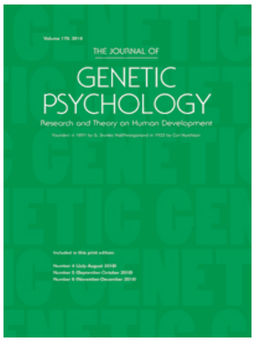

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Performance Effects of Reward-Related Feedback on the Dimensional Change Card Sort Task

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ABSTRACT

The Dimensional Change Card Sort (DCCS) is one of the most widely used measures of preschool executive function, yet relatively little is known about how altering emotional demands of the task affects DCCS performance. This study examined the effects of emotionally evocative reward-related feedback on preschool children's performance on the DCCS in a sample of 105 children aged 3.5–4.5 years. In a within-subjects design, children completed the standard DCCS and a modified version of the DCCS in which sticker rewards were gained or lost after each trial. With a reward at stake, children were more accurate but had slower reaction time on the post-switch DCCS. Another sample ($N = 20$) of 3.5- to 4.5-year-olds who completed the standard DCCS twice without reward showed no change in performance, indicating results are not due to practice effects. Findings demonstrate preschool children's ability to adjust their approach to the DCCS in the presence of emotionally evocative reward-related feedback by prioritizing accuracy over speed. Trial-by-trial reward-related feedback may facilitate cognitive control in early childhood.

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Executive function; preschool; reward; DCCS; hot executive function; cognitive control

Executive functions (EFs) are complex neurocognitive processes that improve rapidly in the preschool years (Garon, Bryson, & Smith, 2008) and strongly predict developmental outcomes such as academic achievement (Nesbitt, Farran, & Fuhs, 2015). The Dimensional Change Card Sort (DCCS; Frye, Zelazo, & Palfai, 1995; Zelazo, 2006) is a widely-used early childhood EF task in which children sort stimuli by one dimension (e.g., color), and then must switch to sort by a different dimension (e.g., shape). Most three-year-olds perseverate, while most five-year-olds switch rules successfully (Zelazo, 2006). Multiple EFs are implicated in the DCCS, including cognitive flexibility (Zelazo, 2006), attention (Honomichl & Chen, 2011), working memory (Marcovitch, Boseovski, & Knapp, 2007), inhibitory control (Diamond, Carlson, & Beck, 2005), and self- monitoring (Bohlmann & Fenson, 2005).

While there is a rich literature on how modifying the cognitive demands of the DCCS affects performance (see for review, Doebel & Zelazo, 2015), there has been limited attention to how DCCS performance is affected by altering the *emotional* demands of the task. The standard DCCS is a "cool" EF task, involving purely cognitive processes, whereas "hot" EF tasks are at the intersection of cognition and emotion (Zelazo & Cunningham, 2007). Cool and hot EF are both conceptually and neurally distinct, with cool EF relying on dorsolateral prefrontal regions and hot EF invoking the ventromedial and orbitofrontal cortices (Chan, Shum, Toulopoulou, & Chen, 2008). Real world contexts often require young children to use their emerging EF skills under "hot" conditions, so it is important to understand how emotional content and context influence EF performance. The DCCS, well-studied as a cool task, provides the

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opportunity to rigorously investigate the interplay of emerging "cool" and "hot" capacities by developing DCCS versions that maintain the same cognitive demands but layer on an affective dimension. In one study, using emotional face stimuli increased DCCS accuracy (Qu & Zelazo, 2007). In a different hot adaptation of the DCCS, Beck, Schaefer, Pang, and Carlson (2011) found that DCCS accuracy was not affected by having a snack reward at stake and changing stimuli to outlines of snacks to remind children of the reward. However, young children may have trouble monitoring their own performance, so a more salient association between reward and performance may be needed for children in this age range to adjust their performance.

There is some evidence that older children and adolescents exert better cognitive control in the context of a reward, performing more accurately and faster on EF tasks (Geier, Terwilliger, Teslovich, Velanova, & Luna, 2010; Padmanahban, Geier, Ordaz, Teslovich, & Luna, 2011). It is unknown how a salient reward would influence EF performance in the preschool years, when both EFs and emotion regulation are just emerging. A highly salient reward may enhance preschool children's motivation and attention. Alternately, emotional reactions to gain or loss of reward could compromise cognitive processes required to succeed.

The goal of this study was to determine how preschool children's DCCS performance is influenced by reward-related feedback. In a within-subjects design, preschool children completed both cool and hot DCCS versions. To ensure that the reward remained emotionally salient throughout the hot DCCS, we tied the reward explicitly to emotionally evocative feedback on each trial. We expected that children would be faster and more accurate in the hot DCCS.

Study 1 methods

Participants were 105 children (58 male) aged 3.5 to 4.5 years (M = 4.18 years, SD = 0.29 years) recruited from a departmental database. Children were born full term and had no known developmental or neurological disorders. Children were Caucasian (51%), Biracial (21.2%), Asian American (16.3%), Latino (7.7%), African American (2.9%), and Middle Eastern (1.0%). Their parents were mainly college-educated (81.7% of mothers and 74.2% of fathers). Another 23 children enrolled but were excluded due to declining to participate ($n = 7$), failing the pre-switch phases of both cool and hot DCCS ($n = 15$), or technical difficulties ($n = 1$), resulting in a final sample of N = 105.

This study was approved by the university Institutional Review Board. A computerized DCCS task was adapted from Espinet, Anderson, & Zelazo (2012). The child was instructed to match a test stimulus (e.g., a red ship or a blue rabbit) to one of two target stimuli, e.g. a blue ship and red rabbit. In the shape-color version, children were instructed to sort by shape for eight practice trials and 15 pre-switch trials, then to sort by color for 30 post-switch trials. It was important that the post-switch rule be novel for both cool and hot DCCS, so we constructed a second task version, shape-number, in which the pre-switch dimension was shape and the post-switch dimension was number. Test stimuli were one blue rabbit or two blue ships, and target stimuli were two blue rabbits and one blue ship. Task version order was counterbalanced for cool and hot DCCS, and was covaried in subsequent analyses.

In the cool condition, there were no rewards. During the pre-switch and post-switch phases, no feedback was given. To examine effects of reward and emotionally salient feedback, we developed a hot DCCS condition in which children were told they could earn fish stickers as prizes by answering the items correctly. For the practice, pre-switch, and post-switch phases, after each correct response the child heard a chime, a happy face flashed on the screen, and then the child saw an animation of four fish stickers appearing one by one, each accompanied by a chime. After each incorrect response, the child heard a buzzer, a sad face flashed on the screen, and then the child saw an animation of four fish stickers disappearing one by one, with a buzzer sound as each fish disappeared. We did not counterbalance the order of cool and hot conditions based on our pilot data that for children of this age, once a reward has been associated with a task, the same task would not be experienced as cool immediately afterward. To address the potential confound of practice effects, we tested an additional sample (see Study 2, below).

Pre-switch and post-switch accuracy and reaction time (RT) were computed for the cool and hot conditions. Mean RT was calculated for correct trials only, and trials with RTs <150ms or >10 sec were

Table 1. 1a. Study 1 descriptive statistics for DCCS post-switch performance by condition.

	Cool DCCS M(SD)	Hot DCCS M(SD)
	n = 87	n = 99
Accuracy (%)***	72.37 (31.19)	84.64 (24.57)
RT (ms)***	2051.50 (816.09)	2896.30 (1008.47)

1b. Study 2 descriptive statistics for cool DCCS post-switch performance by administration.

	Cool DCCS 1 M(SD)	Cool DCCS 2 M(SD)
	n = 20	n = 20
Accuracy (%)	77.80 (33.07)	81.40 (28.24)
RT (ms)	2369.93 (865.96)	2185.02 (636.84)

Note. ***Mean difference between conditions, $p < .001$. *Note*. There were no mean differences by administration.

excluded. For each condition, only children who performed above chance on the pre-switch phase (at least 11/15 correct, $p < .05$) were included in post-switch analyses. Younger children were more likely to fail the cool pre-switch condition, $t\,(104) = -2.49$, p = .014. There were 87 children who passed the cool pre-switch (M = 13.33 correct trials, SD = 1.34) and 99 children who passed the hot pre-switch (M = 14.42, SD = 1.11).

Study 1 results

Descriptive statistics for post-switch accuracy and RT are shown in Table 1. Analyses of performance by condition were conducted for those children (N = 81) who passed the pre-switch for both conditions. Age was unrelated to any of the post-switch accuracy or RT measures among those who passed both pre-switch conditions. Cool and hot post-switch accuracy were positively correlated, $r = .33$, $p = .003$, as were cool and hot post-switch RT, $r = .31$, $p = .006$. Thus, performance relative to the group was moderately stable across conditions. Repeated-Measures Analyses of Variance (RM-ANOVAs) assessed whether post-switch accuracy and RT differed for the cool and hot conditions, with condition as the within-subjects factor and the task version order as a between-subjects factor. For post-switch accuracy, there was a main effect of condition, $F\,(1, 78) = 25.47$, $p < .001$, such that children were more accurate in the hot condition. There was a main effect of task version order, $F\,(1, 78) = 4.83$, $p = .03$, such that children who completed cool shape-color and hot shape-number had higher accuracy than those who completed cool shape-number and hot shape-color. A condition x task version order interaction in post-switch accuracy, $F\,(1, 78) = 16.93$, $p < .001$, was due to higher accuracy on cool shape-color versus cool shape-number, $t\,(54.92) = 3.59$, $p = .001$, but no task version difference in the hot condition. For post-switch RT, there was a main effect of condition, $F\,(1, 75) = 47.90$, $p < .001$, with slower RT in the hot condition. There was a condition x task version order interaction in post-switch RT, $F\,(1, 75) = 6.42$, $p = .01$, but follow-up analyses showed RT did not vary by task version in either condition. In sum, the hot condition was linked to higher post-switch accuracy but slower post-switch RT.

Study 2 methods

In Study 1, the cool condition always preceded the hot condition, and thus practice effects potentially could be responsible for the change in performance. To address this possibility, we tested an additional sample in which children completed the cool DCCS twice with different post-switch rules. Participants (N = 20, 10 male) were aged 3.5 to 4.5 years (M = 4.04 years, SD = 0.38 years). Parents were mostly college-educated (100% of mothers and 90% of fathers). As in Study 1, task version order (shape-color, shape-number) was counterbalanced and covaried.

Study 2 results

Descriptive statistics for post-switch accuracy and RT are shown in Table 1. Post-switch accuracy was positively correlated on the two cool DCCS tasks, $r = .50$, $p = .03$, and there was a non-significant trend toward a positive association of RT on the two cool DCCS tasks, r (18) = .41, p = .096. RM-ANOVAs assessed whether post-switch accuracy and RT differed for cool DCCS 1 and 2, with administration (1 or 2) as the within-subjects factor and task version order as a between-subjects factor. There were no main or interaction effects. Thus, simply repeating the DCCS was not associated with any changes in performance.

Discussion

We examined the effects of emotionally salient reward-related feedback on preschool children's DCCS performance by administering both cool and hot versions of the DCCS. Results demonstrate that, when a sticker reward was at stake and emotionally salient trial-by-trial feedback was provided, children aged 3.5 to 4.5 years engaged in an accuracy-for-speed tradeoff. They improved their hot post-switch accuracy compared to the cool post-switch phase but appeared to achieve this by slowing down. Another group of children completed a cool DCCS twice and showed no practice effects, consistent with prior literature (Beck et al., 2011). Thus, the increases in both accuracy and RT on the hot DCCS likely reflect children's ability to use emotionally salient feedback and the motivation of reward to adjust their performance, prioritizing accuracy over speed. It may be that young children when motivated by highly salient reward exert better cognitive control only through slower RTs, whereas older children and adolescents with more mature EF have been reported to be both faster and more accurate on cognitive control tasks when motivated by reward (Geier et al., 2010; Padmanahban et al., 2011).

To our knowledge, this is the first study to demonstrate that reward-related feedback on the DCCS enhances post-switch accuracy in preschool children. Beck et al. (2011) found that reward alone in the absence of feedback was not related to performance. In the hot DCCS of the current study, stickers appeared on the screen after correct trials and vanished after incorrect trials, so the link between performance and reward was emphasized on every trial. This approach may have served to scaffold self-monitoring and maintain motivation and attention. Bohlmann and Fenson (2005) showed that 3- to 5-year-olds increased post-switch DCCS accuracy when provided with trial-by-trial feedback in which an adult stated if the card was sorted correctly, reminded the child of the sorting rule, and physically demonstrated sorting the card correctly. We extend these findings by showing that preschool children can adjust their DCCS performance in response to feedback even without any explanation or modeling of the correct response.

We were interested in the effects of a highly salient reward at stake, and used reward-related feedback to maintain attention to the reward. Thus, it is not possible in this study to separate effects of reward-related feedback from effects of feedback alone. There may always be some confounding of feedback with reward, as positive feedback is likely to be intrinsically rewarding for preschool children. It will be important for future studies to determine if neutrally delivered feedback in the absence of extrinsic reward would be sufficient to increase accuracy. Another limitation of these analyses is the small sample size of Study 2, in which children repeated the cool DCCS. This sample was sufficient to rule out large practice effects, but future research with a larger sample is needed to have adequate power to detect possible subtle practice effects.

Strengths of this study included the within-subjects design and measurement of both accuracy and RT, allowing for examination of the tradeoff children made to increase accuracy in response to reward-related feedback. This study is innovative in demonstrating that reward-related feedback can facilitate cognitive control in early childhood.

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