



Original Articles

Seeing conflict and engaging control: Experience with contrastive language benefits executive function in preschoolers

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ABSTRACT

Engaging executive function often requires overriding a prepotent response in favor of a conflicting but adaptive one. Language may play a key role in this ability by supporting integrated representations of conflicting rules. We tested whether experience with contrastive language that could support such representations benefits executive function in 3-year-old children. Children who received brief experience with language highlighting contrast between objects, attributes, and actions showed greater executive function on two of three ‘conflict’ executive function tasks than children who received experience with contrasting stimuli only and children who read storybooks with the experimenter, controlling for baseline executive function. Experience with contrasting stimuli did not benefit executive function relative to reading books with the experimenter, indicating experience with contrastive language, rather than experience with contrast generally, was key. Experience with contrastive language also boosted spontaneous attention to contrast, consistent with improvements in representing contrast. These findings indicate a role for language in executive function that is consistent with the Cognitive Complexity and Control theory’s key claim that coordinating conflicting rules is critical to overcoming perseveration, and suggest new ideas for testing theories of executive function.

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1. Introduction

A fundamental aspect of adaptive human functioning is the ability to control thought and action in response to goals, termed executive function (EF). Decades of research indicates EF develops dramatically in childhood (Carlson, 2005; Diamond, 2013; Zelazo et al., 2013), involves the capacity to actively maintain and flexibly switch among goals represented in prefrontal cortical regions (Miller & Cohen, 2001; Miyake & Friedman, 2012; Munakata et al., 2011), and supports a range of positive life outcomes across the lifespan (e.g., academic achievement, employment, health, and wealth; Blair & Razza, 2007; Daly, Delaney, Egan, & Baumeister, 2015; Moffitt et al., 2011).

A large literature also indicates that language plays a key role in EF. In line with classic proposals that higher cognitive functions are mediated by self-directed speech (Luria, 1961; Vygotsky, 2012/1964), empirical studies using diverse methods suggest language supports EF on a range of measures in both children and adults, including task-switching (Emerson & Miyake, 2003;

Kirkham, Cruess, & Diamond, 2003; Kray, Eber, & Karbach, 2008), planning (Fernyhough & Fradley, 2005; Lidstone, Meins, & Fernyhough, 2010), delayed recall (Fitzer & Roebbers, 2012; Flavell, Beach, & Chinsky, 1966), and inhibitory control (Kray, Kipp, & Karbach, 2009; Müller, Zelazo, Hood, Leone, & Rohrer, 2004). These findings are largely consistent with the possibility that language benefits EF by supporting the active maintenance and retrieval of goal-relevant information.

However, language may also support EF in other ways that have not been explored. One way, suggested by the Cognitive Complexity and Control theory (revised) (CCC-r, Zelazo, 2004; Zelazo, Müller, Frye, & Marcovitch, 2003), is by supporting integrated representations of conflicting rules. EF often requires suppressing an overlearned or prepotent response in favor of a novel response that is consistent with one’s current goals. Such ‘conflict EF’ has been measured in a variety of ways in adults and children. For example, the Stroop task (Stroop, 1935) requires overriding the overlearned response of reading words in favor of identifying the color they are printed in (e.g., saying blue when presented with the word ‘red’ printed in blue). In children, the Dimensional Change Card Sort (DCCS; Frye, Zelazo, & Palfai, 1995; Zelazo, 2006) requires switching from a practiced and therefore prepotent rule (sorting bivalent cards by one dimension, such as shape) to a novel rule (e.g., sorting

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by color). Switching turns out to be very difficult for 3-year-olds, who tend to perseverate on the practiced rule despite being reminded of the new rules on each trial, and rather easy for 5-year-olds (Doebel & Zelazo, 2015). According to the CCC-r theory, successfully overriding a conflicting response tendency depends on the ability to coordinate representations of conflicting action rules, consider them in contradistinction, and select a relevant rule. For example, 3-year-olds represent only the simple pre- and post-switch rules of the DCCS (e.g., “The stars go here and the trucks go there” and “The red ones go here and the blue ones go there”), whereas older children and adults integrate these rules (e.g., “If it’s the shape game then the stars go here and the trucks go there, but if it’s the color game the red ones go here and the blue ones go there”). In the Stroop task, overriding conflict would involve representing that one isn’t reading the words (an implicit, overlearned rule) but rather attending and responding to their color. And while adults would not be expected to have difficulty constructing representations that adequately reflect conflict within a task, they may often fail to do so (e.g., due to inattention or fatigue), resulting in reduced EF engagement. Experience with language that can be used to integrate rules in inner speech may support the engagement of conflict EF.

Consistent with this possibility, recent findings indicate that complex language skills are related to EF in 4-year-olds (Kuhn, Willoughby, Vernon-Feagans, & Blair, 2016), and a recent meta-analysis of the DCCS found that greater verbal emphasis on the contrast between the pre- and post-switch rules (e.g., “We’re not playing the color game anymore, no way,” and “The shape game is different,” Kloo & Perner, 2005; Munakata & Yerys, 2001) predicted switching (Doebel & Zelazo, 2015). While suggestive, these findings fall short of providing causal evidence that language supporting integrated rule representations benefits EF.

The current study therefore tested whether providing children with linguistic experience that could support integrated representations of conflicting rules would benefit conflict EF. We targeted children because language skills and EF are still improving in childhood, making it easier to detect any benefit to EF they may obtain from specific linguistic experiences. Specifically, we manipulated children’s exposure to language that highlights contrast: contrastive constructions involving negation and the word *different*. *Contrastive negation*, which has the form *not X, Y*, is usually acquired between 3 and 4 years of age (Bloom, 1970; McNeill & McNeill, 1968; Pea, 1980) and is used in diverse ways, for example, to express antonyms (e.g., “Not up, down”) and commands (“Don’t play with your toys, clean up”), to focus attention (“Not the red one, the blue one”), and to teach words (“Bring me the chromium one. Not the red one, the chromium one.”) (Carey & Bartlett, 1978). The word *different* is often used in a similar manner. For example, one might teach a child about animal categories by saying, “This is a cat and this one is also a cat, and this one is *different*: it’s a dog.” We expected contrastive language to support integrated representations of conflicting rules because of the way it is used to coordinate and represent contrasting information. For example, on the DCCS, experience with contrastive language could help children represent the transition from the practiced set of rules to the new set as: “*Not the shape game, the color game*”, in turn helping children select and activate the appropriate nested rules.

We randomly assigned children to one of three conditions in which they either: received experience with language used to emphasize contrast between objects, actions, and attributes; received experience with the same contrasting stimuli but without contrastive language; or spent equivalent time with the experimenter reading storybooks without exposure to contrastive language or contrasting stimuli, controlling for the possibility that experience with contrasting stimuli could influence EF. EF was assessed both before and after the experimental manipulation via

three measures of conflict EF. We hypothesized that if language can benefit conflict EF by helping children represent conflicting rules, then children given experience with contrastive language should perform better on our conflict EF measures than children given experience with contrasting stimuli only, controlling for baseline EF.

2. Method

2.1. Participants

Sixty 3-year-old children ($M_{age} = 3.70$ years, $SD = 0.08$; 26 boys) were recruited from a database of families living in a large Midwestern city who had volunteered to be contacted to participate in research. Ninety-one percent of participants were white, 98% were non-hispanic, and 77% had a college or higher level of education. Six additional participants were excluded due to uncooperativeness. Among the 60 participants who completed the two sessions (20 per condition), 11 did not complete one of the three EF tasks at one or both sessions: 3 did not complete the m-MEFS scale, 3 did not complete the Day-Night task, and 5 did not complete the Hand Game.

2.2. Procedure

Children completed the study across two sessions held approximately one week apart. At the first session, they completed a baseline EF assessment (3 conflict EF tasks), followed by the first of two doses of the experimental or control manipulation. At the second session, children completed the second dose of the manipulation, followed by the second EF assessment, a manipulation check, and a measure of verbal ability. Verbal ability predicts EF skills (e.g., Carlson & Moses, 2001; Hughes, 1998) and, along with age, was tested and included as a covariate to reduce error variance in our statistical models. The duration of each session was approximately 45 min.

2.3. Measures

The EF tasks were selected for age appropriateness and because they were expected to generate response conflict, in which successful performance requires overriding a prepotent response.

2.3.1. Hand Game (Hughes, 1998; Luria, Pribram, & Homskaya, 1964)

This task requires children to switch from imitating gestures made by the experimenter to doing the opposite of what the experimenter does. The experimenter first demonstrated the gestures, saying, “We are going to play a game where I make a shape with my hand and you make the same shape as me. So if I make a fist, then you make a fist, and if I make a point, then you make a point. Okay?” The experimenter then proceeded with two practice trials, saying, “Let’s try. What do you do if I make a fist? . . . And if I make a point?” Once children imitated both gestures correctly, the experimenter proceeded with the test trials. After children completed 15 imitation trials the experimenter introduced the next phase of the task, saying, “Now, we are going to play a different game where you make a different shape than me. So if I make a point, then you make a fist. And if I make a fist, then you make a point. Let’s try. What do you do if I make a fist? . . . And if I make a point?” Children received corrective feedback if they did not complete the first two trials correctly, which were then counted as practice trials. Once two trials were completed correctly, those trials were counted as test trials and 13 more trials were completed for a total of 15 anti-imitation trials. No corrective feedback was provided on

test trials. Self-corrections (i.e., partial imitation gestures that were quickly modified to anti-imitation gestures) were coded as errors.

2.3.2. Modified Minnesota Executive Function Scale (m-MEFS; Carlson & Zelazo, 2014)

A modified, tabletop version of the MEFS was used. The MEFS is a scaled and validated expansion of the DCCS (Beck, Schaefer, Pang, & Carlson, 2011; Frye et al., 1995; Zelazo, 2006). In the DCCS, children are instructed to sort cards by one dimension (e.g., shape) for 5 trials, and then are instructed to switch to sorting by a new dimension (e.g., color). The MEFS requires children to complete discrete card-sorting tasks at different levels of rule complexity and difficulty, to ascertain the most advanced level that a child can complete. Each child completed a minimum of two separate card sorts so that the highest level that they could pass could be assessed. For a complete description of each level of the m-MEFS, see the [supplementary material](#). The task was composed of nine levels, and all children began at Level 4. If they did not succeed at this level, they proceeded to Level 3 and continued downward until they passed a level or failed to pass the lowest level in the task (Level 1). Likewise, children who passed Level 4 then completed Level 5 and continued upward until they reached a level they could not pass.

2.3.3. Day-Night (Gerstadt, Hong, & Diamond, 1994)

Children were presented with cards depicting a yellow sun against a white background or a white moon against a black background. To warm up, the experimenter showed the child the sun card and asked, “Do you know when the sun comes up?” This procedure was repeated for the moon and then the experimenter said, “We’re going to play a game where when I show you a picture of the sun, you say ‘night’, and when I show you a picture of the moon, you say ‘day.’” Two practice trials with corrective feedback were administered. Once the child completed two trials correctly without feedback, the experimenter proceeded with 18 test trials during which no corrective feedback was provided. Alternate responses such as “morning time” and “dark” were scored as correct.

2.3.4. Peabody Picture Vocabulary Test, Fourth Edition (PPVT-IV; Dunn & Dunn, 2007)

Children were shown a set of four pictures, provided with a word that corresponded to one of the pictures, and were asked to point to the picture that matched the word. Children’s scores reflected the total number of items to which they responded correctly minus their total errors.

2.4. Experimental manipulation

Each child was administered one of the following condition protocols. Each protocol was administered twice, once at each session.

2.4.1. Contrastive language exposure

Children assigned to this condition completed five short tasks in which they were given experience with contrastive negation and the word ‘different’ used to highlight contrast among pairs of situations, attributes, objects, and actions. Tasks were designed to be structurally diverse to mimic natural language exposure across learning contexts. Given the novelty of our research question, we did not have specific predictions about which tasks and forms of contrastive language (e.g., contrastive negation vs. emphasis on difference) might benefit EF more or less. Several tasks engaged the child by asking them to point to or circle a picture, or respond to a question; however, care was taken to minimize EF demands in the tasks. Consistent with low EF demands, children did not demonstrate any difficulty responding appropriately on the tasks.

Here we briefly describe each task, but see the [supplementary material](#) for the complete protocol.

Language used to emphasize contrast between pairs of objects, attributes, and actions. Children were presented with 10 sets of three pictures in which there was a target picture and two pictures that represented similar or contrasting objects, attributes, and actions. The experimenter pointed to a target picture and said, for example, “This one is round. Now can you show me one that is different, that is not round?” After the child made their selection the experimenter said, “Good, this one is not round. It’s different.” Errors were corrected (e.g., “Actually, this one is not round. It’s different”).

Language used to emphasize contrast between categories. Children were shown 12 pictures (one at a time) of category exemplars and were asked about them. For example, children were shown a picture of a banana and were asked, “Is this an apple?” After a response was provided (children were expected to say no), the experimenter said, “No, this is not an apple. It’s different. It’s a banana.” On half of the trials the experimenter’s label matched what was on the card (e.g., “Is this a banana?” when a picture of a banana was presented) to encourage task engagement.

Language used to highlight contrast between associated versus non-associated items. Children completed three trials in which they were presented with six picture cards on a table in no particular arrangement. Four of the cards formed associate pairs, and two were unrelated. The experimenter told children that they were going to find ones that “go together”. The experimenter then pointed to one of the cards (e.g., a baseball bat) and asked the child what was on the card, and then did the same with the associated card (e.g., a baseball) and asked the child whether the cards go together. The experimenter then said, “Yes, these go together,” before moving on to the next pair. The final pair discussed was the unrelated pair. On this trial the experimenter said, “These do not go together; they’re different.”

Language used to highlight contrast between dimensional values. Children were presented with an 8 × 12 inch page depicting 16 randomly distributed shapes or colors (e.g., hearts, zigzags, and stars) and were asked, for example, to “circle the ones that are not hearts, that are different.” On each page there were eight shapes or colors to be circled (e.g., four zigzags and four stars), and eight non-target shapes or colors (e.g., eight hearts). The experimenter repeated the instructions after every other item the child circled.

Language used to highlight contrast between actions. Children were presented with five pictures, each presented on a separate page in a booklet. For each of five pictures, the experimenter used a narrative to emphasize contrast between two courses of action. For example, the experimenter presented a picture of a child with her mother at the grocery store and said, “Jane and her mom could get red apples or they could get green apples. Jane is about to pick the red apple and her mom says, ‘We are not getting the red apples, we are getting something different.’” Children were then asked, “What did Jane’s mom say?” and their responses were recorded.

2.4.2. Stimuli only condition

In this condition, children were exposed to the same stimuli that were used in the contrastive language condition but were not exposed to any contrastive language. In task 1, children were asked to label the pictures one by one with the experimenter facilitating this process. In task 2, children were asked to find the picture that matches the target. In task 3, the experimenter asked children for the name of the object depicted on the card. In task 4, children were instructed to circle a target shape (e.g., “Circle all the hearts.”). In task 5, the narratives were modified so that they did not make any reference to contrasting actions.

2.4.3. Storybook condition

In this condition the experimenter read two storybooks to children at each session: *Go Dog, Go!*, *The Big Road Race*, *Are You My Mother?* and *Flap Your Wings*. Different books were read at each session to ensure that children remained engaged.

2.5. Manipulation check: Attention to Contrast task

This task tested whether children exposed to contrastive language were more likely to attend to contrast, which would be expected if contrastive language supports representations of contrast. The experimenter said that she was going to point to one of four pictures on a page and say something about it and then it would be the child's turn. She then pointed to a target picture and expressed a proposition about it (e.g., "The bear is in the box"). The experimenter then motioned to each remaining picture and said, "Now can you point to one and tell me about it?" The three remaining pictures represented: (1) the negated proposition (e.g., an empty box); the same proposition (e.g., a bear in a box in a slightly different position); and an unrelated situation (e.g., a tree). 12 items were administered (see [supplementary material](#)), yielding two indices: (1) the number of trials on which children pointed to the picture negating the initial proposition, and (2) the number of trials on which children used contrastive negation (e.g., "There's no bear in the box!", "Not a bear in a box," or "No bear"). Higher scores indicated greater attention to contrast.

3. Results

We conducted our primary analyses using Analysis of Covariance (ANCOVA), a general linear model that blends ANOVA and regression approaches, to test the effect of condition on post-intervention EF scores (post-test), controlling for baseline (pre-test) EF scores. This analysis has been recommended over mixed ANOVA and the mathematically equivalent use of difference (gain) scores in a one-way ANOVA framework because of its statistical power (Judd, McClelland, & Ryan, 2011). The ANCOVA framework also simplifies the testing and inclusion of additional probable covariates, age and verbal ability, which can further reduce error variance and increase power (Howell, 2012).

The key a priori comparison with respect to the hypothesis was between the contrastive language and stimuli only conditions, thus for all of our analyses condition was contrast coded to facilitate planned contrasts testing the difference between the contrastive language and stimuli only conditions (contrastive language = 1, storybook = 0, stimuli only = -1), and the difference between the average of the contrastive language and stimuli only conditions and the storybook condition (contrastive language = 1, stimuli only = 1, storybook = -2), the latter comparison being of interest only if the contrastive and stimuli only conditions did not differ (i.e., testing whether experience with contrast generally predicted EF performance, controlling for pre-test EF scores). Post-test means and standard deviations reported in the text are adjusted for covariates included in the models.

Preliminary analyses revealed no effects of gender or experimenter ($ps > 0.250$), thus these variables were not included in

subsequent analyses. Pre-test scores on the three EF measures and PPVT did not significantly differ by group, $ps > 0.250$ (Table 1). Table 2 shows bivariate correlations between all measures and, as expected, pre-test and post-test conflict EF scores were correlated, and some post-test scores were correlated with age and verbal ability. Also, performance on the conflict EF tasks tended to correlate, with the exception of the Day-Night task, which correlated with the m-MEFs but not the Hand Game at pre-test, and did not correlate with either of these tasks at post-test.

Contrastive language training positively influenced children's tendency to attend to contrast. Two one-way Analyses of Variance (ANOVAs) were performed with condition as the between-subjects factor and contrast selection and use of contrastive negation on the Attention to Contrast task as the dependent variables. Children who received experience with contrastive language ($M = 6.9$, $SD = 2.88$) selected contrasting items on the Attention to Contrast task more often than children who received experience with the contrasting stimuli only (adj $M = 1.5$, $SD = 2.04$), $F(1, 57) = 46.92$, $p < 0.001$, 95% CI [3.82, 6.97], $\eta_p^2 = 0.45$. By contrast, there was no evidence that children who read storybooks with the experimenter (adj $M = 4.2$, $SD = 2.48$) differed from children in the other two conditions combined in their selection of contrasting items, $p > 0.250$. Post hoc analyses indicated that children in the contrastive language condition selected contrasting items more often than children in the storybook condition, $F(1, 38) = 10.07$, $p = 0.003$, 95% CI [0.98, 4.42], $\eta_p^2 = 0.21$, who were less likely to select contrasting items than children in the stimuli only condition, $F(1, 38) = 14.14$, $p < 0.001$, 95% CI [4.15, 1.24], $\eta_p^2 = 0.27$.

The same pattern held for children's use of contrastive negation, such that children who received experience with contrastive language (adj $M = 4.45$, $SD = 2.96$) used negation more often on the Attention to Contrast task than children who received experience with the contrasting stimuli only (adj $M = 0.50$, $SD = 0.94$), $F(1, 57) = 32.95$, $p < 0.001$, 95% CI [2.57, 5.33], $\eta_p^2 = 0.37$. As with item selection, there was no evidence that children who read storybooks with the experimenter (adj $M = 2.10$, $SD = 2.12$) differed from children in the other two conditions in their use of negation, $p > 0.250$. Post hoc analyses indicated that children in the contrastive language condition used negation more often than children in the storybook condition, $F(1, 38) = 8.29$, $p = 0.006$, 95% CI [0.7, 4.0], $\eta_p^2 = 0.26$, who were less likely to use negation than children in the stimuli only condition, $F(1, 38) = 9.49$, $p = 0.004$, 95% CI [2.65, 0.54], $\eta_p^2 = 0.20$.

Our first set of ANCOVAs modeling conflict EF as measured by the Hand Game indicated a benefit of contrastive language (Fig. 1). We modeled post-test Hand Game scores with condition (contrast coded) as the between-subjects factor and pre-test Hand Game scores, age and verbal ability as covariates. Age and verbal ability did not significantly predict Hand Game scores at post-test ($ps > 0.250$), so they were removed from the model. As expected, pre-test Hand Game scores significantly predicted post-test scores, $F(1, 54) = 36.97$, $p < 0.001$, 95% CI [0.37, 0.73], $\eta_p^2 = 0.41$.

Children who received experience with contrastive language scored significantly higher on the Hand Game at post-test (adj $M = 9.87$, $SD = 1.96$) than children who received experience with

Table 1
Descriptives for covariate measures indicating no significant differences between the groups at pre-test.

Condition	Hand game pre-test	m-MEFs Pre-test	Day night task pre-test	Age (years)	Verbal ability (PPVT)
Contrastive language	6.95 (3.57)	3.21 (1.51)	12.42 (3.82)	3.72 (0.09)	85.35 (16.39)
Stimuli only	8.10 (2.84)	3.42 (1.30)	13.42 (5.22)	3.74 (0.08)	80.80 (15.15)
Storybook	6.89 (3.48)	2.85 (1.39)	12.21 (5.01)	3.68 (0.06)	88.65 (17.06)

Note. Standard deviations are provided in parentheses. No significant differences were found among the group means on these measures.

Table 2
Bivariate correlations among measures.

	1	2	3	4	5	6	7
1. Age	–	–	–	–	–	–	–
2. PPVT	0.23 [†]	–	–	–	–	–	–
3. Hand-Game – pre-test	0.05	0.22 [†]	–	–	–	–	–
4. m-MEFS – pre-test	0.02	0.40 ^{**}	0.39 ^{**}	–	–	–	–
5. Day-Night task – pre-test	0.00	0.12	0.03	0.24 [†]	–	–	–
6. Hand Game – post-test	–0.03	0.24 [†]	0.59 ^{***}	0.30 [†]	0.00	–	–
7. m-MEFS – post-test	0.23 [†]	0.39 ^{**}	0.40 ^{**}	0.75 ^{***}	0.08	0.37 ^{**}	–
8. Day-Night task – post-test	–0.10	0.21	0.04	0.23 [†]	0.53 ^{***}	0.19	0.09

Note. PPVT: Peabody Picture Vocabulary Test-IV. m-MEFS: Modified Minnesota Executive Function Scale.

^{*} $p < 0.05$.
^{**} $p < 0.01$.
^{***} $p < 0.001$.
[†] $p < 0.10$.

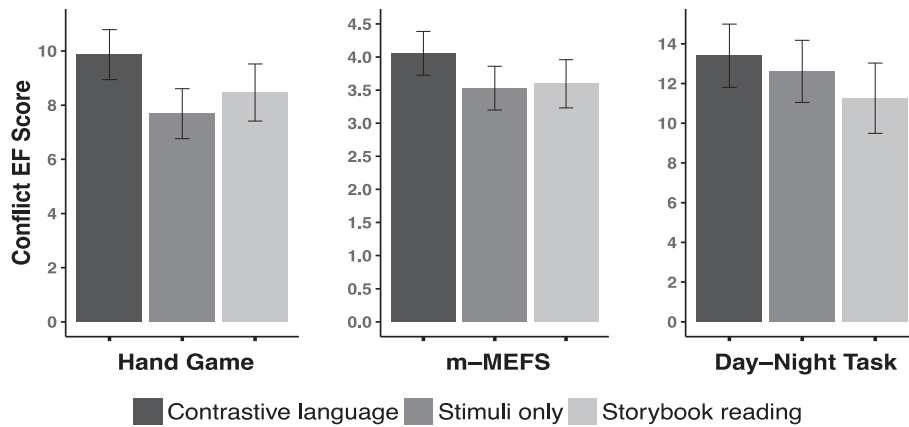


Fig. 1. Adjusted mean post-test scores for three measures of conflict EF. On the Hand Game and m-MEFS, children who received experience with contrastive language scored higher than children who received experience with contrasting stimuli or read storybooks with the experimenter, controlling for pre-test conflict EF (and age in model of m-MEFS performance). On the Day-Night task, children who received contrastive language experience had significantly higher scores relative to the storybook condition only. Error bars indicate 95% confidence intervals.

the stimuli only (adj $M = 7.68$, $SD = 2.06$), controlling for pre-test Hand Game performance, $F(1, 54) = 9.36$, $p = 0.003$, 95% CI [0.76, 3.61], $\eta_p^2 = 0.15$. Children who read storybooks with the experimenter (adj $M = 8.46$, $SD = 2.23$) did not significantly differ from the average of the other two conditions (adj $M = 8.92$, $SD = 2.23$) in their post-test Hand Game scores, $p > 0.250$. Post hoc tests indicated that children who received contrastive language experience had higher post-test scores on the Hand Game than children who read storybooks with the experimenter, controlling for pre-test Hand Game scores, $F(1, 35) = 6.15$, $p = 0.018$, 95% CI [0.28, 2.8] $\eta_p^2 = 0.15$, whereas children who read storybooks did not differ in improvement on the Hand Game from children who received experience with the stimuli ($p > 0.250$).

Our analyses of performance on the m-MEFS indicated the same general pattern. Age was a significant predictor, $F(1, 53) = 5.34$, $p = 0.025$, 95% CI [0.01, 0.10], $\eta_p^2 = 0.09$, and thus was retained in the model, whereas verbal ability was not ($p = 0.19$) and therefore was removed. As expected, pre-test m-MEFS scores predicted post-test scores, $F(1, 53) = 77.96$, $p < 0.00$, 95% CI [0.52, 0.082], $\eta_p^2 = 0.60$. Consistent with our hypothesis, children who received experience with contrastive language had higher scores on the m-MEFS at post-test (adj $M = 4.06$, $SD = 0.74$) than children who received experience with the stimuli only (adj $M = 3.53$, $SD = 0.72$), controlling for pre-test MEFS scores and age, $F(1, 53) = 4.24$, $p = 0.044$, 95% CI [0.01, 1.04], $\eta_p^2 = 0.07$. Children who read storybooks with the experimenter (adj $M = 3.60$, $SD = 0.81$) did not differ from the average of the other two conditions in their post-test m-MEFS scores (adj $M = 3.89$, $SD = 0.80$), controlling for pre-test m-MEFS scores

and age, $p = 0.20$. Post hoc analyses found that children in the contrastive language condition scored marginally higher on the m-MEFS than children in the stimuli only condition, controlling for pre-test m-MEFS scores and age, $F(1, 35) = 3.92$, $p = 0.055$, 95% CI = [–0.01, 1.08], $\eta_p^2 = 0.10$. Conversely, there was no evidence of a difference between the stimuli only and storybook conditions in post-test m-MEFS scores, $p > 0.250$.

By contrast, we did not find evidence that contrastive language experience influenced conflict EF as measured by the Day-Night task. Verbal ability was a marginally significant predictor of post-test Day-Night task performance, $F(1, 50) = 3.72$, $p = 0.058$, 95% CI = [–0.01, 0.13], $\eta_p^2 = 0.07$, and thus was retained in the ANCOVA model, whereas age was not a significant predictor ($p = 0.192$) and was thus removed. Pre-test scores on the Day-Night task predicted post-test scores, $F(1, 50) = 20.70$, $p < 0.001$, 95% CI [0.27, 0.70], $\eta_p^2 = 0.29$. Children who received experience with contrastive language (adj $M = 13.40$, $SD = 3.36$) did not differ at post-test from children who received experience with the stimuli only (adj $M = 12.61$, $SD = 3.30$), controlling for pre-test Day-Night task performance and verbal ability, $p > 0.250$. However, the average of the children in the contrastive language and stimuli only conditions (adj $M = 13.84$, $SD = 3.71$) was higher than that of children in the storybook condition (adj $M = 11.27$, $SD = 3.74$) on the Day-Night task at post-test, $F(1, 50) = 5.62$, $p = 0.022$, 95% CI = [0.39, 4.73], $\eta_p^2 = 0.10$. When verbal ability was not included as a covariate the patterns were similar, with no significant difference between the contrastive language and stimuli only conditions ($p > 0.25$) and a marginal difference between the average of the

Table 3
Post-test conflict EF task descriptives by condition.

	Mean conflict EF scores at post-test		
	Unadjusted	Adjusted for pre-test	Adjusted for PPVT and age
Hand Game			
Contrastive language	9.8 (2.87)	9.87 (1.95)	9.77 (2.01)
Stimuli only	8.25 (2.83)	7.68 (2.06)	7.78 (2.11)
Storybook reading	8.22 (2.90)	8.46 (2.24)	8.25 (2.40)
m-MEFS			
Contrastive language	4.21 (0.98)	4.02 (0.76)	4.04 (0.76)
Stimuli only	3.89 (1.20)	3.57 (0.74)	3.55 (0.74)
Storybook reading	3.3 (1.45)	3.50 (0.82)	3.57 (0.86)
Day-Night task			
Contrastive language	13.95 (3.76)	13.51 (3.45)	13.18 (3.28)
Stimuli only	13.53 (4.86)	12.51 (3.37)	12.82 (3.21)
Storybook reading	11.50 (4.51)	11.60 (3.77)	10.70 (3.77)

Note. Standard deviations are in parentheses.

contrastive language and stimuli only conditions and the storybook condition, $F(1, 51) = 3.69$, $p = 0.059$, 95% CI = $[-0.09, 4.26]$, $\eta_p^2 = 0.07$. Post hoc comparisons indicated that children who received contrastive language experience scored higher on the Day-Night task than children in the storybook condition, controlling for pre-test performance on the Day-Night task and verbal ability, $F(1, 32) = 7.29$, $p = 0.011$, 95% CI = $[0.73, 5.26]$, $\eta_p^2 = 0.19$. No difference was found between children in the stimuli only and storybook conditions on post-test Day-Night task scores, controlling for pre-test Day-Night task performance and verbal ability, $p > 0.250$. Table 3 provides raw means and SDs, alongside estimates adjusted for pre-test only, and estimates adjusted for pre-test, age and verbal ability.

4. Discussion

The current study provides the first evidence that contrastive language can benefit EF. Children who received experience with contrastive language showed increased attention to contrast, and also showed better performance on two of three conflict EF tasks, compared to children who received experience with contrasting stimuli only. The effect on these tasks, Hand Game and m-MEFS, was therefore specific to contrastive language, as opposed to experience with contrast more generally. Children who received experience with contrastive language also showed better conflict EF than children who read storybooks with the experimenter, suggesting that it was contrastive language, and not exposure to language per se, that led to improvements. There was no significant difference between children who read storybooks and those who received experience with contrasting stimuli. Overall, these findings are consistent with the possibility that contrastive language benefits EF by supporting representations of conflicting rules, in line with the CCC-r theory.

Children's performance on the Day-Night task did not provide evidence for or against the hypothesis that contrastive language benefits EF. Receiving experience with contrastive language benefited conflict EF on this task compared to reading storybooks with the experimenter, but not compared to receiving experience with contrasting stimuli. Two ways that this finding can be interpreted are in terms of a more general effect of contrast experience or possible measurement insensitivity that reduced power to detect group differences. The possibility of a more general effect of contrastive experience seems unlikely given that we did not find any difference between the stimuli only and storybook conditions on the other two tasks. Consistent with the latter possibility, performance on the Day-Night task was not consistently correlated with

our other conflict EF measures (which were correlated with one another), suggesting the task may not have effectively measured conflict EF in our sample. Specifically, three-year-olds may not have had sufficiently strong associations between 'day' and 'sun', and 'night' and 'moon' that would generate a prepotent response upon being shown the picture of a sun or moon. Previous research indicates performance on the Day-Night task is not linearly related to age, unlike other widely used child measures of EF (see Montgomery & Koeltzow, 2010, for discussion). Some prior findings are also suggestive of a non-linear, u-shaped developmental pattern (e.g., Sabbagh, Xu, Carlson, Moses, & Lee, 2006), in which 3.5-year-olds and 4.5-year-olds perform better on the task than 4-year-olds (see also Gerstadt et al., 1994).

Our key finding that contrastive language experience improved conflict EF on two widely used measures is consistent with the CCC-r theory's central claim that coordinating conflicting rules is critical to overcoming perseveration, suggesting that such language may play a role in the development of EF via support for coordinated rule representations. Experience with contrastive language may provide the means to represent conflicting rules in contradistinction (e.g., *Not the shape game, the color game*), permitting one to act on relevant action rules (e.g., color rules) instead of prepotent ones (e.g., shape rules). Whereas prior work has found that providing or encouraging labels for goal-relevant information during an EF task can improve performance within the task (e.g., Doebel & Zelazo, 2013; Kirkham et al., 2003; Kray et al., 2008), the current findings indicate that providing contrastive language experience in one context prior to completing the EF tasks improves EF performance. Future work can examine longer-term influences of contrastive language on EF to further test whether such language supports lasting developmental change in EF.

Contrastive language may also support the engagement of conflict EF in adulthood. While the CCC-r theory is foremost an account of how EF *develops* in childhood, it posits continuity in the functional role of integrated representations of conflicting rules (and the language supporting them) across EF development and its engagement in adulthood. Future work can test whether contrastive language supports EF on high conflict tasks in adults. Contrastive representations of conflicting rules may play a role in conflict adaptation, for example, supporting identification of conflict and/or responding to it. If so, one might expect contrastive language fluency or availability (e.g., due to priming) would predict conflict EF in adults.

These findings suggest new possibilities for testing different accounts of EF development using linguistic manipulations. On the CCC-r account, being able to form integrated rule representations is crucial for rule selection, which then results in the dampening of activation of prepotent rules and increasing activation of relevant rules in working memory. A contrasting view is that being able to actively maintain goal-relevant information in working memory is sufficient for inhibition of goal-conflicting information (Morton & Munakata, 2002; Munakata et al., 2011). A question for future research, then, is whether contrastive language facilitates conflict EF to a greater, equal, or lesser degree than language experience designed only to support maintaining relevant rules in working memory.

An alternative interpretation of our findings that is consistent with other developmental theories of EF is that it is experience with negation, rather than contrastive language *per se*, that supported conflict EF in our study, by inhibiting attention to irrelevant rules. For example, attentional control accounts (e.g., Buss & Spencer, 2014; Kirkham et al., 2003) might propose that experience with negation could support task representations in which conflicting rules are negated (e.g., "Not the color game" or "Not reading the word"), attenuating the attentional salience of the prepotent task set, permitting children to reorient to and select the

relevant task set. While this is an intriguing possibility, it is inconsistent with prior work suggesting that negation actually impairs inhibition by drawing attention to the negated information (Wegner, Schnieder, Carter, & White, 1987).

Another possible interpretation of our findings is that contrastive language helped children better learn the task rules, which improved their performance on the conflict EF tasks relative to the other conditions. In both the m-MEFS and the Hand Game the second phase of the task is introduced using contrastive language. One could argue that if children fail to understand this language, then they may not completely understand what they are supposed to do in the task. However, children did not struggle with the first set of rules on either task, and on the Hand Game children were required to demonstrate understanding of the new rules before proceeding. Nevertheless, the idea that experience with contrastive language may have helped scaffold children's parsing of the contrastive language in the task instructions is consistent with our interpretation that such language supports representing the task structure, such that children who understood the contrastive language used in the instructions may have been more likely to represent the task rules as contrasting, facilitating higher order rule selection.

Using language to emphasize contrast may be an effective strategy for supporting the engagement of EF in adults and children alike. For example, there has been debate in the parenting literature about how to most effectively phrase requests to children in order to facilitate compliance, with some recommending the avoidance of negative language, citing the findings that negation impairs control (e.g. Prager & Acosta, 2010). However, there has been little scientific investigation of how negative or contrasting commands influence goal-directed behaviors in children, despite evidence that compliance with parent requests plays a role in the development of self-regulation (Gralinski & Kopp, 1993; Kochanska, Murray, Jacques, Koenig, & Vandegest, 1996). Our findings suggest that using contrastive negation to articulate instructions or goals, to others or perhaps even to oneself, may be an effective tool to support EF.

5. Conclusion

Brief experience with contrastive language improved EF performance in young children, supporting the hypothesis that such language benefits EF via support for integrative representations of conflicting rules, consistent with the CCC-r theory. These findings extend the large literature finding relations between language and EF, and suggest new avenues for testing theories of EF development.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.cognition.2016.09.010>.

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