Color Me This: An Investigation of a Priming Manipulation in the DCCS in Pre-School Aged Children

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Abstract

The Dimensional Change Card Sorting (DCCS) task is commonly used to investigate children’s executive function abilities. In this task, participants are first asked to sort cards by one dimension (e.g., shape) and then switch to sorting by a different dimension (e.g., color). Three-year-old children can sort the cards by the first dimension, however cannot successfully switch to the new dimension. The current project aimed at reducing perseveration errors using a priming manipulation between phases of the task. Results indicated that engaging in a coloring activity between phases for as little as two minutes was enough to help children successfully switch to sorting by the dimension of color; however contrary to previous literature, a two minute break alone with no priming activity was also enough to eliminate perseverations.
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Almost everyone in their lifetime will experience a situation in which they repeat a previous behavior even when that behavior is no longer appropriate. For example, we may find ourselves automatically driving the familiar route to the grocery store, when we know that on this particular instance, we are not going to the grocery store and should be taking a different route.

Perseveration errors are also prevalent in young children. In a common Piagetian task, infants will search for a toy in an old location even when they have seen it hidden in a new location (Piaget, 1954). Children also make such errors in the Dimensional Change Card Sorting (DCCS) task. In the standard version of this task, children are shown target cards with pictures that vary in two dimensions (typically color and shape). First, the child is asked to sort the cards based on one dimension (e.g. shape), which most three-year-olds can do with ease. However, the child is then asked to switch sorting dimensions such that the previously relevant dimension (e.g., shape) is no longer relevant for the sorting task but rather the child must sort by the target items’ color. Three-year olds cannot successfully switch sorting dimensions for the post-switch phase of the task, yet they successfully switch dimensions with ease once they reach four years of age (Zelazo, Frye, & Rapus, 1996). Additionally, adults with brain lesions in the prefrontal cortex fail the adult analog of the DCCS, the Wisconsin Card Sorting Task (Milner, 1963). Researchers have investigated this phenomenon for many years and have performed manipulations to the standard version of the task. Multiple theories have been developed to attempt to explain the mechanism responsible for the phenomenon and its theoretical importance, and many of those
theories include some aspect of executive function. Executive function can be thought of as higher-order mental processes and examples include working memory, mental computation, flexibility of thinking, and response inhibition, among others (Mash & Wolfe, 2007). Theories attempting to account for perseveration errors in the DCCS task are discussed below.

Cognitive Complexity and Control Theory

Cognitive Complexity and Control (CCC) Theory was developed by Zelazo and colleagues (Zelazo, Frye, and Rapus, 1996). According to this theory, changes in behavioral control are explained by the acquisition of an increasingly complex hierarchical rule system. This means a person’s rule system becomes more complex with age. For example, a 3-year-old may have the capacity to acquire an “if, then” rule, but not to integrate two different “if, then” rules together. In the card sorting task, 3-year olds understand both the pre-switch rules and the post-switch rules, but success on the task requires the formation of a hierarchical rule system that is too complex for the 3-year-old. To succeed in the task one must be able to rely on conditional “if then” statements. For example, “if we are playing the color game, then sort by color and blue ones go here; if we are playing the shape game, then sort by shape and stars go here”.

According to CCC theory, knowledge of the pre-switch rules and post-switch rules is not sufficient, but rather the child must form a higher order rule that determines which sorting dimension is appropriate for each part of the task. Under this theory, 3-year olds may still be aware of the post-switch rules even though they are unable to employ them even after as little as one pre-switch trial and even when they are asked to respond using different modalities. Specifically, Zelazo, Frye, & Rapus (1996) showed that children continue to perseverate even when asked to respond verbally rather than manually after as few as one pre-switch trial.

Attentional Inertia/ Inhibition
A different approach to explaining why 3-year-olds fail at the DCCS task is that children have difficulty inhibiting the dimension that is no longer relevant in the post-switch task. Once they adopt the mindset that blue things go with blue things, the child struggles to later switch and think of a blue thing solely based on the object’s shape. Kirkham, Cruess, & Diamond (2003) proposed that inhibition alone was enough to explain why perseverations occur. Similarly, Diamond & Kirkham (2001) showed that on a computerized version of the card sort, adults had slower reaction times on the post-switch dimension. The CCC Theory would not be able to explain this finding because surely adults have formed the hierarchical rule structure for the task. According to the attentional inertia theory, adults may be reacting slower in the post-switch phase due to difficulty inhibiting the previously relevant dimension.

To test their inhibition hypothesis, Kirkham, Cruess, & Diamond (2003) administered the standard version of the DCCS with three manipulations. In the label condition, before a child sorted a card in the post-switch phase, she was asked what value of the post-switch dimension that card had. For example, if the child was sorting by shape and was presented with a blue truck the child would be asked what shape the card was and then was asked to sort it. Thus, instead of the researcher labeling the card the child was required to label the relevant dimension each time. This made the post-switch dimension more salient and easier to inhibit the now irrelevant pre-switch dimension; the results indicated that 78% of 3-year olds successfully switched to sorting the post-switch dimension in this condition. The second condition was the sleeve condition, where the researcher would present the card and then immediately place it in a cardboard sleeve, with the intention of making the pre-switch dimension less salient. Performance in this condition also improved compared to the standard versions of the task. Finally, in the face-up condition, once the child sorted the card it would be sorted face-up to leave a visual cue of the relevant pre-
switch dimension. As predicted, children performed worse in the face up condition than the other experimental manipulations of the task because the visual cue made the pre-switch dimension more salient and thus more difficult to inhibit in the post-switch phase.

**Negative Priming**

Both the CCC theory and Inhibition/Attentional Inertia account make the assumption that the primary reason children have difficulties with the DCCS task come from the inability to properly ignore a previously relevant dimension. However, an alternate explanation could be that in the post-switch phase of the DCCS task, children are having difficulty attending to a previously ignored dimension. In the standard version of the task, the test cards match the target cards on two dimensions, and when sorting correctly on the pre-switch dimension, the child may be suppressing attention to the values of the competing dimension. If this suppression carries over to the post-switch phase of the task, causing difficulty with the post-switch phase, then the phenomenon referred to as Negative Priming (NP) could be accounting for perseveration errors (Perner & Lang, 2002; Muller, Gela, Dick, Overton, & Zelazo 2006). Negative Priming can be specifically defined as the “apparent disruption of the response to an item if it has been previously ignored” (Tipper, 2001).

Perner & Lang (2002) also performed manipulations of the standard version of the DCCS task. They found that children only have difficulty with the task when the switch is extra-dimensional. That is to say that if a child must switch simply within a dimension, even 3-year-olds can succeed. For example, in their reverse-switch version of the task, all cards had the same color and children were first asked to place suns in one box and butterflies in another box. For the post-switch phase, children placed suns in the butterfly box and vice versa. Neither CCC theory nor Attentional Inertia theories can account for this finding because even in this version of
the task, children are required to inhibit a previously correct response. However, NP would not
be occurring in this version of the task and therefore would still explain the difficulty 3-year-olds
have with the standard version of the task.

Similarly, a specific NP version of the DCCS task was created. In this version, the pre-switch
phase contains blue and red bunnies and boats to be sorted by shape, whereas the post-switch
phase contains red and blue flowers and cars to be sorted by color. Three-year-old children still
seem to have difficulty with this version of the task. This is because the pre-switch phase still
contains the same values of the post-switch dimension; for example, in the post-switch phase, the
child must sort reds and blues, which were the same colors of the stimuli in the pre-switch phase.
Therefore, in the pre-switch phase, children are negatively primed and have suppressed attention
to the dimension of color and therefore have difficulty when color later becomes the relevant
sorting dimension (Muller, Gela, Dick, Overton, & Zelazo, 2006).

**Competing Memory Systems**

Another account for perseverations in the DCCS is the competing memory systems view.
Research has identified evidence for two memory systems in humans and has shown that
sometimes competition exists between the two systems (Poldrack & Packard, 2003). Support for
these multiple systems has been provided by studies with non-human animals, as well as from
human neuroimaging studies showing that these different memory systems tend to activate
separate brain areas (Poldrack & Packard, 2003). Latent or habit memory system builds up
memories over time when a behavior is repeated, thus creating a bias for this behavior. Working
memory can be defined as the system that is actively holding information that is currently being
processed (Brace, Morton, & Manakata, 2006). Competition between these systems occurs when
currently relevant information conflicts with previously relevant information, and perseverations
occur when latent memories win the competition (Brace, Morton, & Manakata, 2006). Although
the study described above conducted by Zelazo, Frye, and Rapus (1996) showed that
perseverations occur after as few as one pre-switch trial, supporters of the competing memory
systems view argue that one trial is enough to form a strong latent memory in three-year olds
(Brace, Morton, Munakata, 2006).

To provide support for the competing memory systems account of perseverations in the
DCCS task, Yerys and Munakata (2006) created a manipulation of the task where children were
presented with novel stimuli (for example, the experimenter would say “in the shape game, daxes
go here and gubs go here”). Therefore, when first being asked to sort by shape, the child is
sorting novel, never before seen shapes yet in the post-switch phase when sorting by color, the
child is sorting by familiar colors. Children performed much better in this version of the task
than in the standard version, indicating that the novel stimuli prevented latent memories for
shape from being strengthened to the point where perseverations could occur in the post-switch
phase. Negative Priming would not be able to account for these findings because according to the
NP account, children would be suppressing attention to shape in this novel stimuli condition, so
the use of novel stimuli should have no effect. Yet, children’s performance in this condition was
much better than in the standard version, suggesting that NP did not occur. However, it is
possible that in this condition color is a more salient dimension than shape because values
representing the shape dimension are novel whereas values representing the color are familiar.
This arrangement might be making it more difficult to suppress attention to color. Children
would also lack the if-then structure required under the CCC theory to succeed in this condition,
indicating that an embedded rule system is not required to succeed in the DCCS task.
Further support for the Competing Memory Systems account comes from a study in which Brace, Morton, and Munakata (2006) designed a task intended to weaken latent memories in order for working memory to allow children to successfully sort cards in the post-switch phase. Researchers introduced a scaffolding condition, in which children would complete the pre-switch phase, followed by a scaffolding period, and then would complete the post-switch phase. For the scaffolding period, children would be asked to switch sorting dimensions, but only sort cards that varied in that dimension. Once children could successfully sort two consecutive cards by the new dimension, they were introduced to a set of “morph” cards. Children continued to sort by the new dimension, however each card slowly morphed into the shape of the cards used in the pre-switch trials. Three-year-olds succeeded on this task, indicating that the effects of latent memories from the pre-switch trials were diminished. To examine whether the delay between pre- and post-switch phases (rather than the scaffolding manipulation) could account for the results, a control condition had a similar intermediate task that did not include any of the sorting dimensions. Similar to the standard results, children could not succeed in the control condition. Once again, success on the scaffolding condition suggests that a hierarchical rule structure is not needed. Additionally, inhibition and negative priming would not be able to explain why children can succeed in the scaffolding condition, yet still perseverate in the control condition.

Current Project

The goal of the current project was to reduce perseveration errors in the DCCS task using a priming rather than a scaffolding manipulation between the phases of the task. In Brace, Morton, and Munakata’s (2006) control condition, children were asked to complete an unrelated sorting task after the pre-switch phase. During this intermediate phase, children were asked to sort a total of ten cards that varied on only one dimension. These cards had stimuli completely irrelevant to
the pre and post-switch phases of the task: they consisted of pictures of either one or two black sticks. The child was asked to place all the cards with one stick in one tray and cards with two sticks in the other tray. Results showed that this break before having to perform the post-switch phase of the main experiment did not improve performance in the post-switch phase and only structured scaffolding led to diminishing perseverations. These findings suggest that when given a break in which the child is still asked to sort cards, perseverations still occur. However, it could be the case that because the child is still sorting objects, the task is too similar to the card sorting task and thus does not give the child a proper contextual break from the task at hand. In the current project children were provided with a task that was very dissimilar from the experimental sorting task, and therefore could provide a better contextual break. Furthermore, the current project introduced a priming manipulation in which the newly relevant dimension was primed without scaffolding.

As previously stated, all existing theories that explain the DCCS task phenomenon suggest that the task requires the development of executive function abilities. Just as Brace, Morton, Munakata (2006) found that scaffolding between the pre- and post-switch phases of the task helps performance, this study aims to find an activity that would help improve performance and eliminate perseveration errors. However, this study hopes to find a manipulation that would reduce the task demands on the child’s controlled processing (executive functioning) and would allow the child to rely on involuntary processing through the use of priming. If a child completes a task that primes the post-switch dimension, then the post-switch task would become an automatic process, and three-year-olds’ performance should improve in the post-switch phase. Typically, tasks that require controlled processing require engagement of the prefrontal cortex. In contrast, automatic processing according to Schneider and Shiffrin (1977) is defined as the
activation of a sequence of nodes that “nearly always becomes active in response to a particular input configuration,” and that “is activated automatically without the necessity for active control or attention by the subject” (p. 2). Therefore, automatic processes require a much lighter cognitive load and can even be observed in infants (Schneider & Chien, 2003). The goal of the priming manipulation in the current project was to reduce the cognitive demands of the post-switch phase of the DCCS task whereby making it possible to perform the post-switch task in an automatic fashion.

**Priming**

Certain tasks that have been previously shown to rely on automatic processing include the use of priming. Priming occurs when previous exposure to a stimulus leads to increased performance in a later task. Perceptual priming has long lasting effects, has been characterized as ‘all or none,’ and tends to be an automatic process (Wiggs & Martin, 1998). It has been demonstrated that visual cues such as color may benefit from perceptual priming, even in young children. In particular, (Mecklenbrauker, Hupbach, & Wippich, 2001) presented children with twenty cards that had line drawings of common objects and appeared in one of four colors. In the test portion of the phase, children were shown similar exemplars in black and white and asked to choose which color was best associated with that word. Results showed that even 4-year-old children can be primed in the dimension of color, as children typically picked the color that corresponded to the same color of the card they had seen in the study phase. These findings have multiple implications. Primarily, it shows that young children can successfully be primed using color. Furthermore, it shows that priming is age-invariant indicating that it relies on automatic rather than controlled processing.

**Method**
Participants

Participants were 3 year old children \((M = 3.542, SD = 0.122)\) recruited from a database previously used by the Laboratory for Cognitive Development at Carnegie Mellon University. In addition, children were recruited from various schools in the Pittsburgh Area, including the Children's School at Carnegie Mellon University.

Design and Materials

Materials for this study consisted of blue or red fish and stars. On any given trial, the two sorting "trays" were represented by a black outline around the pictures (see Figure 1). The target object to be sorted appeared on the screen below the sorting boxes equidistant from each box. There were three between-subjects conditions that involved an experimental manipulation to the standard version of the DCCS task: Delay Only, Dimension Priming, and Value Priming. For comparison purposes, there was also a replication of the Standard DCCS task. The present study used the No Conflict trails along with the Conflict trials in both phases of the task. A No Conflict trial is one in which the target object matches the correct sorting object on both dimensions, whereas a Conflict trial is one in which the target object matches the correct sorting object on only the relevant dimension. There were four No Conflict and four Conflict trials in both the pre-switch and the post-switch phases of the task.

A computer version of the DCCS task was created using Super-Lab-Pro software. Computerization of the task made it possible to counterbalance the spatial location of the sorting trays. Additionally, sorting trays were not only counterbalanced in spatial location, but all four possible color-shape combinations were used to mark sorting “trays.” For example, if the child was sorting by color, one trial might have the trays be a red fish and a blue star, whereas the next trial would have a red star and a blue fish. These manipulations eliminated the possibility that
perseveration errors stem from location-dimension associations. Throughout the whole duration of the task, the experimenter controlled all keyboard commands, such as recording the child's response and moving between trials.

**Standard DCCS**

This version contained two demonstration trials, followed by eight pre-switch trials where the child was asked to sort by shape. Next, the experimenter instructed the child that they would now be playing the color game, and the child was asked to sort by color. Before each test trial in both phases of the task, the experimenter reminded the child the rules of the game and then identified the target object by shape during the pre-switch phase (e.g. "this one is a fish... where does it go?") and by color in the post-switch phase (e.g., “this one is blue … where does it go?”). Children were provided with corrective feedback only after the demonstration trials; no feedback was given after the test trials. The post-switch phase immediately followed the pre-switch phase.

**Priming Conditions**

After all of the pre-switch trials, the experimenter told the child (s)he did a great job, but that it was time to take a little break. The activity done during the break varied with the specific condition in which the child was participating (i.e., Dimension Priming, Value Priming, or Delay Only). In all conditions, the child engaged in a different activity for the duration of approximately two minutes (\(m = 2.172\)). After the break, children were asked to return to the computer game, but told that this time they would be playing a new game called the color game. The post-switch phase that followed the break was identical to the post-switch phase in the Standard DCCS task described above.

The Value Priming condition was designed to prime the dimension of color using the specific dimension values that were relevant in the post-switch task, (i.e. red and blue). During
the break between phases, the experimenter presented the child with a coloring page depicting a beach scene with a crab, beach balls, a beach umbrella, and the ocean, as well as a red and blue crayon. The children were asked to identify the colors of the crayons and then use the crayons for coloring for two minutes. If the child tried to stop coloring before the two minute break was over, the experimenter encouraged the child to keep coloring. After the two minutes, the child was then asked to complete the post-switch phase of the task (i.e., play the color game).

The procedure in the Dimension Priming condition was the same as in the Value Priming condition, however the crayons used were green and yellow instead of blue and red. The purpose of this condition was to investigate if it was possible to prime the dimension of color in general, rather than just the specific values of the color dimension used in the post-switch phase of the main sorting task.

The goal of the Delay Only condition was to investigate if the children were actually being primed or if taking a break from the sorting task was enough to attenuate perseverations. Similar to the previous conditions, children first sorted cards by shape. During the break, children were presented with the same coloring page, however in this condition they were asked to verbally identify objects seen in the picture. This activity was used during the break because it was a similar activity with the same stimulus as in the Value and Dimension Priming Conditions and dissimilar from the experimental task. Children were asked to identify various objects in the beach scene. Because accuracy was not necessary for this phase of the task, the experimenter was allowed to help and/or correct the child to keep him engaged for the full two minutes. Then, the child would complete the post-switch phase sorting by color.

Procedure
Participants were tested individually in a quiet area of the child’s school or in a room in the Cognitive Development Lab at Carnegie Mellon’s campus. The data were collected on a computer using Super-Lab-Pro software.

Results

The final sample included 64 participants. Three participants were excluded from the final sample due to failure to correctly sort three out of the four no-conflict trials in either phase of the task. Data from the rest of the participants were distributed non-normally, such that most children responded correctly to all or none of the post-switch questions. A child was classified as a switcher if (s)he responded correctly on at least three out of four of the conflict trials in the post-switch phase (binomial \( p = 0.056 \)). A child was classified as a non-switcher if (s)he responded incorrectly on at least two of the four conflict trials in the post-switch phase. The majority of children were classified as switchers in the priming conditions (9 out of 11 in the Value Prime and 11 out of 13 in the Dimension Prime conditions) and in the Delay Only condition (12 out of 15), whereas only a few children were classified as switchers in the Standard condition (3 out of 16) (see Figure 2). Because of the non-normality of the data, data were analyzed using non-parametric chi-square test. All experimental conditions (Delay Only Condition, Value Priming Condition, Dimension Priming Condition) were significantly different from the Standard DCCS condition (all \( \chi^2 > 8.1, ps < 0.005 \)). Furthermore, none of the priming conditions significantly differed from each other, all \( \chi^2 > .15, ps > .69 \).

Findings indicated that as predicted, the priming manipulations were successful in eliminating perseveration errors. Unexpectedly, participants in the Delay only condition also exhibited attenuated perseveration errors. Therefore, none of the experimental manipulations differed from
each other, however all experimental manipulations significantly differed from the Standard DCCS. Overall, a two-minute break was sufficient in eliminating perseveration errors.

Discussion

As predicted, the priming manipulations helped to reduce perseveration in three-year-old children. Interestingly, delay alone also eliminated perseverations contrary to the findings of Brace, Morton and Munakata (2006). In this study, delay alone was not enough to eliminate perseverations when given an intermediate phase in which the participant had to sort objects with irrelevant shapes and colors. A scaffolding manipulation was necessary to build up to the post-switch dimension. Therefore, because a delay was also effective in eliminating perseverations, it is unclear if priming actually occurred in the way predicted.

The discrepancy between previous findings and the current study brings up an interesting possibility that the nature of the task performed during the break may have an important effect on reducing or maintaining perseveration errors. In the Brace, Morton, and Munakata (2006) study, the task in the intermediate phase was similar to the main sorting task in that it still involved sorting, even though the stimuli to be sorted were not relevant to the main task. In the present study, though temporally the break was of the same duration, the task completed during the break was extremely different from the main sorting task (i.e., children were asked to name objects from a beach scene). This may indicate that the nature of the task done during the intermediate phase has an effect on eliminating perseverations. For example, coloring a picture is extremely different than sorting and may give the child a greater contextual break so as s(he) can successfully switch to sorting by the post-switch dimension.
According to the previous finding of Brace, Morton, & Munakata (2006), no theory can reconcile why the direct instruction condition versus scaffolding does not eliminate perseverations. According to Attentional Inertia/Inhibition, the break might attenuate attentional weights of the previously relevant dimension such that attention to it does not need to be inhibited during the post-switch phase. Similarly, NP effect could be diminished over time. Competing Memory systems view would argue that sorting during the intermediate phase still maintains latent memories. A dissimilar intermediate task allows latent memories to weaken.

The findings of this project evoke many questions for future research. In particular, an investigation of the potential intermediate-task effect would give further insight into which tasks are dissimilar enough from sorting so as to eliminate perseveration errors. Furthermore, it remains unknown how long the delay needs to be to diminish perseveration errors.
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References


Figure Captions

*Figure 1.* Example of stimuli used in the computerized version of the DCCS. Pane 1 (A) represents example of a no-conflict trial and panel (B) represents an example of a conflict trial.

*Figure 2.* Graph depicting the proportion of switchers and non-switchers in each condition.
Figure 1

(A)

(B)
Figure 2

The bar chart illustrates the number of participants in different conditions. The chart compares Standard DCCS, Delay-Only, Value Prime, and Dimension Prime conditions. The number of participants is represented for Non-Switchers and Switchers.