

The Dimensional Change Card Sort (DCCS): a method of assessing executive function in children

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Published online 27 June; corrected after print 31 August 2006; doi: 10.1038/nprot.2006.46

The dimensional change card sort (DCCS) is an easily administered and widely used measure of executive function that is suitable for use with participants across a wide range of ages. In the standard version, children are required to sort a series of bivalent test cards (e.g., first according to one dimension (e.g., color), and then according to the other (e.g., shape). Most 3-year-olds perseverate during the post-switch phase, exhibiting a pattern of inflexibility similar to that seen in patients with prefrontal cortical damage. By 5 years of age, most children switch when instructed to do so. Performance on the DCCS provides an index of the development of executive function, and it is impaired in children with disorders such as attention-deficit/hyperactivity disorder (ADHD) and autism. We describe the protocol for the standard version (duration = 5 min) and the more challenging border version (duration = 5 min), which may be used with children as old as 7 years.

INTRODUCTION

The DCCS^{1–3} is an easily administered and widely used (see refs. 4–10) measure of executive function that is suitable for use across the lifespan. In the standard version of this task (Fig. 1), which is usually used with healthy children between the ages of 3 and 5 years, children are shown two target cards (e.g., a blue rabbit and a red boat) and asked to sort a series of bivalent test cards (e.g., red rabbits and blue boats) according to one dimension (e.g., color). During a post-switch phase, they are told to sort the same types of test cards according to the other dimension (e.g., shape). Regardless of which dimension is presented first, the majority of normal 3-year-olds perseverate during the post-switch phase of the standard version by continuing to sort test cards by the first dimension. Moreover, they do this despite being told the new rules on every trial, despite having sorted cards by the new dimension on other occasions, and despite correctly answering questions about the post-switch rules (e.g., “Where do the rabbits go in the shape game?”). In other words, most 3-year-olds show a pattern of inflexibility on this task that resembles that exhibited on the Wisconsin Card Sorting Test (WCST) by adult patients with damage to dorsolateral prefrontal cortex¹¹. By 5 years of age, most children switch immediately when instructed to do so.

The standard version of the DCCS provides an index of the development of executive function during the preschool years, and it has been useful in the assessment of individual differences in executive function in this age range; children’s performance on the DCCS is correlated with their performance on other measures of executive function as well as measures that have been linked theoretically to executive function, such as self- and social-understanding (i.e., theory of mind)^{1,12,13}. Versions of the DCCS have proven sensitive to disorders that involve impairments in executive function (e.g., ADHD¹⁴ and autism^{15,16}). Research reveals that performance on the DCCS improves with training and that these improvements generalize to performance on a measure of theory of mind⁹. The

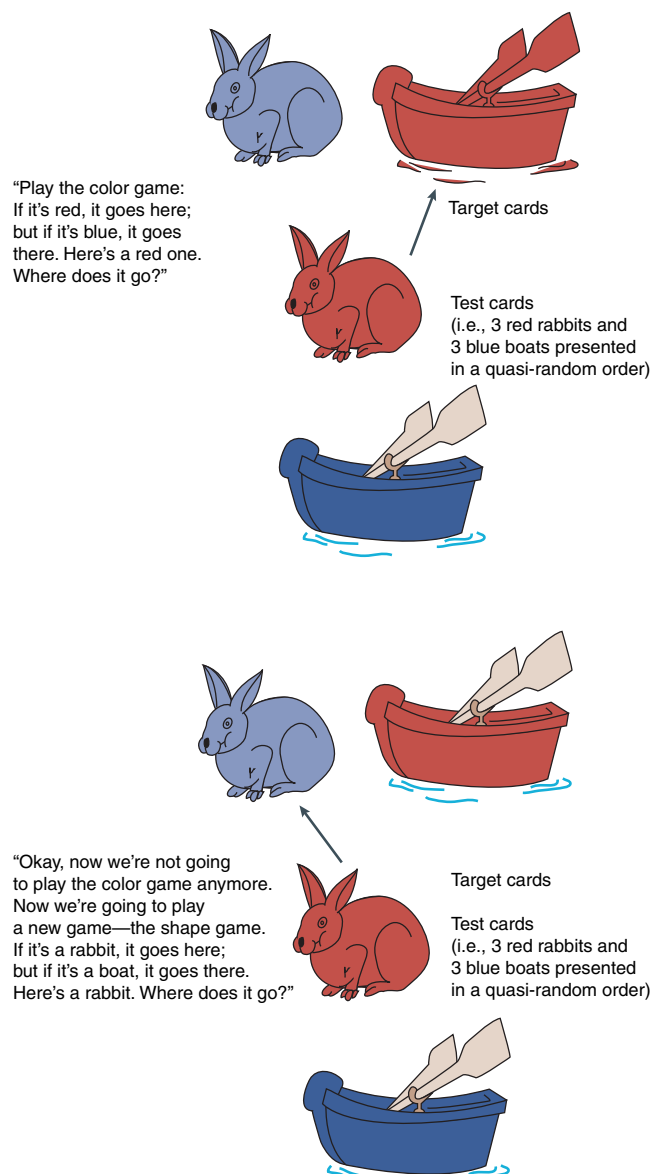


Figure 1 | Sample target cards and test cards used during the pre- and post-switch phases of the standard version of the DCCS.

implications of this finding for therapeutic intervention remain to be explored.

One advantage of the DCCS as a measure of executive function—particularly for use with children—is its relative simplicity. Unlike in the WCST, for example, children are told exactly what to do on every trial. This feature of the DCCS makes it suitable for use with young children, and it also constrains interpretation of the subject's difficulties with the task. Difficulty cannot be attributed to problems with hypothesis testing or memory for the relevant rules. Instead, the DCCS provides a more direct measure of flexible rule use—the selection and use of a pair of rules to sort bivalent stimuli despite interference from previous trials.

More precise assessments are also possible. The task is easily adapted to assess specific aspects of flexible rule use in relative isolation. For example, by changing the target and test cards between the pre- and post-switch phases as shown in Fig. 2 (negative priming version), it is possible to obtain a relatively pure measure of a child's ability to sort by stimulus values that were not selected during the pre-switch phase—to select rules that were previously inhibited¹⁷. Moreover, by changing the motivational significance of the stimulus values, it is possible to assess not only more 'cool' cognitive aspects of executive function usually associated with dorsolateral prefrontal cortex, but also more 'hot' affective aspects that are usually associated with the orbitofrontal cortex¹³. Finally, more challenging versions of

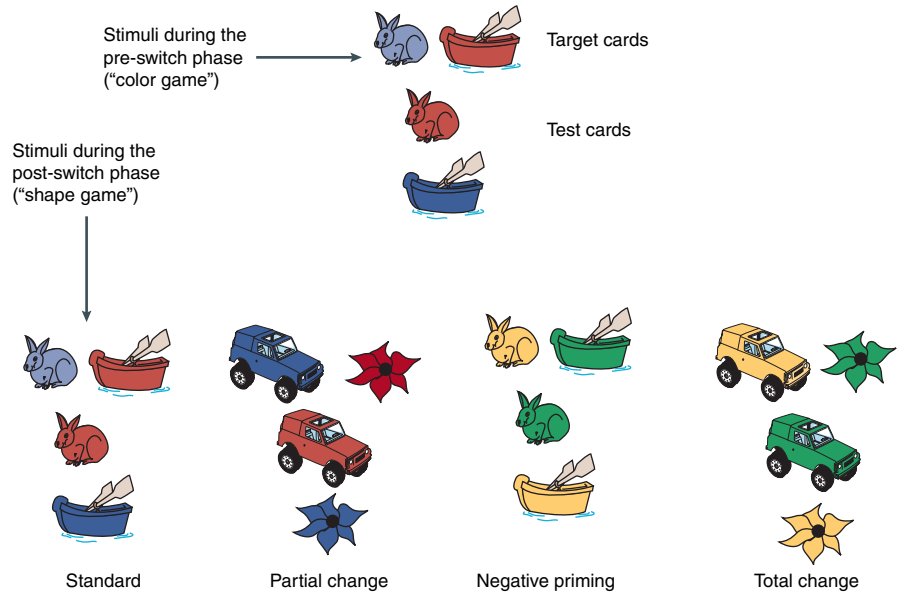


Figure 2 | Sample target cards and test cards used during the pre-switch phase of the DCCS (top panel). The bottom panel shows the target cards and test cards used during the post-switch phase for several versions of the DCCS (based on the assumption that color is the initial, pre-switch dimension).

the DCCS, such as the border version, have been used successfully with older children^{6,13} and adults across the lifespan^{18,19}. In these versions, switches are presented randomly (e.g., on 20% of trials) and cued via visual symbols, and participants may be instructed to respond as quickly as possible. Dependent measures may include not only accuracy but also reaction time. The following procedure includes only the standard version of the DCCS and the border version. For an overview of the entire sequence, see Fig. 3.

MATERIALS

- For the standard version of the DCCS, suitable participants include children with mental ages between about 2.5 and 5.0 years. For the border version, participants include children with higher mental ages (between 5.0 and 7.0 years) who pass the standard version (see Step 5, below). When used together, these two versions provide an index of executive function across the mental age range of 2.5 to 7.0 years. Parents provide informed consent allowing their children to participate, and confirm that their children have normal or corrected-to-normal vision and are not color blind.
- Two sorting trays: each tray is 11.5 cm long, 9.5 cm wide and 2 cm deep, and there is a display panel behind each tray that supports the target cards and allows them to be displayed throughout the task. Trays may be made out of wood. Target cards may be affixed to the display panel by Velcro or tape.
- Two target cards: each card is 10.75 cm × 7 cm and laminated. These cards display color drawings on a white background. One target card shows a blue rabbit and the other shows a red boat.

- Fourteen standard test cards for use in the standard version. These are identical in style to the target cards, but half of them ($n = 7$) depict a red rabbit and half ($n = 7$) depict a blue boat. Two of these standard test cards are used in the demonstration phase.
- In addition to the above materials, seven border test cards are needed for the border version. These are identical in style to the standard test cards except that they have a 5 mm black border around them (see Fig. 4). Four of these cards depict a red rabbit and three depict a blue boat. For the border version, these cards are used together with seven standard test cards (4 red rabbits and 3 blue boats).
- Alternative shapes and colors may be used, as long as the cross-mapped relation between test and target cards is maintained (i.e., each test card matches one target card on one dimension and the other target card on the other dimension). Use shapes and colors that are easily distinguishable and that will be familiar and engaging to the youngest children tested.

PROCEDURE

1 | Decide which dimension will be relevant during the pre-switch phase of the standard version. In the examples that follow, it is assumed that color has been chosen as the pre-switch dimension.

2 | During the demonstration phase, place the two sorting trays side by side in front of the subject, ensuring that they are within reaching distance. Sit beside the child so that you are able to view the display panels. Affix target cards to the display panels behind the sorting trays (e.g., a blue rabbit behind the tray on the child's left and a red boat behind the tray on the child's right). Label the target cards by both dimensions. Say, "Here's a blue rabbit and here's a red boat." Then say, "Now, we're

going to play a card game. This is the color game. In the color game, all the blue ones go here [pointing to the tray on the left], and all the red ones go there [pointing to the tray on the right]." Sort one type of test card (e.g., a blue boat) by color, saying, "See, here's a blue one. So it goes here [place it face down in the tray on the left]." Repeat the pre-switch rules, "If it's blue it goes here, but if it's red it goes there." Show children the other type of test card (e.g., a red rabbit), and say, "Now here's a red one. Where does this one go?" If the child takes the card and sorts it correctly, or simply indicates the correct tray by pointing, say, "Very good. You know how to play the color game." If they point, say, "Can you help me put this red one down?" Ensure that the card is placed *face down* in the appropriate tray, turning the card over if necessary. If the child sorts incorrectly, say, "No, this one's red, so it has to go over here in the color game. Can you help me put this red one down?" Ensure that the card is placed face-down in the appropriate tray.

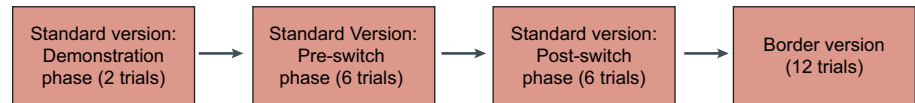


Figure 3 | Summary of the phases involved in the standard and border versions of the DCCS (see text for detail). Children who pass the post-switch phase may proceed to the border version.

3 | Proceed immediately to the pre-switch phase. On the first pre-switch trial, say, "Now it's your turn. So remember, if it's blue it goes here, but if it's red it goes there." Randomly select a test card (e.g., a red rabbit), show it to the child, and label it by the relevant dimension only. Say, "Here's a red one. Where does it go?" The child may take the card and place it in a tray or simply point to one of the trays, in which case you may sort the card for them. In either case, ensure that the card is placed face down in the appropriate tray. Whether or not children sort correctly, simply say, "Let's do another one" (or, for variety, "Let's do it again," or "How about another one?"), and proceed to the next pre-switch trial; that is, respond to children in a neutral, non-evaluative, non-corrective fashion (e.g., do not say, "Okay"). On each pre-switch trial, repeat the pre-switch rules, select a test card (ensuring that the same type of test card, e.g., a red rabbit, is not selected on more than two consecutive trials), show the card to the child, label it by the relevant dimension only, and ask the child where it goes: "Here's a red one, where does it go?" or "Here's a red one, where does this one go?"

4 | After six pre-switch trials, say, "Now we're going to play a new game. We're not going to play the color game anymore. We're going to play the shape game. In the shape game, all the rabbits go here [pointing to the tray on the left], and all the boats go there [pointing to the tray on the right]. Remember, if it's a rabbit, put it here, but if it's a boat put it there. Okay?" Do not remove the target cards or the cards that were sorted during the pre-switch phase, and do not pause between pre- and post-switch phases. Select a test card (still ensuring that the same type of test card is not selected on more than two consecutive trials), show the card to the child, label it by the relevant dimension only, and ask, "Where does this one go?" Whether or not the child sorts correctly, simply say, "Let's do another one" (or, for variety, "Let's do it again," or "How about another one?"), and proceed to the next post-switch trial.

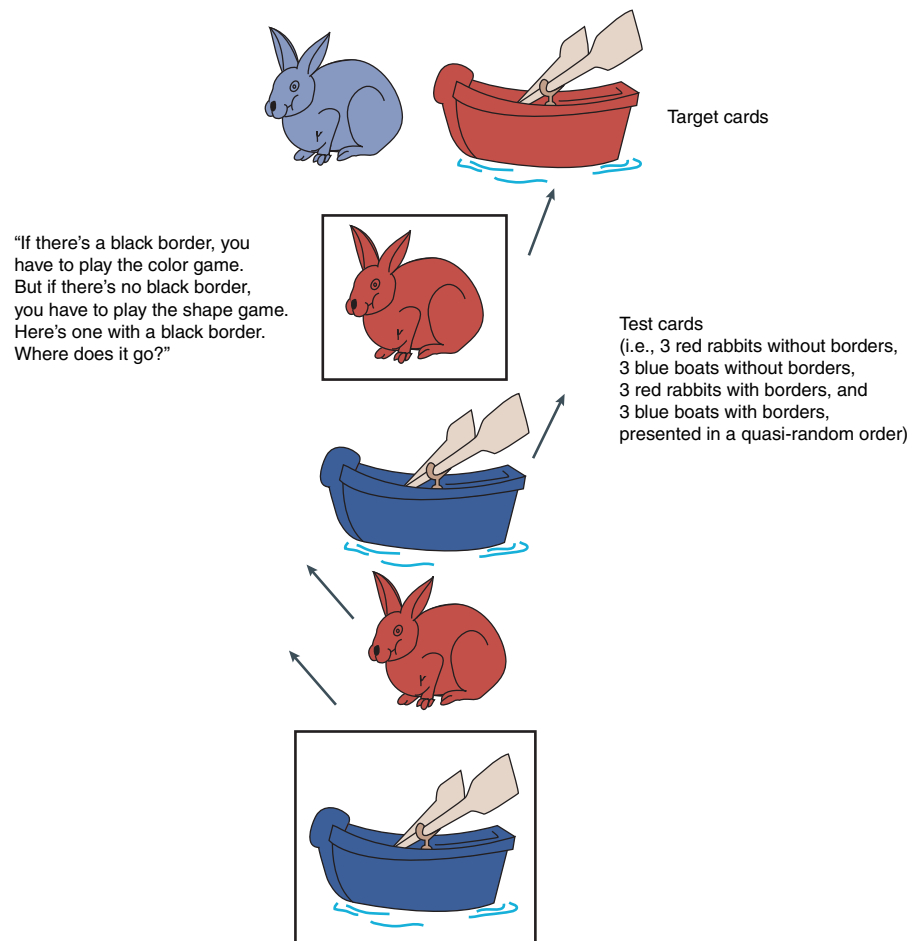


Figure 4 | Sample target cards and test cards used during the border version of the DCCS.

PROTOCOL

- 5| Children who are 36 months of age and older usually sort correctly on all six pre-switch trials. Scores on the post-switch phase of the DCCS are usually bimodally distributed (i.e., either correct or incorrect on all post-switch trials), so children are usually classified as passing or failing the DCCS. A child needs to sort at least five out of six post-switch trials correctly in order to pass. Analyses of post-switch performance are usually based only on children who sort five or more out of six pre-switch trials correctly (but see ANTICIPATED RESULTS below).
- 6| Children who pass the post-switch phase of the standard version of the DCCS may proceed immediately to the border version, which uses the same target cards as the standard version. Remove the already-sorted cards from the sorting trays, reserving four red rabbits and three blue boats. Set the remaining cards aside. Combine the four red rabbits and three blue boats with the additional Border test cards. Say, “Okay, you played really well. Now I have a more difficult game for you to play. In this game, you sometimes get cards that have a black border around it like this one [showing a red rabbit with a border]. If you see cards with a black border, you have to play the color game. In the color game, red ones go here and blue ones go there [pointing to the appropriate trays]. This card’s red, so I’m going to put it right there [placing it face down in the appropriate tray]. But if the cards have no black border, like this one [show them a red rabbit without a border], you have to play the shape game. In the shape game, if it’s a rabbit, we put it here, but if it’s a boat, we put it there [pointing to the appropriate trays]. This one’s a rabbit, so I’m going to put it right here [placing it face down in the appropriate tray]. Okay? Now it’s your turn.”
- 7| The border version consists of 12 trials. On each trial, repeat the rules (“If there’s a border, play the color game. If there’s no border, play the shape game”), select a test card (ensuring that the same type of test card—with or without a border—is not selected on more than 2 consecutive trials), label the card as having a border or not, and ask the child where it goes. After the child sorts it, simply say, “Let’s do another.” For example, “Remember, if there’s a black border, you have to play the color game. But if there’s no black border, you have to play the shape game. Here’s one with a black border. Where does it go? [Children sort] Let’s do another.” As in the standard version, respond to children in a neutral, non-evaluative, non-corrective fashion.
- 8| Performance on the border version is scored as the number correct out of 12. Children are considered to pass this task if they sort nine or more cards correctly out of 12 test trials.

● TIMING
Steps 2–4, 5 min; Steps 6+7, 5 min.

? TROUBLESHOOTING
See **Table 1**.

TABLE 1 | Troubleshooting table.

PROBLEM	SOLUTION
Steps 2–4, 6+7 Children hesitate	Label the card by the relevant dimension and ask where it goes (e.g., “Here’s a rabbit, where does it go?”). If the child still hesitates, say, “Let’s do another one,” return the skipped card to the pile of to-be-sorted cards, select a new card, label it by the relevant dimension, and ask where it goes.
Children refuse to complete the task	If a child refuses to continue sorting, suggest that he or she may point to the correct box and show you where each card goes. If the child refuses to do this, then terminate the task, as their data will be unusable unless all trials are completed.
Children change response	Allow children to change their responses, scoring only their final response. Do not provide evaluative feedback. Simply say, “Are you sure?” and then proceed to the next trial, saying, “Let’s do another one.”
Children ask for feedback	Do not provide evaluative or corrective feedback. Simply encourage them to keep playing, saying, “Sort the card,” or “Let’s do another one,” as appropriate.
Children pick up previously sorted cards	Prevent children from picking up previously sorted cards. Tell them, “Those cards have to stay there, but let’s do another one.”
Children take a break during the task	Discourage children from taking a break until the procedure has been completed, saying, “We’re almost done.” If children need to take a break during Steps 2, 3, 6 or 7, repeat the interrupted step when they return and then complete the procedure. Only use data from the completed (re-administered) step, not the interrupted one. Children should not take a break during Step 4; this would render the data unusable.

ANTICIPATED RESULTS

The majority of healthy 3-year-old children (i.e., children between 36 and 47 months) fail the post-switch phase of the standard version of the DCCS; the majority of 4- and 5-year-olds pass this phase. Most 4-year-olds fail the border version of the DCCS, as do approximately half of all 5-year-olds. The precise percentages of children passing in any particular sample will vary. Data from the standard version are usually scored categorically, as passing or failing. Data from the border version may be treated continuously or categorically. When both versions are used in a single study, it is possible to score performance as follows: assign a score of 0 if children fail the pre-switch phase of the standard version; assign a score of 1 if they pass the pre-switch phase of the standard version but fail the post-switch phase; assign a score of 2 if they pass both the pre- and post-switch phases of the standard version but fail the border version; assign a score of 3 if they pass both phases of the standard version and pass the border version.

Both versions of the DCCS assess the flexible use of rules to govern behavior—a key aspect of executive function. According to the Cognitive Complexity and Control theory-Revised³, switching on the DCCS (both versions) requires the formulation and use of a higher-order rule for selecting which pair of rules (i.e., the color rules or the shape rules) to use on any particular trial. That is, both the post-switch phase of the standard version and the border version require children to formulate and use a rule that says, in effect, “If shape game, then if rabbit here and if boat there; if color game, then if red here and if blue there.” The ability to use higher-order rules may be tied to the development of self-reflection²⁰, and it is hypothesized to rely on the function of specific regions within the prefrontal cortex²¹.

ACKNOWLEDGMENTS Preparation of this article was supported, in part, by a grant from the Natural Sciences and Engineering Research Council of Canada and by a Canada Research Chair. Many individuals have been involved in the creation and refinement of the DCCS and its many versions, but the author would like to acknowledge in particular the valuable contributions of D. Frye and T. Palfai, co-authors of the article in which the protocol was first described.

COMPETING INTERESTS STATEMENT The author declares that he has no competing financial interests.

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Erratum: The Dimensional Change Card Sort (DCCS): a method of assessing executive function in children

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Nat. Protocols 1, 297–301 (2006); published online 27 June 2006; corrected after print 31 August 2006.

In the version of the article originally published, the boat in the upper right of the figure was blue. It should be red. The error has been corrected in the HTML and PDF versions of the article.