Individual Differences in Inhibitory Control Skills at Three Years of Age

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Sixty-eight 3-year-old children participated in an investigation of inhibitory control (IC). Child IC was measured using various tasks in order to determine the impact on child performance of manipulating task demands. Performance on a nonverbal IC task, but not performance on more difficult motivational or traditional IC tasks, was explained by medial frontal electroencephalographic activity and by language abilities. Because of the unique relations of nonverbal IC with concurrent developmental measures, and because of its potential to predict later social problems, we conclude that it is important to include nonverbal IC measures in investigative IC batteries in early childhood.

Inhibitory control (IC) is a key executive function of great importance to the developing child. It is involved in the inhibition of a dominant response, including the inhibition of thoughts and behaviors that are not relevant to the task at hand. Such control processes are vital to a child’s social, emotional, and cognitive development. The ability to withhold incorrect responses translates to practical childhood skills such as raising one’s hand before speaking in the classroom (Ponitz, McClelland, Matthews, & Morrison, 2009) and inhibiting the urge to use physical aggression in response to a peer who stands in the way of one’s goals (Rhoades, Greenberg, & Domitrovich, 2009).

It follows, then, that IC plays an important role in socialization and school readiness (Mahone & Hoffman, 2007). Indeed, Denham (2006), in a study of school readiness, found that teachers believe children to be more prepared to begin formal schooling when the children are able to effectively inhibit their context-inappropriate emotions and behaviors. Children low in IC are at risk for a multitude of problematic outcomes including externalizing behaviors (Eisenberg et al., 2001), lower mathematical and linguistic abilities (Blair & Razza, 2007), and disruptive social behaviors (Hughes, White, Sharpen, & Dunn, 2000). In contrast, children with stronger inhibitory abilities have higher academic competence and more school enjoyment (Valiente, Lemery-Chalfant, & Castro, 2007).

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Because of the important role that IC plays in early academic and social experiences, it is important to look closely at its development in early childhood. IC abilities first begin to emerge during the first year (Bell & Adams, 1999; Rothbart, Derryberry, & Posner, 1994) and then develop rapidly during the preschool years (Carlson, 2005). This development is very closely related to the development of language, as well as to developmental changes in the brain as measured via the electroencephalogram (EEG; Wolfe & Bell, 2004, 2007). Because 3-year-olds are at the cusp of rapid developmental changes in self regulation, we chose that age group for our study of early IC (Diamond & Taylor, 1996).

MEASURING DIFFERENT TYPES OF IC

Researchers have developed a number of IC measures but none of these tasks possess the ability to purely measure IC. Because of this, the choice of measurement often depends on the researcher’s particular theoretical conceptualization of IC.

Some researchers divide IC tasks into two distinct categories based on whether they require inhibition under conditions of delay or inhibition under conditions of conflict (Carlson & Moses, 2001; Carlson, Moses, & Breton, 2002). Delay IC requires children to delay the initiation of a certain dominant response (Carlson & Moses, 2001). For example, during the Marker Delay task, children are left alone with coloring materials but are asked not to color until an experimenter returns to the room (Calkins, 1997). This measure, therefore, tests children’s ability to delay their dominant coloring response. In contrast, conflict IC involves the ability to suppress a dominant response in order to perform a conflicting action. The Day–Night task, for instance, asks children to say “day” when presented with a picture of a moon and to say “night” when presented with a picture of a sun (Gerstadt, Hong, & Diamond, 1994). This requires children to first inhibit their dominant response that connects the image of the sun with “day” and the image of the moon with “night” and then to override this response with the conflicting response of labeling these images in the opposite manner. Because we are interested in the unique effects of varying other types of task demands, all of our chosen measures could be classified as tasks of conflict IC.

In a very similar distinction, IC tasks can also be thought of as either simple or complex (Garon, Bryson, & Smith, 2008). Simple response inhibition tasks involve repressing a dominant response (Garon et al., 2008). The Marker Delay task mentioned earlier (Calkins, 1997) is an example of a simple inhibition task as it merely asks children to inhibit a dominant coloring response. Complex response inhibition tasks, however, also ask children to overcome an automatic response (Garon et al., 2008). The Hand Game (Hughes, 1996), Less is More (Carlson, Davis, & Leach, 2005), and Day–Night tasks (Gerstadt et al., 1994), each tasks of interest to this study, could all be considered complex response inhibition tasks. In the Hand Game task, children must inhibit their natural response to mimic the actions of the researcher as well as initiate the conflicting response of manipulating their hand into the opposing shape. In the Less is More task, children must inhibit their dominant urge to point to the larger number of treats and must initiate the opposing action of pointing to the smaller number of treats. Finally, the Day–Night task requires children to inhibit their prepotent response to respond with each cue card’s typical label and initiate the contradictory action of naming it with the opposite label.
Other Distinctions

There exist a number of unique aspects to IC tasks beyond the classifications noted earlier. For example, the Day–Night task requires children to give a *verbal* response (“day” or “night”) to the visual cue of a sun or moon stimulus card. In contrast, the Hand Game requires children to provide a *motoric, nonverbal* response to a cue. There is evidence in disadvantaged 4- and 5-year-old children that Luria’s Peg Tapping task, a nonverbal IC task, is a more robust predictor of child social–emotional factors than is the verbal IC task, Day–Night (Rhoades et al., 2009). However, we know of no research to date that examines differences in how typically developing 3-year-old children perform on tasks that do and do not require a verbal response. For this reason, we collected data on children’s performance during the Hand Game in order to determine whether this difference in verbal versus nonverbal task demands affects the nature of the IC being measured.

In addition, IC tasks seem to vary in the amount of motivation required for successful performance. For example, in the Day–Night and Hand Game tasks, it could be argued that children have no strong incentive to perform well aside from the desire for praise following a successful performance. In contrast, during the Less is More task, children must balance their motivation for later praise and later food rewards with their immediate desire to choose more treats. Perhaps this taxes IC differently or more strongly than a non-motivationally driven task. Again, more research is needed to explore the effects of these varying task demands on IC task performance, and we have chosen to explore this through the inclusion in our protocol of the Less is More task. The common Day–Night task has similarly been included as a comparison for both the Hand Game and Less is More tasks.

IC and 3-Year-Old Children

Researchers disagree about the age at which IC skills develop, but most seem to agree that these skills emerge in infancy (e.g., Diamond & Goldman-Rakic, 1989; Rothbart et al., 1994). It is during the toddlerhood and preschool years, however, that IC skills develop rapidly (Carlson et al., 2005; Kochanska, Murray, & Harlan, 2000). Thus, the 3-year-old children of focus in this investigation are undergoing drastic changes in their regulatory abilities. Because of the important developmental outcomes of childhood regulation, it is crucial to examine its formation in early childhood. By investigating important differences in children’s performance on IC tasks with varying demands, the field gains a stronger understanding of those task demands which pose the most difficulty for young children and those for which these children are more prepared at an early age. Furthermore, by investigating the correlates of task performance, we stand to gain a better understanding of why certain task demands are difficult for young children, for example, if the difficulties relate to levels of language or to electrophysiological development.

Performance on the Less is More task, a complex IC task, is low in 3-year-old children. These children produce correct responses on only 49% of trials, as opposed to 61%, 73%, and 78% of trials at 3.5, 4, and 4.5 years, respectively (Carlson et al., 2005). Furthermore, researchers report difficulties in administering the Day–Night task to 3-year-old children (Gerstadt et al., 1994), whereas 3.5-, 4-, and 4.5-year-olds respond correctly on 62%, 74%, and 78% of trials, respectively (Wolfe & Bell, 2007). Performance, of course, is not uniform among all individuals,
and the statistics reported above are merely averages based on children who participated in these studies. Some children develop IC skills at a much younger age than others, suggesting that these children have some unique characteristics that aid in their performance. Because of this, the Less is More and Day–Night tasks may be of great use in determining some of the unique personal characteristics that could be associated with children performing well on these tasks at 3 years of age. Furthermore, examination of the correlates of task performance may help us to understand why these tasks are difficult for most 3-year-old children.

Finally, the Hand Game was used, in one study, with children ranging from 3 years 3 months to 4 years 7 months in age (Hughes, 1998). There was a significant main effect for age in this study, with older children performing better than younger children. In another investigation (Hughes, 1996), young preschoolers ranging in age from 2 years 6 months to 3 years 5 months demonstrated poorer performance on the Hand Game than older preschoolers ranging in age from 3 years 6 months to 4 years 4 months. In fact, only three out of 14 young preschoolers performed optimally (producing a run of 6 correct responses within 15 trials), while all members of the older preschooler group performed at this level. Because these studies utilize samples with wide age ranges, however, it is important to examine performance in a more narrow age sample (e.g., 3 years) in order to better understand the early performance on this task.

**Correlates of IC**

*Psychophysiology.* There are psychophysiological data showing relations between IC and brain development. Performance on the A-not-B task, a task used to measure IC (combined with working memory) in infancy, is related to electroencephalogram (EEG) power values at frontal scalp locations (Bell & Fox, 1992, 1997). Infants who perform well on the A-not-B task exhibit increases in frontal EEG activity from baseline to task, whereas infants who have less developed IC skills show no change in activity (Bell, 2001). Similarly, 4.5-year-old children had higher medial frontal EEG activity during IC tasks than during baseline, and children who performed well on the IC tasks had higher overall medial frontal activity than those who performed poorly (Wolfe & Bell, 2004). This is consistent with the finding that 4-year-old children who perform well on representational theory of mind tasks, which require children to inhibit their urge to report the true location of an object in order to report a false location, differ in EEG activity levels localized to the dorsal medial prefrontal cortex from children who perform poorly on these tasks (Sabbagh, Bowman, Evraire, & Ito, 2009). Our study extends these findings by focusing on EEG data as 3-year-old children perform nonverbal and motivational IC tasks, as well as traditional verbal IC tasks.

*Language.* It has been hypothesized that language development, along with frontal lobe development, may result in advances in the voluntary control of behavior (Ruff & Rothbart, 1996). Research demonstrates an association between language and executive functions. Namely language is related to working memory performance (Hughes, 1998). Similarly, other research indicates that children with higher working memory and IC abilities score higher on language assessments than their peers (Wolfe & Bell, 2004). More specifically, studies show an association between verbal abilities and performance on a variety of IC tasks (Carlson, Mandell, & Williams, 2004; Carlson & Moses, 2001). In particular, associations in preschool-aged children have been found between language and performance on the Less is More task (Carlson et al., 2005) and
between language and a composite score including Day–Night task performance (Wolfe & Bell, 2007), but not between language and an IC composite including the Hand Game task (Hughes, 1998).

Many IC tasks, such as the Day–Night task, require children to give a verbal response, whereas other tasks, such as Less is More, require children to understand complex verbal task instructions. It is possible, then, that the associations that have previously been found between IC task performance and language are due, at least in part, to the language demands of the IC tasks themselves. Because of this, an important research question is that of whether language remains related to IC when the language demands of the IC task are lessened.

**Temperament.** IC performance is also predicted by various aspects of temperament. As would be expected, several studies demonstrate an association between parental-report measures of IC and laboratory-based measures of IC (Carlson & Moses, 2001; Kochanska, Murray, & Coy, 1997; Wolfe & Bell, 2004). IC is also related to other aspects of temperament. Namely, laboratory IC task performance is positively related to the Children’s Behavior Questionnaire (CBQ) attentional focusing scale and negatively related to the approach/anticipation scale (Wolfe & Bell, 2004). Such a relation between IC and temperament implies that children with certain temperament traits might struggle with developing IC skills. Research also shows relations between children’s temperament and their performance on tasks in which there is strong motivation to violate the rules of the task (Kochanska et al., 1997). Furthermore, motivational IC tasks such as the tongue task and gift-delay tasks, show different, surprising, relations to temperament than do other measures of inhibitory control. For example, children who performed well on the tongue task and gift delay showed higher CBQ anger/frustration scale scores (Wolfe & Bell, 2004). This surprising performance on these motivationally based IC tasks implies that motivational IC tasks draw upon different temperamental traits than do tasks that do not require children to overcome such strong motivation.

**SUMMARY AND HYPOTHESES**

The goals of this study were to (1) compare task performance among three IC tasks with different IC demands and (2) examine EEG, language, and temperament contributions to performance on three different IC tasks. We focused on 3-year-olds because the rapid developmental changes that 3-year-old children experience make their age group ideal for the study of early IC development. One IC task, Less is More, contained a motivational component, while another, Hand Game, had a nonverbal component. Our third IC task, Day–Night, was included as a representation of traditional verbal, non-motivational IC tasks for comparison with these two unique tasks.

We hypothesized that overcoming the motivation to point to the larger array taxes inhibition more than does producing a correct response on other typical IC tasks. For this reason, we believed that performance on Less is More would be poorer than performance on our other IC tasks, because the motivation to point to a larger amount of treats will be too high for most children to overcome.

We predicted that frontal EEG, language, and temperament would have unique contributions to variance in task performance on Day–Night and Less is More, but that only frontal EEG and temperament would be associated with performance on Hand Game. Based on previous research
(e.g., Wolfe & Bell, 2004, 2007) we expected frontal EEG to be most strongly related to task performance, followed by language and temperament.

METHOD

Participants

Sixty-eight participants (28 boys, 40 girls; 3 Hispanic, 65 Non-Hispanic; 62 Caucasian, 1 African American, 5 Multi-Racial) of a larger longitudinal study on cognition-emotion integration from infancy through early childhood contributed data to the current study. This report contains data collected when the children were 3 years of age ($M = 3.11$, $SD = .08$; Range = 3.00–3.32). Children and their parents were recruited from a rural university community using a commercial list of new parent names and addresses. All mothers and 96% of fathers who reported educational information had at least a high school diploma at the time of testing. Sixty-nine percent of the mothers had college degrees, as did 58% of the fathers. At the time of the child’s birth, mothers were approximately 29.5 years old and fathers were approximately 32.1 years old. All children were full term and were healthy at the time of testing. Parents were paid for their children’s participation in the study.

Design

Upon arrival at our research lab, each participant and his or her mother were greeted by a research assistant who explained the study procedures and obtained signed consent from the mother and verbal assent from the child. Mothers were seated beside and slightly behind the child throughout the visit.

Participants spent approximately 2 hours in the laboratory, participating in a number of tests of IC, including the Less is More, Hand Game, and Day–Night tasks, as well as a number of cognitive, socioemotional, and other executive function tasks not referenced here. All of the tasks that are the focus of this study required the child to pay attention to a given set of rules, to remember the rules throughout the task, and to inhibit a dominant response tendency, which are the hallmarks of IC tasks. In addition, one task required the child to respond verbally (i.e., Day–Night), whereas some of the tasks required the child to respond nonverbally (i.e., Less is More, Hand Game). Furthermore, one task (i.e., Less is More) required the child to overcome strong motivation to respond incorrectly, thus measuring children’s ability to overcome this motivation. Two additional measures of IC, the Dimensional Change Card Sort and the Marker delay, as well as measures of language, electrophysiology, and maternal education were also included in order to examine their differing relations to performance on each of our IC tasks.2

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1These data are from one cohort of children who represent approximately 25% of the participants in a larger longitudinal study. The Less is More task was administered only to the children in this cohort as part of the first author’s master’s thesis research project.

2The Marker Delay and Dimensional Change Card Sort tasks were administered in a separate room after the electrophysiological portion of the lab visit. These tasks were part of our overall IC battery, but they were performed without the EEG cap so as to allow children more freedom of mobility as they approached the end of the laboratory appointment.
Measures

With the exception of Less is More and the Hand Game, all tasks were presented in a fixed order as part of our laboratory protocol. This order matches the order in which the tasks are presented below. Less is More and the Hand Game, however, were counterbalanced with one another in order to prevent effects from fatigue.

**Day–Night.** The Day–Night Stroop-like task has been used in the developmental literature with children 3.5–7 years of age and is hypothesized to involve the functioning of the dorsolateral prefrontal cortex (Diamond & Taylor, 1996; Diamond, Prevor, Callender, & Druin, 1997; Gerstadt et al., 1994). One set of laminated cards (10 cm × 15 cm) was used. In typical administration of this task, each child is instructed to say “day” when shown a card with a picture of the moon and stars and to say “night” when shown a card with a picture of the sun, thus measuring the child’s ability to inhibit the urge to call each card by its intuitive name.

In response to reported difficulties in administering this task to 3-year-old children (Gerstadt et al., 1994), our lab discovered that children in this age group spontaneously labeled the aforementioned stimulus cards as “sun” and “moon” rather than “day” and “night.” Thus, each child was asked to say “sun” when shown a card with a picture of the moon and stars and to say “moon” when shown a picture of the sun. The child was given two practice trials during which he or she was praised or corrected, and then 16 test trials were administered, eight with the sun card and eight with the moon card arranged in a fixed pseudorandom order. No feedback was given during testing. The total administration time for this task was approximately 3 min. The percentage of correct trials was calculated. Interrater reliability was calculated for 29% of the sample and the resulting Intraclass Correlation Coefficient was .990.

**Less is More.** The Less is More task is a reverse-reward contingency task which requires children to point to a smaller array of treats in order to receive a larger number of treats (Carlson et al., 2005). Children were given their choice of treats (e.g., goldfish crackers, colorful cereal) and were then asked to choose between arrays of two or five pieces of the treat of their choice. This was done in order to determine that the reward was tempting to the child and that the child preferred more, rather than less, of this reward. Children were then introduced to a “naughty” puppet and were told that whenever they pointed to a plate of colorful cereal/crackers, the contents of that plate would be given to the puppet and that they would be given the contents of the other plate. After two practice trials and a verbal rule check, task administration began.

Each child completed 16 test trials, with plates being refilled after each trial from pre-prepared arrays of cereal/crackers. The child was not given verbal feedback after each trial, but received implicit feedback from watching the accumulation of cereal/crackers in the clear cups belonging to themselves and the puppet. After eight trials, the puppet and its cup were moved to the child’s opposite side, in order to control for a possible side bias. Directly following this switch, the child, regardless of performance, was given another verbal rule check. The remaining eight trials continued as usual. Administration time was approximately 5 min. The percentage of correct trials (trials during which the child pointed to the plate with two pieces of cereal/crackers) was

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3Simpson and Riggs (2005) report no differences in the performance of 3.5-year-old children between the day–night and sun–moon conditions.
calculated. Interrater reliability was calculated for 40% of the sample and the resulting Intraclass Correlation Coefficient was .988.

**Hand Game.** The Hand Game task used in our study is a variation of Luria’s hand game task, which was originally used to measure IC deficits in adults with frontal lesions (Luria, Pribram, & Homskaya, 1964), and which was adapted more recently for use with children (Hughes, 1996). During this task, the child was asked to place a flattened hand on the table whenever the researcher presented her fist and to present a fist whenever the researcher placed her flattened hand on the table. Each child was first seated at a table with the researcher and was asked to mimic the researcher as she presented her fist and flattened hand on the table in front of the child. This was done in order to demonstrate that the child possessed the ability to manipulate his or her hand into these shapes. The child was then taught the instructions of the task. The child was given at least two practice trials during which he or she was praised or corrected, and then 16 test trials were administered, eight with the experimenter’s fist as the stimulus, and eight with the experimenter’s flattened hand as a stimulus, arranged in a fixed pseudorandom order. Total administration time was approximately 3 min. The percentage correct trials was calculated. Interrater reliability was calculated for 43% of the sample and the resulting Intraclass Correlation Coefficient was .987.

**EEG.** EEG data were collected for the Less is More, Hand Game, and Day–Night tasks. Baseline EEG was measured as each child sat quietly for 2 min and watched a short, soothing, clip from the Disney film, *Finding Nemo* (sea turtles riding the East Australian Current). Mothers sat in a chair beside the child and did not interact with the child throughout this recording. Task administration began immediately after baseline recording. EEG recordings were made from eight left and eight right scalp sites: frontal pole (Fp1, Fp2), medial frontal (F3, F4), lateral frontal (F7, F8), anterior temporal (T3, T4), posterior temporal (T7, T8), central (C3, C4), parietal (P3, P4), and occipital (O1, O2). EEG was recorded using a 21-lead stretch cap (Electro-Cap, Inc.) with electrodes in the 10/20 pattern (Jasper, 1958). Data of interest for this report focused on medial frontal (F3/F4) location, because previous research has shown an association between IC task performance and baseline-to-task changes in medial frontal EEG (Wolfe & Bell, 2004). After the cap was placed on the head, recommended procedures regarding EEG data collection with young children were followed (Pivik et al., 1993). Specifically, a small amount of abrasive gel was placed into each recording site and the scalp gently rubbed. Next, conductive gel was placed in each site. Electrode impedances were measured and accepted if they were below 20 kΩ.

The electrical activity from each lead was amplified using separate SA Instrumentation Bioamps and bandpassed from 1 to 100 Hz. Activity for each lead was displayed on the monitor of an acquisition computer. All electrodes were referenced to Cz during the recording. The EEG signal was digitized online at 512 samples per second for each channel so that the data would not be affected by aliasing. The acquisition software was Snapshot-Snapstream (HEM Data Corp.) and the raw data were stored for later analyses.

EEG data were examined and analyzed using EEG Analysis System software developed by James Long Company (Caroga Lake, NY). First, the data were rereferenced via software to an average reference configuration. The EEG data were then artifact scored for eye movements using a peak-to-peak criterion of 100 uV or greater. Artifact associated with gross motor movements
over 200 uV peak-to-peak was also scored. These artifact-scored epochs were eliminated from all subsequent analyses.

The data were then analyzed with a discrete Fourier transform (DFT) using a Hanning window of 1-second width and 50% overlap. Across the children, the mean number of artifact-free DFT windows during baseline and tasks were, respectively \( M = 141.15 \) (SD = 48.39) for baseline, \( M = 150.69 \) (SD = 100.43) for Less is More, \( M = 33.23 \) (SD = 33.88) for Hand Game, and \( M = 37.97 \) (SD = 23.09) for Day–Night. The large amount of artifact-free data for Less is More, as compared to the other IC tasks, can be attributed to its longer task administration time. Child task data were included if the number of artifact-free DFT windows was equal to or exceeded 10. Power was computed for the 6 to 9 Hz frequency band. This particular frequency band is a dominant frequency in the early childhood years (Marshall, Bar-Haim, & Fox, 2002) and has been used previously with preschool children (Wolfe & Bell, 2004, 2007). For the current study, the power was expressed as mean square microvolts and the data were transformed using the natural log (ln) to normalize the distribution.

**DCCS.** The Dimensional Change Card Sort (DCCS) has been used in the developmental literature to assess EF and rule use in young children (Zelazo, Frye, & Rapus, 1996; Zelazo, Muller, Frye, & Marcovitch, 2003), and requires the skills of focused attention, working memory, and IC. One set of laminated cards (11 cm \( \times \) 7 cm) was used. There were two target cards (i.e., a blue car and a red flower) to be matched to a series of 14 test cards that displayed the same shape but colors opposite of the target cards (i.e., red cars and blue flowers). Each child was first instructed to sort seven test cards by color (pre-switch condition) and then was instructed to switch and to sort the remaining seven test cards by shape (post-switch condition). The dimension (i.e., color or shape) that was relevant during the pre-switch phase was counterbalanced across participants. In the post-switch condition, the child was reminded of the rule after each trial. However, the child was not told whether or not she sorted the cards correctly; the experimenter simply said, “Okay,” and began the next trial. The total administration time of this task was approximately 7 min. The percentage correct of post-switch sorts was of interest in this analysis. Interrater reliability was calculated for the post-switch trials for 24% of the sample, and the resulting Intraclass Correlation Coefficient was .988.

**Marker Delay.** The Marker Delay task (Calkins, 1997), adapted from the Telephone task (Vaughn, Kopp, & Krakow, 1984), measures children’s ability to inhibit coloring when left alone with coloring supplies. Each child was shown a box of markers and paper and was asked if he or she would like to color. The box of markers was opened such that the markers themselves were readily accessible and visible to the child, and both the markers and paper were pushed toward the child. The researcher then explained that she needed to leave the room for a short while in order to retrieve materials for a new game. The child was instructed not to color or touch the paper, markers, or marker box until the researcher returned. Each child was left with the markers and paper for 2 min. Child performance was scored based on ability to follow instructions. Scores ranged 1 to 6 (1 = “colors with markers,” 2 = “takes markers out of box,” 3 = “picks up box,” 4 = “touches box,” 5 = “touches paper,” 6 = “does not touch”). Interrater reliability was calculated 29% of the sample in and the resulting Intraclass Correlation Coefficient was .950.

**PPVT.** Language ability was measured through the Peabody Picture Vocabulary Test (PPVT–IV, Dunn & Dunn, 2007), a nationally standardized instrument that measures receptive
vocabulary and verbal comprehension. During laboratory administration, each child was shown arrays of four pictures and instructed to point to the picture that best described a particular word. Analyses utilized children’s raw scores on this measure.

**CBQ.** The Children’s Behavior Questionnaire (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001) was used to examine parent perceptions of child temperament. The CBQ is a 196-item questionnaire designed to measure general patterns of behavior in children of 3–7 years of age. It consists of 15 scales, of which the IC scale is of most interest to this investigation. Furthermore, three higher order factors are consistently yielded with this instrument: effortful control, surgency, and negative affectivity. All three scales are of interest to this investigation. Internal consistency data for this measure is not available for 3-year-olds, but individual temperament scales have moderate to high internal consistency (Range; $\alpha = .64–.92$) in 4- and 5-year-olds (Rothbart et al., 2001). The questionnaire was mailed to the mothers shortly after they scheduled their laboratory appointment and was collected at the laboratory visit.

**Maternal education.** Mothers self-reported the highest level of education that they had completed. Scores ranged from 0 to 4 (0 = “did not complete high school,” 1 = “high school,” 2 = “technical school,” 3 = “college,” 4 = “graduate school”).

**RESULTS**

Task performance scores were calculated for all tasks, as described above. Table 1 displays the means and standard deviations for all IC tasks, language, medial frontal baseline-to-task change EEG scores, temperament-based IC, and maternal education.

**Missing Data**

Every effort was made to collect data for all children on all tasks. Full data, however, were not available for all children in the sample because of child refusal to participate in the task, child inability to demonstrate understanding of task rules after multiple practice trials, and parental interference during task administration. In addition, the first five children in the dataset are missing data for the Less is More, Hand Game, and PPVT tasks because the tasks were not yet added to the experimental protocol when they visited the laboratory. Finally, because we are interested in the typically developing population, we excluded data from one child who was diagnosed with developmental delays after the lab visit. Table 2 explains reasons for missing data. All analyses were conducted with all available data.

**Differences Between Task Participants and Non-Participants**

Table 3 shows how the children missing data for each of the three main IC tasks differ from those with complete data with respect to maternal education, language, and maternal-reported temperament. Those who completed the Day–Night task had more highly educated mothers than did those who did not complete the task. Those who completed the Less is More task were both less surgent and had better language capabilities than those who did not complete the task. Finally,
TABLE 1
Descriptive Statistics and Bivariate Correlations

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<td>.45**</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Less is More EEG</td>
<td>.13</td>
<td>.17</td>
<td>.01</td>
<td>−.02</td>
<td>.12</td>
<td>−.13</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Hand Game EEG</td>
<td>.07</td>
<td>.44**</td>
<td>.20</td>
<td>.11</td>
<td>.33*</td>
<td>.16</td>
<td>.67**</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. IC (CBQ)</td>
<td>.03</td>
<td>.14</td>
<td>−.30*</td>
<td>.17</td>
<td>.29*</td>
<td>.02</td>
<td>.16</td>
<td>−.04</td>
<td>.17</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>11. Maternal Education</td>
<td>.24</td>
<td>.17</td>
<td>.04</td>
<td>.04</td>
<td>.32**</td>
<td>.47**</td>
<td>−.07</td>
<td>.17</td>
<td>−.02</td>
<td>−.07</td>
<td>—</td>
</tr>
</tbody>
</table>

n: 52 41 57 59 67 60 49 38 51 67 104
M: .47 .68 .47 .83 4.97 61.13 −.06 −.01 −.02 4.42 2.68
SD: .23 .26 .30 .34 1.28 18.85 .24 .29 .29 .79 1.22

Note. All IC task scores are based on proportion correct. The Peabody Picture Vocabulary Test (PPVT) is a raw score on a standardized measure. Electroencephalogram (EEG) measures are reflective of baseline-to-task changes in F3/F4 EEG. IC = inhibitory control; CBQ = the Children’s Behavior Questionnaire.

* p < .05. ** p < .01. (two-tailed).

TABLE 2
Reasons for Missing Data

<table>
<thead>
<tr>
<th>Task</th>
<th>Included</th>
<th>Not in Protocol</th>
<th>Task Refusal</th>
<th>Didn’t Understand Rules</th>
<th>Parental Interference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less is More</td>
<td>52</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Hand Game</td>
<td>41</td>
<td>5</td>
<td>14</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Day–Night</td>
<td>57</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>PPVT</td>
<td>60</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>EEG</td>
<td>64</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note. One additional child was excluded from analyses due to developmental delays. EEG = electroencephalogram; PPVT = Peabody Picture Vocabulary Test.

those who completed the Hand Game task were less surgent, had more highly educated mothers, and had more developed language skills than those who did not complete the task. Those children who completed the tasks did not differ from those who did not on any other variable of interest (i.e., CBQ IC temperament scale, or effortful control or negative affectivity temperament factors) all Fs < 3.64 and all ps > .06.

Correlations Among Tasks

Table 1 also displays the correlations among all IC tasks, language, baseline-to-task change EEG scores, temperament-based IC, and maternal education. With the exception of the correlation between Day–Night task performance and maternal-reported IC, all significant correlations were positive.
TABLE 3

Differences Between Task Participants and Non-Participants for Each IC Task

<table>
<thead>
<tr>
<th>Maternal Education</th>
<th>PPVT Language</th>
<th>CBQ Surgency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day–Night</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F(1, 65) = 4.26$; $\eta^2 = .06^*$</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Complete: $M = 2.82, SD = 1.18$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing: $M = 2.00, SD = 1.05$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less is More</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n.s.</td>
<td>$F(1,58) = 11.30; \eta^2 = .16^{***}$</td>
<td>$F(1,55) = 5.37; \eta^2 = .09^*$</td>
</tr>
<tr>
<td>Complete: $M = 64.88, SD = 16.86$</td>
<td>Complete: $M = 4.66, SD = .75$</td>
<td>Missing: $M = 5.34, SD = .87$</td>
</tr>
<tr>
<td>Missing: $M = 44.44, SD = 16.55$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand Game</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F(1,60) = 5.56; \eta^2 = .08^*$</td>
<td>$F(1, 58) = 19.41; \eta^2 = .25^{***}$</td>
<td>$F(1,55) = 4.39; \eta^2 = .07^*$</td>
</tr>
<tr>
<td>Complete: $M = 2.88, SD = 1.08$</td>
<td>Complete: $M = 67.98, SD = 17.05$</td>
<td>Complete: $M = 4.61, SD = .72$</td>
</tr>
<tr>
<td>Missing: $M = 2.14, SD = 1.31$</td>
<td>Missing: $M = 48.53, SD = 13.02$</td>
<td>Missing: $M = 5.07, SD = .89$</td>
</tr>
</tbody>
</table>

Note. All inhibitory control (IC) task scores are based on proportion correct. Those children who completed the tasks did not differ from those who did not on any other variable of interest (i.e., IC temperament scale, or effortful control or negative affectivity temperament factors) all $F$s < 3.64 and all $p$s > .06. Participants = “complete”; non-participants = “missing.” CBQ = the Children’s Behavior Questionnaire; PPVT = Peabody Picture Vocabulary Test.

* $p < .05$. ** $p < .001$ (two-tailed).
Among the tasks themselves, Hand Game task performance was correlated with task performance on Less is More, DCCS, and Marker Delay. DCCS performance was further positively related to Marker Delay performance. Day–Night did not show any relations to performance on any IC tasks. Several tasks (Hand Game, DCCS, and Marker Delay) also related to language. Baseline-to-task changes in medial frontal EEG during the Hand Game task related both to performance on the Hand Game itself and to performance on the Marker Delay task. Parental-reported IC related to task performance on the Marker Delay task and on Day–Night. Maternal education related only to Marker Delay task performance and to language. Baseline-to-task changes in medial frontal EEG were related across all tasks.

Differing Performance Among IC Tasks

We used paired samples t-tests to test the hypothesis that performance on Less is More would be poorer than performance on the Hand Game and Day–Night tasks (see Table 1 for task means). The t-tests revealed no difference between Less is More and Day–Night performance, \( t(48) = 0.43, p = .669, \) Cohen’s \( d = .95 \). Performance on Less is More, however, was poorer than performance on the Hand Game, \( t(38) = 3.88, p < .001, \) Cohen’s \( d = 7.61 \). Post-hoc analyses revealed that Day–Night performance was also poorer than Hand Game performance, \( t(38) = 3.55, p = .001, \) Cohen’s \( d = 6.81 \).

Alternative Measures of Task Performance

In order to provide further evidence for differing performance between tasks, we investigated alternative measures of task performance. First, we compared, using paired samples t-tests, the number of trials per task that children completed before giving their first incorrect response. This number of trials did not differ between Day–Night and Less is More, \( t(48) = 1.32, p = .19 \) (Day–Night \( M = 3.71, SD = 4.37 \); Less is More \( M = 2.59, SD = 3.84 \)). However, children produced an incorrect response earlier on the Day–Night task than on the Hand Game task, \( t(39) = 2.60, p = .01, \) Cohen’s \( d = .57 \) (Day–Night \( M = 4.15, SD = 4.67 \); Hand Game \( M = 7.25, SD = 6.13 \)). Children also produced an incorrect response earlier on the Less is More Task than on the Hand Game task, \( t(39) = 4.13, p < .01, \) Cohen’s \( d = .87 \) (Less is More \( M = 2.75, SD = 4.20 \); Hand Game \( M = 7.25, SD = 6.13 \)).

We also compared task performance using the metric of the proportion of correct responses given during both the first and second half of the task. Performance during the first half of the Day–Night task did not differ from performance during the first half of the Less is More task, \( t(48) = .01, p = .99 \) (Day–Night \( M = 0.42, SD = 0.34 \); Less is More \( M = 0.42, SD = 0.34 \)). Similarly, performance on the second half of these tasks did not differ, \( t(48) = .86, p = .40 \) (Day–Night \( M = 0.46, SD = 0.32 \); Less is More \( M = 0.51, SD = 0.28 \)). Children, however, made more correct Hand Game than Day–Night responses during both the first \( t(39) = 3.91, p < .01, \) Cohen’s \( d = .84 \); Hand Game \( M = 0.69, SD = 0.28 \); Day–Night \( M = 0.42, SD = 0.36 \) and second half of the tasks \( t(39) = 2.57, p = .01, \) Cohen’s \( d = .67 \); Hand Game \( M = 0.64, SD = 0.29 \); Day–Night \( M = 0.48, SD = 0.31 \). Children also made more correct Hand Game than Less is More responses during both the first \( t(39) = 4.86, p < .01, \) Cohen’s \( d = .89 \); Hand Game \( M = 0.69, SD = 0.28 \); Less is More \( M = 0.45, SD = 0.26 \) and second half of the tasks \( t(39) =
2.19, \( p = .03 \), Cohen’s \( d = .56 \); Hand Game \( M = 0.69, SD = 0.29 \); Less is More \( M = 0.53, SD = 0.28 \). Within the tasks themselves, performance on Day–Night and the Hand Game remained the same from the first to second half of the tasks, Day–Night \( t(56) = 1.07, p = .29 \) (first Half \( M = 0.45, SD = 0.35 \); second Half \( M = 0.49, SD = 0.32 \)), Hand Game \( t(40) = 1.50, p = .14 \) (first Half \( M = 0.70, SD = 0.28 \); second Half \( M = 0.65, SD = 0.29 \)). Performance improved from the first half to the second half of Less is More, \( t(51) = 2.54, p = .01 \), Cohen’s \( d = .87 \) (first Half \( M = 0.42, SD = 0.24 \); second Half \( M = 0.65, SD = 0.29 \)).

Contributions to IC Task Performance

We used hierarchical regression to explore the contributions of electrophysiology, language, temperament, and maternal education to Less is More, Hand Game, and Day–Night performance. We created one regression equation for each task, with the dependent variable as the percentage of trials during which children gave a correct response on that particular task. We entered the following variables, in this order, into the regression equations (1) EEG power baseline-to-task change values at the medial frontal scalp location averaged across hemispheres, (2) PPVT raw language score, (3) temperament-based IC from the CBQ, and (4) maternal education. Variables were entered into the equation in this order, as it was hypothesized that EEG power would have the largest contribution to task performance, followed by language and temperament. Maternal education was included in the last step, because previous research has shown an association between maternal education and effortful control (Graziano, Keane, & Calkins, 2010).

**Less is More.** The regression equation for Less is More was not significant after any of the four steps; final \( F(4, 34) = 0.74, p = .570 \); Step 1 \( R^2 = .02, p = .43 \); Step 2 \( \Delta R^2 = .03, p = .42 \); Step 3 \( \Delta R^2 = .01, p = .58 \); Step 4 \( \Delta R^2 = .03, p = .57 \).

**Hand Game.** Table 4 provides the results from the regression analyses investigating the contributions of medial frontal electrophysiology, language, temperament-based IC, and maternal education to performance on the Hand Game task.

Together, medial frontal baseline-to-task changes in EEG activity, along with language, temperament-based IC, and maternal education accounted for 39% of the variance in Hand Game performance. This model confirmed that medial frontal baseline-to-task change in EEG activity were a significant contributor to Hand Game performance, uniquely accounting for 25% of the

<table>
<thead>
<tr>
<th>TABLE 4</th>
<th>Results of Multiple Regression Analyses Predicting Hand Game Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>SE(B)</td>
</tr>
<tr>
<td>Predicted: Hand Game Performance</td>
<td></td>
</tr>
<tr>
<td>Step 1: F3/F4 baseline-to-task changes</td>
<td>.39</td>
</tr>
<tr>
<td>Step 2: PPVT</td>
<td>.01</td>
</tr>
<tr>
<td>Step 3: Inhibitory Control (CBQ)</td>
<td>.01</td>
</tr>
<tr>
<td>Step 4: Maternal Education</td>
<td>-.04</td>
</tr>
</tbody>
</table>
| Final \( R^2 = .39, F(4, 27) = 4.35, p = .008 \)

*Note.* CBQ = the Children’s Behavior Questionnaire; PPVT = Peabody Picture Vocabulary Test.
INHIBITORY CONTROL IN TODDLERS AND PRESCHOOLERS

variance in task performance. Performance on the PPVT language assessment accounted for an additional 11% of the variance. Neither temperament-based IC nor maternal education accounted for any variance task performance.

Day–Night. The regression equation for Day–Night was not significant after any of the four steps: final $F(4, 35) = 0.75, p = .565$; Step 1 $R^2 < .01, p = .87$; Step 2 $\Delta R^2 = .01, p = .80$; Step 3 $\Delta R^2 = .07, p = .41$; Step 4 $\Delta R^2 < .01, p = .57$.

DISCUSSION

Our study examined IC task performance in 3-year-old children. We focused on the impact on task performance of modifying task demands, specifically focusing on the effects of introducing motivational and nonverbal task demands. We also focused on the differing contributions of electrophysiology, language, temperament, and maternal education to performance on these tasks.

Hand Game as a Suitable Task

Perhaps the most important finding of this investigation is that of the Hand Game as a suitable IC task for use with 3-year-old children. Average performance on the task was 68% correct, as opposed to 47% on both the Day–Night and Less is More tasks. Furthermore, performance on the task related to performance on other measures of IC, including the Less is More, DCCS, and Marker Delay tasks. As additional evidence of its utility, we found that 36% of the variance in performance on the task could be described by medial frontal EEG and by receptive language. Such an association is significant in two ways. (1) The EEG association shows that task performance relates to activity at medial frontal scalp locations, just as would be expected of an IC task, as based on previous research (Wolfe & Bell, 2004). (2) The language association implies that language is an important component of IC task performance even when language is not used by the experimenter or child during administration itself.

Knowing the utility of the Hand Game in young children opens doors for clinicians and researchers to measure early nonverbal IC in order to explore those factors that performance predicts in later childhood. Research suggests that children’s ability to inhibit motor responses during early childhood may predict their later social–emotional competence (Rhoades et al., 2009). Moreover, impulsivity in school-aged children, as measured by performance on Luria’s Hand Game, is related to both parent and teacher ratings of social problems (Fahie & Symons, 2003). It would be extremely helpful to learn if Hand Game performance in early childhood could be used to predict social problems in later childhood, such that the task could be used as an early screening tool to allow for interventions for those children most at risk for social problems.

Differing Performance on IC Tasks

This investigation also informs us regarding 3-year-old performance on the Less is More and Day–Night tasks. We hypothesized that, because Less is More contains a motivational component that could possibly make the task more difficult than IC tasks without this motivational
component, performance on Less is More would be poorer than performance on our other IC tasks. As expected, child performance on Less is More was poorer than performance on the Hand Game tasks, however it did not differ from Day–Night performance.

It could be argued that this poor performance on Less is More in comparison to Hand Game is due in part to the difficult nature of the Less is More task instructions, and, indeed, six children were excluded from analyses for demonstrating a lack of understanding of task rules. In order to be included in analyses, however, children were required to demonstrate both before the task and at a half-way point in the task that they understood the rules of the game. Less is More task performance improved slightly at the halfway point of the task as a result of these instructions, but even with this improvement, children still performed less well, by all standards of measure, on the Less is More task than they did on the Hand Game. Because of this, it is likely that poor performance on the task is due to the difficult nature of the task itself. Because all of the involved tasks tax IC, it may be that Less is More task difficulty is caused by its unique motivation component. Research shows that Less is More performance improves when 3-year-olds are asked to play the game with rocks or with dotted papers, rather than with tempting candies (Carlson et al., 2005). It follows then, that our Less is More task with desirable snacks would be much more difficult for children than our Hand Game task that simply requires children to manipulate their hand into different shapes.

Performance on Less is More did not differ from performance on Day–Night, with children scoring at chance levels on both tasks. Gerstadt and colleagues (1994) report difficulties in administering Day–Night to 3-year-old children; most children either refuse to play or fail the pretest. Most children in our study both agreed to play and demonstrated an understanding of task rules, but their poor performance is indicative of the difficult nature of the task. We are not aware of a report demonstrating that 3-year-olds can perform above chance on the Day–Night task.

In contrast, it is worth reiterating that performance on the nonverbal Hand Game was at 68% correct, which exceeded performance on both Day–Night and Less is More. In a comparison of verbal and nonverbal IC tasks in children ages 3.5–7, Diamond and Taylor (1996) reported that the nonverbal Tapping Task was easier for the children than the verbal Day–Night task. The researchers suggested that the inhibitory requirements of the nonverbal tapping task are less demanding because children’s inclination to copy the experimenter may not be not as strong as their tendency to link the drawing of the sun with the word “sun” and the drawing of the moon with the word “moon.” Thus, the IC demands of the Hand Game may be less strong for 3-year-olds, allowing for better performance. As such, the Hand Game may be more appropriate for use in this age group.

Contributors to IC Task Performance

The second purpose of our investigation was to examine the contributions of medial frontal EEG activity, language, and temperament to IC task performance. None of these factors described a sufficient amount of variability in either Less is More or Day–Night performance to be included in a regression equation for these tasks. It is possible that these factors truly do not contribute to variance in task performance, or it is also possible that this lack of contribution is due to the poor performance on both of these tasks. In contrast, Hand Game, on which children performed well, was explained by a combination of language and baseline-to-task changes in EEG power.
in the medial frontal scalp locations. Contrary to our original hypothesis, language explained a reasonable amount of variance in Hand Game task performance above and beyond EEG activity.

We had hypothesized that, because of the nonverbal nature of the task, Hand Game task performance would be less strongly associated with language than would performance on other IC tasks. Receptive vocabulary (measured here with PPVT) is critical to a child’s ability to understand task instructions. The Hand Game had fairly difficult instructions, with seven children failing to demonstrate an understanding of task rules and an additional 14 refusing to participate in the task (see Table 2), perhaps indicating a lack of interest in attempting to understand task demands. Performance on the task, then, if related to an understanding of rules, would likely be related to a child’s receptive language, explaining the relation between PPVT score and task performance.

We expected language to significantly contribute to both Day–Night and Less is More task performance, as it has been proposed that language development, along with frontal lobe development, plays an important role in the development of self control (Ruff & Rothbart, 1996). Furthermore, previous research demonstrates an association between language and working memory and inhibitory control ability in 3.5- to 4.5-year-old children (Wolfe & Bell, 2004, 2007). Still, performance on both tasks in our current study was around 50%, which is what would be expected by chance alone, so perhaps the tasks are too difficult in this age group and the variability that we see is due to natural statistical variations in performance.

Indeed, previous research confirms that 3-year-old children perform at chance level, in this case a mean of 49% correct responses, on the Less is More task (Carlson, 2005). Furthermore, others have reported difficulties in administering the Day–Night task to 3-year-old children (Gerstadt et al., 1994), and others report that only 50% of young 3-year-old children are able to “pass” the task by correctly completing 12 of 16 trials (Carlson, 2005). In older children, who perform well above chance levels on the Day–Night task, PPVT language was associated with a composite score based on performance on a number of working memory and IC tasks, including Day–Night (Wolfe & Bell, 2007). This suggests that if the children in our current study were slightly older and could perform slightly better on these tasks, we would be more likely to see an association between task performance and language.

It is possible that our findings regarding contributions to task performance, as well as our other findings, may have been influenced by which children contributed data to our tasks. In general, those children who contributed data to each of our IC tasks had more highly educated mothers, had greater language capabilities, and were less surgent than those who did not contribute data. Participants in the Hand Game task, the task with the most missing data, differed from nonparticipants on each of these dimensions. Had all children understood task rules and agreed to play said tasks, it is possible that our findings might have differed. It is noteworthy, though, that participants and nonparticipants did not differ from one another in maternal-reported IC, suggesting that missing data did not impact our ability to accurately depict IC abilities.

LIMITATIONS AND FUTURE DIRECTIONS

These data represent an important attempt in describing the effects that various task demands have on IC task performance and the subsequent relations between this performance, language, and brain electrophysiology. Still, further research is needed in order to advance understanding of these results. First and foremost, this investigation has provided vital information regarding the
developmental appropriateness of the Hand Game. We found evidence that 3-year-old children are able to perform well on the Hand Game task. Previous data from 3-year-olds (Hughes, 1996, 1998) included these children only as part of larger subsets of children, meaning our study provides important new information about the developmental appropriateness of this task in the small window of time following the third birthday. Furthermore, our investigation provides important insight into those factors that contribute to Hand Game task performance, demonstrating the important relations that both language and electrophysiology share with Hand Game performance. Knowing the utility of the Hand Game as well as the importance of nonverbal IC, it would now be informative for future research to explore those factors that Hand Game performance predicts in later childhood.

This investigation also informs us regarding the utility of the Less is More and Day–Night tasks. While previous research indicated the difficulties that 3-year-old children face when completing these tasks (e.g., Carlson et al., 2005; Gerstadt et al., 1994), our research suggests that, in addition, performance on the tasks does not relate to electrophysiology or language. This was true even after altering Day–Night task demands in an attempt to make the task more accessible to these young children. For this reason, it seems that the Less is More and Day–Night tasks are not appropriate to use with this age group. However, it would be helpful to repeat this investigation in a larger sample of 3-year-old children in an attempt to find a sufficient number of children performing at optimal levels to conduct regressions relating their performance to language, electrophysiology, and temperament. Alternatively, data could be collected in a slightly older group of children who have been shown to perform at higher levels on these tasks. Such replication would likely provide a more representative picture of children’s inhibitory abilities and would, therefore, make it easier to understand the factors that contribute to these abilities.

More research should also be conducted in an attempt to address the limitations of this study. Perhaps most importantly, our study is limited by its language measure. The PPVT informs very well regarding children’s receptive language, but does not inform us to children’s ability to produce language, a skill that might better differentiate children’s performance on verbal versus nonverbal IC tasks. For this reason, further research should include an expressive language measure. The study is also limited by missing data. Children who completed the tasks showed similar levels of maternal-reported IC to those children who did not complete the tasks, eliminating the concerns caused by previous research which had demonstrated relations between IC and compliance (e.g., Kochanska et. al, 1997). Still the differences between completers and non-completers are problematic and should be addressed in future studies, particularly in regards to why children fail to complete the Hand Game and how the differences between completers and non-completers affects average performance on the task.

Finally, this investigation is limited by its small, highly educated, Caucasian sample. Data from a more diverse population could provide valuable insight into our findings, and replication in a larger sample would increase our chances of finding children who perform well on the Less is More and Day–Night tasks. Data from such children could allow for analyses to better determine those unique characteristics of children who perform well.

CONCLUSIONS

IC is a key executive function involved in the inhibition of a dominant response or of thoughts and behaviors not relevant to the task at hand. These inhibitory abilities are vital to a child’s
social, emotional, and cognitive development. We examined various IC tasks and reported that performance on the individual tasks showed different patterns of relations to language and electrophysiology. Performance on Day–Night and Less is More, our measures of classic and motivation-based IC, respectively, was not related to measures of language or psychophysiology, perhaps because children performed at chance levels on these tasks, suggesting that the tasks are simply too difficult for 3-year-old children. In contrast, performance on the Hand Game, our measure of nonverbal IC, was explained by medial frontal EEG and by language abilities, perhaps because of the receptive language capabilities necessary to understand task instructions. Because of the Hand Game’s relations to concurrent developmental measures, and because of its potential to predict later social problems, it is important to include measures of nonverbal IC in investigative IC batteries in early childhood.

ACKNOWLEDGMENTS

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