Individual Differences in Inhibitory Control Skills at Three Years of Age

Amanda J. Watson

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
In
Psychology

Martha Ann Bell, Chair
Kirby Deater-Deckard
Brad White

April 15th, 2011
Blacksburg VA

Keywords: Early childhood, Developmental cognitive neuroscience, EEG, Inhibitory control

Individual Differences in Inhibitory Control Skills at Three Years of Age

Amanda J. Watson

(ABSTRACT)

Seventy-three children participated in an investigation of inhibitory control (IC) at 3 years of age. Child IC was measured under various conditions in order to determine the impact that nonverbal and/or motivational task demands had on child IC task performance. Furthermore, task performance was examined with respect to measures of language, temperament, and psychophysiology. Tasks showed different patterns of relations to each of these variables. Furthermore, performance on the Hand Game, our measure of nonverbal IC, was explained by frontal EEG activity and, surprisingly, by language abilities. In contrast, performance on two other IC tasks, Day-Night and Less is More, was not related to measures of language or frontal EEG, perhaps because children performed at chance level on these tasks, indicating that these tasks may be too difficult for 3-year-old children. Implications of these findings are discussed.

Acknowledgements

This research was supported by grant HD049878 from the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (NICHD).

I gratefully acknowledge the assistance of Morgan L. Hubble, Vinaya Raj, Leslie King, Katie Rainey, and Andrew Ranicke with data collection and coding. I would also like to thank Bethany Bray for her help with data analysis, and my committee members, Brad White and Kirby Deater-Deckard, for their comments and suggestions. Finally, I send a heartfelt "thank you" to my advisor and mentor, Martha Ann Bell, whose patient guidance and advice over the last two years has been absolutely invaluable.

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

Inhibitory control (IC) is a key executive functioning process of great importance to the developing child. It is involved in the inhibition of a dominant response and/or the inhibition of thoughts and behaviors not relevant to the task at hand, inhibition processes that are vital to a child's social, emotional, and cognitive development. This ability to prevent incorrect responses, in practical examples, translates to childhood skills such as remembering to raise one's hand 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 these children were able to effectively inhibit their emotions and behaviors. Those 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, those children with stronger inhibitory abilities had higher academic competence and enjoyed school more (Valiente, Lemery-Chalfant, & Castro, 2007).

Because of the important role that IC plays in early academic and social experiences, it is important to look closely at the factors that affect its development in early childhood. IC abilities first begin to emerge during the first year of life (Kochanska, Murray, & Harlan, 2000; Wolfe & Bell, 2004) and then develop rapidly during the preschool years (Carlson, 2005). This development is very closely related to the development of language and temperament, as well as to developmental changes in the brain as measured via the electroencephalogram (EEG; Wolfe & Bell, 2004, 2007). The rapid developmental changes that 3-year-old children experience make their age group ideal for the study of early IC development.

Measuring Different Types of IC

Researchers have thus far developed a number of measurements to determine the correlates of IC. There are no tasks available with the ability to purely measure IC. Because of this, the choice of measurement often depends on the way in which one wishes to conceptualize IC. Some common conceptualizations categorize IC by (1) whether it requires the simple delay of a response or also the ability to suppress this response in order to perform a conflicting action, (2) whether it is simple or complex in its task demands, (3) or by whether it requires a stronger temperamental or executive functioning component. One may also wish to manipulate task demands to understand the ways in which task performance changes in response to increased motivational components or decreased verbal task demands.

Conflict vs. Delay IC. First, IC measures can be divided 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 on their 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. For example, the common Day-Night task (Gerstadt, Hong, & Diamond, 1994) 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. 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, second, override this response with the conflicting response of labeling these images in the opposite manner.

Similarly, the Less is More task (Carlson, Davis, & Leach, 2005), which requires children to point to a smaller array of treats in order to ultimately receive more, could be considered a measure of conflict IC, as it requires children to both inhibit their natural response to point to the larger amount of treats and to override this response by pointing to the smaller array of treats. The Hand Game (Hughes, 1998), which requires children to present their flattened hand when a researcher presents a fist and to present a fist when a researcher presents a flattened hand, would also belong to this second category.

Simple vs. Complex 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 simply 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 the child to inhibit a dominant coloring response. Complex response inhibition tasks, however, also ask a child to also overcome an automatic response (Garon et al., 2008). The Hand Game, Less is More, and Day-Night tasks could all be considered to be 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 to initiate the conflicting response of manipulating their hand into the opposing shape. In the Less is More task, children must inhibit their natural urge to point to the larger number of treats and must initiate the conflicting action of pointing to the smaller number of treats. Finally, the Day-Night task requires children to inhibit their natural response to respond with each cue card's typical label and initiate the conflicting action of naming it with the opposite label. In this way, it seems that there are large similarities between the conflict/ delay and simple/ complex distinctions.

Executive Functioning vs. Temperament-based IC. Beyond this, researchers may wish to classify IC skills as being based either in executive function or in temperament. In reality, it is likely that IC contains aspects of both executive functioning and temperament, as correlations have been found that link both measures of IC (Wolfe & Bell, 2004), but the classification is still helpful in understanding the unique aspects of different tasks.

Executive function abilities are involved in the deliberate, conscious processing of information, and are helpful in situations requiring one to concentrate, to make choices, or to override a "strong internal or external pull" (Diamond, 2006, p. 70). Components of executive function include working memory, the shifting and sustaining of attention, and IC (Blair, Zelazo, & Greenberg, 2005).

Markovitch and Zelazo (2009) have proposed a theoretical model, the Hierarchical Competing Systems Model (HCSM), to describe the development of executive functioning in early childhood. This model is especially useful in the example of the Piagetian A-Not-B task, in which children watch an object being hidden in a new location yet often still search for the object in its previous location. Piaget attributed this error to a failure in object permanence, theorizing that children who continued to reach for the wrong location believed that the object disappeared when hidden and would only reappear if they were to keep reaching for the same hiding place. The HCSM, however, provides an alternative explanation, with children performing well on this task only when they, first, remember the new location of the object and, second, inhibit their natural response to return to the same hiding place. In this way, a habit system, which would lead children to reach towards the same location, is in direct competition with a representational system, which would lead to conscious reflection that would help the child to choose the new location (Marcovitch & Zelazo, 2009).

This model can also be used to describe the thought processes of children in other laboratory measures of IC. For example, the common Day-Night task (Gerstadt et al., 1994) requires children to both remember the new word that they must say (representational system) as well as to inhibit their natural urge to say the word that normally corresponds with the picture (habit system). Another good example of this type of task is the Hand Game task (Hughes, 1998), as, once again, children are being asked to both remember the rules of the game and to inhibit their urge to mimic the actions of the researcher.

Other researchers conceptualize IC as an aspect of temperament. Temperament is an early, biologically-based precursor to children's later personality that can be seen through individual differences in children's reactions to life events (Rothbart & Bates, 2006). Those who view IC as an aspect of temperament often assess IC ability through the use of a parental-report questionnaire. One common tool for doing this is the Child Behavioral Questionnaire (CBQ) (Rothbart et al., 2001). The CBQ asks parents to report on a number of their child's activities and behaviors, and these reports are then used to classify the children's behavior along 16 dimensions. These dimensions are then combined to create three large factors, one of which is effortful control. Effortful control is composed of loadings of dimensions such as IC, low-intensity pleasure, attentional focusing, and perceptual sensitivity (Rothbart et al., 2000). These dimensions are consistent with the finding that parental ratings of self-regulation are positively correlated with ratings of attention focusing, attention shifting, and perceptual sensitivity (Gerardi-Caulton, 2000).

Many researchers will supplement these parental-report measures with laboratory observation of IC ability. One way to measure the temperamental aspects of IC is through the Marker Delay task mentioned earlier (Calkins, 1997). In order to perform well on this task, children must possess the ability to suppress their urge to color, an ability that requires strong self-control, a control that is presumably linked with their temperament.

Other distinctions. There exist a number of unique aspects to IC tasks beyond the delay/suppress, simple/complex, or temperament/ executive functioning classifications noted earlier. For example, consider the Day-Night task, which requires children to give a verbal response ("day" or "night") to the visual cue of a sun or moon stimulus card. In contrast to this task, the Hand Game requires children to provide a motoric, nonverbal, response to a cue. Research is needed to determine whether this difference in verbal vs. motoric task demands affects the nature of the IC being measured. Does, for example, removing the demand for a verbal response weaken the association typically found between language abilities and IC task performance?

Beyond this, one may wish to explore the effects that motivation have on IC task performance. In the Day-Night and Hand Game tasks, it could be argued that children have no strong motivations to perform well aside from the desire for praise following a successful performance. In contrast, during the Marker Delay children must balance this motivation for later praise with the immediate gratification of coloring, meaning that there is also strong motivation to perform poorly. Similarly, the Less is More task asks children to balance their motivation for later praise and later food rewards with the 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.

IC Development

Researchers disagree about the age at which IC skills develop, but most seem to agree that these skills emerge very early in infancy. Wolfe and Bell (2004) relate the development of IC skills to the development of the Anterior Attention System during the second half of the first year of life. Kochanska, Murray, and Harlan (2000) similarly describe the emergence of IC skills late in the first year of life, but also describe how these skills develop more rapidly during toddlerhood and the preschool years. Garon et al. (2008) describe measures of simple response inhibition such as the antisaccade and object retrieval to measure inhibition in children as young as 4 and 6 months of age, respectively. Development of such measures for a certain age group, however, does not necessarily imply that a child of that age will perform well on that task. Instead, age-inappropriate tasks are developed so as to have a way to measure the small percentage of children who do well on that task. For example, while the antisaccade was developed for use in 4-month-olds, it is not until 12 or 18 months that the majority of children are able to produce an antisaccade (Scerif, Cornish, Wilding, Driver, & Karmiloff-Smith, 2004). For this reason, Garon et al. (2008) can only estimate that the ability to perform well on these tasks generally develops some time during the first year of life.

Research also shows differential performance on other similar tasks, with performance peaking earlier on some tasks than others. Carlson (2005) conducted a cross-sectional study that demonstrated the ways in which performance on certain tasks improves between 24 and 48 months of age, and which also helps to point to the ways in which performance varies by task. For example, Carlson (2005) reported that 50% of 2-year-olds were able to wait for 1 minute to eat a snack, whereas 72% of 4-year-olds were able to wait for a full 5 minutes, which suggests that ability to perform well on this task peaks much later than ability to perform well on the antisaccade. Similarly, Carlson (2005) pointed to later development of more complex IC abilities. Performance on these complex tasks develops around the age of 3, with 51% of young 3-year-olds able to pass the bear/dragon task, whereas 76% of older 3-year-olds are able to pass the task (Carlson, 2005).

Similarly, performance on the Less is More task, another complex IC task, is low in 3-year-old children. Only 49% perform optimally at 3 years, as opposed to 61% at 3.5 years, 73% at 4 years, and 78% at 4.5 years of age (Carlson et al, 2005). Performance, of course, is not uniform among all individuals, and the statistics reported above are merely averages based on children who took part 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 task may be of great use in helping to understand the unique personal characteristics that could cause children to perform well on this task at 3 years of age.

Furthermore, researchers report difficulties in administering the Day-Night task to 3-year-old children (Gerstadt et al., 1994), whereas 3.5-year-old children respond correctly on 62% of trials, 4-year-old children on 74% of trials, and 4.5-year-old children on 78% of trials (Wolfe & Bell, 2007). Clearly, some developmental change is occurring between 3- and 3.5 years of age to cause such a drastic change in performance, and it would be interesting to, once again, attempt data collection in 3-year-olds in an effort to capture characteristics of the early stages of this change.

Correlations with Language, Temperament, and Psychophysiology

Language. Performance on IC tasks also varies within normally developing children with respect to their language abilities. Fahie and Symons (2003) found that receptive language capabilities, as measured by performance on the Peabody Picture Vocabulary Test (PPVT) was predictive of executive functioning abilities. More specifically, research shows that performance on two measures of language ability, the MacArthur Bates Communicative Development Inventory and the Internal States Language Questionnaire, is positively correlated with performance on IC tasks such as the shape Stroop, snack delay, and gift delay (Carlson, Mandell, & Williams, 2004).

It is unclear, however, if language and IC are directly related to one another or if they merely develop at the same time. 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 demands. 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 interesting 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 measured by the CBQ. 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; Morasch & Bell, in press; Wolfe & Bell, 2004). IC is also related to other aspects of temperament. Namely, laboratory IC task performance is positively related to the CBQ attentional focusing scale and negatively related to the approach/

anticipation scale (Wolfe & Bell, 2004). Such a relationship 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, 1997). Furthermore, motivational 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.

Psychophysiology. Finally, there is psychophysiological data showing a relationship between IC and brain development. Performance on the Piagetian A-not-B task, a task used to measure IC in infancy and early childhood, is related to EEG power values at frontal scalp locations (Bell & Fox, 1992, 1997). Infants who perform well on this same task experience increases in frontal EEG activity from baseline to task, whereas infants who have less developed inhibitory skills show no change in activity (Bell, 2001). Similarly, a study of 4.5-year-old children shows that children had higher medial frontal EEG activity during IC tasks than during baseline, and that those 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 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 from children who perform poorly on these tasks

(Sabbagh, Bowman, Evraire, & Ito, 2009). We hope that this study can extend our understanding of the electrophysiological contributions to IC to include the contributions to 3-year-old performance on IC tasks requiring nonverbal or motivational demands.

Summary of Research Questions

In conclusion, IC is a facet of executive functioning that represents the ability to suppress a dominant response as well as to suppress irrelevant thoughts and behaviors. IC abilities are evident in the first year of life, and they grow at an especially fast pace during the preschool years. Performance on IC tasks is related to language ability, temperament, and brain development. Levels of IC vary within normally developing populations of children. Thus, because IC abilities develop especially rapidly during the preschool years, it is important to look into individual differences in performance on these tasks while holding age constant.

The purpose of this study was to examine the different contributions to IC task performance by exploring child performance on four IC tasks. One IC task, Less is More, contains a motivational component, while another, Hand Game, contains a nonverbal component. Two others, Day-Night and Marker Delay, were included as representations of traditional IC tasks for comparison with these two unique tasks. Task performance was compared to measures of language, temperament, and psychophysiology. Information from these measures was used to test the following hypotheses:

Verbal vs. Nonverbal IC. The Hand Game, unlike classic tasks such as Day-Night, requires no verbal response from the child. In addition, its instructions, unlike those of the Marker Delay and Less is More, can be largely demonstrated nonverbally. Because of this, I hypothesized that performance on this task would be less strongly correlated with language than is performance on other tasks of IC.

Motivational vs. Nonmotivational IC. Successful performance on Less is More requires pointing to a smaller array of treats in order to ultimately receive a larger array. I 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, I 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 cereal would be too high for most children to overcome.

Electrophysiological activity and task performance. Performance on various IC tasks is related to EEG activity (Wolfe & Bell, 2004). Because of this, I believed that children who performed well on the Less is More and Hand Game tasks would demonstrate higher overall EEG power values at frontal scalp locations than would children who performed poorly on these tasks. In addition, I hypothesized that they would show higher baseline-to-task increases in this activity than would children who performed less well.

Differing contributions to task performance. Finally, I explored contributions to performance on the Less is More, Hand Game, and Day-Night tasks using multiple regression. This allowed me to determine the unique and collective contributions of language (PPVT), temperament (CBQ IC scale), and frontal EEG (lateral frontal, medial frontal, and frontal pole locations) to performance on these tasks. Based on previous research (e.g. Wolfe & Bell, 2004, 2007), I expected EEG to have the strongest contribution to this prediction, followed by temperament and language. Furthermore, because of the motivation component of Less is More, I expected that temperament would have a larger contribution to Less is More performance than to Hand Game or Day-Night performance. Because of the nonverbal nature of the Hand Game, I expected that language would play a smaller role in task performance than it did for Less is More and Day-Night, and that Hand Game performance would be largely dominated by frontal EEG data.

Chapter 2

Method

Participants

Seventy-three participants (31 boys, 42 girls) 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 (M = 3.11, SD = .08, Range = 3.00-3.32) years of age. The study originally included 105 healthy 5-month-old infants (46 boys, 59 girls; 4 Hispanic, 101 Non-Hispanic; 94 Caucasian, 2 African-American, 1 Asian-American, 8 Multi-Racial). Children and their parents were recruited using birth announcements in the local newspaper and a commercial list of new parent names and addresses. Ninety-nine percent of mothers and 97% of fathers who reported educational information had at least a high school diploma at the time of their child's birth. Sixty-nine percent of the mothers had college degrees, as did 61% of the fathers. At the time of the child's birth, mothers were approximately 29.5 years old (range 15-40) and fathers were approximately 32.1 years old (range 14-56). 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 executive functioning and IC, including the Less is More, Hand Game, Day-Night, and

Marker Delay tasks, as well as a number of cognitive and socio-emotional tasks not referenced here. All of the tasks that are the focus of this thesis project 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, some of the tasks required the child to respond verbally (ie, Day-Night), whereas some of the tasks required the child to respond motorically (ie, Less is More, Hand Game). Furthermore, some of the tasks (ie, Less is More and Marker Delay) required the child to overcome strong motivation to respond incorrectly, thus measuring children's ability to overcome this motivation. Measures of language and temperament were also included in order to explore their differing relations to performance on each of our IC tasks.

My contribution to the 36-month research protocol of this ongoing longitudinal study was the addition of the Less is More and Hand Game tasks. Previously, this study had primarily included measures of verbal IC with no measures of motoric or motivational IC measured during EEG data collection, meaning that these two new tasks provided a key opportunity to explore other varieties of IC.

Measures

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). Each child was presented with two plain white plates, one containing two pieces of colorful cereal, and one containing five pieces. In order to establish that the child prefers more cereal, the researcher first pushed these two plates toward the child and asked which one he or she preferred. If the child did not spontaneously choose the array with more cereal, he or she was encouraged by the researcher to choose this array ("Wouldn't you like to have the one with more cereal?").

The experimenter then re-introduced the child to a "naughty" puppet from an earlier game in the protocol. ("This is naughty Mr. Cow. Do you remember him from earlier? He likes to gobble up everyone's treats. That's why he's naughty."). The puppet was placed to the child's right, with a small clear cup placed in front of him. A small clear cup was also placed in front of the child. The researcher explained that whenever the child pointed to a plate, the cereal on that plate would be poured into the puppet's cup, and that the puppet would receive the cereal in that cup. The researcher then informed the child that the cereal on the other plate would be poured into his or her cup and that he or she would receive the cereal in that cup. Cups were clear in order to allow children to see the accumulation of cereal in these cups throughout the task.

To demonstrate these rules, the child was presented with two plates of cereal and asked to point to one of them. The cereal on the chosen plate was poured into the puppet's cup and the cereal on the other plate was poured into his or her cup. Each child was also given a verbal rule check ("When you point to a plate, who gets the cereal on that plate?") in order to determine that he or she understood the rules of the task.

Test trials were carried out in the same way, with each child choosing between two plates of cereal and with this cereal being poured into the corresponding cups based on the child's decision. Each child completed 16 test trials, with plates being refilled after each trial from pre-prepared arrays of cereal. The child was not given verbal feedback after each trial, but received implicit feedback from watching the accumulation of cereal in the cups. After eight trials, the puppet and its cup were moved to the child's left, 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 following 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) was calculated. Interrater reliability was calculated for 40% of the sample and the resulting Intraclass Correlation Coefficient was .994.

Hand Game. The Hand Game task used in this experiment 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). 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.

The child was first asked to mimic the researcher as she presented her first and flattened hand, so as to demonstrate that he or she possessed the ability to manipulate his or her hand into these shapes. The child was then instructed to present his or her hand in response to the experimenter's fist. Instructions were repeated until the child performed the correct action. Difficulty in understanding resulted in demonstration of the rules of the task between the experimenter and the child's mother. The child was then instructed to present his or her first in response to the experimenter's flattened hand. Again, instructions were repeated and demonstrated as necessary. Following instructions, the child was given at least one teaching trial for each condition. More teaching trials were administered if necessary to demonstrate that the child understood the rules of the game.

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 pseudorandom order. Total administration time was approximately 5 min. The percentage correct trials was calculated. Interrater reliability was calculated for 41% of the sample and the resulting Intraclass Correlation Coefficient was .994.

Day-Night. The Day-Night Stroop-like task has been used in the developmental literature with children 3 ½ to 7 years of age and is hypothesized to involve the functioning of the dorsolateral prefrontal cortex (Diamond, Prevor, Callender, & Druin, 1997; Diamond & Taylor, 1996; 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 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 30% of the sample and the resulting Intraclass Correlation Coefficient was .993.

Marker Delay. The Marker Delay task, adapted from the Crayon Delay task (Calkins, 1997), which was previously 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 latency (measured in seconds) to touch the marker box, markers, and paper. Scores ranged from 0-120 s. Interrater reliability was calculated for 26% of the sample. The Intraclass Correlation Coefficient was .937.

EEG. EEG data were collected throughout most of the appointment, and were collected for the Less is More, Hand Game, and Day-Night tasks. Baseline EEG was measured as each child sat quietly and watched a short, soothing, clip from the Disney film, Finding Nemo. Parents 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 was recorded during these tasks using a stretch cap (Electro-Cap, Inc.) with 28 electrodes in the 10/20 pattern (Jasper, 1958). 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. The EEG signal was digitized on-line 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). The EEG data were 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. 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 in our lab with preschool children (Wolfe & Bell, 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.

PPVT. Language ability was measured through the Peabody Picture Vocabulary Test (PPVT-IV, L.Dunn & D. 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. A standardized score was calculated based on the child's age and performance.

CBQ. The Children's Behavior Questionnaire (CBQ; Rothbart et al., 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 that load into 3 factors. Internal consistency data for this measure is not available for

3-year-olds, but individual temperament scales have moderate to high internal consistency (Range; α = .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.

Chapter 3

Results

Task performance scores were calculated for all tasks, as described above. Table 1 displays the means, standard deviations, minimum performance, maximum performance, sample size, and skewness and kurtosis data for all IC and language tasks.

Missing Data

Every effort was made to collect data for all children on all tasks. Full data, however, were not available for all accessible children in the sample (i.e., those who had not moved out of the local area) because of missed laboratory appointments, child refusal to participate in the task, parental interference during task administration, and child inability to demonstrate understanding of task rules after multiple practice trials. In addition, the first 5 children in the dataset are missing data for the Less is More and Hand Game 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, I excluded data from one child who has recently been diagnosed with developmental delays. Table 2 explains reasons for missing data. All analyses were conducted for all available data.

A series of one-way ANOVAs was calculated in order to determine if there were temperamental differences, measured by CBQ scale and factor scores, between those who complied with task instructions and those who refused to complete tasks. No children refused to participate in the Marker Delay task, but some children refused participation in the Less is More, Hand Game, and Day-Night tasks. Temperamental differences were found between those who participated in the Hand Game task and those who refused participation, as well as between those children who agreed to wear our EEG cap and those who refused to wear it. Those who participated in the Hand Game had lower activity level, falling reactivity/ soothability, and smiling scale scores than those who refused the task. Children who wore the cap had higher impulsivity scale scores than children who refused to wear the cap. See Table 3 for more information about these temperamental differences.

Normality of Data

Table 1 includes skewness and kurtosis values as a measure of task performance distribution normality. One may compare skewness and kurtosis to the typical 0 values found in normally distributed data using a z test: $z = (K-0)/ s_k$, where K represents skewness or kurtosis and s_k represents the standard error of this skewness or kurtosis (Tabachnick & Fidell, 2007). In this case, a distribution would be considered to be skewed or kurtotic if the value of its skewness/kurtosis divided by the standard error of this statistic exceeded ± 1.96. By this definition, Marker Delay is considered skewed, Hand Game is nearly skewed, and Day-Night is nearly kurtotic. Furthermore, Aiken (2005) expresses concern about the normality of data with negative kurtosis values, which include our Less is More, Day-Night, and Marker Delay variables. For this reason, I include in further analyses calculations appropriate for both normal and non-normal data.

Relations among IC Tasks

Table 4 contains both the bivariate and Spearman's correlations among children's performance on IC tasks. As shown in the table, Less is More performance is positively related to Hand Game performance. No other tasks are related to one another (*p*'s $\geq .235$).

Relations between IC Tasks and Temperament

Table 4 also contains both the bivariate and Spearman's correlations between children's IC task performance and their temperamental IC scale scores from the CBQ . As shown in the table, temperamental IC is negatively related to Day-Night performance and positively related to Marker Delay performance. Neither Less is More nor Hand Game performance scores are related to temperamental IC (p's $\geq .389$).

Relations between IC Tasks and Language

In order to test the hypothesis that Hand Game performance would be less strongly related to language than would performance on other IC tasks, I calculated both bivariate and Spearman's correlations between PPVT language scores and IC task performance scores. Results show a positive bivariate relation between Hand Game and language ($r = .37$, $p = .018$) as well as between Marker Delay and language ($r = .39$, $p = .003$), but not between either Less is More or Day-Night and language (p's $\geq .130$). There is also a significant Spearman correlation between language and Marker Delay ($r = .37$, $p = .004$) and a marginal Spearman correlation between language and Hand Game ($r = .29$, $p = .066$), but, again, no relation between either Less is More or Day-Night and language (p's $\geq .148$).

I then used a series of Fisher r-to-z transformations to calculate the significance of the differences between the correlations between language and the various tasks. The relation between language and Hand Game performance was not weaker than that between language and Marker Delay performance or language and Less is More performance (p's $\geq .218$). The relation between language and Hand Game performance was *stronger* than the relation between language and Day-Night in terms of both the bivariate correlations ($z = 1.87$, $p = .031$) and Spearman correlations ($z = 1.65$, $p = .049$).

Differing Performance between IC Tasks

I used both paired samples t-tests and one-sample Wilcoxon ranks tests to test the hypothesis that performance on Less is More would be poorer than performance on the Hand

Game, Day-Night, and the Marker Delay tasks (see Table 1 for task means). Because Hand Game, Day-Night, and Less is More performance were measured through proportion scores, I converted Marker Delay performance into a proportion score by dividing the time that children were able to refrain from coloring by the total time that they were asked to refrain from coloring (120 s). Paired samples t-tests revealed no difference between Day-Night and Less is More performance t (48) = .43, p = .669. Performance on Less is More, however, was poorer than performance on the Hand Game, t (38) = -3.88, p < .001, and poorer than performance on the Marker Delay task, t (49) = -4.32, p < .001. Wilcoxon ranks tests were used to compare median performance on the Hand Game, Day-Night, and Marker Delay tasks to the median performance on the Less is More task (Median = .49). Again, Day-Night performance was not different from Less is More performance (p =.586), but both Hand Game and Marker Delay performance were different from Less is More performance (p's < .001).

EEG and IC Task Performance Groups

Continuous EEG data were collected during the Less is More, Hand Game, and Day-Night (but not Marker Delay) tasks. Because IC task performance has previously been related to EEG activity at the frontal scalp locations (Bell 2001, Wolfe & Bell, 2004, 2007), I have included EEG power information from both the medial and the lateral frontal scalp locations as well as from the frontal pole area.

In order to test the hypotheses that greater levels of Less is More and Hand Game task performance were related to higher baseline EEG power values as well as to larger increases in activity from baseline to task, I conducted repeated-measures MANOVAs, with condition (baseline, task) and hemisphere (left, right) as the within-subjects factors and high/low performance group as the between-subjects factor. High and low performance groups were based on a median split, with children performing below the median performance level placed into a low performance group and children performing above the median performance level placed into a high performance group. Because I am interested in the relation of EEG power with task performance, I report here only those main effects and interactions involving task performance group.

Less is More. No main effects or interactions involving task performance group were found in the lateral frontal (all *p*'s ≥ .126), medial frontal (all *p*'s ≥ .376) or frontal pole (all *p*'s ≥ .321) areas.

Hand Game. In the lateral frontal area, there was a Condition x Performance Group interaction, F (1,30) = 8.41, p = .007. As shown in Figure 1, children in the high performance group displayed an increase in EEG power from baseline to task, F7: t (15) = -1.71, p = .054; F8: t (15) = -1.99, p = .033. Children in the low performance group showed no change in EEG from baseline to task (both *p*'s ≥ .285). Children in the high performance group did not differ from children in the low performance group at baseline (both *p*'s ≥ .348), but children in the high performance group showed higher EEG power during the task than those in the low performance group, F7: t (15) = 1.97, p = .034; F8: t (15) = 2.15, p = .024.

This Condition x Performance Group interaction was also found for the medial frontal electrode pair, F (1,30) = 4.13, p = .051. As shown in Figure 2, neither the high or low performance groups showed a change in EEG from baseline to task (all *p*'s ≥ .172), but visual inspection reveals that the high performance group showed a trend towards an increase in EEG power from baseline to task, while the low performance group showed a trend toward a decrease in EEG power from baseline to task, creating the overall effect. Children in the low performance group did not differ in EEG power from children in the high performance group at baseline (both *p*'s ≥ .414) or during the task itself (both *p*'s ≥ .102).

The Condition x Performance Group interaction was also found for the frontal pole electrode pair, F (1,29) = 4.82, p = .036. As shown in Figure 3, children in the high performance group displayed an increase in EEG power from baseline to task, Fp1: t (15) = -2.00, p = .032; Fp2: t (15) = -2.48, p = .012. Children in the low performance group showed no change in EEG from baseline to task (both *p*'s ≥ .247). Children in the high performance group did not differ from children in the low performance group at baseline (both *p*'s ≥ .421), but children in the high performance group showed marginally higher EEG power during the task at Fp1 (t (15) = 1.37, p = .096) as well as higher EEG power during the task at Fp2 (t (15) = 2.46, p = .013).

Finally, there was a Hemisphere x Performance Group interaction found for the frontal pole electrode pair, F (1,29) = 7.10, p = .012. As shown in Figure 3, there was no hemispheric difference in EEG activity between the high and low performance groups (all *p*'s ≥ .164). Visual inspection, however, reveals higher right frontal pole EEG activity in the high performance group and relatively higher left frontal pole EEG activity in the low performance group.

No main effects for performance group were found in any of the three regions (all *p*'s ≥ .31).

Day-Night. No main effects or interactions involving task performance group were found in the lateral frontal (all *p*'s ≥ .133) or frontal pole (all *p*'s ≥ .194) areas. In the medial frontal area, there was a Hemisphere x Performance Group interaction, F (1,39) = 5.77, p = .021. As shown in Figure 4, there was no hemispheric difference in activity for the low performance group (both *p*'s ≥ .325). The high performance group also showed no hemispheric differences in EEG activity during baseline, t (17) = .53, p = .301, but showed higher left medial frontal activity during task, t (17) = 1.93, p = .035. Despite this, this interaction was *not* superseded by a Condition x Hemisphere x Performance Group interaction, F (1,39) = 2.32, p = .136.

Predicting IC Task Performance

Finally, I used multiple regression to explore the contributions of physiology, language, and temperament to Less is More, Hand Game, and Day-Night performance. I created three separate regression equations for each task, one for each the lateral frontal, medial frontal, and frontal poles' EEG power contribution to task performance. I entered the following variables, in this order, into the regression equations (1) EEG power baseline-to-task change values at the appropriate frontal scalp location (lateral frontal, medial frontal, or frontal pole) averaged across hemispheres, (2) PPVT standard language score, and (3) temperamental IC scale score from the CBQ. 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.

Less is More. The regression equation for Less is More was not significant after any of the three steps. See Table 5.

Hand Game. Table 6 provides the results from the regression analyses investigating the contributions of frontal electrophysiology, language, and temperament-based IC to performance on the Hand Game task.

Together, *lateral frontal* baseline-to task changes in EEG activity, along with language, and temperament-based IC accounted for 38% of the variance in Hand Game performance, $F(3,29) = 6.03$, p = .003. This model confirmed that lateral frontal baseline-to-task changes in EEG activity were a significant predictor of Hand Game performance, uniquely accounting for 29% of the variance in task performance. Additionally, performance on the PPVT language assessment was predictive of task performance, accounting for 9% of the variance. Temperament-based IC did not explain any significant additional variance in task performance.

Similarly, 31% of the variance in Hand Game performance can be explained by a combination of *medial frontal* baseline-to-task changes in EEG activity, language and temperament-based IC, F (3,29) = 4.26, p = .013. Medial frontal baseline-to-task changes in EEG activity account for 12% of the variance in task performance, with PPVT language scores accounting for an additional 18% of the variance. Again, temperament-based IC did not account for any significant additional variance in task performance.

Finally, 34% of the variance in Hand Game performance can be explained by a combination of *frontal pole* baseline-to-task changes in EEG activity, language, and temperament-based IC, F (3,28) = 4.71, p = .009. Frontal pole baseline-to-task changes in EEG activity account for 14% of the variance in performance, with PPVT language scores accounting for an additional 18% of the variance. Temperament-based IC did not account for any significant additional variance in task performance.

Day-Night. The regression equation for Day-Night was not significant after any of the three steps. See Table 7.

Chapter 4

Discussion

This study explored the contributions of various factors to IC task performance in 3-year-old children. I focused on the impact on task performance of modifying task demands, specifically focusing on the effects of introducing motivational and nonverbal task demands. I also focused on the differing contributions of electrophysiology, language, and temperament to these novel varieties of tasks, discovering some surprising patterns of relations.

Relations between IC tasks and Language

First, this investigation revealed unexpected relations between task performance and language. I hypothesized that, because of the nonverbal nature of the task, Hand Game task performance would be less strongly correlated with language than would performance on other IC tasks. In contrast, the relation between Hand Game and language was not any weaker than the relation between Marker Delay or Less is More performance and language and, in fact, was stronger than the relation between Day-Night performance and language. Surprisingly, performance on both the Hand Game and Marker Delay tasks, neither of which require a verbal response from the child, were moderately positively correlated with language. In contrast, neither Day-Night nor Less is More task performance scores were related to language, even though Day-Night requires verbal responses during the task itself and Less is More requires some minimal verbal responses while the researcher establishes that the child understands the rules of the task.

The PPVT is a measure of receptive vocabulary, which is doubtlessly important in a child’s ability to understand task instructions. This investigation demonstrates that the Hand Game has fairly difficult instructions, with 7 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. In addition, some of those children who participated in the task could have passed the task's rule check without fully understanding the instructions, hindering their performance in comparison to their peers who *did* fully understand instructions. 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.

The Marker Delay, in contrast, fits the classification of a "simple" IC task, requiring children to merely inhibit their dominant coloring response without initiating some kind of conflicting response (Garon et al., 2008). This makes for task rules that are likely easier to understand, which is demonstrated by the fact that no children needed to be excluded from the task due to a failure to understand its rules. Because of this, some other explanation must exist for the relation between task performance and language ability. The association found supports previous research showing associations in 3-year-old children between PPVT language scores and both the Snack Delay and Gift Delay tasks, tasks very similar in nature to the Marker Delay task (Carlson et al., 2004), meaning that this finding is likely not spurious in nature. One possible explanation for this finding is through that of self-speech. Researchers have suggested that self-speech is important in self-control (Carlson, 2003; Zelazo, 1999). Perhaps children who perform well on our Marker Delay task are (silently or verbally) coaching themselves through the task, continually reminding themselves not to color. Thus children who possess the necessary language for self-speech are better able to coach themselves through to successful task performance.

The fast-paced Less is More and Day-Night tasks may not allow enough time for self-speech, but an association between language and task performance would still be expected 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 ability (Wolfe & Bell, 2004, 2007), meaning that the working memory demands of Less is More and Day-Night should relate task performance to children's verbal abilities. Still, performance on both tasks is 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 there is previous data from our lab showing that children in this age group produce a mean of 42% correct responses on this task, again around chance level (Watson, Kraybill, & Bell, 2011). In contrast, another study from our lab demonstrates that 3.5-year-old children respond correctly on 62% of trials, 4-year-old children on 74% of trials, and 4.5-year-old children on 78% of trials (Wolfe & Bell, 2007). PPVT language was associated with a composite score based on performance on a number of working memory and IC tasks, including Day-Night, in each of those age groups (Wolfe & Bell, 2007). This suggests that if the children in this study were slightly older and could perform slightly better on these tasks, it would be possible to see an association between task performance and language.

Differing Performance between IC Tasks

Secondly, I 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 either the Marker Delay or Hand Game tasks, but 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 and Marker Delay is due in part to the difficult nature of the Less is More task instructions, and, indeed, 6 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. 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 is likely 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 tempting snacks would be much more difficult for children than our Hand Game task that simply requires children to manipulate their hand into different shapes.

It is less clear why performance on Less is More would also be poorer than performance on the Marker Delay task, which also requires children to demonstrate IC in the face of a tempting incorrect response, in this case, coloring while prohibited. It is possible, however, that children view the possible consequences of poor performance on Less is More as less severe than those of poor performance on the Marker Delay. Whereas Less is More simply asks children to follow the rules of a “game”, Marker Delay involves a direct adult instruction: “So while I’m gone, no coloring!” Children, accustomed to the consequences of disobeying the instructions of the adults in their lives (e.g., parents, teachers, and caregivers), may give more weight to the instruction not to color than they give to the suggestion in Less is More that “We want naughty Mr. Cow to get fewer treats.” Thus, performance on the Marker Delay should be better than performance on Less is More, because the perceived consequences of poor performance on Less is More are less strong than those of poor performance on the Marker Delay task.

Finally, performance on Less is More did not differ from performance on Day-Night, with children performing at chance levels on both tasks. It is possible that Day-Night’s demands on working memory are too difficult for 3-year-olds. Whereas Marker Delay requires children to initiate only one response (“no coloring”), as does Less is More (pointing), Day-Night requires children to remember and produce two separate responses (saying “sun” and “moon” at the appropriate times). Hand Game, too, requires children to produce two separate responses (placing either their flat hand or fist on the table in front of them), but children are constantly exposed to these responses, as the experimenter produces her fist and flat hand throughout the task. In contrast, the experimenter does not say the words “sun” or “moon” after the child has established rule understanding during Day-Night. As a consequence, it is easy for a child to forget one response (i.e. saying “moon”) and to perseverate with the other response (saying “sun” for every trial) for the remainder of the task trials. Because of this, children are likely to perform at chance levels on Day-Night, making performance on this task equally as poor as performance on Less is More.

EEG and IC Task Performance Groups

My third hypothesis regarded the contributions of frontal EEG activity to IC task performance. First, I believed that children who performed well on our tasks would have higher frontal EEG power values than did children who performed poorly. There were, however, no main effects for performance group on activity in the lateral frontal, medial frontal, or frontal pole locations for any of our IC tasks. Poor performance on Less is More and Day-Night would likely mask any associations between electrophysiological activity and performance on those tasks, but it is interesting that no main effects were seen for Hand Game, either.

Instead, electrophysiological effects during the Hand Game were demonstrated through Condition x Performance Group interactions, with children who perform well on the task generally demonstrating an increase in frontal activity from baseline to task and children who perform less well showing no change. Because this higher activation in high-performers, as compared to low-performers, was limited to times when children were completing the task, it seems that high- and low- performers differ from one another not in overall frontal maturation, but instead in the amount of attention that they allocate for the task itself. The anterior cingulate cortex, which plays a role in cognition and attention (Bell & Wolfe, 2004), could be activated more strongly during the Hand Game in the high-performing children, explaining their greater activity in the three frontal areas.

There were also Hemisphere x Performance Group interactions found during the Hand Game and Day-Night tasks. Children who performed well on the Hand Game appeared to have higher right frontal EEG activity at frontal pole locations as compared to children who performed less well. Fox (1994) demonstrated how the right frontal region is associated with control over negative emotions, so it is possible that the children who perform well on the Hand Game task do so because they are better able to control the negative emotions that arise as a consequence of being asked to stay in their chair, wear an EEG cap, and participate in our tasks. Children who perform well on Day-Night show more left medial frontal activity than those who perform less well. Infants experiencing left frontal EEG asymmetry are also high in positive affect (Fox, 1994), so perhaps children who perform well on this task are happier to be in the laboratory setting, participating in our "games" and this enjoyment aids their performance.

Predicting IC Task Performance

The final purpose of this investigation was to use multiple regression to explore the varying contributions of 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, but Hand Game performance was predicted by a combination of electrophysiology and language. Again, poor performance on Less is More and Day-Night likely masks any contributions of these variables to task performance. Furthermore, children were prone to multiple brief distractions during these tasks, and, because EEG data were collected continuously through these tasks, our EEG data includes activity while children were not focused on the tasks themselves, further masking any possible electrophysiological differences between high and low performers during the "on time" of the task itself.

In contrast, Hand Game was explained by a combination of language and baseline-to-task changes in EEG power in each the lateral frontal, medial frontal, and frontal pole scalp locations. Contrary to my original hypothesis, language explained more variance in Hand Game task performance than did EEG activity at both the medial frontal and frontal pole scalp locations. Given the newly considered importance of language to task performance considered above, however, it seems appropriate that language explain a large amount of variance in task performance.

It is interesting that temperament-based IC did not explain any additional variance in Hand Game task performance in the third step of these regression equations. One possible explanation for this lack of a contribution is that children who agreed to play our Hand Game differed in temperament from those who refused participation, making those who participated in the task a more homogenous group, which would make it more difficult to find temperamental differences between high- and low- performing children. Still, compliers and refusers did not differ on the temperament-based IC scale, suggesting that there may be another reason for the lack of a temperamental IC contribution to task performance. Mother's ratings of their children's IC increase with age (Kochanska et al., 1997), so it is possible that these ratings are also indicative of an aspect of child maturation. Similarly, children's linguistic abilities also improve as they mature (Gleason, 2005), so perhaps the inclusion of language in the regression equations already explains an aspect of child maturation, leaving no room for any additional variance from the maturational component explained by temperament-based IC. More research is needed to better understand the lack of a temperamental contribution to task performance.

Limitations and Future Directions

These data represent an important attempt in describing the effects that modifying task demands have on IC task performance. Still, future research is needed in order to further understanding of these results. First and foremost, while it is important to have evidence that 3-year-olds are incapable of performing above chance levels on the Less is More and Day-Night tasks, this study is limited by its resulting inability to relate performance on these tasks to electrophysiology, language, or temperament. It would be extremely helpful to repeat this investigation 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.

Furthermore, this investigation provides important insight into those factors that contribute to Hand Game task performance. More research is needed, however, to explore those factors that Hand Game performance predicts. Research suggests that children's ability to inhibit motor responses during early childhood may predict their later social-emotional competence (Rhoades et al., 2009). Furthermore, 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.

Conclusions

IC is a key executive functioning process 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. This investigation explored the effects of varying task demands on inhibitory performance. Performance on the various tasks showed different patterns of relations to language, temperament, and psychophysiology. Performance on Day-Night and Less is More, our measures of traditional and motivation-based IC, respectively, was not related to measures of language, temperament, 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 frontal EEG and, surprisingly, 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 motoric IC in investigative IC batteries in early childhood.

References

Aiken, L (2005). *Notes for a lecture on multivariate data analysis.* Arizona State University, Tucson, AZ.

Bell, M.A. (2001). Brain electrical activity associated with cognitive processing during a looking version of the A-not-B task. *Infancy, 2,* 311-330. doi:10.1207/S15327078IN0203_2

Bell, M. A. & Fox, N. A. (1992). The Relations between frontal brain electrical activity and cognitive development during infancy. *Child Development, 63,* 1142–1163. doi: 10.1111/j.1467-8624.1992.tb01685.x

Bell, M. A. & Fox, N. A. (1997). Individual differences in object permanence performance at 8 months: Locomotor experience and brain electrical activity. *Developmental Psychobiology, 31*, 287–297. doi: 10.1002/(SICI)1098-2302(199712)31:4<287::AID-DEV6>3.0.CO;2-N

Bell, M. A. & Wolfe, C. D. (2004). Emotion and cognition: An intricately bound developmental process. *Child Development, 75,* 366–370. doi: 10.1111/j.1467-8624.2004.00679.x

Blair, C., & Razza, R.P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. Child Development, 78(2), 647-663. doi:10.1111/j.1467-8624.2007.01019.x

Blair, C, Zelazo, D. & Greenberg, M.T. (2005). The measurement of executive function in early childhood. Developmental Neuropsychology, 28, 561-571. doi: 10.1207/s15326942dn2802_1.

Calkins, S.D. (1997). Cardiac vagal tone indices of temperamental reactivity and behavioral regulation in young children. Developmental Psychobiology, 31, 125-135. doi:10.1002/(SICI)1098-2302(199709)31:2<125::AID-DEV5>3.0.CO;2-M

Carlson, S. M. (2003). Executive function in context: Development, measurement, theory and experience. Monographs of the Society for Research in Child Development, 68, 138–151. doi:10.1111/j.0037-976X.2003.00270.x

Carlson, S. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology*, *28*, 595-616. doi:10.1207/s15326942dn2802_3

Carlson, S., Davis, A., & Leach, J. (2005). Less is more: Executive function and symbolic representation in preschool children. *Psychological Science*, *16*, 609-616. doi:10.1111/j.1467-9280.2005.01583.x

Carlson, S., Mandell, D., & Williams, L. (2004). Executive function and theory of mind: Stability and prediction from ages 2 to 3. *Developmental Psychology, 40*, 1105-1122. doi:10.1037/0012-1649.40.6.1105

Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development, 72*, 1032-1053. doi:10.1111/1467-8624.00333

Carlson, S.M., Moses, L.J., & Breton, C. (2002). How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory. *Infant and Child Development*, *11*, 73-92. doi:10.1002/icd.298

Denham, S. (2006). Social-emotional competence as support for school readiness: What is it and how do we assess it? *Early Education and Development*, *17*, 57-89. doi:10.1207/s15566935eed1701_4

Diamond, A. (2006). The early development of executive functions. In E. Bialystok & F. Craik (eds.), *Lifespan Cognition: Mechanisms of Change* (pp. 70-95). NY: Oxford University Press.

Diamond, A., Prevor, M.B., Callender, G., & Druin, D.P. (1997). Prefrontal cortex cognitive deficits in children treated early and continuously for PKU. *Mongographs of the Society for Research in Child Development, 62*, 1-206. doi:10.2307/1166208

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "Do as I say, not as I do.". Developmental Psychobiology, 29, 315-334. doi:10.1002/(SICI)1098-2302(199605)29:4<315::AID-DEV2>3.0.CO;2-T

Dunn, L. M., & Dunn, L. M. (2007). *PPVT-IV. Test kit for form IV*. Circle Pines: AGS.

Eisenberg, N., Cumberland, A., Spinrad, T.L., Fabes, S.R., Shepard, S.A., Reiser, M., Murphy, B.C., Losoya, S.H., & Guthrie, I.K. (2001). The relations of regulation and emotionality to children's externalizing and internalizing problem behavior. *Child Development*, *72*, 1112 – 1134. doi:10.1037//0022-3514.68.3.505

Fahie, C., & Symons, D. (2003). Executive functioning and theory of mind in children clinically referred for attention and behavior problems. *Journal of Applied Developmental Psychology*, *24,* 51-73. doi:10.1016/S0193-3973(03)00024-8

Fox, N.A. (1994). Dynamic cerebral processes underlying emotion regulation. *Monographs of the Society of Research in Child Development*, *59,* 152-166. doi:10.1111/j.1540-5834.1994.tb01282.x

Garon, N., Bryson, S., & Smith, I. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin*, *134*, 31-60. doi:10.1037/0033-2909.134.1.31

Gerardi-Caulton, G. (2000). Sensitivity to spatial conflict and the development of self-regulation in children 24-36 months of age. *Developmental Science*, *3*, 397-404. doi:10.1111/1467-7687.00134

Gerstadt, C., Hong, Y., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 3 1/2-7 years old on a Stroop-like day-night test. *Cognition*, *53*, 129-153. doi:10.1016/0010-0277(94)90068-X

Gleason, J.B. (2005). *The Development of Language.* Colombus, OH: Merrill.

Hughes, C. (1998). Executive function in preschoolers: Links with theory of mind and verbal ability. *British Journal of Developmental Psychology*, *16*, 233-253.

Hughes, C. (1998). Finding your marbles: Does preschoolers' strategic behavior predict later understanding of mind? *Developmental Psychology*, *34*, 1326-1339. doi:10.1037/0012-1649.34.6.1326

Hughes, C., White, A., Sharpen, J. & Dunn, J. (2000), Antisocial, angry, and unsympathetic: “Hard-to-manage” preschoolers' peer problems and possible cognitive influences. *Journal of Child Psychology and Psychiatry, 41*, 169–179. doi: 10.1111/1469-7610.00558

Isquith, P., Crawford, J., Espy, K., & Gioia, G. (2005). Assessment of executive function in preschool-aged children. *Mental Retardation and Developmental Disabilities Research Reviews, 11*, 209-215. doi:10.1002/mrdd.20075

Jasper, H.A. (1958). The ten–twenty system of the International Federation. *Electroencephalography and Clinical Neurophysiology*, *10*, 371–375.

Kochanska, G. (1997). Multiple pathways to conscience for children with different temperaments: From toddlerhood to age 5. *Developmental Psychology, 33,* 228-240. doi:10.1037//0012-1649.33.2.228

Kochanska, G., Murray, K., & Coy, K.C. (1997). Inhibitory control as a contributor to conscience in childhood: From toddler to early school age. *Child Development, 68*, 263-277. doi:10.2307/1131849

Kochanska, G., Murray, K., & Harlan, E. (2000). Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. *Developmental Psychology, 36*, 220-232. doi:10.1037/0012-1649.36.2.220

Luria, A. R., Pribram, K. H., & Homskaya, E. D. (1964). An experimental analysis of the behavioral disturbance produced by a left frontal arachnoidal endothelioma (meningioma). *Neuropsychologia, 2*, 257—280.

Mahone, E., & Hoffman, J. (2007). Behavior rating of executive function among preschoolers with ADHD. *Clinical Neuropsychologist*, *21*, 569-586. doi:10.1080/13854040600762724

Marcovitch, S., & Zelazo, P. (2009). A hierarchical competing systems model of the emergence and early development of executive function. *Developmental Science*, *12*, 1-18. doi:10.1111/j.1467-7687.2008.00754.x

Marshall, P., Bar-Haim, Y., & Fox, N. (2002). Development of the EEG from 5 months to 4 years of age. Clinical Neurophysiology, 113, 1199-1208. doi:10.1016/S1388-2457(02)00163-3

Morasch, K., & Bell, M.A. (in press). The role of inhibitory control in behavioral and physiological expressions of toddler executive function. Journal of Experimental Child Psychology. doi:10.1016/j.jecp.2010.07.003

Pivik, R. T., Broughton, R. J., Coppola, R., Davidson, R. J., Fox, N., & Nuwer, M. R. (1993). Guidelines for the recording and quantitative analysis of electroencephalographic activity in research contexts. Psychophysiology, 30, 547-558. doi:10.1111/j.1469-8986.1993.tb02081.x

Ponitz, C.C., McClelland, M.M., Matthews, J.S., & Morrison, F.J. (2009). A structured observation of behavioral self-regulation and its contribution to kindergarten outcomes. *Developmental Psychology, 45*, 605-619. doi:10.1037/a0015365

Reed, M., Pien, D., & Rothbart, M. (1984). Inhibitory self-control in preschool children. Merrill-Palmer Quarterly, 30, 131-147.

Rhoades, B.L., Greenberg, M.T., & Domitrovich, C.E. (2009). The contributions of inhibitory control to social-emotional competence. Journal of Applied Developmental Psychology, 30, 310-320. doi:10.1016/j.appdev.2008.12.012

Rothbart, M. K., Ahadi, S. A., & Evans, D. E. (2000). Temperament and personality: Origins and outcomes. *Journal of Personality and Social Psychology,* 78, 122-135. doi:10.1037/0022-3514.78.1.122

Rothbart, M. K., Ahadi, S. A., Hershey, K. L., & Fisher, P. (2001). Investigations of temperament at three to seven years: The children's behavior questionnaire. *Child Development*, *72*, 1394–1408. doi:10.1111/1467-8624.00355

Rothbart, M., & Bates, J. (2006). Temperament. In N. Eisenberg, W. Damon, & L. M. Richard (Eds.), Handbook of child psychology: Vol. 3, Social, emotional, and personality development (6th ed.) (pp. 99-166), John Wiley & Sons, Inc.

Ruff, H. A., & Rothbart, M. K. (1996). *Attention in early development: Themes and variations.* New York: Oxford.

Sabbagh, M., Bowman, L., Evraire, L., & Ito, J. (2009). Neurodevelopmental correlates of theory of mind in preschool children. *Child Development*, *80*, 1147-1162. doi:10.1111/j.1467-8624.2009.01322.x

Scerif, G., Cornish, K., Wilding, J., Driver, J., & Karmiloff-Smith, A. (2004). Visual search in typically developing toddlers and toddlers with Fragile X or Williams syndrome. *Developmental Science, 7*, 116–130. doi:10.1111/j.1467-7687.2004.00327.x.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using Multivariate Statistics (5th Ed.).* Boston, MA: Allyn and Bacon.

Valiente, C., Lemery-Chalfant, K., & Castro, K.S. (2007). Children's effortful control and academic competence. *Merrill-Palmer Quarterly, 53,* 1-25.

Vaughn, B., Kopp, C., & Krakow, J. (1984). The emergence and consolidation of self-control from eighteen to thirty months of age: Normative trends and individual differences. *Child Development, 55,* 990-1004. doi:10.2307/1130151.

Watson, A.J., Kraybill, J., & Bell, M.A. (2011). *A longitudinal investigation of conflict and delay inhibitory control in toddlers and preschoolers*. Manuscript submitted for publication.

Wolfe, C., & Bell, M.A. (2004). Working memory and inhibitory control in early childhood: Contributions from physiology, temperament, and language. *Developmental Psychobiology*, *44*, 68-83. doi:10.1002/dev.10152

Wolfe, C.D., & Bell, M.A. (2007). Sources of variability in working memory in early childhood: A consideration of age, temperament, language, and brain electrical activity. *Cognitive Development, 22,* 431-455. doi:10.1016/j.cogdev.2007.08.007

Zelazo, P. D. (1999). Language, levels of consciousness, and the development of intentional action. In P. D. Zelazo, J. W. Astington, & D. R. Olson (Eds.), Developing theories of intention: Social understanding and self-control (pp. 95–117). Mahwah, NJ: Erlbaum.

Table 1

Descriptive Statistics for IC and Language Tasks

Task Type	Task	*M*	*SD*	Min.	Max.	*n*	Skew (SE)	Kurtosis (SE)	Skew/ SE	Kurtosis/ SE
IC	Less is More	.47	.23	.00	1.00	52	.25 (.33)	-.11 (.65)	.76	-.17
	Hand Game	.67	.26	.00	1.00	41	-.69 (.37)	.14 (.72)	-1.86	.19
	Day-Night	.47	.30	.00	1.00	57	.21 (.32)	-1.02 (.62)	.66	-1.65
	Marker Delay	88.14	47.01	.00	120.00	65	-1.02 (.30)	-.69 (.59)	-3.40	-1.17
Language	PPVT Std.	115.28	15.57	78.00	147.00	60	-.21 (.31)	-.35 (.61)	-.68	-.57
Temperament	CBQ IC Scale	4.42	.79	2.60	6.33	67	-.06 (.29)	-.19 (.58)	-.21	-.33

Note: All scores are based on proportion correct, with the exception of Marker Delay (based on a score 0-120 s), PPVT (a standardized score), and CBQ IC scale (based on an average of questions rated on a Likert-type scale, 1-7).

Table 2

Reasons for Missing Data

Task	Included	Surveys Only	Not in Protocol	Didn't Understand Rules	Task Refusal	Parental Interference
Less is More	52	5	5	6	3	1
Hand Game	41	5	5	7	14	0
Day-Night	57	5	0	5	5	0
Marker Delay	65	5	0	0	0	2
PPVT	60	5	5	0	1	1
EEG	64	5	0	0	3	0

Note: One additional child was excluded from analyses due to developmental delays. In addition, 6 children are missing temperamental data because of parental failure to return a completed CBQ form.

Table 3

Temperamental Differences Between Children Who Complied with Task Instructions and Those Who Refused Participation

Task	Temperament Scale	F	P	Refuser M	Refuser SD	Complier M	Complier SD
Hand Game	Activity Level	F(1,50) = 4.53	.038	5.51	.81	4.99	.73
	Falling Reactivity/ Soothability	F(1,50) = 4.11	.048	5.42	.78	4.90	.80
	Smiling	F(1,50) = 5.97	.018	6.27	.57	5.67	.81
EEG Cap	Impulsivity	F(1,60) = 4.59	.036	3.50	.13	4.66	1.07

Note. Data are not presented for the Marker Delay, because no children refused to participate in this task. Data are not presented for Less is More and Day-Night, because all temperamental differences were nonsignificant (*p*'s $\geq$.063).

Table 4

Bivariate and Spearman's Correlations Among IC Tasks and Between IC Tasks and Temperamental IC

	Less is More	Hand Game	Day-Night	Marker Delay	CBQ IC
Less is More	--	.34 (.032)	-.04 (.803)	-.02 (.890)	.04 (.802)
Hand Game	.40 (.012)	--	.14 (.413)	.19 (.235)	.14 (.389)
Day-Night	-.01 (.952)	.14 (.389)	--	-.07 (.616)	-.30 (.029)
Marker Delay	-.01 (.967)	.18 (.281)	-.10 (.481)	--	.37 (.004)
CBQ IC	.02 (.914)	.10 (.549)	-.30 (.03)	.29 (.03)	--

Note. Upper triangle contains bivariate correlations. Lower triangle contains Spearman's correlations. *P*-values are in parentheses. All tests were two-tailed.

Table 5

Results of Hierarchical Regression Analyses Predicting Less is More Performance from Frontal Electrophysiology, Language, and Temperament

	B	SE(B)	β	*t*	*p*	sR^2
Predicted: Less is More Performance						
Lateral frontal baseline-to-task changes	.38	.21	.31	1.80	.080	.11
PPVT	.00	.00	.18	1.05	.301	.03
IC (CBQ)	-.02	.05	-.06	-.34	.734	.00
R^2 = .15, F (3, 31) = 1.76, p = .175						
Predicted: Less is More Performance						
Medial frontal baseline-to-task changes	.22	.17	.22	1.31	.199	.03
PPVT	.01	.00	.29	1.72	.095	.08
IC (CBQ)	-.01	.05	-.04	-.24	.816	.00
R^2 = .11, F (3, 32) = 1.36, p = .273						
Predicted: Less is More Performance						
Frontal pole baseline-to-task changes	.21	.17	.21	1.25	.222	.05
PPVT	.01	.00	.29	1.69	.101	.08
IC (CBQ)	-.01	.05	-.02	-.10	.920	.00
R^2 = .13, F (3, 31) = 1.53, p = .226						

Note. None of the entered variables explain significant variance in task performance.

Table 6

Results of Hierarchical Regression Analyses Predicting Hand Game Performance from Frontal Electrophysiology, Language, and Temperament

	B	SE(B)	β	*t*	*p*	sR^2
Predicted: Hand Game Performance						
Lateral frontal baseline-to-task changes	.40	.13	.46	3.08	.004	.29
PPVT	.01	.00	.30	1.97	.059	.09
IC (CBQ)	.02	.04	.08	.53	.603	.01
R^2 = .38, F (3, 29) = 6.03, p = .003						
Predicted: Hand Game Performance						
Medial frontal baseline-to-task changes	.30	.13	.35	2.27	.031	.12
PPVT	.01	.00	.41	2.60	.014	.18
IC (CBQ)	.03	.05	.11	.72	.478	.01
R^2 = .31, F (3, 29) = 4.26, p = .013						
Predicted: Hand Game Performance						
Frontal pole baseline-to-task changes	.26	.11	.38	2.44	.021	.14
PPVT	.01	.00	.42	2.68	.012	.18
IC (CBQ)	.03	.04	.11	.67	.506	.01
R^2 = .34, F (3, 28) = 4.71, p = .009						

Note. Temperamental differences did not explain significant additional variance in any of these equations.

Table 7

Results of Hierarchical Regression Analyses Predicting Day-Night Performance from Frontal Electrophysiology, Language, and Temperament

	B	SE(B)	β	*t*	*p*	sR^2
Predicted: Day-Night Performance						
Lateral frontal baseline-to-task changes	.07	.16	.07	.46	.651	.00
PPVT	.00	.00	-.13	-.81	.421	.03
IC (CBQ)	-.09	.05	-.28	-1.72	.094	.08
R^2 = .101, F (3, 35) = 1.37, p = .267						
Predicted: Day-Night Performance						
Medial frontal baseline-to-task changes	.02	.14	.03	.16	.874	.00
PPVT	.00	.00	-.13	-.79	.435	.03
IC (CBQ)	-.09	.06	-.28	-1.70	.098	.07
R^2 = .10, F (3, 35) = 1.31, p = .288						
Predicted: Day-Night Performance						
Frontal pole baseline-to-task changes	.12	.14	.14	.88	.387	.03
PPVT	.00	.00	-.12	-.77	.448	.02
IC (CBQ)	-.09	.06	-.26	-1.62	.114	.07
R^2 = .12, F (3, 34) = 1.58, p = .213						

Note. None of the entered variables explain significant variance in task performance.

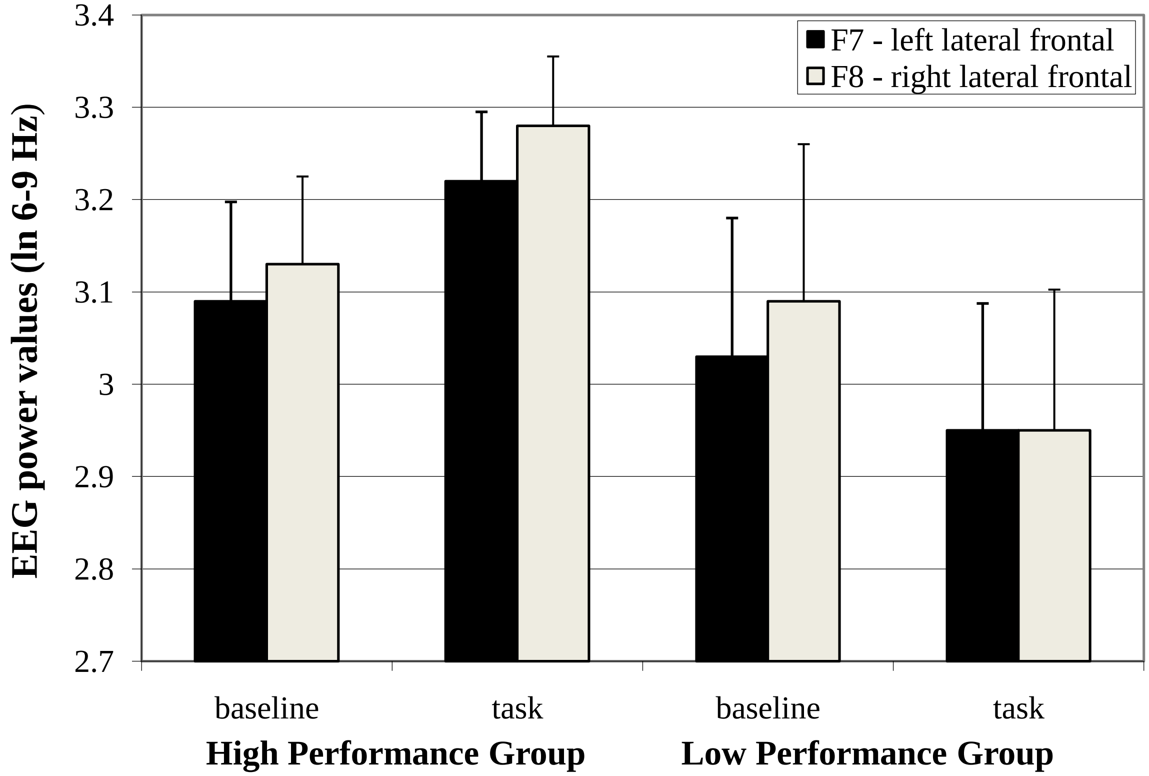

Figure 1. EEG power values (ln 6-9 Hz) from lateral frontal (F7, F8) locations for the high and low performance groups during baseline and the Hand Game.

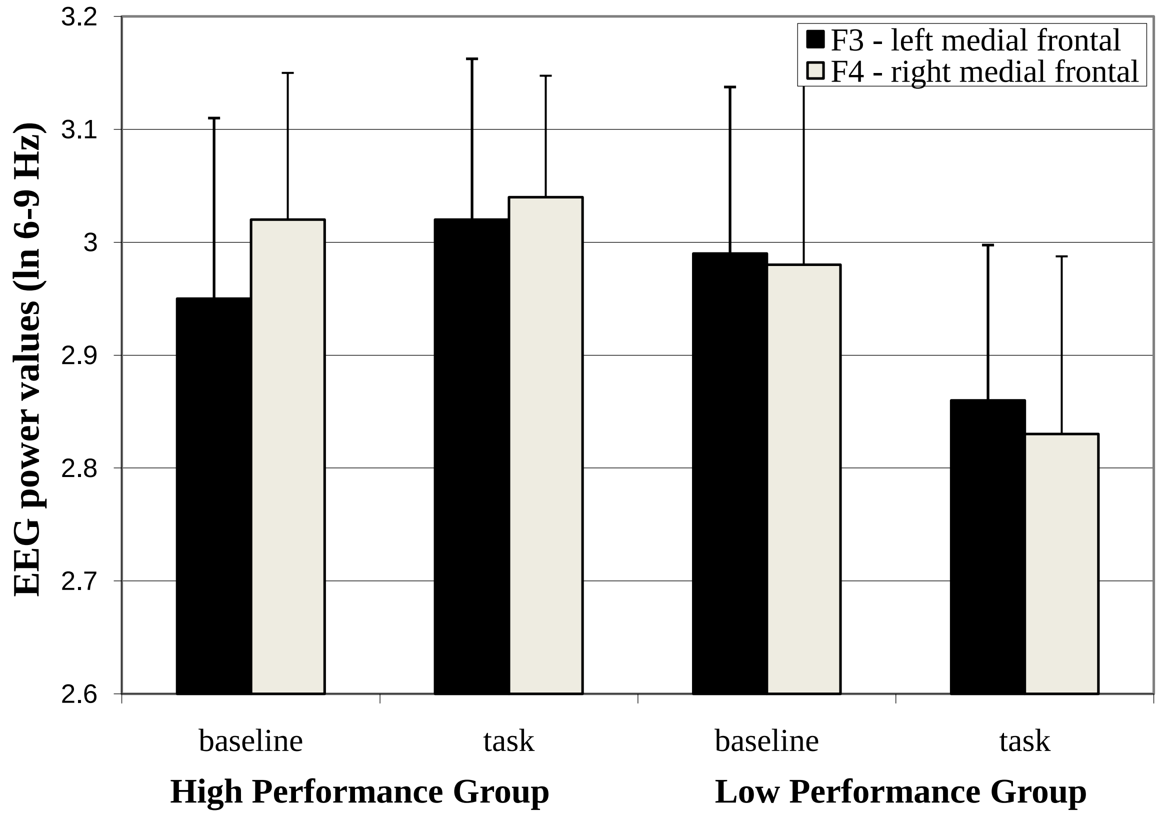

Figure 2. EEG power values (ln 6-9 Hz) from medial frontal (F3, F4) locations for the high and low performance groups during baseline and the Hand Game.

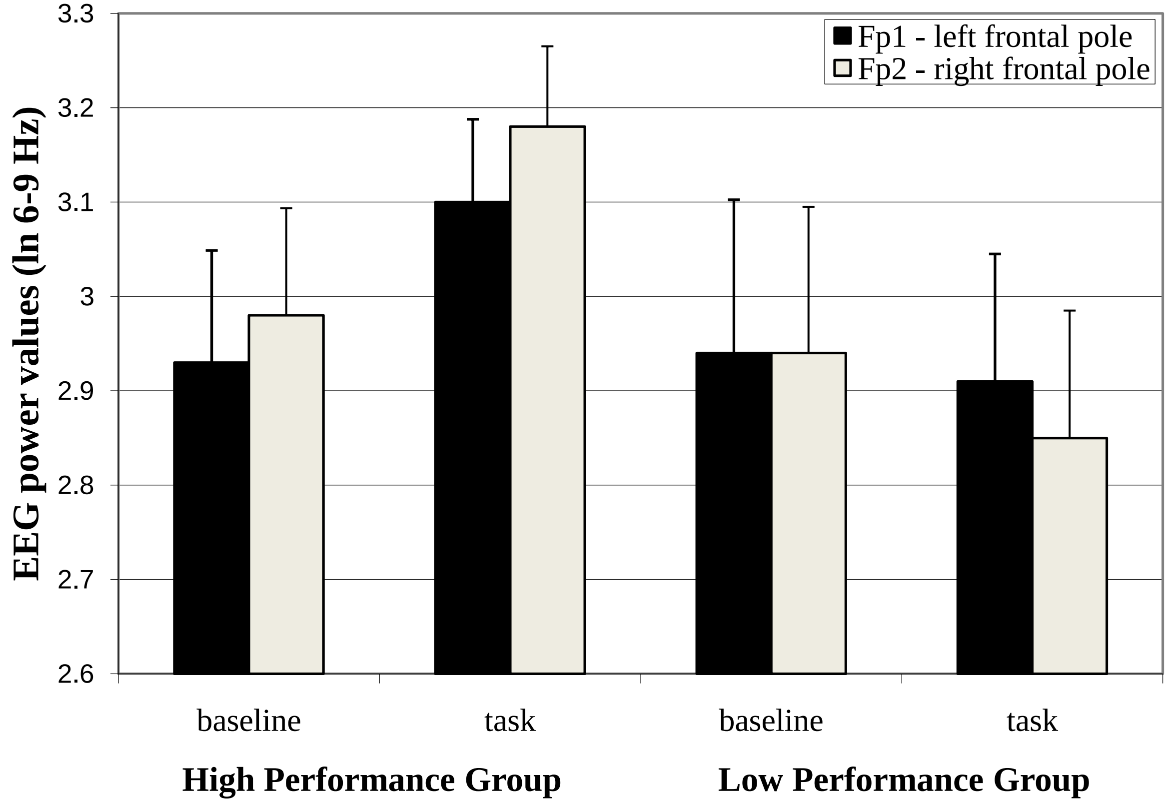

Figure 3. EEG power values (ln 6-9 Hz) from frontal pole (Fp1, Fp2) locations for the high and low performance groups during baseline and the Hand Game.

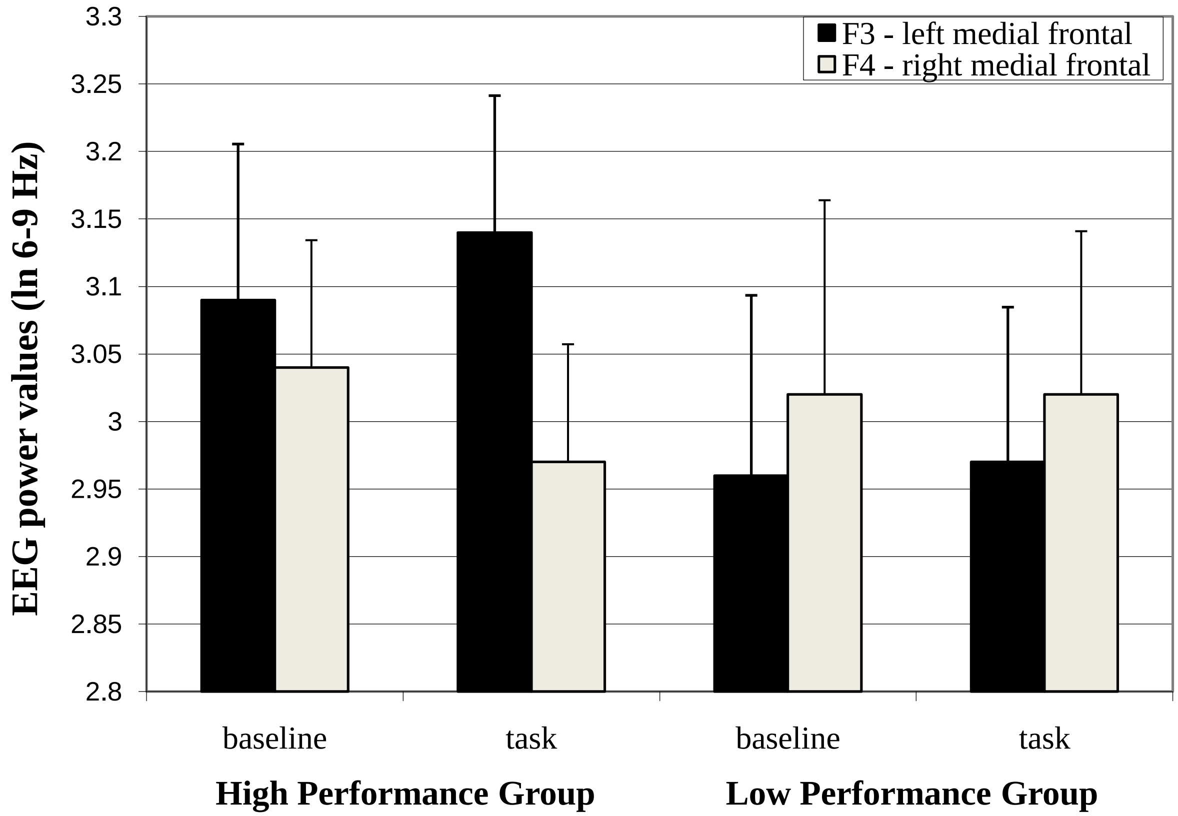

Figure 4. EEG power values (ln 6-9 Hz) from medial frontal (F3, F4) locations for the high and low performance groups during baseline and Day-Night.