevant, preswitch, dimension; 16 children (26.7%) passed phase 2. Those who perseverated were significantly younger than the children who sorted correctly on Phase 2 (43.0 months vs. 52.3, $t(58)=5.064$, $p<.001$).

Performance on Phase 3 was similar to that in Experiment 1 and lends support to those results. First, sorting behavior was decisive and strongly bimodal, with a majority of children sorting either all cards incorrectly by the preswitch dimension or all cards correctly by the postswitch dimension (93.3% of Phase 3 scores were ≥ 5 or ≤ 1). Secondly, those who perseverated on Phase 2 formed two fairly large groups, with the proportion of children in each group similar to that in Experiment 1: 17 children (38.6%) who failed sorting on Phase 2, went on to pass Phase 3; the other 27 children (61.4%) who failed to sort by the postswitch dimension on Phase 2, also failed to sort correctly by the postswitch dimension on Phase 3. The two perseverator groups did not differ in mean age. All of those who passed Phase 2 also passed Phase 3 (all 16 children).The results of Experiment 2 therefore replicate the findings of the 3-phase version in Experiment 1 and provide corroborating evidence for two types of perseveration.

On Phase 4, children were asked to sort the same cards as Phase 3, but to switch sorting back to the original, preswitch, dimension. The main question is whether the two types of perseverators from Phase 3 would continue to show the same pattern of perseveration on Phase 4. In particular, would children who perseverate at the level of values perseverate again with the second card set, sorting incorrectly by the postswitch dimension on Phase 4? Analogously, would children who perseverate at the level of dimensions continue to sort by the preswitch dimension, and, therefore, sort correctly by the preswitch dimension on Phase 4? Moreover, would children who switched sorting dimensions successfully on the first 3 phases sort successfully again on Phase 4, demonstrating a robust ability to switch selective attention with task instructions?

The first important result is that performance on Phase 4 was again bimodal, with the majority of children either sorting all cards correctly or all cards incorrectly (88.3% of Phase 4 scores were ≥ 5 or ≤ 1). Second, children's sorting behavior matched the predicted pattern and aligned with performance on the previous phases (see Figure 4). Specifically, almost all children who appeared to perseverate at the level of values--perseverating when the cards were the same (Phase 2), but switching successfully when new cards were introduced (Phase 3)--perseverated again with the second card set on Phase 4 (88.2% sorted incorrectly; 15 of 17 children). The almost unanimous tendency of this group to sort incorrectly on Phase 4 is consistent with the interpretation that these children selectively attend and perseverate on values. In stark contrast, almost all children who appeared to perseverate on the first relevant dimension--sorting all cards by the preswitch dimension, even when the cards changed on Phase 3--continued to sort, correctly, by the preswitch dimension on Phase 4 (88.9% sorted correctly; 24 of 27 children). Again this pattern was almost unanimous, which is consistent with the interpretation that these children selectively attend and perseverate at the level of dimensions, irrespective of dimension values. Finally, consistent with flexible selective attention, almost all children who passed the first 3 phases, switching sorting dimensions successfully, continued to sort correctly on Phase 4 (81.3%; 13 of 16 children).

In summary, children's performance on Phase 4 of Experiment 2 aligned cleanly with their sorting behavior on the previous phases. Those who switched successfully continued to do so, and those who perseverated continued in their particular pattern of perseveration, value-based or dimension-based. Furthermore, these differences were clear and distinct since children sorted unambiguously on all phases of the task.

General Discussion

The experiments in this article provide the new insight that not all children who perseverate on the postswitch phase of the standard DCCS do so in the same way. Although children

who fail to switch on postswitch trials appear identical in the standard task (sorting equally and unambiguously by the preswitch relevant dimension), the new versions of the DCCS introduced here clearly differentiate two large groups of perseverating children. Around one third of these children appear to perseverate at the level of values, switching successfully only when the values change, while the other two-thirds appear to perseverate at the level of dimensions, persisting in sorting by the first relevant dimension even when the values change. The difference in performance between the two groups of perseverators is very clear in their pattern of responses, with most children sorting unambiguously by one dimension or the other on every phase of the task. To the author's knowledge, this is the first demonstration of different types of perseveration in the DCCS, and the first indication that a large number of children may perseverate at the level of dimensions, not values.

One question that follows from this finding is whether the two types of perseveration patterns reflect individual differences which are stable across retest, or whether they reflect passing, situational factors, such as children's level of arousal at a particular moment. A pilot study in our lab begins to answer this question and suggests that the differences may be stable. Forty-six children who had participated in the study described above were randomly selected to be retested in the 3-phase version of the DCCS task (see Experiment 1) approximately one week later. All 46 children received the same first card set and the same first relevant dimension on both test days. Results indicate that children's performance was relatively stable across the two days. Specifically, most children continued to either pass or fail the standard task (Phases 1 and 2) on retest: 78.6% of those who switched sorting rules successfully on the first day, did so again on retest (11 of 14); 84.4% of those who perseverated during the first test, perseverated again on retest (27 of 32). The tendency for those who perseverate in the standard DCCS to perseverate again when retested was also reported by Bohlmann & Fenson (2005). The critical question is whether children who perseverated on both test and retest did so in the same way on both days, either perseverating on values or on dimensions both times as indicated by performance on Phase 3. Results show that children's patterns of perseveration appear to be quite stable between test and retest: 87.5% (7 of 8) of those who perseverated on values on the first day perseverated on values again on retest; 84.2% (16 of 19) of those who perseverated on dimensions on the first day perseverated on dimensions again on retest. Thus, these preliminary results suggest that differences in perseveration reflect stable individual differences in children, rather than momentary situational factors. Whether these differences indicate different points in development or whether they indicate different developmental trajectories remains to be seen and can be investigated in future studies using a longitudinal approach.

The revelation that there are individual differences in DCCS perseveration presents a challenge to theories. Most current theories of perseveration in the DCCS predict perseveration at the level of values, not at the level of dimensions. For example, Cognitive Complexity and Control (CCC) theory (Zelazo et al., 2003) posits that children's difficulties on postswitch trials arise from an inability to represent a hierarchy of if-then rules (e.g., if shape, then if rabbit … but if color, then if red …); children get stuck on the lower-order rules (e.g., if red, it goes here; if blue, it goes there). CCC theory predicts, therefore, that changing the values makes it possible to learn new low-order rules (e.g., if car, it goes here; if flower, it goes there), and that children should sort new cards values successfully when the sorting dimension switches. Contrary to this prediction, this is not the case for the large number of perseverators in Experiments 1 and 2 who continued to sort by the incorrect dimension even with new values. Similarly, Kloo and Perner (2005) propose that perseveration is an indication that young children cannot re-describe an object in a new way, again predicting that new values--which constitute new objects--should allow children to switch sorting dimensions successfully, a prediction that conflicts with the findings

presented here. Likewise, memory-based theories (Morton & Munakata, 2002; Munakata, 2001) suggest that perseveration is the result of strong latent memories for specific stimuli which overpower weaker working memories for new rules, and this predicts easier postswitch sorting if the stimuli change. In their current form, these theories do not easily accommodate dimension-based perseveration. Attentional inertia (Kirkham & Diamond, 2003) explains perseveration in terms of continued attention to preswitch relevant information, and does not clearly specify whether the information is stimulus features (values) or dimensions. While the idea of being stuck attending to information is compatible with the findings in this study, the theory would have to explain the differences found among children.

One approach to explaining the two types of perseveration--values and dimensions-- is in terms of the development of selective attention. The literature on selective attention in preschool children indicates a developmental trend starting with attention to combinations of features and progressing to attention to single dimensions. This change starts to take place during the preschool years, and may overlap with changes in DCCS performance (see Hanania & Smith, 2009, for a review and discussion). It may be that children who perseverate on values in the DCCS have less mature selective attention processes than those who perseverate on dimensions since the ability to focus on dimensions appears later in development. Three- and four-year old children may be at different stages of this development and may therefore focus more on values or more on dimensions. Furthermore, it may be that dimension perseverators are also still undergoing developmental changes in their facility to selectively attend which make them unsuccessful at switching in the DCCS. For instance, it may be that those who perseverate on dimensions are slow to build focused attention to one dimension and slow to change focus. This slowness would be consistent with the possibility that dimension perseverators are sensitive to trial frequency, as mentioned in the discussion of Experiment 1. Perhaps the ability to switch rules successfully in the DCCS requires selective attention which can quickly focus on a dimension and, thus, can quickly switch to another. This explanation predicts a developmental progression in performance on the DCCS such that children start by perseverating on values, advance to perseverating on dimensions, and, finally, develop the ability to switch flexibly. Future work can test this prediction.

The experiments in this study present new results which challenge current explanations of perseveration in the DCCS. Clearly, more research is needed to better understand the nature of the differences between value-based and dimension-based perseverators, and whether these differences relate to developmental trends in selective attention. Pursuing these questions may be important in reaching a deeper understanding of the mechanisms involved in perseveration in the DCCS task and beyond.

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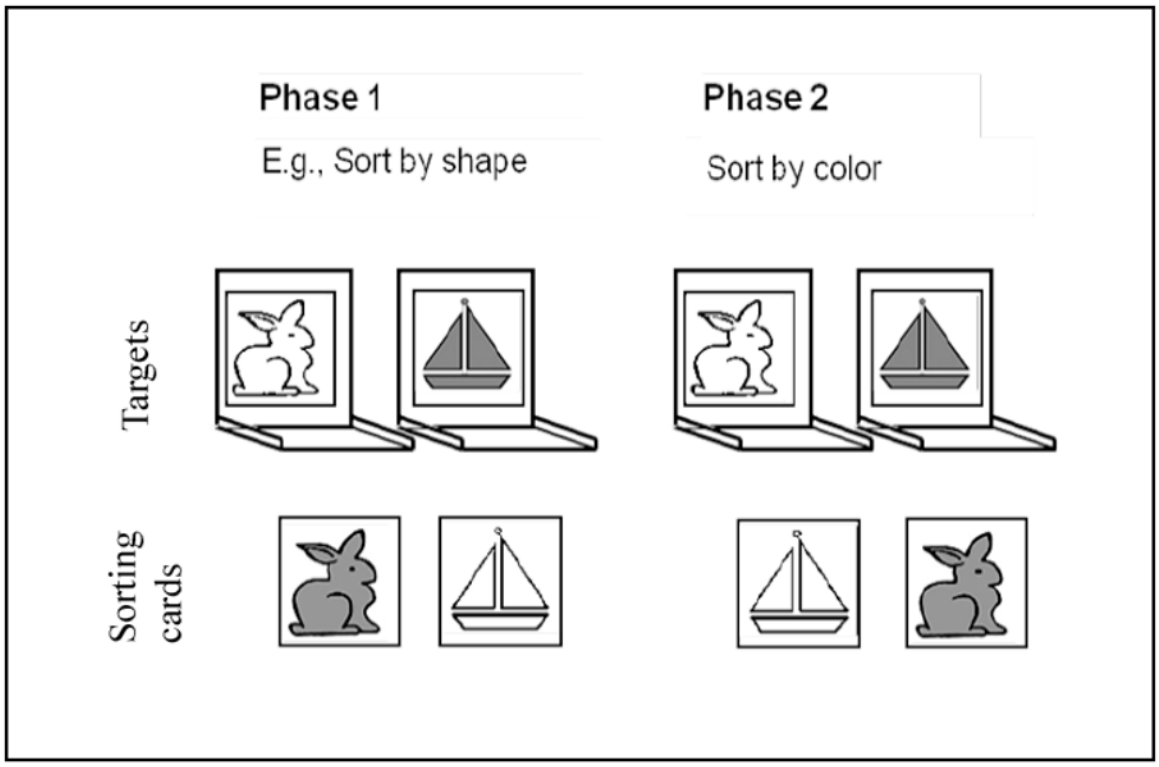

Figure 1.
The standard DCCS task with two phases using the same cards and switching sorting dimensions. White=blue; grey = red

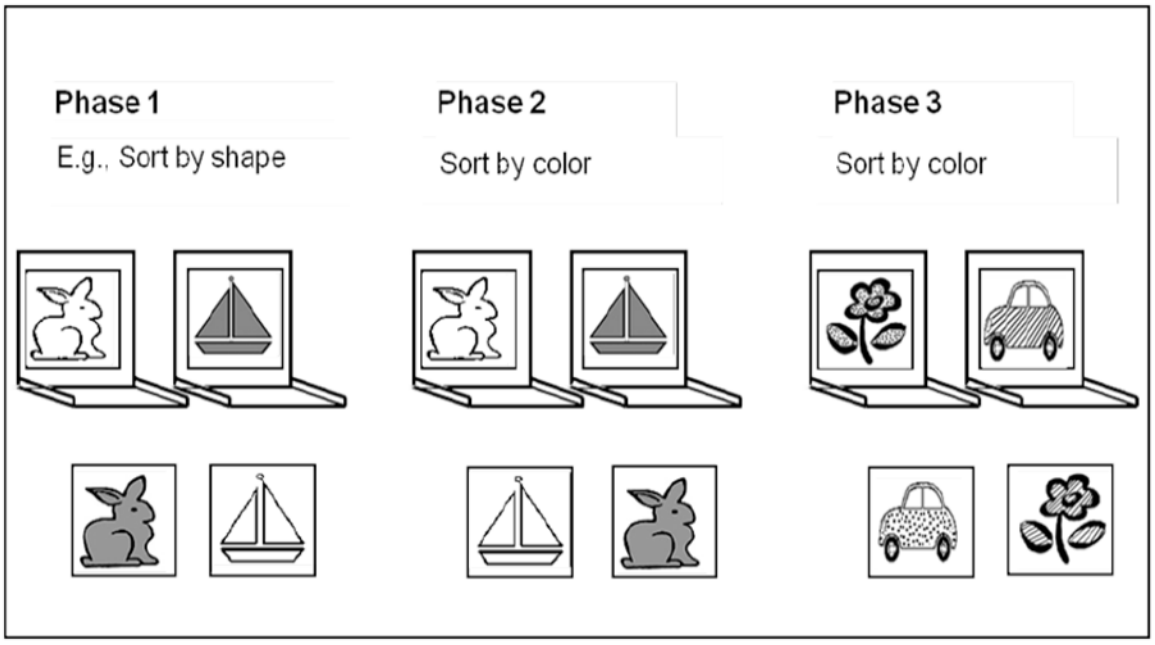

Figure 2.
The 3-phase DCCS task (Experiment 1). White = blue; gray=red; dotted=yellow; lined=green. Phases 1 and 2 are equivalent to the standard DCCS task; Phase 3 introduces new cards to be sorted by the same dimension as on Phase 2.

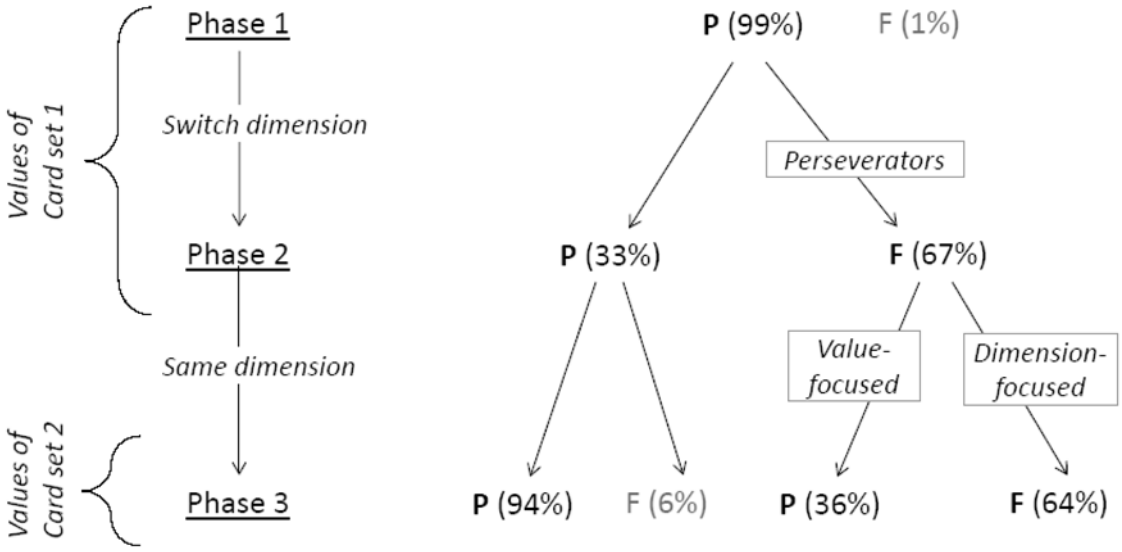

Figure 3.
Left side: Structure of the 3-phase DCCS (Experiment 1). Right-side: Percent children passing (P) and failing (F) each sorting phase.

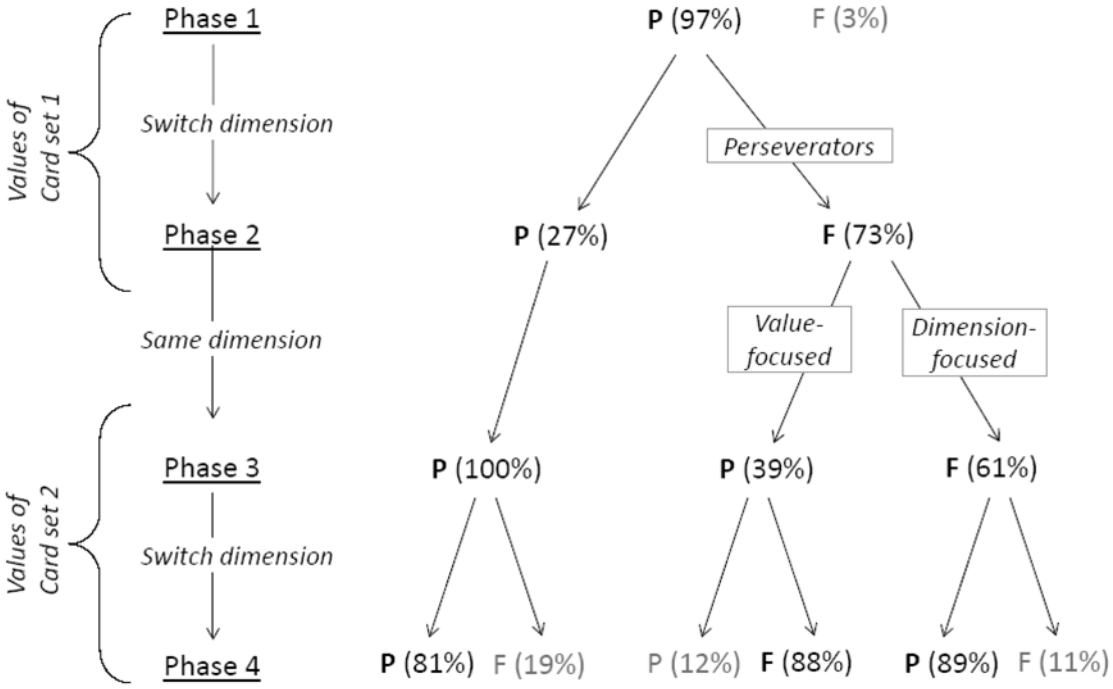

Figure 4.
Left side: Structure of the 4-phase DCCS (Experiment 2). Right-side: Percent children passing (P) and failing (F) each sorting phase.