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Inclusion of a Mixed Condition Makes the Day/Night Task More Analogous to the Adult Stroop

Alleyne P.R. Broomell and

Department of Psychology, Virginia Tech

Martha Ann Bell

Department of Psychology, Virginia Tech

Abstract

In a study with 4-year-old children, we added a mixed condition the traditional day/night task to examine performance and response times for congruent and incongruent trials within the same condition. There were no differences in percentage correct performance between the incongruent and mixed conditions; however, children performed best on the congruent condition. EEG recordings showed differential patterns of frontal power and coherence suggesting increasing cognitive load from congruent to incongruent to mixed conditions. Our pattern of findings suggest that the mixed condition of the day/night Stroop task is a more appropriate child equivalent to the adult color-word Stroop task.

Keywords

preschool children; inhibitory control; day/night task; EEG

Introduction

Inhibitory control is important for school readiness and is a vital precursor to self-regulation, which is the ability to adapt one's behavior and emotions to the requirements of the situation (e.g. Bierman, Nix, Greenburg, Blair, & Domitrovich, 2008; Carlson & Wang, 2007).

Inhibitory control has been shown to predict performance in vocabulary, reading, and math in elementary school (McClelland et al., 2007). There is some evidence that programs such as mindfulness training or aerobic exercise can improve inhibitory control in children (Diamond & Lee, 2011), suggesting it is possible to improve these inhibitory control skills. Thus, having a fine-grained assessment of inhibitory control in young children is critical. The purpose of our study was to explore the modification of a classic child inhibitory control task to make its presentation more closely aligned with the adult task on which it was modeled.

Originally conceived as an interference task (Stroop, 1935), the color/word Stroop is now considered a prototypical inhibitory control task by researchers focused on executive

functions (e.g., Miyake et al., 2000). The Stroop task evaluates the participant's ability to override the prepotent response of reading a word, rather than evaluating a color and is often presented in different conditions. The first condition of the Stroop task asks the participant to report, either verbally or manually, the color of a series of Xs. After several trials the next condition is introduced, asking the participant to report the color that is spelled out in black ink. This is followed by a condition in which the participant is still given the goal of reporting the color ink, but with an incongruent color word written (e.g., the word GREEN written in blue ink). The "mixed" condition asks the participant to report the color ink, unless the word is written in black ink, in which case they are to report the color word written. Within the mixed condition, which minimizes practice effects, response time for the incongruent trials is increased relative to the congruent trials. Frontal lobe patients show increased difficulty with this task (Vendrell et al., 1995). Response times during different conditions or different types of trials, rather than correct vs incorrect performance in different conditions, is used as a continuous measure of inhibitory control in many studies and shows individual differences in typical adults (for a review see MacLeod, 1991).

There are several Stroop-like assessments used to measure inhibitory control in young children. They include tasks such as snow/grass, yes/no, the hand game, and day/night (Carlson, 2005; Gerstadt, Hong, & Diamond, 1994; Passler, Isaac, & Hynd, 1985; Simpson & Riggs, 2009; Wolfe & Bell, 2004). The day/night task has emerged as one of the more popular measures for quantifying inhibitory control in children. The congruent condition of the task requires the child to label the cards as they appear, with the sun card labeled "day" and the moon card labeled "night." As this is simple labeling, no inhibitory control is required for the congruent condition of the day/night task, just as there is no inhibitory control required for congruent condition of the adult color/word Stroop task. The incongruent condition of the day/night task requires the child to say "day" in response to a picture of moon and stars and "night" in response to a picture of a sun (Gerstadt et al., 1994). Similar to the adult version of the Stroop, the incongruent condition requires the child to suppress the automatic response to a stimulus and report a less dominant response. Gerstadt, and colleagues reported that performance on the incongruent condition of the day/night task increases from age three to four-and-a-half, with Simpson and Riggs (2005) reporting most five year olds able to perform very well (i.e., 90% correct). Performance on the day/night task during kindergarten has been shown to predict reading and math achievement later in elementary school (Monette, Bigras, & Guay, 2011). Most researchers working with young children focus on number/percentage of correct trials, rather than reaction time, when using Stroop-like tasks such as day/night with young children, although reaction times appeared in early reports of the day/night task (e.g., Gerstadt et al., 1994).

One of the main factors that distinguishes most child Stroop-like tasks like day/night from the adult color/word Stroop is that the child versions have no "mixed" condition to further tax inhibitory control. There is one exception of which we are aware, however. The Directional Stroop Task (DST) has two versions: the Dots version (e.g., Davidson, Amso, Anderson, & Diamond, 2006) and the Hearts and Flowers version (e.g., Diamond, Barnett, Thomas & Munro, 2007). For example, the Dots version of the task requires the child to press a button on the congruent side if a solid dot appears on the side of the screen and on the incongruent or opposite side if the dot is patterned. This task is often conceptualized as

both a working memory and inhibition task (Davidson et al., 2006) because the child is given the instructions for the task one time at the beginning of the mixed block: “Remember, gray same side; striped opposite” (p. 2041; Davidson et al., 2006). Behavioral results for this task show a pattern different than that seen in the adult Stroop, with both response time and performance changing across the three conditions. Specifically, Davidson and colleagues (2006) reported that response time increased and proportion correct decreased from the congruent, to incongruent, to mixed conditions. Thus, performance on the mixed condition of the DST supports Davidson and colleagues’ supposition that both working memory and inhibitory control processes are involved in the most difficult condition of the task. Our goal was to remove the working memory requirement and see if the result was a mixed condition in a preschool Stroop-like task that exhibited reaction time differences between congruent and incongruent trials but no performance differences, similar to the adult color-word Stroop task.

In order to remove the working memory requirements from the mixed trials condition, we utilized methodology from the Dimension Change Card Sorting task (DCCS). The DCCS requires the child to sort cards according to one dimension, such as color (pre-switch condition) before changing to sorting by another dimension, such as shape (post-switch condition). If the child sorts five of the six cards correctly in the post-switch condition, the child enters a mixed trial condition during which sorting is done by the color dimension if there is a black border around the card and by the shape dimension if there is no border. Importantly, the child is given the sorting rules at the beginning of each trial so that the rule does not have to be kept in mind throughout the mixed condition (Zelazo, 2006).

Thus, the borders version of DCCS suggests an opportunity to add borders to the traditional day/night in order to create a mixed condition, analogous to the mixed condition of adult Stroop in which reaction times vary between congruent and incongruent trials but where overall performance on the mixed condition is not degraded because working memory is not required, as it is for DST (Davidson et al., 2006). This provides three conditions of the same task: day/night congruent, day/night incongruent, and day/night mixed. Each of these conditions likely probes different aspects of executive function. The congruent condition requires simple sorting and can be thought of as a baseline condition, whereas the incongruent condition of day/night taxes inhibitory control, as shown by Diamond, Kirkham, and Amso (2002). The mixed condition acts as a broader measure of executive functions, with elements of set-shifting and inhibitory control, but no working memory. Adding a mixed condition to day/night has the potential to make it more similar to the adult Stroop and potentially a more taxing assessment of early inhibitory control.

We also examined brain correlates of the congruent, incongruent, and mixed conditions of the day/night task. Rapid changes in inhibitory control during early childhood occur simultaneously with rapid rate of neurological development during the same time period. Longitudinal work by Gogtay and colleagues (2004) obtained structural MRI scans at ages four and six for thirteen children. They found progressive pruning of grey matter over the frontal lobe between the two scans. This pruning of grey matter and changes in functional connectivity could be underlying age-related differences in inhibitory control task performance.

Thatcher has used the electroencephalogram (EEG) to demonstrate similar age related changes in neurological function (Thatcher, 1994). EEG uses scalp electrodes to measure changes in frequency and amplitude of electrical signals emitted from the brain. EEG, as well as the stimulus- or response-locked event related potential (ERP) derived from the EEG record, has excellent temporal frequency and is able to record electrophysiological changes much faster than other methodologies. Because it is noninvasive and provides compelling information about neural function, EEG is a preferred neuroimaging method to use with children (Bell & Cuevas, 2012). The continuous EEG is observed in frequency bands, with different frequencies thought to relate to different psychological functions. The band from 6–9 Hz, “child alpha”, has been established to be the dominant frequency band from infancy through early childhood (Bell, 1998; Bell & Fox, 1994; Marshall, Bar-Haim, & Fox, 2002). EEG power is a measure of EEG magnitude and reflects the excitation of groups of neurons. EEG coherence is a measure of functional connectivity and is thought to reflect white matter connections between areas and is calculated as the squared cross-correlation between two electrode sites (Thatcher, 1994). Coherence values vary from 0 to 1 to reflect levels of low to high levels of synchronicity and, thus conceptually, functional connectivity.

EEG coherence has been linked with executive functioning skills in adults, such as working memory. For example, there is significant coherence between frontal and association cortices during a working memory task, compared to baseline (Sarnthein, Petsche, Rappelsberger, Shaw, & Stein, 1998). Synchrony between these brain areas provides evidence that executive functions rely not only on the frontal and prefrontal cortices, but also on associations across the brain.

However, much of the work with preschool children has focused on EEG power, rather than EEG coherence. For example, task related changes in EEG power at frontal electrodes measured pre-kindergarten added significant unique variance to a model statistically predicting executive functioning in post-kindergarten aged children (Cuevas, Hubble, & Bell, 2012). Similarly, 4-year old children have greater EEG power at frontal electrodes during Stroop-like tasks than at baseline, suggesting greater cognitive effort during the task than during baseline (Wolfe & Bell, 2007) and children who perform better on these Stroop-like tasks have greater EEG power values at frontal, as well as temporal, electrodes than children who perform less well (Wolfe & Bell, 2004). This work suggests frontal EEG electrodes as a common focus in examining EEG power and coherence during different conditions of the day/night Stroop-like task.

V. Molfese, D. Molfese, and colleagues used ERPs to examine cognitive processing during various conditions of the DST with six- and eight-year-old children (Molfese, Rudasill, & Molfese, 2013). When comparing ERP activity during the mixed condition of the DST between children who performed well on the task (-1 SD above the group mean; $n=63$), versus children who performed poorly (-1 SD below the group mean; $n=11$), there were group by electrode interactions (V. Molfese et al., 2010). The authors interpreted this to indicate that the two performance groups used different brain areas to process information during the DST. No simple effects testing was done to indicate which scalp locations differed between the two DST performance groups with respect to the ERPs recorded during the DST. Thus, we do not know which brain areas differed between performance groups.

In another study by this same research team, six boys between six and eight years of age performed the DST after typical sleep and again a week later after a one-hour sleep restriction. When examining the ERPs recorded during the mixed condition of the DST, the authors reported that the late slow wave component of the ERP (524 to 700 ms) differed between control and restricted sleep conditions at parietal and occipital scalp electrodes for congruent trials and at parietal scalp locations for incongruent trials (D. Molfese et al., 2013). Although highly informative regarding specific circumstances (i.e., high/low performance groups, control/restricted within subjects sleeping), these ERP studies do not help disentangle the potential brain responses to various conditions of the DST using a within subjects framework and normal variation in task performance.

In sum, we added a mixed condition to the day/night task to go along with the traditional congruent and incongruent conditions used by developmental scientists. We used recordings of EEG power and coherence to investigate the patterns of brain electrical activity at frontal electrodes associated with each of the three conditions of the day/night task. We focused on EEG power at frontal scalp locations because previous research studies using the day/night task and these brain measures reported performance group and/or baseline versus task differences using EEG power. We focused on EEG coherence to examine connectivity within frontal areas during the three task conditions. Finally, we recruited four-year-old children because they are the youngest age in the original DST study (Davidson et al., 2006) and because of the research literature on EEG and the day/night task (Wolfe & Bell, 2004, 2007). We hypothesized that the mixed condition of the day/night task would be more difficult, resulting in increased response times and increased frontal EEG activation patterns relative to the incongruent and congruent conditions.

Method

Participants

Forty-one children (21 girls) participated in this study. They were recruited from the area surrounding a rural university in the mid-Atlantic area using existing participant data bases and flyers in areas populated by young families, including parks, recreation centers, and daycare facilities. Children were between 48 and 59 months at the time of appointment. Two additional boys participated and were excluded from all analyses, one because of a recruiting error (he was over 72 months of age) and the other because he repeatedly expressed distress about being in the research lab and would not tolerate the EEG cap. The average age of children included in the study was 4.46 years (SD 0.30); the average age for mothers at the time of the child's birth was 32.83 years (SD 4.55) and for fathers was 32.37 years (SD 5.05). Most parents were college educated, with 75.6% of mothers and 73.2% of fathers completing a college degree. Six sets of parents did not report education. In terms of ethnicity, 7.3% of parents identified their child as Hispanic, 78% as non-Hispanic, and 14.6% did not report ethnicity. In terms of race, 4.9% of children were reported as Asian, 2.4% as Black or African American, 9.8% as Other/Multiracial, 82.9% as White. Parents were compensated with a gift card and the children were allowed to choose a toy to take home at the end of the appointment.

Procedure

Upon arrival at the research lab, a brief verbal description of the research visit was given and the parent signed a written consent form. Verbal assent was obtained from the child and witnessed by both the parent and another lab member.

An Electrocap was used to record EEG and was placed on the child's head following lab protocol (Cuevas, Calkins, & Bell, 2016; Wolfe & Bell, 2004). Electrode impedances were accepted if they were under 10K ohms. Electrical activity from each lead was amplified using James Long Company Bioamps. The signal was sampled at 512 samples per a second. Editing for excessive movement artifacts was done using simultaneously collected electrooculogram to control for eye movements. EEG power and coherence were analyzed at the 6–9 Hz frequency band using EEG Analysis System software from the James Long Company (Caroga Lake, NY). Details of EEG data collection and spectral analysis procedures from our lab can be found elsewhere (e.g., Cuevas et al., 2016; Wolfe & Bell, 2004).

After EEG cap placement, the children were administered a battery of executive function and episodic memory tasks. This report focuses on the day/night task. All analyses were completed on IBM SPSS 23.

Day/night task

The novel aspect of this study was the use of the day/night mixed condition. First the child completed the congruent version of the day/night game, simply labeling the sun card “day” and the moon card “night. After 12 trials, they then progressed to the traditional incongruent version of day/night which requires children to say “day” in response to a picture of moon and stars and “night” in response to a picture of a sun. Regardless of performance on the incongruent trials, after 12 incongruent trials, the child moved to a mixed condition of day/night where they were instructed to label the moon card as “day” when the card has a red border and as “night” when there is no border. They were then told that they should label the sun card as “night” when there was a red border and as “day” when there was not a border (Figure 1). The rule, “borders is the silly way, not border is the regular way,” was repeated before every trial, as is done in DCCS (Zelazo, 2006). The variable of interest was the total proportion correct, with half a point being given if the child self-corrected an incorrect answer. Reliability coding was done for 20% of the sample and the ICC was 0.98 for the congruent condition, 0.96 for the incongruent condition, and 1.00 for the mixed condition.

For the first 19 participants, response time was coded from video and for the latter 22 response time was coded live by an event marker in an adjacent room. For the congruent and incongruent conditions the response time began as the experimenter flipped the card to face the child and concluded when the child finished giving a response. For the mixed condition the response time began as the experimenter began the reiteration of the rule, “Borders is the silly way, no border is the regular way. This one does/doesn't have a border.” Response time ended when the child concluded giving a response. Thus, response times between the congruent and incongruent conditions and the mixed condition cannot be compared; however, response times between the congruent and incongruent conditions were compared

and response times between congruent and incongruent trials within the mixed condition were compared. Reliability coding was completed for 20% of the sample (equally divided between the two types of response time coding) and the resulting ICC was acceptable at .72.

The entire protocol for each laboratory visit lasted approximately 60 minutes. After the final task, the EEG cap was gently removed and the gels were washed from the child's hair while the child chose a toy to take home.

Results

Data analysis began by examining the distributions of the variables for outliers and calculating correlations between day/night conditions (Table 1). Scores more than three standard deviations from the mean were investigated to ensure that they were accurate representations of the child's performance. There were three outliers more than three standard deviations below the mean on the congruent condition of the day/night task, two on the incongruent condition, and two on the mixed condition. After reexamining the video recordings of the lab visits, it was determined that the outliers were valid representations of performance and not errors in coding or data entry. In the response time values, there were four children with outliers in the mixed condition and three children with outliers in the congruent and incongruent outliers. For each of these seven children the individual videos were re-watched and response time trials were removed that were more than three standard deviations from the child's average response time. One child had two congruent trials removed, one had two incongruent trials removed, and a third had one each incongruent and congruent removed. Of the four children who were outliers in the mixed condition, one had three mixed incongruent trials removed, another had two mixed congruent trials removed, a third had two mixed congruent trials removed, and the fourth had 8 trials removed. Although this fourth child had several trials removed, the significance of the analyses remained the same whether or not he was included. Thus, we decided to include his usable trials. This meant that there were 20 trials removed from a total of 1,476 trials administered across the forty-one children completing three twelve-trial conditions. Every trial that was removed across the child was distracted, so the recorded response time was not an accurate representation of their actual response time. After removal of outliers, the average response times for the congruent and incongruent conditions were calculated. In addition, two average response times were calculated for the mixed condition, one for incongruent trials within the mixed condition and the other for congruent trials within the mixed condition.

Upon further examination, the data from two children's data were removed from some analyses. One child's data was excluded from the incongruent and mixed conditions because, although he passed the pretests, during the incongruent and mixed condition he answered two questions correctly and then gave all incorrect answers while laughing, giving the impression that the errors were on purpose. Another child was removed from congruent and incongruent conditions because of experimenter error in the number of trials administered (i.e., 8 were administered rather than 12). Thus, 40 children contributed data to the congruent and mixed condition, while 39 children contributed data to the incongruent condition.

Behavioral data

Performance on the mixed condition of the task did not differ from performance on the incongruent condition, $t(37) = -1.14, p > .05$. Children performed worse on both the incongruent, $t(37) = 3.45, p < .01$, and mixed, $t(38) = 2.83, p < .01$, conditions relative to the congruent condition.

Mean performance for boys was .93 (SD= .08) on the congruent condition, .82 (SD= .10) for the incongruent condition and .79 (SD= .21) on the mixed condition. The performance mean for girls in the congruent condition was .93 (SD=.10), .76 (SD=.29) for the incongruent condition, and .88 (SD= .20) for the mixed condition. There was no difference in performance by gender for the congruent $F(38) = .43, p = .52$; incongruent $F(37) = 1.10, p = .30$; or mixed condition $F(38) = .66, p = .42$; nor was performance correlated with child age in days (Table 1).

A paired-sample t-test showed the response time increased from the congruent to incongruent condition, $t(38) = -5.41, p < .01$. Responses time also differed between congruent and incongruent trials within the mixed condition, $t(39) = -2.26, p < .05$ (Table 1).

Next we plotted the associations between performance on the mixed and incongruent variations of the task and superimposed 75% cutoffs to indicate passing (Figure 2). The cutoff of 75% to indicate passing was based on work by Carlson (2005). Eight children passed the mixed condition but did not pass the incongruent condition, whereas three passed the incongruent condition, but did not pass the mixed condition. Four children failed both conditions and the remainder (24) passed both the incongruent and mixed conditions.

EEG data

We conducted a series of analyses to determine if the neural patterns during the mixed condition were different from those during the congruent and incongruent and mixed conditions of the day/night task. We examined each of the frontal power (medial frontal: F3, F4; lateral frontal: F7, F8) and coherence pairs (F3/F7 and F7/F8).

To investigate the neural patterns associated with each of the conditions of the day/night task, we conducted a 3 (condition) x 2 (F3 and F4 EEG power) repeated measures MANOVA. This MANOVA showed no effect for condition, $F(2, 37) = 0.53, p = .59$; or hemisphere, $F(2, 37) = 0.29, p = .60$; nor an interaction between the two, $F(2, 37) = 1.42, p = .26$ (Figure 3). We also conducted a 3 (condition) x 2 (F7 and F8 EEG power) repeated measures MANOVA. There was a main effect for condition, $F(2, 37) = 4.27, p < .05$; and no effect for hemisphere, $F(2,37) = 0.81, p = .37$; or interaction between the two, $F(2, 37) = .063, p = .94$ (Figure 4). To understand the main effect for condition, we averaged power from F7 and F8 during each of the task conditions and performed paired t-tests between those values. Our analysis showed no difference in power between the congruent and incongruent conditions, $t(37) = 1.15, p = .26$. The difference in lateral frontal power between incongruent and mixed conditions was approaching significance, $t(37) = 1.84, p = .07$. There was a difference in lateral frontal power between the congruent and mixed conditions, $t(37) = 2.82, p < .01$.

To examine frontal coherence during the conditions, we conducted a 3 (condition) x 2 (F3/F7 and F4/F8 EEG coherence) repeated measures MANOVA. There was a main effect for condition, $F(2, 37) = 13.29, p < .01$; and for hemisphere, $F(1, 38) = 15.68, p < .01$; but no interaction between the two, $F(2, 37) = .633, p = .54$ (Figure 5). Regarding the main effect for hemisphere, right hemisphere coherence was greater than left hemisphere coherence. To investigate the main effect for condition we averaged coherence from both hemispheres during each condition. There was no difference in coherence between the congruent and incongruent conditions, $t(37) = 1.63, p = .11$. However, there was less coherence during the mixed condition compared to both the incongruent, $t(37) = 3.53, p < .01$, and congruent, $t(37) = 4.98, p < .01$, conditions.

Discussion

The addition of a mixed condition to the traditional day/night task yielded a pattern of results that provides insight into the abilities and structure of executive functions in four-year-old children. Unlike results on the DST task with this age group, there was no observed difference in percentage correct performance between the incongruent and mixed conditions, although children performed better on the congruent condition than either the incongruent or mixed conditions. No inhibitory control is required in the congruent condition. The most likely explanation for the lack of performance difference between incongruent and mixed conditions is because of the reduced working memory component of the day/night mixed condition; unlike the DST, we reminded participants of the rule before every mixed trial. By reducing the working memory load, we were better able to measure inhibitory control and make the task more appropriate for younger children. It is valuable to note that in healthy adult populations, there is little variability in performance on the color/word Stroop. What varies in adults is the time needed to respond correctly to incongruent compared to congruent trials (Bugg, Jacoby, & Toth, 2008).

For the 4-year-old children in our study, response time was significantly increased in the congruent relative to incongruent conditions, which replicates findings by Diamond and colleagues (2002). This finding also supports our claim that the day/night task is similar to the adult Stroop pattern of increased response times in incongruent trials. This response time can be interpreted as an increase in difficulty and more time required to process the inhibitory control demands of the task. In addition, we found that within our mixed condition, children took longer to respond to incongruent trials (with a border) than congruent trials (no border). The adult Stroop shows an identical pattern of response time: slower reaction time to incongruent trials in the mixed condition.

Regarding the EEG data, significant effects of condition were seen in the F7 and F8 power and F3/F7 and F4/F8 coherence analyses for the three versions of the day/night task, but not for the F3 and F4 power analysis. The repeated measures MANOVA task F7 and F8 power analysis showed a bilateral step-wise increase in power from the congruent to incongruent to mixed condition. This suggests that the lateral frontal areas of cortex were significantly more active as the task progressed from the simple congruent condition to the more difficult mixed condition. Work by West and Bell (1997) has shown that older adults had more frontal

power activation during the Stroop than younger adults, which was interpreted as older adults working harder to perform the same task.

Contrary to power values, coherence between frontal areas decreased as the task progressed. The decrease in coherence signifies that the cortical areas are working independently of each other. Similar patterns have been found in adults, with fronto-frontal coherence decreasing as cognitive load increases beyond capacity (Zhang, Zhao, Bai, & Tian, 2016). In addition, Swingler and colleagues (2011) reported decreases in EEG coherence from baseline to task in preschoolers during the performance of executive function tasks. This suggests that in young children as well, an increase in cognitive load is associated with a decrease in EEG coherence. That is, in order for children to maintain the same level of performance between the incongruent and mixed conditions, they had to tax neurological systems in different ways.

The EEG coherence differences between day/night conditions appeared despite the lack of behavioral performance differences in the incongruent and mixed condition. These neurological differences suggest that the mixed condition required more cognitive effort than the incongruent condition. It seems possible that there may have been performance differences if there was not a ceiling effect for each condition of the day/night task. Perhaps in younger children there might have been significant differences in performance on the congruent and mixed conditions, as there is ample evidence that younger children have more trouble with Stroop-like tasks (Gerstadt et al., 1994; Simpson & Riggs, 2009; Wolfe & Bell, 2004).

There were some patterns in the data that could be seen as limitations of the study. The correlation between the incongruent and mixed conditions of the day/night task was not robust. Some of this can be attributed to the overall strong performance of the children during both conditions. However, there were some children who performed well on the incongruent version of the task, but performed poorly on the mixed condition. These children's results suggest that the incongruent condition was easier than the mixed condition. However, there were eight children who failed the incongruent condition, but passed the mixed condition. There is the possibility that these children did not fully understand the rules of the game during most of the incongruent condition and with the added practice were able to understand the rules of the mixed condition better than they might have if the conditions were altered. Unfortunately, this is a difficult hypothesis to test, because, like the adult color/word Stroop and child DCCS, the conditions naturally build on each other. More work is needed to resolve these individual differences in task performance.

In sum, by adding a mixed condition to the child day/night task we made it more analogous to the adult color/word Stroop. We showed similar response time patterns between the congruent and incongruent trials of the mixed condition of the day/night task and the adult Stroop. Just like the adult Stroop, there were no differences in overall percentage correct performance between incongruent and mixed conditions. Yet the EEG showed an increase in frontal power and a decrease in fronto-frontal coherence during the more difficult mixed condition, suggesting that more cognitive effort was required.

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Figure 1.
Day/night stimuli without borders (left) and with borders (right).

Figure 2. Scatter plot of performance on incongruent and mixed conditions of the day/night task.
Note. $N = 39$. Dotted lines at 75% correct signify passing the task (Carlson, 2005).

Figure 3.
Medial frontal (F3, F4) EEG power during 3 conditions of the day/night task.

Figure 4. Lateral frontal (F7, F8) EEG power during 3 conditions of the day/night task.
Note. ** $p < .01$.

Figure 5. Fronto-frontal (F3/F7, F4/F8) EEG coherence during 3 conditions of the day/night task.
Note. * $p < .05$. ** $p < .01$.

Table 1.

Task condition means and intercorrelations between conditions.

Variable	1.	2.	3.	Proportion correct mean (SD)	Response time (sec) mean (SD)	N
1. Congruent	–			0.93 (0.09)	2.34 (0.26)	40
2. Incongruent	.09	–		0.79 (0.26)	2.71 (0.39)	39
3. Mixed	.21	.20	–	0.84 (0.20)	Mixed congruent trials: 7.19 (1.16) Mixed incongruent trials: 7.61 (1.31)	40
4. Age in days	.03	–.23	–.07	1627.37 (109.85)		41